University of San Carlos
Department of Chemical Engineering
Talamban, Cebu City, Philippines 6000

CHE 3110L
Laboratory Simulation of Industrial Product Manufacture

Carrageenan Production:
Refined Carrageenan

A laboratory report submitted to

Dr. Francis Dave C. Siacor
CHE 3110L Instructor

by

Illaga, Chillann Kirk D.
Monsanto, Jerold J.
Rosal, Jean Mercy C.
Salde, Sheena Stella A.
Villo, Francis John S.

November 06, 2021

1. Introduction

Carrageenan is polysaccharides extracted from certain red algae and formed by D-galactose and 3,6-anhydrogalactose units which are linked by α-1,3 and β-1,4 glycosidic. The carrageenan contains sulphate ester about 15 % to 40 % and average molecule mass above 100 kDa. It is classified into several types such as λ, κ, ι, ε, μ, which contain 22 % to 35 % of the sulphate group (Manuhara et al., 2016).

In this experiment, the carrageenan is extracted specifically from a seaweed algae *Eucheuma cottonii* or locally known as "guso". It contains carrageenan in the range of 61.5-67.5 % on a dry weight basis (Ninghidayati et al., 2017). Kappa carrageenan is predominantly produced from *E. cottonii* (red seaweed) (Van De Velde et al, 2002) that normally found in the ocean of Philippines, Malaysia and Indonesia. It is widely used since it has excellent physical functional properties such as gelling, thickening and stabilizing abilities (Hoffman et al, 1995).

Procedures for the production of semi-refined carrageenan (SRC) from local red seaweed, *E. cottonii* involve pre-treatment, alkali extraction, neutralization, filtration, precipitation, drying and grinding, and packaging (Normah & Nazarifah, 2003).

Prior to plant-scale extraction the seaweed undergoes a pre-treatment process where it is washed to remove adhering salts, sand, stones, and marine organisms (Stanley, n.d.). The chopped seaweed is then digested with hot water under alkaline conditions to exhaustively extract the carrageenan. Generally, the base used in this study is an alkali or alkaline earth metal such as sodium hydroxide, calcium hydroxide and potassium hydroxide. This aqueous base leads to the formation of 3,6-anhydro linkages in the galactose units of carrageenan.

The *E. cottonii* can be extracted by hot alkaline solution of $Ca(OH)_2$ and then recovered from the solution (Manuhara et al., 2016). The alkaline solution removes some of the sulphate groups from the molecules and increases the formation of 3,6-AG that leads to increased gel strength of carrageenan (Yasita, 2010).

After the extraction, the waste of algae (solid materials) is then separated from the viscous filtrate in preparation for the neutralization process (Manuhara et al., 2016). Carrageenan in solution has a maximum stability of pH=9 and should not be heat processed at pH below 3.5. At pH=6 or above, carrageenan solutions withstand processing conditions. Also, at neutral pH, carrageenan is stable. Because of the alkaline treatment, the initial pH of the mixture or the pH before neutralization tends to be basic. By addition of HCl, the resulting mixture can achieve neutralization.

After extraction the mixture undergoes a filtration process. *E. cottonii* has a very high kappa carrageenan content and when purified by filtration it is then possible to precipitate the carrageenan using potassium chloride, generally this forms a large jelly like mass that can be pressed to remove water (Cyber Colloids, n.d.). KCl is used for gel formation and prevention of the dissolution of carrageenan at normal temperatures since carrageenan's dissolving rate and solubility is sensitive to the presence of another solute. The mechanism of gelation of a κ-carrageenan like *E. Cottonii* in the presence of K^+ ions is presented in Figure 1 (Rhein-Knudsen et al., 2015).

Following the final wash, the coagulum is dried under conditions permitting recovery of the residual alcohol. The fibrous carrageenan from the dryer is ground and sifted to specified particle sizes which may range from 80 mesh to 270 mesh. This is to ensure that the final carrageenan product comes out fully refined with no lumps. Finally, the refined carrageenan product is then collected and packaged.

The aim of this report is to produce refined carrageenan in a lab-scale production setting, as well as, monitoring overall and component energy and mass flows, yields, and identifying critical steps in every process step and for the entire process of cheese production.

2. Objectives of the Experiment

1. Prepare a process flowsheet for the manufacture of carrageenan complete with details in process conditions and stream specification;
2. Monitor overall and component mass and energy flows during the lab-scale implementation of the carrageenan manufacture;
3. Calculate component yields in every process step and for the entire process; and
4. Identify critical steps in the process based on laboratory data and the entire experience of generating the carrageenan.

