Salt and Iodine Control, Bio-foul Reduction, and Storage of Fresh Sugar Kelp - June 2023

Introduction:

In spring 2023, several studies were undertaken to evaluate ways to reduce the iodine content, salt content and bio-fouling on sugar kelp (*Saccharina latissima*) using minimal food-safe processing techniques. In addition, various temperature and relative humidities were tested for short term storage of the sugar kelp, to develop guidance for holding fresh product in storage immediately post-harvest but prior to further processing. The goal of the studies was to identify potential commercial solutions to manage quality while maintaining a "fresh" product able to be packaged like salad greens or as a fresh input to value-added processing.

Previous studies conducted by Qfresh Lab and GreenWave showed promising results for shelf-life. Respiration rates and quality in modified atmosphere were captured on 5 replications of sugar kelp in the spring of 2022. The results showed sugar kelp retained color with minimal senescence through 14 days in modified atmosphere, and up to 18 days in some cases.

An exhaustive literature search was undertaken, summaries of which are included in this report. There was a lot of literature summarizing high tech processing which would render the sugar kelp no longer fresh. Literature on fresh processing was sparse. This literature is summarized at the bottom of this report.

Executive Summary:

Salt Reduction

- The largest increase in salinity released from the kelp into water occurred in brackish water (20ppt). The second largest was in fresh water.
    - Changes in salt values were low, showing salt does not easily release from sugar kelp.
    - The largest change in salinity was 5.2%, representing a reduction of about 450mg/lb of internal sodium chloride in the sugar kelp.
- Based on these results, a more active salt gradient method is necessary to remove salt from fresh sugar kelp.

Blister Testing

- Blistering does not begin if the sugar kelp is removed from the water before blistering begins. This is true for completely fresh water and various low concentrations of salt.
- Blistering begins on the outer surfaces of the kelp, followed by the main blade 3 to 5 minutes later.
- Sugar kelp can withstand ~7 minutes in fresh water without blistering, up to 12 minutes in some cases.
- Blistering could be pushed out to ≥60 minutes with as little as 5ppt inclusion of salt. No blistering was found up to 75 minutes at 10ppt.
- The onset of blistering appears to be influenced by other factors inherent to the specifics of the kelp used, as we observed two separate onset times of the 2 distinct batches of kelp.

Iodine Reduction

- Ozone treatment, which Qfresh Lab expected to give the best oxidation and therefore the largest iodine release, actually caused no iodine release. The ozone was consumed almost immediately after seaweed was introduced to the ozonated water.
- Peracetic acid (PAA) in a hypersaline environment caused the most iodine to release into the water, most likely due to hypersalinity boosting the conductivity of the water. This has implications for other technologies, such as electrolyzed water or electrolysis, which can boost conductivity while leaving a fresh product.
- Internal iodine levels in the kelp ranged from 165 to 316ppm using ICP-mass spec. Internal iodine levels of the sugar kelp did not match up to amount of iodine released from samples during the oxidizer testing.

Bio-foul Reduction

- Chlorine applied to bryozoan bio-fouling loosened the organism and made removal easier.
- PAA loosened the organism even quicker and made removal significantly easier.

Temperature & Humidity Study

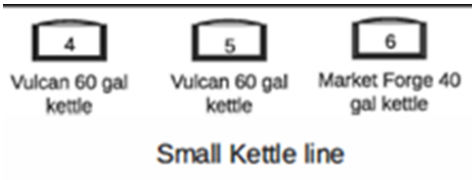
- Sugar kelp may be held up to 5 days prior to processing if stored below 45°F and kept moist and in an environment that is at least 83% relative humidity.

Salt Reduction

Background:
Sodium levels in sugar kelp are very high (up to ~186mg/cup). There are multiple studies on removing salt in dried and processed sugar kelp, but very few methods of extraction while keeping the product fresh. Literature also points to other negative effects that may occur with salt reduction; these include loss of calcium and iron and other minerals, loss of texture and reduced nutrition. Therefore, this study was designed to reduce salt using a minimal processing method. Salt reduction was accomplished by stepping down salinity in the tanks to find the maximum rate of salt reduction by pulling salt gradient from the sugar kelp.

