New York Sea Grant Kelp Value Added Processing Report

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Sea Grant
NEW YORK

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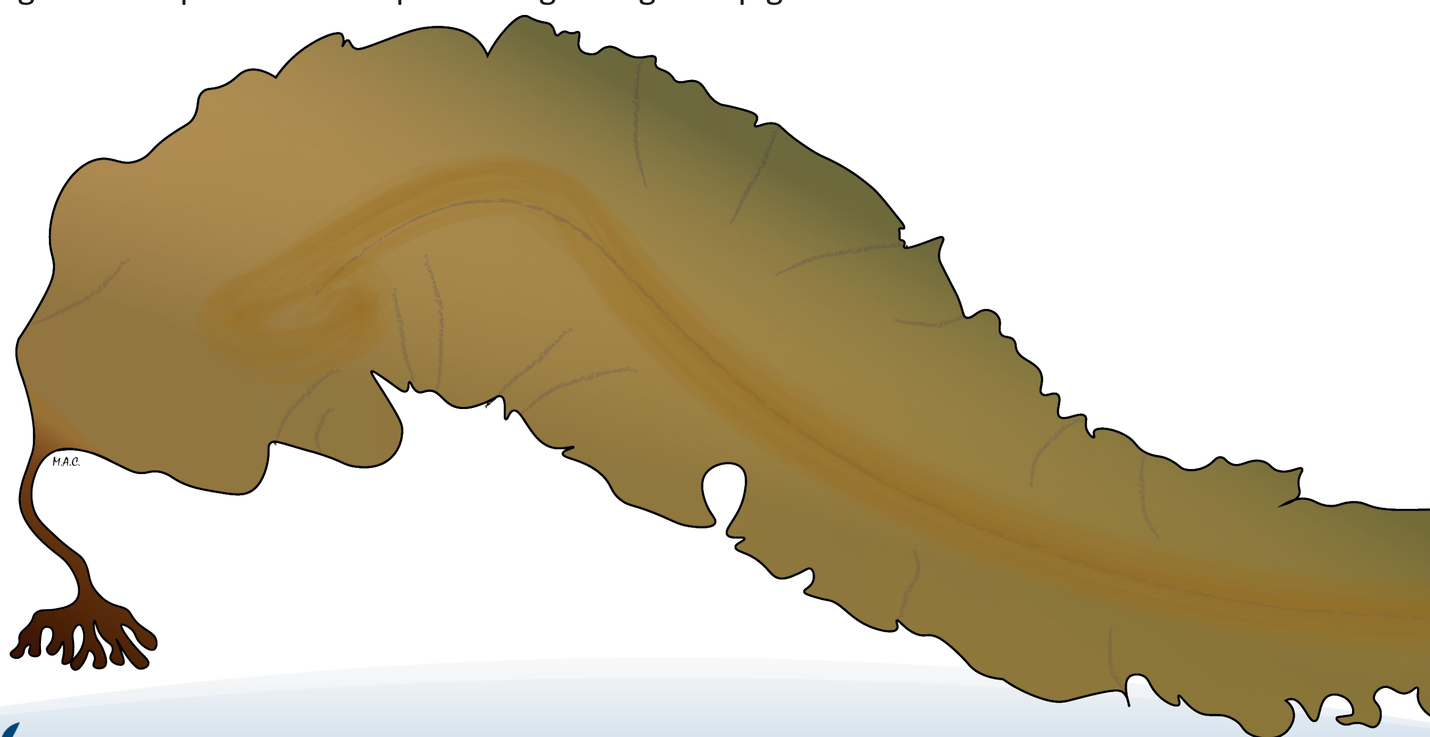
This report was developed by New York Sea Grant in partnership with the Cornell Food Venture Center and support from Lazy Point Farms. Contents represent findings from pilot studies exploring the transportation and processing of sugar kelp grown in New York waters.



Introduction

Seaweed has been consumed by humans for centuries, eaten in coastal regions around the world (McHugh 2003). More recently, seaweed is being recognized as a multi-use, climate-friendly crop that is becoming more prominant across the US and Europe (Bruhn et al. 2019). For this exciting food to safely reach consumers, it must be harvested and processed in a timely manner to maintain quality and ensure safety. In collaboration with the Cornell Food Venture Center, New York Sea Grant is working to identify best practices for harvesting, handling, and processing seaweed for human consumption.

The brown seaweed, or Phaeophyta, *Saccharina latissima*, also referred to as “sugar kelp” or “kelp” is the most commonly farmed species in the United States (Grebe et al. 2019). Kelp contains many vitamins, minerals, proteins, and other valuable nutrients (Mouritsen et al. 2018) and has a wide variety of applications: it is used in many food products, as an ingredient in condiments and seasonings, and as a functional ingredient in beauty, pharmaceutical, and industrial products such as fertilizers, makeup, and medicine (Tibbets et al. 2016 and Bruhn et al. 2019).

The expanding US kelp industry needs detailed and science-based processing methods to assure the quality and safety of its seaweed products. Assuring product safety and quality is essential to the growth of the industry and the acceptability of new value-added products (McHugh 2003; FAO and WHO 2022). Kelp harvested for human consumption falls under the FDA Food Safety Modernization Act jurisdiction, which requires compliance with Preventive Controls Rule for facilities that do not meet the listed exemptions. This regulation requires producers to develop a food safety plan for each processed kelp product to address any biological, chemical, physical, and radiological hazards of concern. In order to develop effective food safety plans producers need to understand the processes and products that can and will be created and the food safety hazards associated with them.

Blanched Sugar Kelp

Pilot studies conducted in partnership with Lazy Point Farms and the Cornell Food Venture Center examined several options for value-added sugar kelp products. While these studies do not constitute rigorous scientific study worthy of peer review and publicaiton, the results are a good starting point for learning and understanding some methods for processing and holding sugar kelp products. These pilot studies provide insights into handling and processing options including transport, blanching, drying, chemical sanitation, and fermentation of sugar kelp. In addition, nutritional analysis and sensory evaluation was carried out to assess the various processing and stabilization methods.

Transport

Evaluating and Optimizing Kelp Transport Methods

Sugar Kelp was harvested from Moriches Bay in April of 2022 and transported in coolers to Cornell's Food Venture Center in Geneva, NY to conduct stabilization and value-added processing studies. A second harvest from Setauket Harbor in May of 2022 was shipped overnight to the Food Venture Center. During the April harvest several transport methods were assessed as described below.

Cooler #1

Cooler #2

Cooler #3

Wet Sugar Kelp was placed in plastic bags with air and twisted at the top to prevent crushing of the kelp. Rubber bands were use to keep the bags closed. Ice packs were placed at the bottom of the cooler and on top of the bags.

Wet sugar kelp was placed in plastic tubs with and without sterile saltwater. Plastic lids were secured and tubs were surrounded by ice in the cooler. There were four tubs in the cooler, two with water and two without.