3. Methodology

3.1. Methodological Framework

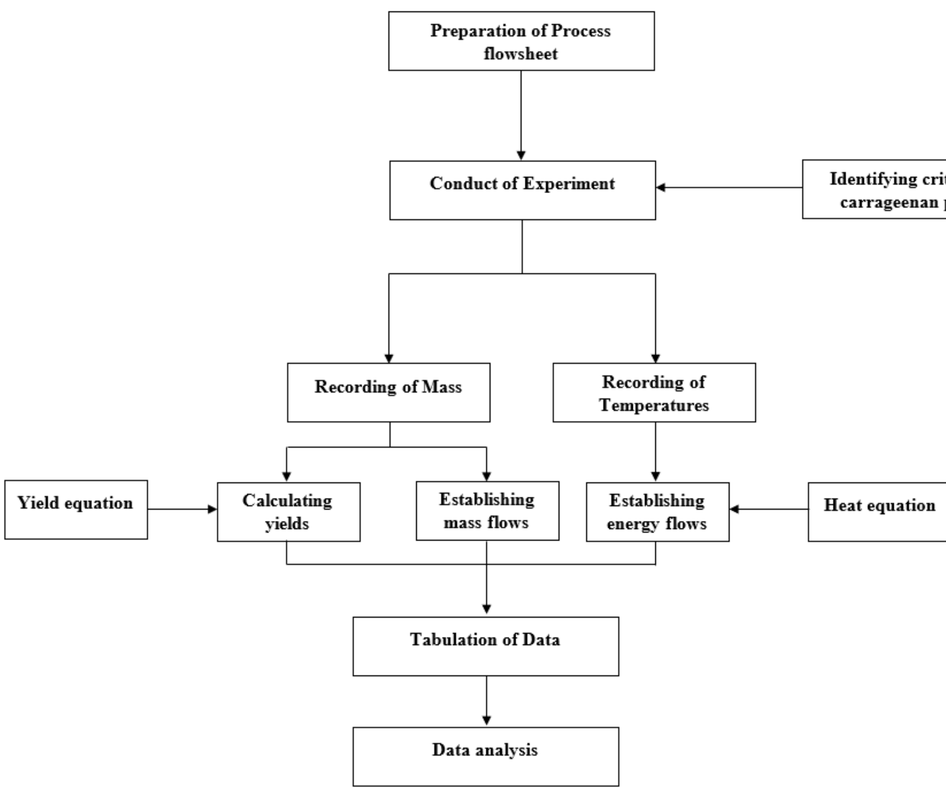


Figure 1. Methodological Framework in carrageenan production

A process flowsheet describing the manufacturing process of carrageenan with details in process conditions and stream specification was initially prepared. The basic process used in producing the carrageenan is shown in Annex A. Mass inputs and outputs in each process were monitored. This was done by recording the mass of the raw materials, the intermediate products, and the by-products in each unit process and operation. The overall mass and component yields was calculated using equation (insert equation). In addition, the energy flow during the production process was also monitored by recording the initial and final temperature of each unit process and unit operation. This recorded data was used to establish the mass and energy flows of the carrageenan production process as well as in calculating the overall and component yields of each unit process and unit operation. Since heat absorbed/evolved is not directly measured and obtained, the heat equation shown in equation…was used. The critical steps were then identified based on laboratory data and the entire experience of producing carrageenan.

3.2. Materials

One kilogram of E. cottoni seaweed was used as the raw material in producing carrageenan. The alkali used to in the extraction process was sixty grams of Potassium hydroxide (KOH) diluted in one liter of distilled water. Approximately 120 milliliters of Hydrochloric acid (HCl) were used to neutralize the seaweed mixture. Finally, the carrageenan was precipitated using fifteen grams of Potassium chloride (KCl) diluted in one liter of distilled water. A cheesecloth was also used during the filtration and gel pressing process.

3.3. Equipment

The apparatuses used in the production process included beakers, mortar and pestle, droppers, scissors, a casserole pot, and tongs. A digital scale was used to accurately measure the masses and an alcohol thermometer was used to monitor the temperature of each unit process and operation.

The key equipment used in the experiment included an electric stove, a blender, and a pH meter.

Figure 2. Electric stove

In this experiment an electric stove was used as the source of heat during the alkali treatment process. The electric stove is a stainless-steel stove that has five heat levels: low heat, medium-low heat, medium heat, medium-high heat, and high heat.

Figure 3. Electric blender

In this experiment, a blender was used to help dissolve undissolved seaweed during heating.

Figure 4. pH meter

The pH meter was used to monitor the pH of the seaweed mixture in the neutralization process.

.