Equipment:

- ATC portable refractometer
- Orapxi salinity meter
- Scale
- Fresh sugar kelp
- Non-iodized salt



Protocol:

1. Fill 40 gallons water into 60-gallon tank
    a. Use salt concentration calculator to calculate amount of salt to add
    b. Measure initial salt concentration prior to introduction of kelp
2. Add kelp, *be sure to measure and capture pounds added*
    a. Stir with light agitation, being sure not to damage kelp which may cause release of salt and other compounds
    b. Stir and check salt concentration every 2-5 minutes
    c. Document salt concentration changes on data collection sheets
3. Repeat testing steps 1 and 2 for lower salt concentrations. The following were used in this protocol:
    a. Atlantic Ocean levels (34.5ppt ±2ppt)
    b. Brackish (20ppt ±2ppt)
    c. Low salinity (10ppt ±2ppt)
    d. No salinity (0ppt + 0.5ppt)
4. Note any changes throughout testing such as color/texture/appearance/turgor pressure, etc.
5. Note bio-foul removal in water and on kelp after each salinity change.

Results:

- Color staining of kelp into the water decreased with each subsequent water bath. This has implications for a multi-step washing process to remove color, extraneous matter, sloughed off pieces, and bio-fouling.
- The largest increase in salinity released from the kelp into water occurred in brackish water (20ppt). The second largest was in fresh water. The maximum reduction was 5.2%, representing ~450mg of sodium chloride removed per lb of sugar kelp.
- Blistering in sugar kelp seemed to be a response to hold onto salt or a rapid stress response to a hyposaline environment causing a rupture with subsequent filling with water. The blisters increased the surface area of the kelp. There was an initial increase in salinity in the water after 5 minutes, but subsequent measurements showed less salt release into the water. This coincided with blister development and advancement.

Discussion:

This study was designed to use a simple salt gradient to try and pull salt from inside the sugar kelp. The goal is for a processor to have a simple solution for contending with the high salt content of fresh sugar kelp. The largest increase in salinity into the water was found with brackish water at 20ppt. The second largest increase on average was in water with no salinity. In high salinity water, the kelp took up a small amount of salt. This may have been due to a slight mismatch between salinity of the water tested and salinity the sugar kelp was in during growth. A gradient of lower levels of salt was found to pull out salt, but not as a very high rate (max increase of 1.1ppt).

According to literature, other nutrients may be released along with the salt (calcium, iron, loss of texture and nutrition). This was not tested as a part of this protocol.

Another option designed by Qfresh based on literature, but not tested during these studies, is a 3-tank system, using + and - electrodes to actively pull the salt from the sugar kelp. Based on the minimal salt excreted using a lowered salt gradient, this would be a logical next test to attempt to reduce salt content in a fresh sugar kelp product.

Results Table:

Change in salinity. Table is the average. Readings were taken every 5 minutes until 3 measurements, then transferred to the next tank with lower salinity.

Salt concentration and rep	Average Δ in salinity (ppt)
Rep 1	
37.5ppt (atlantic ocean)	0.33
20ppt (brackish)	1.47
10 ppt (low salinity	1.02
0ppt (no salinity)	0.78
Rep 2	
37.5ppt (atlantic ocean)	-0.78
20ppt (brackish)	0.72
10 ppt (low salinity	0.30
0ppt (no salinity)	0.79
Rep 3	
37.5ppt (atlantic ocean)	-0.93
20ppt (brackish)	1.13
10 ppt (low salinity	0.33
0ppt (no salinity)	0.89

Recommendations for Future Research:

- Electrolysis or electrolyzed water
- Temp ranges in wash water (warmer than temperature harvested)
- Time in wash water
- Additional sanitizer concentrations

Blister Testing:

Background:
Literature repeatedly mentioned blistering if sugar kelp is washed in fresh water, but no studies mentioned any time intervals for how fast this blistering arises. We also could not find any mention of blistering in water with lowered salt concentrations, or how long sugar kelp could persist without blistering at various salt concentration and time combinations.

To remedy this, we subjected sugar kelp to water at various salt concentration and time intervals, to determine the time to blister and extent of blistering. These results should help processors understand the level of salinity needed in process water to prevent this defect. Lower levels of salt in process water should also help minimize equipment rusting.