Ice packs were placed at the bottom of the large cooler with cheese cloth on top. Kelp was loosely placed into the cooler on top of the ice packs covered in cheese cloth.

Ultimately all three methods allowed for transport of kelp and maintained temperatures below 50°F. The method used in cooler #3, was identified as the most effective because it involved minimal effort and handling of the kelp and resulted in similar transport temperatures to the other methods. It is also the least costly of the three and most realistic for mass transport of kelp. While maintaining temperatures below 50°F were sufficient to produce a safe shelf stable dried product, the use of temperatures above refrigeration temperatures of 41°F (US FDA Food Code) should still be adhered to for product intended for raw consumption. The presence of potential microbial pathogens on raw product not subject to a sanitation/stabilization step was not evaluated in this study. Temperatures above 41°F are known to support pathogen growth in most foods, thus the subsequent sanitation steps were necessary to ensure products transported above these temperatures were safe for consumption (USFDA 2022).


2022 Sugar Kelp Harvest, Moriches Bay, Violet Cove Oyster Co.

Harvest and Transport of Kelp for Consumption

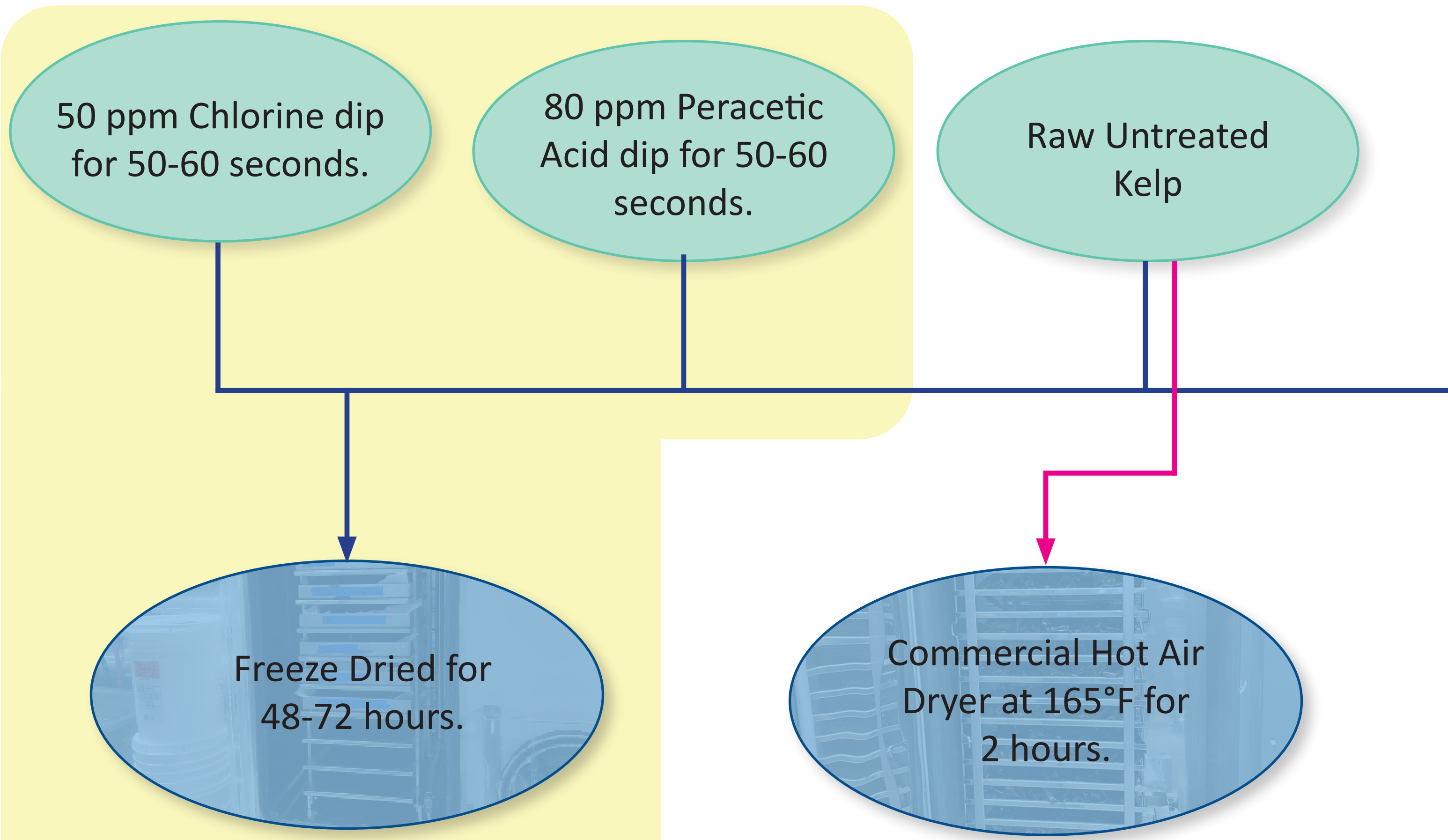
Sugar kelp destined for raw consumption warrants extra precautions during transport to prevent pathogen contamination and growth. The recomendations below are based on general guidelines for food handling outlined in the FDA's Food Code. Ammendments to the procedures below require scientific evidence that alternative practices will not result in significant pathogen contamination and growth on raw kelp. While the handling recommendations below are necessary for raw kelp, it is best practice to implement during harvest and handling of any kelp destined for food to maintain quality and reduce the risk of contamination and transfer of pathogens to processing facilities.

1) Harvest kelp using clean gloves and harvest utensils.
2) Collect blades in clean and sanitized food grade containers and store under refrigeration, ≤ 41ºF covered and protected from environmental contamination.
3) Handling and storage of kelp should be done under hygienic conditions that reflect Good Manufacturing Practices guidelines stated in 21 CFR Part 117.
4) Processing should be done within 48 hours of harvest if kept under 41°F. If kept under 38°F, processing can be done within 72 hours of harvesting.

Stabilization

Sugar kelp was transported to the Cornell University Food Venture Center in Geneva, NY for value-added processing studies. Kelp was subject to sanitation and drying steps to reduce pathogen loads and generate a shelf stable dry powdered product. The diagram below depicts the various treatments used on the sugar kelp and highlights some key findings.