3.4. Procedures

3.4.1 Gathering of Materials

One kilogram of E. Cottoni seaweed was purchased from the local marketplace of Minglanilla, Cebu. The chemicals used in this experiment such as Potassium chloride (KCl), Potassium hydroxide (KOH), and Hydrochloric acid (HCl) were purchased from the Far Eastern Drug, Inc.

3.4.2 Carrageenan manufacture

One kilogram of fresh E. Cottoni seaweed were thoroughly washed with one liter of tap water to remove foreign debris. After repeating the process three times, the mass of the washed seaweed was recorded using a digital scale. The washed seaweed was then sun dried for three days. The dried seaweed was trimmed into smaller pieces of about 2-3 cm in length before undergoing alkali treatment. To extract the carrageenan from the trimmed seaweed, the seaweed was mixed with one liter of 6% potassium hydroxide solution and was heated to 90 ^{o}C for 30 minutes. To dissolve the undissolved seaweed, the treated seaweed mixture was blended thoroughly using an electric blender. The blended mixture was poured in a basin and was added one liter of hot water. The blended mixture was then neutralized by adding one hundred twenty milliliters of hydrochloric acid. The hydrochloric acid was added dropwise until the pH meter recorded a neutral (7) pH level. The undissolved seaweed was strained using a piece of cheese cloth. One liter of 1.5% potassium chloride solution was added to the filtered carrageenan extract to form the carrageenan gel. To remove the excess water from the carrageenan gel, it was pressed gently inside a cheesecloth. Finally, the pressed carrageenan gel was dried using an oven at 30 ^{o}C for a day. The dried carrageenan was refined by grinding it using a mortar and pestle. The initial and final temperatures as well as the masses were recorded in each unit process and unit operation.

4. Results and Discussions

4.1 Lab-scale carrageenan production process flow, process conditions, and stream specifications

The production process of carrageenan entails eight major steps namely washing, sun-drying, cutting, alkali treatment, blending, neutralization, filtration, precipitation, drying and grinding. In each unit process and unit operation, the components, mass, temperature, process conditions, and stream specifications were monitored. A more detailed process flow diagram is shown in Annex A.

Shown in the detailed process flow diagram are the complete process conditions like the temperature range, pressure, and the pH at which the production process was conducted. These parameters were monitored during the whole production process to ensure optimal conditions to produce appropriate yield of carrageenan. The stream specifications were determined using the mass balance equation. The masses that could not be directly measured like water vapor were also determined using mass balance.

4.2 Mass and energy flows

The mass balance and energy flows during the whole production process was monitored carefully. The data gathered were used to show the overall material balance and the energy requirement for the lab-scale production of carrageenan. The mass balance was computed manually using the formula derived from the law of conservation of mass. Mathematically, the mass balance for a system without a chemical reaction at a steady state is as follows:

$$m_{in} = m_{out} \tag{1}$$

where m_{in} is the total mass input (g), and m_{out} is the total mass output (g).

As for the energy requirements, the calculated values were determined indirectly since the heat absorbed or evolved cannot be directly measured and obtained. The direction of the heat transfer for each process was determined from the ΔT which could be expressed as

$$q = mCp\Delta T \tag{2}$$

where q is the heat absorbed or released from by a substance (kJ), m is the measurement of the total amount of substance (kg), Cp is a thermodynamic property specific of a substance used to transfer heat (kJ kg^{-1} $^oC^{-1}$), and ΔT is the difference in temperature before and after heat transfer (^oC).

Table 1. Overall material balance and energy requirements for production of carrageenan

Process	Incoming Stream <Stream number>	Amount (g)	Outgoing Stream <Stream Number>	Amount (g)	Energy requirement (kJ)
Washing	Raw seaweed <1>	1000	Washed seaweed <3>	1000	-
	Tap water <2>	2991	Wastewater <4>	2991	
	Total	**3991**	**Total**	**3991**	
Sun-drying	Washed seaweed <3>	1000	Dried seaweed <6>	99.34	**20.93**
			Water vapor	900.66	