Protocol:

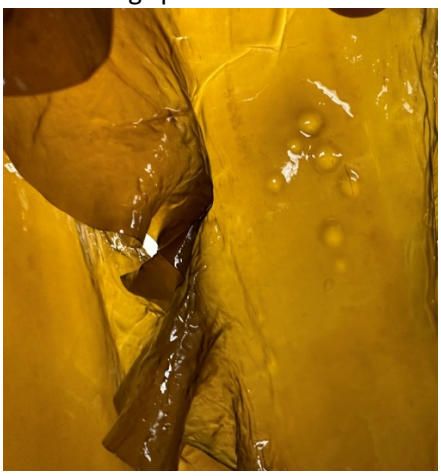
1. Submerge 1lb kelp in 5 gallons of water at various salt concentrations: 0ppt, 2.5ppt, 5ppt, 7.5ppt, and 10ppt
2. Check kelp every minute for blistering development and advancement.

Results:

- Blistering does not begin if the sugar kelp is removed from the water before blistering begins. This was true for fresh water and various low concentrations of salt.
- Blistering begins on the outer surfaces of the kelp, followed by 3 to 5 minutes later the main blade blistering.
- Sugar kelp can withstand about 7 minutes in fresh water prior to blistering. There was variability based on different harvests/lots of kelp.
- Blistering could be delayed to ≥60 minutes with as little as 5ppt salt. No blistering was found up to 75 minutes submerged at 10ppt.
- If left in low to no salinity, blistering increases with time.

Blister begins on outer, frilly surface areas first

Blistering spreads to blade next



Results Table:

Salt concentration	Time to blister	Notes
0ppt	7-10 minutes	-Blistering begins on frilly outer surface of sugar kelp first -Blistering was independent of thickness of kelp -If seaweed was removed from water prior to Blistering beginning, it did not begin to blister out of the water
2.5ppt	25 minutes	Started on frilly, spread to center.
5ppt	>60 mins	blistering noted at 60 minutes, none prior
7.5ppt	>60mins	blistering noted at 60 minutes, none prior
10ppt	none @75 minutes	No blistering after 75 minutes exposure. No blistering after removal from water for 75 minutes

Recommendations for Future Research:

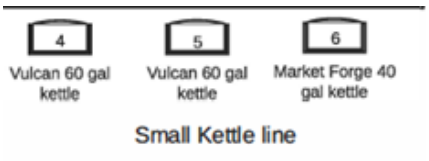
- Mechanical agitation in a flume or wash tank
- The effects of blistering on shelf-life outcomes
- The effects of blistering on nutrient degradation

Iodine Reduction

Background:
Like the salt reduction, there are multiple studies that have evaluated reductions in iodine with processing methods that no longer render the sugar kelp fresh. These include drying, fermenting, extraction with alcohols, encapsulation, cooking and pulsed electric fields. According to literature, 31 to 90% of the iodine in sugar kelp is bioavailable (absorbed into the blood stream). High iodine intake can lead to hyperthyroidism. Some minimally invasive techniques to reduce iodine were considered for this study. These methods include: high light intensity, application of an oxidizing agent, hypersalinity, warmer wash temperatures than harvest, extended time in water. Ultimately, we chose oxidizers and hypersaline environments. The hypothesis was oxidizers would help not only with iodine release, but also with general cleanliness of the product and removal of bio-fouling.

Equipment:

- Ozo-pod 50 ozone generator
- Milwaukee MW13 iodine testing for water
- Dissolved ozone meter/ozone test kit K-7404
- Orapxi salinity meter
- Scale
- Fresh Kelp
- Stopwatch
- Peracetic acid (PAA)
- Chlorine (50ppm)
- Iodine testing by ICP mass spec (AOAC 2012.15)



Protocol:

1. Fill 40 gallons water into 60-gallon tank
    a. Use salt concentration calculator to calculate amount of salt to add to target Atlantic salinity (34.5ppt)
2. Insert Ozo-pod 50 ozone generators into water.
    a. Tanks are located under a hood so ozone off gassing should be minimal
    b. Allow 30-60 minutes to generate ozone
    c. Target 1-3ppm ozone
    d. Measure ozone periodically throughout testing.
    e. Capture on data capture form
3. Additional oxidizers tested:
    a. 30ppm PAA
    b. 30ppm PAA with hypersalinity to increase conductivity (76ppt)
    c. 50ppm chlorine
    d. Control- no oxidizer at 37.5ppt salinity
    e. Hypersalinity (76ppt) with no oxidizer

4. Add x amount of seaweed to tank, stir slowly with agitation for 10 minutes.
    a. Measure any changes in salinity using dissolved salt meter
    b. Measure change in ozone
    c. Measure changes in iodine levels inside water
5. Repeat this every 5 minutes for changes in iodine.
    a. Send fresh kelp sample for baseline iodine level
    b. Bag samples from each trial to send to Eurofins for *internal* kelp iodine testing
    c. Onsite, we will be testing for *iodine release in the water*
6. Measure bio-foul levels due to ozone (oxidative stress)
7. Note any changes in kelp due to ozone throughout trialing, such as color/texture/appearance/ turgor pressure, etc.