Sanitation and Drying Procedures



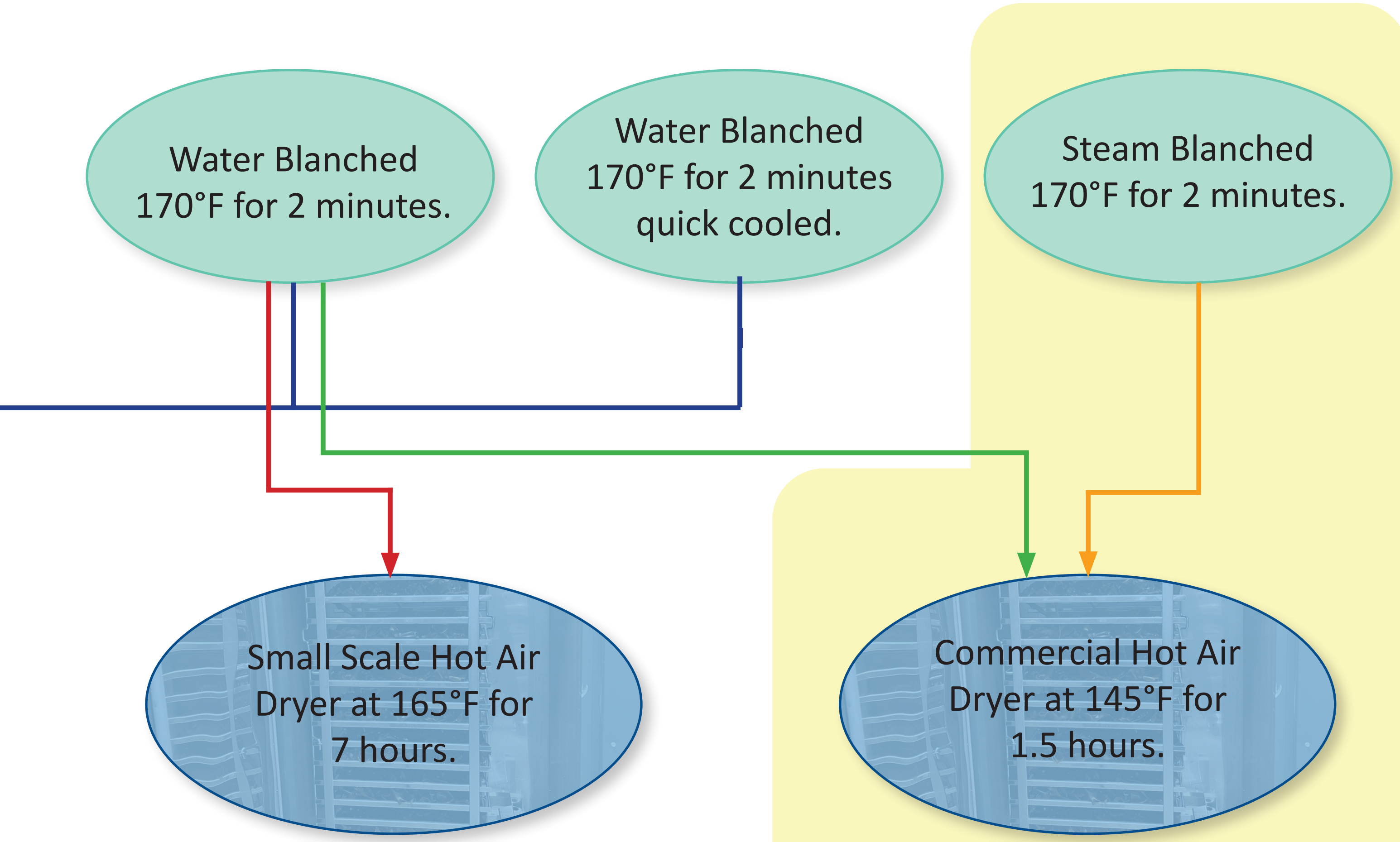
Inefficient sanitation and leaching.

Chemical sanitizer concentrations quickly dropped after the addition of kelp. Inability to effectively maintain appropriate sanitizer concentrations suggests that this will be an inefficient and costly method of stabilizing sugar kelp.

Equipment

Below is the list of equipment used for these pilot studies.

- » Freeze Dryer: Freeze Dryer Max 53 Millrock Technology, Kingston, NY
- » Commercial Air Dryer: Nyle Systems FD 2.5 Food Dehydrator, Brewer, ME
- » Small Scale Dryer: Model D-20, The Sausage Maker Inc., Buffalo, NY



Ideal method for maintaining quality

The small scale hot air dryer was inefficient and took too long to fully dry the kelp. Commercial drying equipment will be important for quick and effective drying. All drying methods resulted in shelf stable product with a water activity below 0.6.

Sanitation Trials

Several sanitation steps were assessed to initially decrease the number of potential pathogens present on the raw kelp products before they were dried. The subsequent drying step reduced water activity in the products, which limits future growth of any remaining pathogens. There were two categories of sanitation assessed, the first was chemical sanitation and the second was thermal. Each of these methods and the observations made will be discussed below.

Sanitation Procedures for Sugar Kelp

Chemical

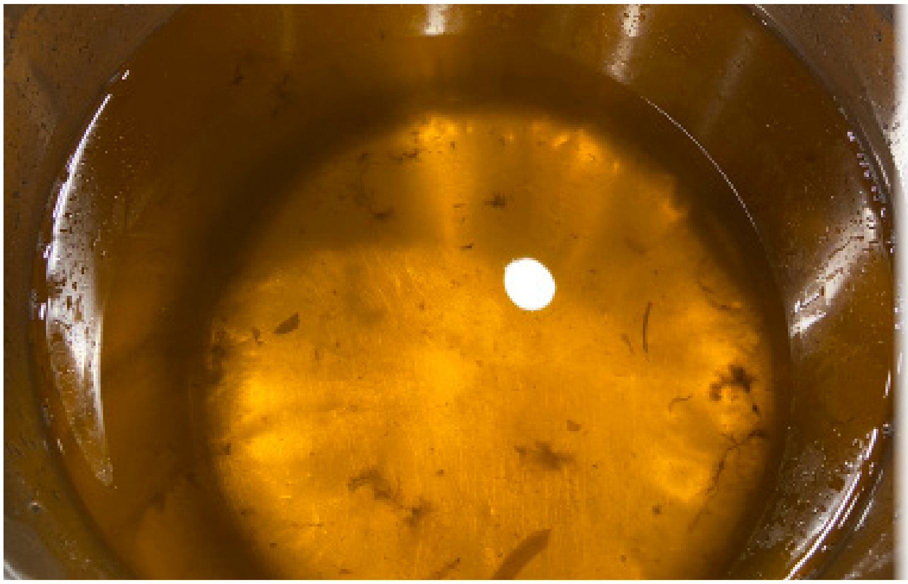
Chemical sanitation was achieved through the use of chlorine and peracetic acid, two common food grade chemical sanitizers. Sanitizers were diluted in freshwater to 50ppm (chlorine) and 80ppm peracetic acid, which are commonly used for other raw agriculture products like fruits and vegetables. The kelp was submerged in the sanitizer solution as shown below for 50-60 seconds then drained and removed for drying.

Thermal

Temperature was also used as a sanitation step for the sugar kelp. Temperature was applied through a hot water bath or steam blancher at 170°F for two minutes before drying.

Blistering

The chemical dips in freshwater resulted in blistering of the kelp. While this is likely not an issue for kelp destined to be dried and milled, it would be unappealing for kelp destined for raw consumption. Thus, chemical sanitation is likely not a realistic method for extending the shelf life of kelp for raw consumption.