			<5>		
	Total	**1000**	**Total**	**1000**	
Cutting	Dried seaweed <6>	99.34	Trimmed seaweed <7>	99.34	-
	Total	**99.34**	**Total**	**99.34**	
Alkali treatment	Trimmed seaweed <7>	99.34	Treated seaweed mixture <10>	1085.21	**266.22**
	KOH solution <8>	1057	Water vapor <9>	71.13	
	Total	**1156.34**	**Total**	**1156.34**	
Blending	Treated seaweed mixture <10>	1085.21	Blended seaweed mixture <12>	1085.21	-
	Total	**1085.21**	**Total**	**1085.21**	
Neutralization	Blended seaweed mixture <12>	1085.21	Neutralized mixture <15>	2223.81	**83.78**
	Hot water <13>	997			
	HCl solution <14>	141.6			
	Total	**2223.81**	**Total**	**2223.81**	
Filtration	Neutralized mixture <15>	2223.81	Filtered mixture <17>	1990.82	-
			residue <16>	232.99	
	Total	**2223.81**	**Total**	**2223.81**	
Precipitation	Filtered mixture <17>	1990.82	Carrageenan gel <20>	223.56	-
	KCl solution <18>	1012	Filtrate <19>	2779.26	
	Total	**3002.82**	**Total**	**3002.82**	

Gel pressing	Carrageenan gel <20>	223.56	Pressed carrageenan gel <22> Filtrate <21>	148.26 75.3	**-**
	Total	**223.56**	**Total**	**223.56**	
Drying	Pressed carrageenan gel <22>	148.26	Carrageenan <24> Vapor <23>	19.39 128.87	**3.10**
	Total	**148.26**	**Total**	**148.26**	
Grinding	Carrageenan <24>	19.39	Powdered carrageenan <25>	19.03	**-**
	Total	**19.39**	**Total**	**19.03**	

As shown in Table 1, there is no deviation for the mass balance in each unit process and unit operation except for the grinding process which had a percentage error of 1.86%. This percent error is acceptable since it does not exceed 5% and was sourced from the repeated grinding process using a mortar and pestle. For the energy requirement, a positive value indicates that the substance is absorbing heat from a heat source, or its chemical reaction is releasing heat to the body, or it undergoes an exothermic reaction.

The treatment with alkali induces desulfation of the polysaccharide, causing formation of a 3,6AG bridge (between C3 and C6 in the 4-linked-α-L-galactose units) which leads to increase in the gel strength (Rees,1970). Among all the processes, the alkali treatment had the highest energy requirement which means that the energy required to initiate the formation 3,6 AG linkages and induce desulfation of the polysaccharide is relatively high.

4.3 Overall and component yields of every unit process and operation

The overall and component yields of every unit process and operation were calculated using the yield equation which is

$$\%yield = \frac{refined\ carrageenan\ mass}{dried\ seaweed\ mass} \times 100 \qquad (3)$$

Table 2. Overall and component yields of lab-scale carrageenan production

Process	**Yield (%)**
Washing	100.00
Sun-drying	9.93

Cutting	100.00
Alkali treatment	93.85
Blending	100.00
Neutralization	100.00
Filtration	89.52
Precipitation	7.45
Gel pressing	66.32
Drying	13.08
Grinding	98.14
Overall carrageenan yield	**19.52**

As shown in table 2, the sun-drying process percent yield was very low at only 9.93%. This signifies that around 90% of the moisture content was lost from the seaweed. This is significantly greater than the 60% average reduced moisture (Mayol et al, 2019).

On a dry weight basis, the yield range of carrageenan is 61.5-67.5% (Ninghidayati et al, 2017). In this experiment, the carrageenan yield is significantly low at only 19.52%. This indicates optimal process conditions were not achieved during the experiment. The carrageenan yield can be increased by optimizing the KOH concentration, extraction time, precipitation time, heating temperature, and seaweed to solution ratio (Webber et al, 2012).

4.4 Critical steps in the production of cheese

Carrageenan, a hydrocolloid, is an important material which has found applications in human food and the pet-food industry. It is used as a stabilizer, thickener, gelling agent and emulsifier (Van de Veldeet al., 2002). The production of high-quality carrageenan entails critical steps namely alkali treatment, neutralization, precipitation and drying.

In the extraction process or alkali treatment, 99.34 grams of dried seaweed was soaked in one liter of 6% potassium hydroxide and was heated to 90 ◦C for thirty minutes. An appropriate temperature of 70-90 ºC is required to initiate the extraction process (Rideout & Bernabe, 1997). The treatment with alkali induces desulfation of the polysaccharide, causes the formation of 3,6AG bridges (between C3 and C6 in the 4-linked-α-L-galactose units) which leads to increase in the gel strength (Rees,1970).

After the extraction process, the treated seaweed mixture was neutralized by adding 120 milliliters of hydrochloric acid. The extracted carrageenan in the solution has a maximum stability of pH=9 and should not be heat processed at pH below 3.5. At pH=6 or above, carrageenan solutions withstand processing conditions. Also, at neutral pH, carrageenan is stable (Manuhara et al., 2016).