Iodine Results:

- Several oxidizers were chosen for this test (ozone, peracetic acid (PAA), chlorine). These oxidizers have been proven safe and effective to reduce food safety risks and improve the quality of various fruits and vegetables. They are also widely used in these industries, with ample supply and accessibility to processors.
- Peracetic acid (PAA) showed the most promise in this study for the release of iodine from the sugar kelp.
- PAA in a hypersaline environment released the most iodine into the water (see results below). Hypersalinity (76ppt), fresh water (0ppt), standard salinity (37.5ppt) and ozone alone did not release any iodine from the sugar kelp.
    - Electrolyzed water may be an option for even higher iodine release. This process utilizes an anode and cathode in water with sodium chloride to produce the disinfectants hypochlorous acid and sodium hydroxide. Seaweed would then be introduced to this water.
    - Electrolysis inside the water also has a high probability of successfully coaxing the seaweed to release iodine. This differs from electrolyzed water in that the electrolysis would occur with the seaweed in the water.

Results Table:

In addition to iodine, four heavy metals were tested to see if the treatments indicated any reduction in their levels. Because this was not the primary focus of this study and no obvious trend was identified, we did not include heavy metals in our discussion of results below. We included the data in this table in case it is of use to others doing work in this area.

		All units in ppb				
Test date	**Test**	**Iodine by ICP mass spec (ppm)**	**arsenic (ppb)**	**cadmium (ppb)**	**lead (ppb)**	**mercury (ppb)**
25-May	30PPM PAA @ 10ppt salinity	306	5200	31.3	30.5	7.7
25-May	30ppm PAA @ 37.5ppt salinity	286	6550	47.8	30.7	8.22
25-May	30ppm PAA @ hypersalinity (76ppt)	196	6100	23.7	25.8	7.3
25-May	50ppm CL @ 10ppt salt	218	3820	24.2	21.3	8
25-May	Hypersaline (76ppt)	316	8500	76.9	25.9	7
25-May	Control (kelp in fresh water)	165	3200	34.2	15.2	5.7
25-May	Control (fresh kelp)	235	6830	44.5	29.6	8.45

Discussion:

The largest release of iodine from the sugar kelp into the water was found with 30ppm PAA in a hypersaline environment (76ppt). The second largest release of iodine was found with 30ppm PAA in 10ppt salinity. It appears that increasing the conductivity in the water increases the iodine extraction from the kelp by boosting the action of the oxidizer.

Chlorine at 50ppm caused a small amount of iodine to be released. The chlorine was used up rapidly, reducing to 5ppm after 10 minutes exposure and 0ppm after 15 minutes. This is a relatively large chlorine dose for washing, showing the kelp had a high potential to reduce the oxidizer. Higher salinity may have improved the efficacy but was not tested in this project.

The following tests showed no iodine release:

1. A hypersaline environment
2. Fresh water
3. Ozone
4. Standard salinity (37.5ppt)

Shortcomings of this test included no continual change or removal of iodine from the water as the test progressed. Our literature searches indicated that as iodine increases in the water, it will inhibit more release. We did not have a good method of removal of iodine. The iodine measured in the water was total iodine.

Ozone was used up almost immediately, and therefore did not cause any iodine release. This may be due to the way ozone was generated (bubbled into water), and not in a continuous manner. This testing was done as a batch process.

In addition to iodine release into the water, the sugar kelp was also sent to Eurofins labs for internal total iodine measurements of the sugar kelp. This was accomplished using ICP mass spec (AOAC 2012.15). This sugar kelp was taken from each test outlined above, product was frozen and evaluated several days later. Only one sample of each was taken, and results ranged from 165 to 316ppm total iodine. The control (untreated sample) and kelp from fresh water had the lowest ppm total iodine. It appears iodine content internally in the kelp has a wide range, and more data points will need to be taken to correctly evaluate the reduction in iodine by various oxidizers.