Leaching

During the water blanch and the chemical dips, leaching of pigment from the kelp occurred, quickly resulting in the water discoloration in the photo to the left. More work needs to be done to identify exactly what is leaching out of the seaweed during blanching. This could have significant impacts of the nutritional components of the kelp. Additional research is needed to fully understand what is leached out of the kelp during blanching and freshwater dips.

Blanching

While both steam and hot water blanching were effective, the water blanching resulted in more leaching and ultimately a bland tasting final dried product. Steam blanching caused less leaching and the final dried product had a more distinct salty seaweed flavor. Initial results suggest blanching method will depend on the final product characteristics you are looking for.

Microbial Analysis

Microbial Plate Counts

To assess the microbiological quality of the dried samples, samples were analyzed for total aerobic plate counts (APC), which is a measure of the total number of spoilage and pathogenic microbes, and for yeast and mold counts (PDA). Nearly all samples from both harvests had APCs well below 6-log CFU/g, which is the commonly accepted spoilage threshold for foods. The exception was the water blanched quick cooled + freeze dried sample, which had a APC close to 6-log (CFU/g) at 5.41 log (CFU/g). The water blanched freeze dried samples all showed higher microbial counts. These data indicate the water blanching method applied at 170°F for 2 min may not be sufficient, and higher temperature and/or time may be needed to decrease microbial counts. Methods like steam blanching or using sanitizers seemed to be more effective based on the results obtained. These initial results indicated the sanitizer dips are effective in reducing plate counts, but the impact chemical dips have on product quality (such as leaching) indicates steam blanching may be the optimal sanitizing method to retain high quality products.

Table 1: Microbial Analysis of kelp samples.

Sample	Total PCA (Log CFU/g)	PDA (Log CFU/g)
Chlorine + Freeze Dry	2.08	<1.00
Peracetic Acid + Freeze Dry	3.18	<1.00
Raw + Hot Air Dry	3.92	<1.00
Raw + Freeze Dry	2.66	<1.00
Steam Blanch + Hot Air Dry	2.82	<1.00
Water Blanch, Quick Cool + Freeze Dry	5.41	2.11
Water Blanch + Hot Air Dry	3.40	3.29
Water Blanch + Freeze Dry	4.09	<1.00
Water Blanch + Small Hot Air Dry	5.52	3.91

PCA = Aerobic Plate Count; PDA = Yeast and Mold Count

Drying

Drying Procedures

Many dried products in the modern food system control water activity (aw) at a level of 0.85 or less to avoid the growth of pathogens and other spoilage microorganisms such as molds, bacteria, and yeasts (USFDA 2014). To completely control the possibility of any organism growth the aw of a product must be at 0.6 or below (USFDA 2014). Through these pilot studies several drying methods were tested to reduce the water activity of the kelp to limit microbial growth after applying the sanitation steps, which are designed to reduce the number of microbes present.

Hot Air Drying

Sugar kelp was dried in a commercial Nyle hot air dryer. Drying was carried out at either 165°F for two hours or 145°F for one and a half hours. The lower time and temperature process achieved similar results and is recommeded to reduce time and energy required for kelp stabilization. A small-scale hot air food dryer (Model D-20; The Sausage Maker Inc., Buffalo, NY) was also used but required seven hours to adequately dry the kelp, thus it is not recommended for commercial production.

Commercial Air Dryer: Nyle Systems FD 2.5 Food Dehydrator (discontinued but new models available)

Freeze Drying

Kelp samples were also freeze dried (depicted below) for 24-48 hrs. Freeze drying is a method of drying that removes moisture from a frozen product under high pressure, which results in vaporization and removal of water. This method is commonly used to reduce nutrient loss and product changes that can result when heat is applied through more traditional drying procedures. While freeze drying was effective, the high cost of the equipment may be cost prohibitive without a significant market in place for freeze dried kelp.

Freeze Dryer Max 53 Millrock Technology

Large-scale dryers are more expensive, but they do perform better and create a safer, better quality dried product. Co-op style sharing could be an alternative to buying expensive equipment.

Impact of Sanitation and Drying on Color and Flavor

The visual appearance and flavor profiles for the dried sugar kelp were evaluated to assess quality and potential uses and are shown in pictures 1-8 on the following pages. Focusing on samples harvested at the same time and location, treatment had an impact on overall visual appearance (color) of the processed kelp. Hot air dried kelp was darker in color, with freeze dried kelp maintaining more green coloration. Chemical sanitation also altered the color of the kelp (pictures 3 and 4). Taste tests revealed that those not subject to submersion in water had the most flavor. Submerging the kelp in fresh water resulted in a muted, less salty flavor profile.

Dried Kelp Sensory Evaluation

Raw Hot Air Dried

Raw Freeze Dried Kelp

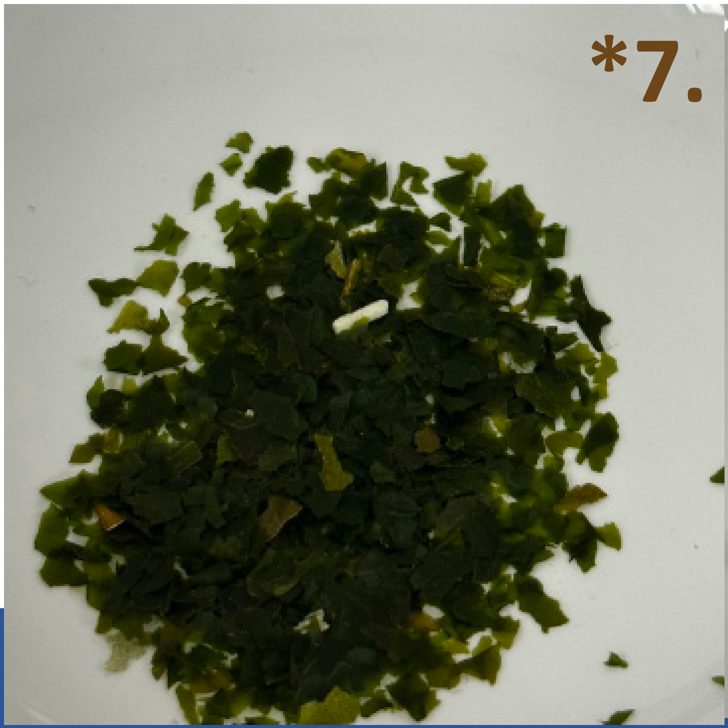
Steam Blanched Hot Air Dried

Water Blanched Hot Air Dried

*Note that samples 1-4, and 8 were from the first harvest from Violet Cove in Moriches Bay, Samples 5-7 were harvested at a later date from Setauket Harbor, NY.

Chlorine Dip Freeze Dried

PAA Dip Freeze Dried



Water Blanched Quick Cool Freeze Dried

Water Blanched Freeze Dried

Visual evaluation of sugar kelp subject to different sanitation and drying processes.