At neutral condition, the carrageenan was precipitated by adding one liter of 1.5% potassium chloride solution which increases the gel strength of the produced refined carrageenan (Arfini, 2011). In this step, optimizing the precipitation time and KCl concentration increases the yield of carrageenan gel (Astuti et al, 2017). The carrageenan gel was dried at 30 ºC in an oven for 24 hours. This step ensures that the excess KCl and moisture content is removed. The drying temperature was kept low and constant to avoid burning the carrageenan gel.

5. Conclusions

In the production of carrageenan from E. cottoni, the raw material undergoes eight major steps namely washing, sun-drying, cutting, alkali treatment, blending, neutralization, filtration, precipitation, drying and grinding. The unit process and unit operation process conditions as well as stream specifications were monitored. The data recorded was used to determine the mass balance and energy specification of the whole production process.

The process has produced 19.09 grams of refined carrageenan or approximately 20% carrageenan yield from 99.34 grams of dried seaweed. The total energy requirement in this production is 374.03 kJ of energy. The critical steps identified in this production process are alkali treatment, neutralization, precipitation and drying.

References

Arfini, F., 2011. Optimasi Proses Ekstraksi Pembuatan Karaginan dari Rumput Laut Merah (Eucheuma cottonii) serta Aplikasinya sebagai Penstabil pada Sirup Markisa. Retrieved on October 30, 2021 from http://jurnalpertanianumpar.com/index.php/jgt/article/viewFile/39/41

Cyber Colloids. (n.d.). *Introduction to Carrageenan - Production.* Retrieved from http://www.cybercolloids.net/information/technical-articles/introduction-carrageenan-production

Manuhara, G. J., Praseptiangga, D., & Riyanto, R. A. (2016). Extraction and Characterization of Refined K-carrageenan of Red Algae [Kappaphycus Alvarezii (Doty ex P.C. Silva, 1996)] Originated from KarimunJawa Islands. *Aquatic Procedia,* 7, 106–111.

Ninghidayati, S., R., A. N., Gunardi, I., & Roesyadi, A. (2017). *Production of carrageenan from seaweed (Eucheuma cottonii) with KOH treatment*.

Normah, O., & Nazarifah, I. (2003). Production of semi-refined carrageenan from locally available red seaweed, Eucheuma cottonii on a laboratory scale. *J. Trop. Agric. and Fd. Sc,* 31(2), 207–213.

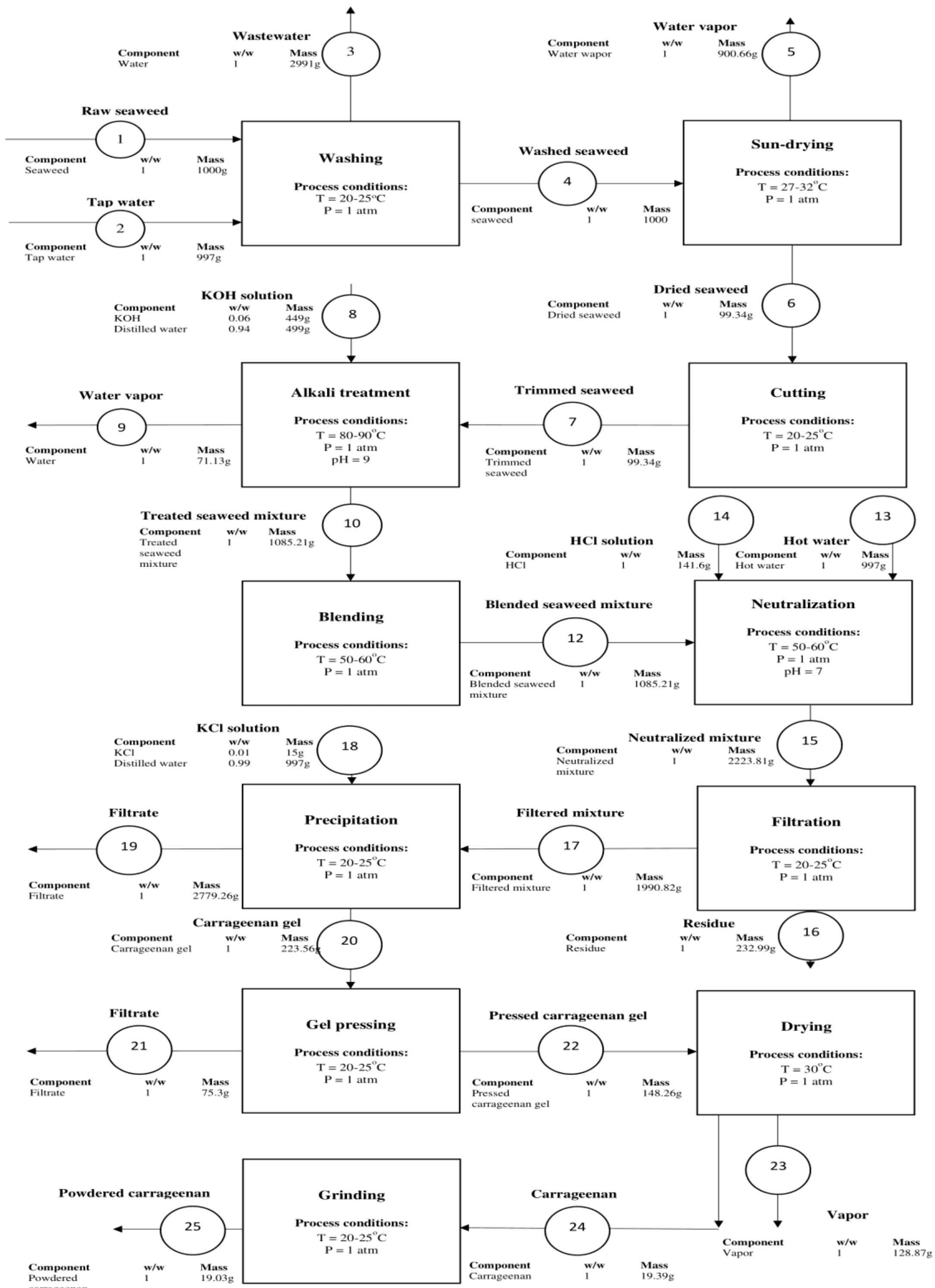
Rhein-Knudsen, N., Ale, M., & Meyer, A. (2015). Seaweed Hydrocolloid Production: An Update on Enzyme Assisted Extraction and Modification Technologies. *Marine Drugs*, 13(6), 3340–3359. Stanley, N. (n.d.). Chapter 3 - Production, Properties and Uses of Carrageenan. Food and Agricultural Organization of the United Stations. Retrieved from http://www.fao.org/3/x5822e/x5822e05.htm