There was a reduction in iodine on the three PAA tests at various salinity levels. The trend was the higher salinity (and therefore higher conductivity) reduced the total iodine.

Recommendations for Future Research:

- Higher ozone concentration and a faster generation of the ozone
- Additional sanitizer concentrations
- High light intensity

Temperature/Relative Humidity Storage

Background:
To expand upon previous shelf-life studies of fresh kelp, the proper holding temperature range and humidity levels were tested. This builds upon previous testing undertaken by Qfresh and GreenWave after confirming the appropriate container types for sugar kelp storage prior to processing (venting is required to allow respiration!). The hypothesis was fresh kelp would require similar holding temperatures (<40F) and humidity (>80%) as leafy greens. Too little moisture could lead to dehydration and too much moisture can increase spoilage and pathogenic organisms.

For this study, an additional lot of fresh sugar kelp was delivered to WMFPC in vented RPC totes a few hours after harvest from the Groton farm site on May 25, 2023, and testing took place through June 1, 2023.

Equipment:

- Scale
- Fresh Kelp
- Temperature and relative humidity probes
- RPC totes
- Shrouds
- Needles for perforation

Protocol:

1. Seaweed delivered in vented RPC totes
    a. Measure temperature of seaweed (IR or probe) on arrival
    b. Note general condition of seaweed and any off odors
2. Seaweed re-packed in the following packages to simulate various commercial storage options:
    a. Micro-perforated packaging to boost humidity and maintain moisture.
    b. Macro-perforated packaging to boost humidity and allow some moisture retention.
    c. Open slit package for top of RPC tote
3. Parameters to monitor:
    a. Appearance
    b. Odor
    c. Color
    d. Senescence/decay
    e. Microbial growth
    f. Moisture changes
4. Packaging seaweed:
    a. Target is 1-3lbs per package except for at least one RPC, then use full RPC.
    b. If seaweed is too long, make a clean cut to fit in package.
    c. Seal package

   d. Make 5ea, 1-3# packages of each type except RPC.
5. Seaweed storage - temp profiles
   a. Target: 37F - Place packages in coldest part of storage fridge
   b. Target: 42F - Place in warmest part of fridge
6. Seaweed evaluations
   a. Evaluate through package for first 1-3 days. Once changes are seen, start with bullet point b
   b. Remove 2ea bags from each treatment and temperature.
   c. Note general condition and same parameters as before: appearance/odor/color/decay/ growth and moisture changes.

All totes were placed inside WMFPC Food Center refrigerated warehouse. Temp ranges in storage ranged from 33 near the freezer to 34 in middle of floor to 36 near outer warehouse door. Seaweed was packaged the following ways:

- Sealed bags with 5 macro- perforations (large holes)
- Sealed bags with 15 macro-perforations (large holes)
- Sealed bags with 40 micro-perforations (100 micron in size target)
- RPC with a package sealed and taped around RPC
- RPC with a package left open at one end of RPC
- Open uncovered RPC (exposed to air movement and humidity in the cooler)

Packages were placed in the cooler at three locations:

- Near Freezer (coldest) 33°F
- middle of cooler 34°F
- near exit door (warmest) 36°F
- Humidity in cooler ranged from 74% on the 25th to 83% on June 1st.

Packages were evaluated on the day of arrival, day 1, day 5 and day 6 in storage.

Results:

Seaweed placed in a perforated packages looked the same over time. The micro, macro, and totally sealed RPC package all exhibited high humidity >95% inside the package and did not show any appreciable degradation over the length of the study.

The only packaging that showed any degradation was the bag propped open in the front covering the RPC, and the RPC that was left uncovered.

The propped open packaging RPC showed drying in the front near the opening but the remainder of the RPC the kelp looked moist and of good quality.

When the kelp was mixed, it all looked moist again. However, there could still be some unobservable quality differences.

The results gained from the open-end bag RPC prompted us to leave an RPC for two days in the cooler with no covering at all. We expected complete dehydration of the product but found even though the surface areas of kelp were a bit dehydrated the bulk of the kelp looked good. The humidity in the cooler during this portion of the test was 83%.

Again, when the dried kelp was mixed with the moist kelp, it demonstrated surprising recovery to a re-moistened state.