Nutrition

Compositional Analysis of Dried Kelp

Table 2. Proximate Analysis of Sugar Kelp.

Sanitation Method	Drying Method	Moisture (%)	Crude Protein (%)	Crude Fiber (%)	Crude Fat (%)	Ash (%)
Chorine Dip	Freeze Dried[1]	7.7	13.7	4.0	2.59	34.62
Peracetic Acid Dip	Freeze Dried[1]	7.6	14.3	4.6	1.97	32.55
Steam Blanched	Commercially Hot Air Dried[2]	6.2	6.3	4.9	1.37	31.88
Water Blanched	Quick Cooled Freeze Dried[1]	12.0	20.2	12.1	3.56	9.44
	Freeze Dried[1]	9.7	20.2	10.2	3.69	12.89
	Commercially Hot Air Dried[2]	10.3	9.7	13.2	2.83	17.55
	Small Scale Hot Air Dried[1]	11.4	19.6	10.3	3.48	15.02
Raw	Air Dried[1]	6.6	12.9	3.8	1.93	38.17
	Freeze Dried[1]	6.9	13.6	4.6	2.05	39.47

[1]Harvested April 8, 2022; Moriches Bay [2]Harvested May 25, 2022; Setauket Harbor

Proximate analysis is a commonly used means of measuring the main components of a food. There are five main components that are measured, which include moisture, crude protein, crude fiber, crude fat, and ash.

Moisture - The percent moisture in a food is a measure of the amount of water in the food.

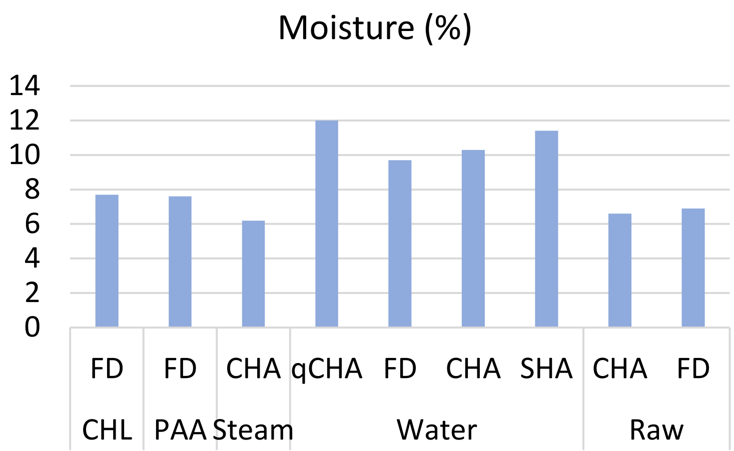
Crude Protein - Crude protein is an estimation of a food's protein content based on the amount of nitrogen, a major component of protein, present in the food.

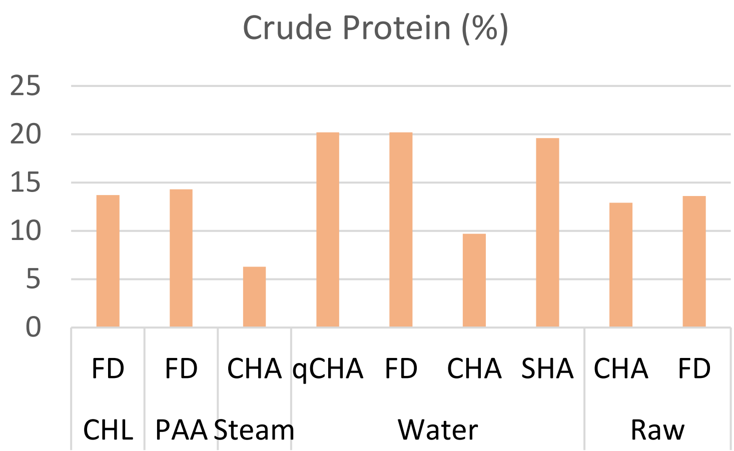
Crude Fiber - The percent crude fiber is a measure of components in a food that are insoluble in dilute acid and alkali, which indicate they are indigestible.

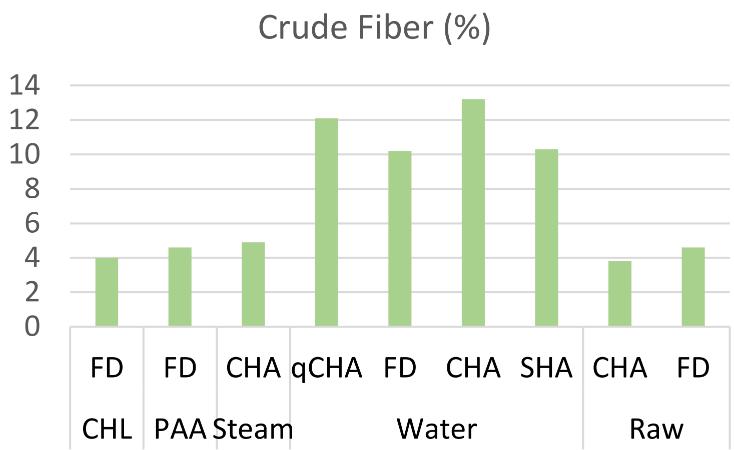
Crude Fat - The percent crude fat is an estimate of the fat content in food that typically relies on ether extraction of free fats. This is considered an estimate or crude because there are other components of the food that are soluble in the solvents and some bound fats are not easily extracted using these metods.

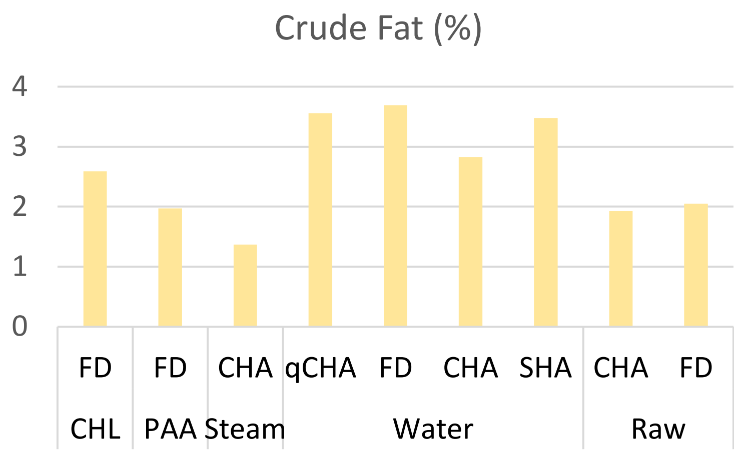
Ash - The percent ash is a measure of inorganic compounds in foods, which is largely comprised of minerals. It is measured by burning off all organic components (protein, fats, and carbohydrates) and weighing what remains.