Webber, V., Carvalho, S., Ogliari, P., Hayashi, L., & Barreto, P. (2012). Optimization of the extraction of carrageenan from Kappaphycus alvarezii using response surface methodology. Food Science and Technology, 32(4), 812-818. doi: 10.1590/s0101-20612012005000111

Yasita, D., (2010). Optimization of Extrusion Process of Carrageenan Manufacturing from Eucheuma cottonii to Food Grade]. [Undergraduate Thesis]. Semarang: Jurusan Teknik Kimia Fakultas Teknik Universitas Diponegoro. [Bahasa Indonesia].

ANNEX

ANNEX A: Process Flowsheet



ANNEX B: Financial Report

Table 1. Proposed Budget for Materials

Item Description	*Quantity*	*Cost/Unit*	*Subtotal*
[1] Distilled Water	2 L	25/L	₱ 50.00
[2] Hydrochloric Acid (HCl)	300g	0.255/g	₱ 76.50
[3] Potassium Chloride (KCl)	15 g	0.075/g	₱ 1.25
[4]Potassium hydroxide (KOH)	60 g	1.60/g	₱ 96.00
[5] Seaweed (E.cottonii)	1 kg	50/kg	₱ 50.00
[6] Tap Water*	8 L	15/m^3	₱ 0.12
		Total	₱ **273.87**

*Note: Materials with * are available in the household.*

Table 2. Proposed Budget for Laboratory Equipment/Apparatus Use

Item Description	*Quantity*	*Cost/Unit*	*Subtotal*
[1] Beaker	1 pc	90/pc	₱ 90.00
[2] Blender*	1 unit	399/unit	₱ 399.00
[3] Casserole Pot*	1 pc	370/pc	₱ 370.00
[4] Container/s*	1 pc	114/pc	₱ 114.00
[5] Digital pH Meter*	1 unit	399/unit	₱ 399.00
[6] Digital Scale*	1 unit	149/unit	₱ 149.00
[7] Dropper	3 pcs	36/pc	₱ 108.00
[8] Filtration Cloth	1 roll	100/roll	₱ 100.00
[9] Measuring Set*	1 set	135/set	₱ 135.00
[9] Mortar & Pestle	1 pc	100/pc	₱ 100.00
[10]Scissors*	1 pc	85/set	₱ 85.00
[11] Thermometer*	1 pc	129/pc	₱ 129.00
[12] Timer	1 pc	273/pc	₱ 273.00
[13] Tongs*	2 pcs	100/pc	₱ 200.00
		Total	₱ **4,410.00**

*Note: Equipments/Apparatuses with * are available in the household.*

Table 3. Proposed Energy Costs

Room	*Use*	*kWh*	*Cost/Unit*	*h/day*	*No. of days*	*Subtotal*
[1] Monsanto's House	Interior Lighting	0.005	12.02/kWh	24	30	₱ 43.27
	Electric Blender	2.4	12.02/kWh	2	2	₱ 115.39
	Oven	2.3	12.02/kWh	2	2	₱ 110.58
					Total	₱ **269.24**

Note: The effective (kwh) rate for residential customers is based on VECO electricity rate for August 2021.