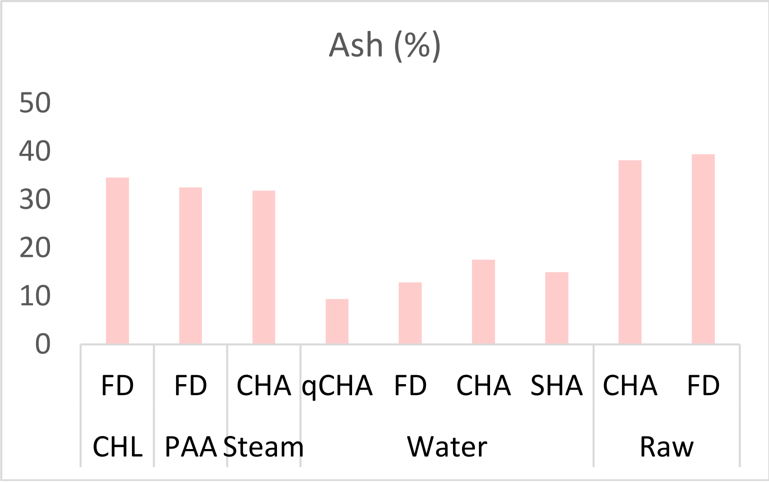
Review of the proximate analysis indicates that nutritional composition of seaweeds is highly dependent on growing waters (table 2). Specifically protein content, which was higher in the South Shore samples harvested from Moriches Bay.











CHL = Chlorine Dip | PAA = Peracetic Acid Dip | CHA = Commercial Hot Air Dried | qCHA = Quick Cooled Commercial Hot Air Dried | FD = Freeze Dried | SHA = Small Scale Hot Air Dried | Steam = Steam Blanched | Water = Water Blanched

Blanching the sugar kelp resulted in the leaching of mineral content (ash) from the product. Water blanched resulted in a large decrease in ash content compared to steam blanching (table 2). Table three provides additional insights into the changes in mineral content caused by water blanching. However, additional research is needed to fully understand what is leached out of the kelp during blanching.

Mineral Content of Dried Kelp

Table 3: Mineral content of dried kelp.

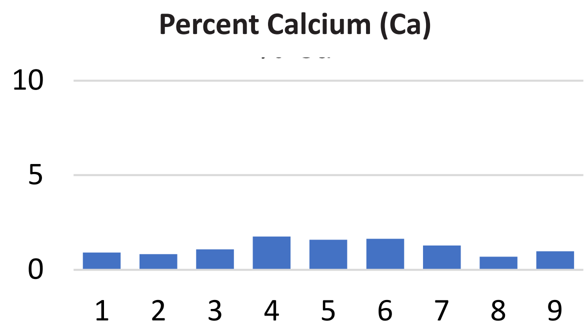
#	Sanitation Method	Drying Method	Ca %	P %	Mg %	K %	Na %	Fe ppm	Cu ppm	Mn ppm	Mo ppm
1	Chorine Dip	Freeze Dried[1]	0.9	0.26	0.63	11.81	2.37	248	1	17	1.1
2	Peracetic Acid Dip	Freeze Dried[1]	0.83	0.25	0.55	10.91	2.16	280	5	18	1.8
3	Steam Blanched	Commercially Hot Air Dried[2]	1.08	0.53	0.67	5.44	2.91	2,950	11	400	1.4
4	Water Blanched	Quick Cooled Freeze Dried[1]	1.76	0.22	0.71	0.72	0.53	323	9	28	<1
5	Water Blanched	Freeze Dried[1]	1.58	0.23	0.74	1.59	0.77	375	2	21	<1
6	Water Blanched	Commercially Hot Air Dried[2]	1.64	0.18	0.72	0.89	0.61	3,080	17	507	1.3
7	Water Blanched	Small Scale Hot Air Dried[1]	1.28	0.24	0.66	2.99	1.06	327	5	20	<1
8	Raw	Air Dried[1]	0.69	0.22	0.67	10.51	3.98	213	5	13	<1
9	Raw	Freeze Dried[1]	0.97	0.23	1.08	8.88	5.78	287	<1	65	<1

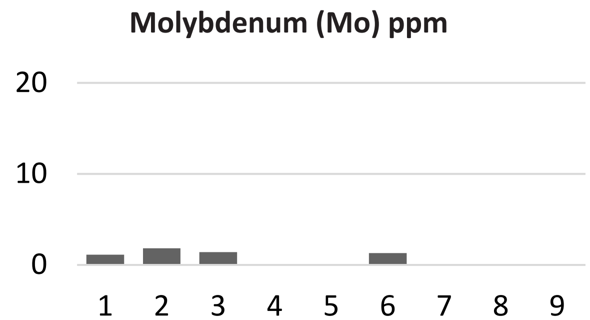
[1]Harvested April 8, 2022 [2]Harvested May 25, 2022

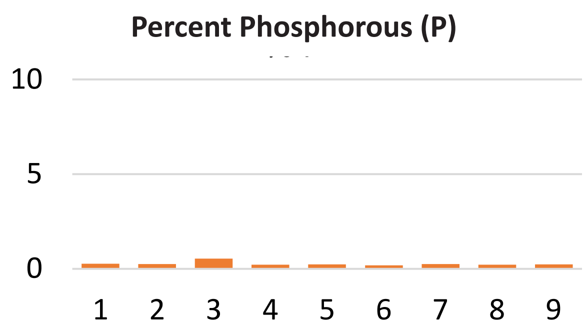
Nutritional analysis was run on all samples. Key findings from initial observations of mineral content and the impacts of harvest location and treatment are as follows:

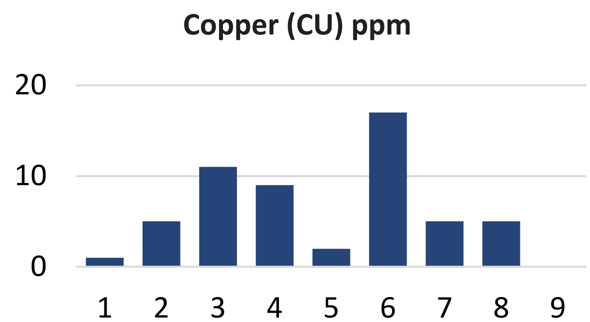
- Water blanching, and to a lesser extent steam blanching, resulted in a reduction of some minerals, most notable, potassium (K) and sodium (Na), while others like calcium (Ca) seemed to increase as a result.
- Mineral loss due to blanching supports the reduction in ash content observed in blanched kelp.
- Harvest location impacts mineral content, most notable here, iron (Fe) and manganese (Mn).

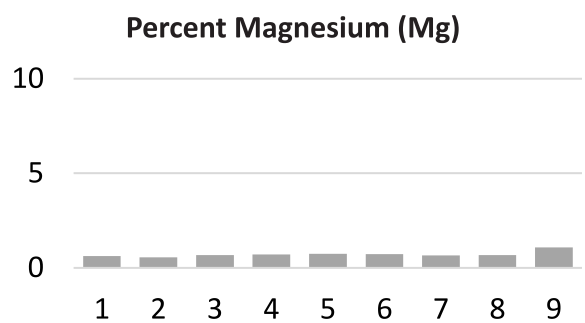
When growing and harvesting kelp, it will be important to assess the chemical content of the kelp to fully understand the nutritional and potential chemical contaminants prominent in your waterways. This should be assessed based on the final product being marketed as processing methods can alter the nutritional content of the kelp.

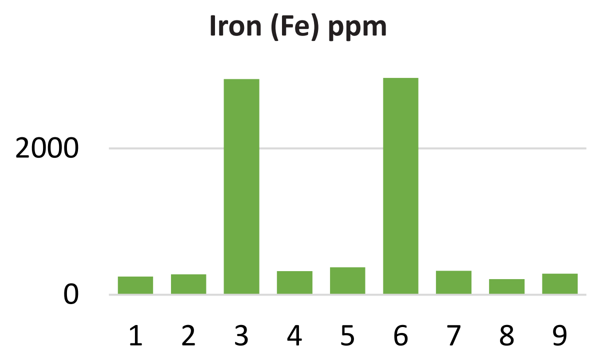

Percent Calcium (Ca)
10
5
0
1 2 3 4 5 6 7 8 9

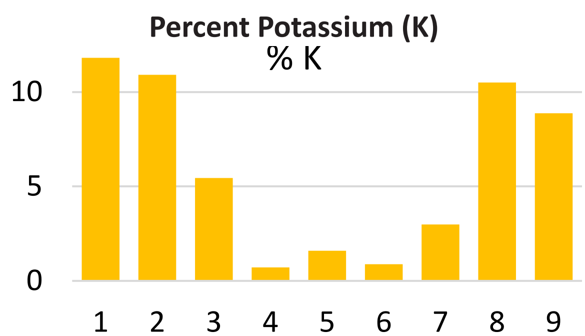

Molybdenum (Mo) ppm
20
10
0
1 2 3 4 5 6 7 8 9

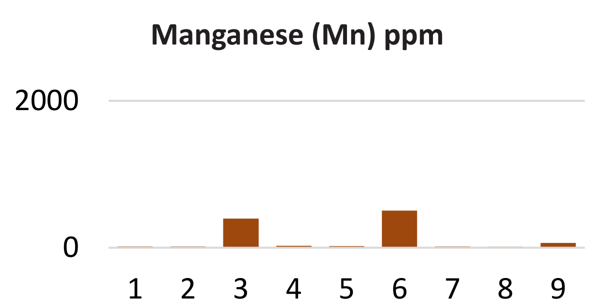

Percent Phosphorous (P)
10
5
0
1 2 3 4 5 6 7 8 9

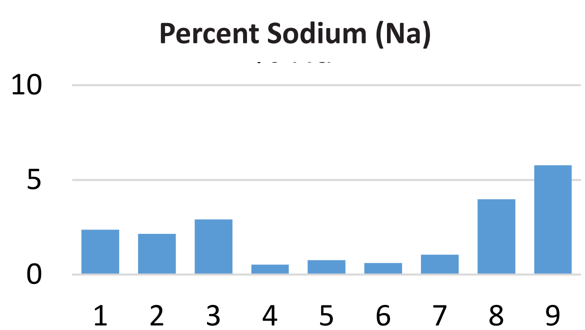

Copper (CU) ppm
20
10
0
1 2 3 4 5 6 7 8 9


Percent Magnesium (Mg)
10
5
0
1 2 3 4 5 6 7 8 9


Iron (Fe) ppm
2000
0
1 2 3 4 5 6 7 8 9


Percent Potassium (K)
% K
10
5
0
1 2 3 4 5 6 7 8 9

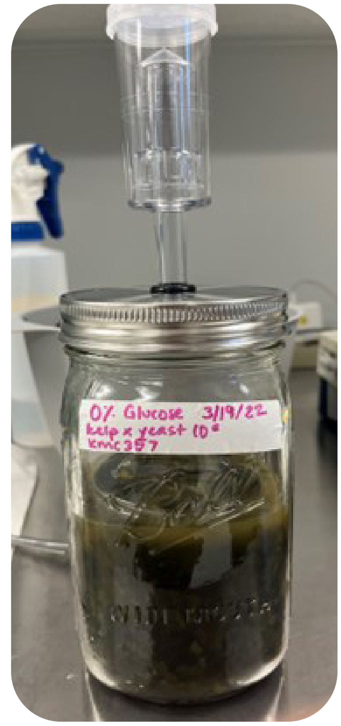

Manganese (Mn) ppm
2000
0
1 2 3 4 5 6 7 8 9

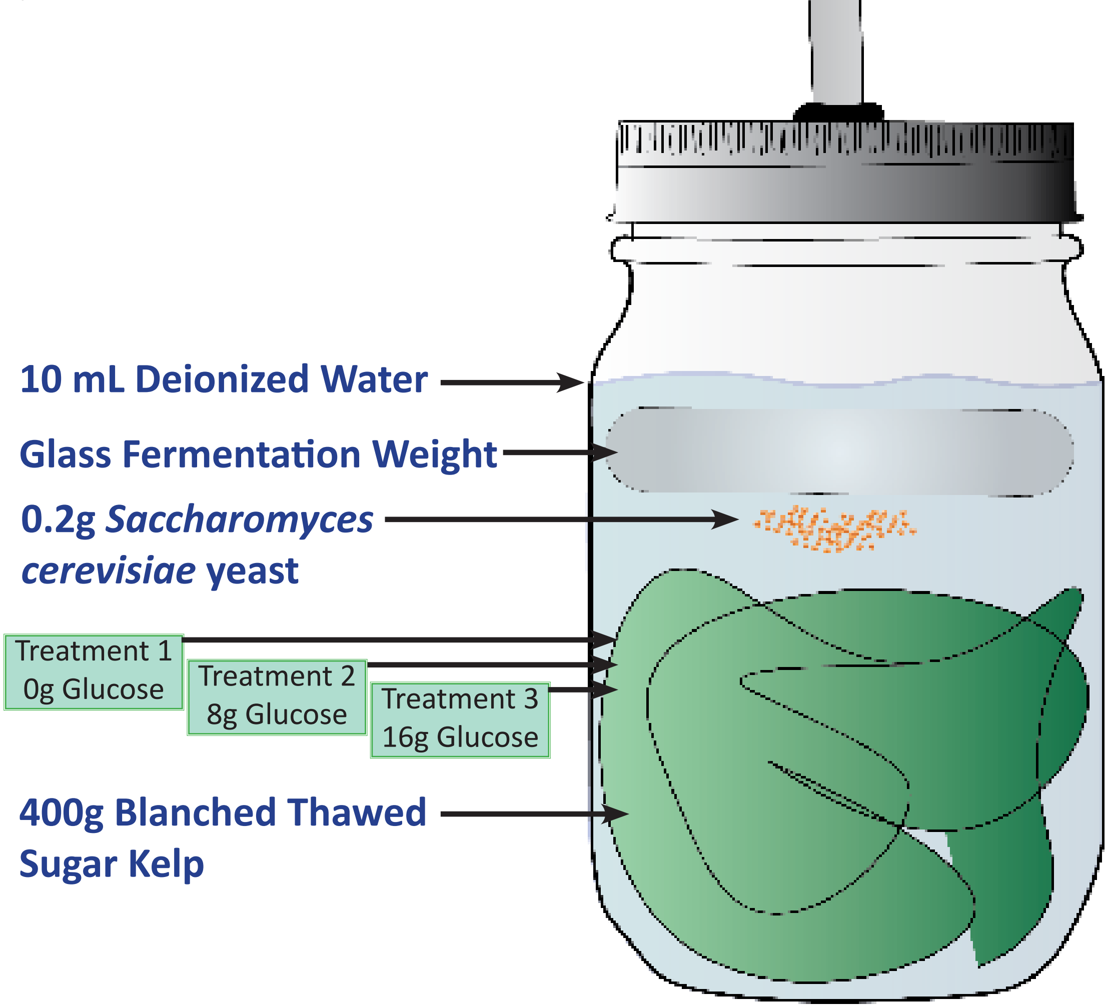

Percent Sodium (Na)
10
5
0
1 2 3 4 5 6 7 8 9

Fermentation

Fermentation Procedures

The goal of this study was to evaluate the effectiveness of Sourvisiae ®, a *Saccharomyces cerevisiae* yeast strain often used to ferment sour beers, as a kelp fermentation agent. Kelp used in this study was blanched frozen kelp purchased from Atlantic Sea Farms, ME. How different amounts of glucose impacted the pH and acids produced was also examined. The pH was measured daily along with visual and olfactory observations. After 13 days of fermentation samples were collected and acid analysis was conducted. The fermentations were performed in duplicate. The fermentation procedures and treatments are illustrated below.

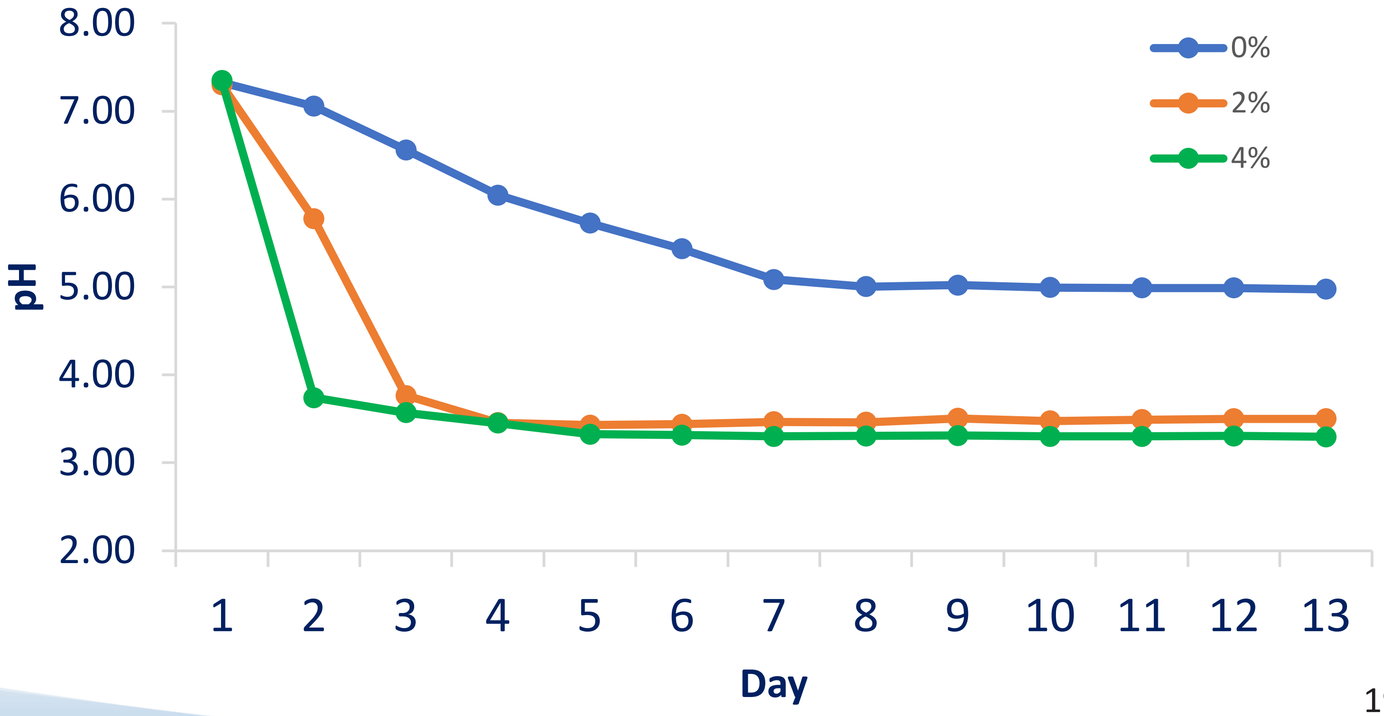




Glucose addition was necessary for the acid fermentation of sugar kelp (Figure 1). The level of glucose added to the kelp fermentation was found to impact both the rate of acidification and type of acid produced. The fermentations with a higher percent of glucose showed higher levels of alcohol, above the 0.5%, the FDAs maximum threshold for alcohol in food products. For kelp and yeast fermentation at this concentration, addition of 2% glucose is recommended as it resulted in lower % ABV and still reached a pH below 4.6 in under 48 hours. It is essential to the food safety of this product for acidification to occur rapidly, as pH is the main control for pathogens in this fermented product.