Table 4. Overall Costs

Grand total	₱ 4,953.11
Grand total (with 20% contingency)	*₱ 5943.73*

ANNEX C1: Raw Data Sheets

Table 1. Preparation of Raw Materials

Mass of raw seaweed, g	**1000 g**
Number of Washing	**3**
Liters of water per washing, L	**1 L**
Liters of wastewater in first washing, L	**1 L**
Liters of wastewater in second washing, L	**1 L**
Liters of wastewater in third washing, L	**1 L**
Mass of dried seaweed, g	**99.34 g**

Table 2. Masses of input and output materials

ALKALI TREATMENT	
Mass of seaweed, g	**99.34**
Liters of KOH solution, L	**1**
Mass of container, g	**323.58**
Mass of container with blended seaweed mixture, g	**1408.79**
Mass of blended seaweed mixture, g	**1085.21**
NEUTRALIZATION	
Liters of hot water, L	**1**
Liters of 100% HCl, L	**0.12**
Mass of container with mixture, g	**2550.39**
Mass of mixture, g	**2226.81**
FILTRATION	
Mass of residue, g	**234.99**
Mass of container with filtered mixture, g	**2315.40**
Mass of filtered mixture, g	**1990.82**

KCl PRECIPITATION	
Liters of KCl solution, L	**1**
Mass of container with carrageenan gel, g	**346.78**
Mass of carrageenan gel, g	**223.56**
GEL PRESSING	
Mass of pressed carrageenan gel, g	**148.26**
DRYING	
Mass of vapor, g	**128.87**
Mass of carrageenan, g	**19.39**
GRINDING	
Mass of container with carrageenan powder, g	**142.25**
Mass of carrageenan powder, g	**19.03**

Table 3. pH readings

pH of water	**7**
pH of KOH solution	**13**
pH of carrageenan mixture (alkali treatment)	**12**
pH of HCl	**3**
pH of carrageenan mixture (neutralization)	**7**
pH of KCl	**6**

Table 4. Temperature readings

Temperature of KOH solution, ^oC	**38**
Temperature before heating, ^oC	**35**
Temperature during heating, ^oC	**90**
Room temperature, ^oC	**25**

Temperature before neutralization, ^oC	**50**
Temperature during neutralization, ^oC	**59**
Temperature before drying, ^oC	**25**
Temperature during drying, ^oC	**30**

Table 5. Observations

In sun drying process	After 4 hours of sun drying, the pigment of the seaweed changed from green to white. After sun drying for three days, the pigment of the seaweed changed from white to light brown. By observation, I saw that the volume of the seaweed drastically lowered after sun drying for three days.
In alkali treatment	After adding the KOH solution, bubbles started to form in the seaweed mixture. As the seaweed mixture was heated, more bubbles were observed, and the seaweed started to look gelatinous. After 30 minutes of heating at 90^oC, the mixture became viscous and had a dark brown color.
In blending	The seaweed mixture was relatively easy to blend using an electric blender. After adding hot water, the mixture had a light brown color and was less viscous.
In neutralization	During neutralization, a total of 120 mL of HCl was added to the mixture dropwise. As more and more HCl was added, the mixture also started to heat up and bubble formation was also observed. I stopped adding HCl after seeing the pH paper turn green.
In KCl precipitation	After adding the KCl solution, a clear white gel started to precipitate in the mixture. There was no observable change in the temperature of the mixture.
In gel pressing	The clear white gel had a lot of excess water which was removed by pressing the gel.
In drying	It took 1 whole day to dry the carrageenan gel using an oven. After the drying process, the carrageenan gel became lightweight and had a rough texture. The color of the gel also changed from clear white to light brown.
In grinding	The carrageenan was very hard to grind using a mortar and pestle. After grinding for 2 hours, the carrageenan particles were still large, and it still had a coarse texture.