Further experimentation could include increasing the yeast concentration to increase the rate of acidification and adding 1 to 1.5% glucose to limit the alcohol produced during fermentation. Further nutritional analysis is recommended, along with organoleptic testing.

Figure 1: Sugar Kelp fermentation with yeast at three different glucose concentrations.



Conclusions

These pilot studies suggest that steam blanching followed by hot air drying at 145°F for 1.5 hours was the most effective means of drying the kelp to stabilize it. The water blanching method resulted in leaching and loss of flavor. Higher microbial loads were also observed in all water blanched kelp. Chemical dips such as PAA or chlorine were inefficient and likely difficult to maintan appropriate concentrations during commercial processing. Yeast-based fermentation was also identified as a potential method for stabilization. Glucose is needed to promote fermentation but optimal concentrations need to be further explored. The optimal addition of glucose is likely between 1 and 2% w/w.

To ensure safety and reduce product degradation a sanitation step is recommended for ready-to-eat seaweed products, however additional research is necessary to understand how and when sanitation procedures are most effective and necessary during processing of kelp products.

There are variety of ways to process kelp to extend shelf-life and add value, but most still warrant additional research and development to optimize techniques and best practices. Regardless of the intended use, it is important to store raw kelp in refrigerated conditions as a preventive food safety control and to maintain quality.

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