ANNEX C2: Data Processing & Analysis Report

Table 1. Energy requirement for each process in soap production

Process	Mass (g)	Heat Capacity	Initial Temperature (^oC)	Final Temperature (^oC)	Energy Requirement (kJ)

		(kJ kg^{-1} ^{o}C^{-1})			
Washing	3991	4.19	25.0	25.0	-
Sun drying	1000	4.19	25.0	30.0	20.93
Cutting	99.34	4.19	25.0	25.0	-
Alkali treatment	1156.34	4.19	34.0	34.0	266.22
Blending	1085.21	4.19	60.0	60.0	-
Neutralization	2223.81	4.19	50.0	59.0	83.78
Filtration	2223.81	4.19	25.0	25.0	-
Precipitation	3002.82	4.19	25.0	25.0	-
Gel pressing	223.56	4.19	25.0	25.0	-
Drying	148.26	4.19	25.0	30.0	3.10
Grinding	19.39	4.19	25.0	25.0	-

Table 2. Overall and component yields of lab-scale soap production

Process	**Input mass (g)**	**Output mass (g)**	**Yield (%)**
Washing	1000	1000	100.00
Sun drying	1000	99.34	9.93
Cutting	99.34	99.34	100.00
Alkali treatment	1156.34	1085.21	93.85
Blending	1085.21	1085.21	100.00
Neutralization	2223.81	2223.81	100.00
Filtration	2223.81	1990.82	89.52
Precipitation	3002.82	223.56	7.45
Gel pressing	223.56	148.26	66.32
Drying	148.26	19.39	13.08
Grinding	19.39	19.03	98.14
Overall carrageenan yield	**99.34**	**19.03**	**19.52**

Sample Calculations:

Energy Requirement:

Process: Alkali treatment

Data Required: m = 1156.34 kg

Cp = 4.19 kJ kg^{-1} ^{o}C^{-1}

$T_{initial}$ = 35.0 ^{o}C

T_{final} = 90.0 ^{o}C

Solution:

$$q = mCp\Delta T$$
$$= (1156.34kg)\left(4.19\frac{kJ}{kg\cdot ℃}\right)(90.00 - 35.0)℃$$
$$= \mathbf{530.68\ kJ}$$

Component Yield:

Process: Alkali treatment

Data Required: Mass of input = 1156.34 g
Mass of output = 1085.21 g

Solution:

$$\%yield = \frac{total\ product\ mass}{raw\ material\ mass} \times 100$$
$$= \frac{1085.21\ g}{1156.34\ g} \times 100$$
$$= \mathbf{93.85}\ \%$$

Overall Yield:

Data Required: Mass of raw material = 99.34 g dried seaweed
Mass of product = 19.03 g refined carrageenan

Solution:

$$\%yield = \frac{product\ mass}{raw\ material\ mass} \times 100$$
$$= \frac{19.03\ g}{99.34\ g} \times 100$$
$$= \mathbf{19.52}\ \%$$

ANNEX D: Pictures of Actual Conduct of Experiment

1. Washing


Figure 1.1 First washing


Figure 1.2 Second washing


Figure 1.3 Third washing

2. Sun drying


Figure 2.1 Day 1 of sun drying


Figure 2.2 Day 2 of sun drying


Figure 2.3 Day 3 of sun drying

3. Cutting


Figure 3.1 Cutting of dried seaweed

4. Alkali treatment


Figure 4.1 Preparation of KOH solution


Figure 4.2 Alkali treatment of dried seaweed

5. Blending


Figure 5.1 Blending of extracted seaweed mixture

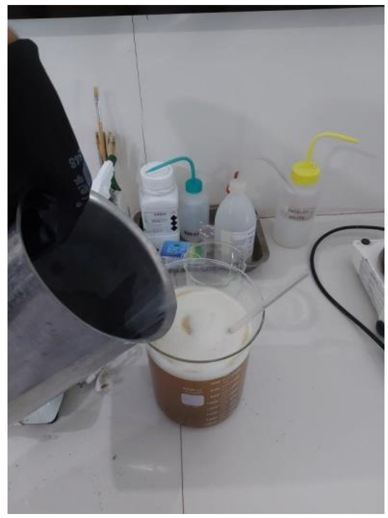


Figure 5.2 Addition of hot water

6. Neutralization

Figure 6.1 Addition of HCl

Figure 6.2 Checking of pH

7. Filtration

Figure 7.1 Straining of undissolved seaweed

8. KCl precipitation


Figure 8.1 Preparation of KCl Solution


Figure 8.2 Addition of KCl solution

9. Gel pressing


Figure 9.1 Filtration of carrageenan gel


Figure 9.2 Pressing of carrageenan gel

10. Drying

Figure 10.1 Oven drying of carrageenan gel

11. Grinding

Figure 11.1 Grinding of carrageenan