A separate home refrigerator test was run on the initial delivery of kelp. This was to evaluate the kelp in macroperforated packages in a warmer environment. Temp was 42-43 degrees F, and the product was stored for a week. Product looked good for 5 days and then started to show minor deterioration on day 6 and 7.

Salt and Iodine Control, Bio-foul Reduction, and Storage of Fresh Sugar Kelp - June 2023

Discussion:

- Sugar kelp, if stored below 45°F and kept moist and at least above 83% relative humidity, held quality through 5 days prior to processing.
- This can be accomplished through storage conditions using packaging, including vented RPC totes, packaging, or by maintaining a cold room with a high humidity environment.
- A pallet shroud over a bin will also work. An important note on shrouds are they should allow the product to cool properly. This will require punctures in the bag, which is a commonly used shroud in the produce industry.

Recommendations for Future Research:

- Additional temperatures and humidity levels
- Repeat at different times in the season to capture the seasonality of the kelp on storage temp and RH requirements
- Packaging post storage for determining maximum days to use

Bio-foul Reduction

Background:

Bio-fouling is the accumulation of microorganisms, plants, algae, or small animals on surfaces where they are not wanted. Bio-fouling impacts seaweed production by reducing growth, increasing mortality, altering behavior, and increasing disease risk. Currently, the primary way of managing bio-fouling on kelp is via monitoring as the water warms, harvesting the kelp at the first sign of bio-foul. However, there may be cases where attempts at early detection fail, and in those cases having a mechanism for removing bio-foul post-harvest would be extremely advantageous.

Protocol:

1. Weigh out seaweed for an estimate of poundage of kelp inspected
2. Document bio-fouling present:
    a. Bucket both the type of bio-foul and amount found
    b. Use data collection sheet
3. Bio-fouling reduction will be tested separately, spelled out in this document
    a. Bio-fouling will also be tested in the salt and iodine studies.
    b. The initial raw data (bio-foul types and amounts) will be counted very closely for the bio-foul study, however will be estimated for other tests.
4. Water used to wash kelp will be salinated to 34.5ppt (Atlantic Ocean average). Otherwise blistering may occur and effect bio-foul removal
    a. Measure salinity and capture on data capture form
    b. Kelp will be weighed prior to washing and washed in 25 to 50lb batches in either kettles or green barrels
    c. Transfer the seaweed to the Kronen unit for drying
    d. Kronen unit will dry product
        i. Check bio-foul reduction from the wash process, prior to spin drying
    e. Choose 2 different wash times
    f. Choose 2 different spin lengths/speeds for drying
5. Also measure bio-foul removal due to ozone
6. Measure bio-foul removal due to lowered salt concentrations

Results:

- Overall, this lot of sugar kelp had minimal bio-fouling. Bio-fouling that was found was primarily in the barrel of seaweed provided and not in the supplied tote that was examined.
- Relatively small amounts of bio-fouling (bryozoans) were found on the edges of the main blade where the frilly portion of the blade formed. You could scrape bio-fouling off, but it required effort and firm scrubbing.
- Chlorine applied to the bio-fouling loosened the organism and made removal easier. PAA applied to the bio-fouling loosened the organism even quicker and made removal significantly easier.

- PAA plus mechanical agitation should be able to remove the majority of bio-foul. May be able to combine bio-foul removal and salt reduction and /or iodine reduction for a more holistic approach.

Example of bio-fouling:

Discussion:
Although bio-fouling was minimal, we still ran experiments to see if different treatments could ease the removal process. It was determined that it was not necessary to use the Kronen spin drying unit for dewatering. Mechanical agitation and removal of the bio-fouling was performed manually.

Treating fresh produce with an antimicrobial in wash water, combined with agitation, is a common practice in produce processing facilities. This agitated wash sloughs off surface materials loosely attached, removes insects, and removes extraneous matter such as mud and other field materials. During the iodine and salt reduction testing, positive results were found using antimicrobials. Therefore, the ease of removal of biofilm was done in the following ways:

- Control: Salt water with minimal agitation for 3 minutes:
    - There was variability within the seaweed in how firmly the bryozoans attached themselves. However, in general it required moderate to aggressive manual pressure to remove all the bio-fouling
- Chlorine in salt water with minimal agitation for 3 minutes:
    - Pressure, time, and effort required to remove bryozoans were less than the control.
- PAA in salt water with minimal agitation for 3 minutes:

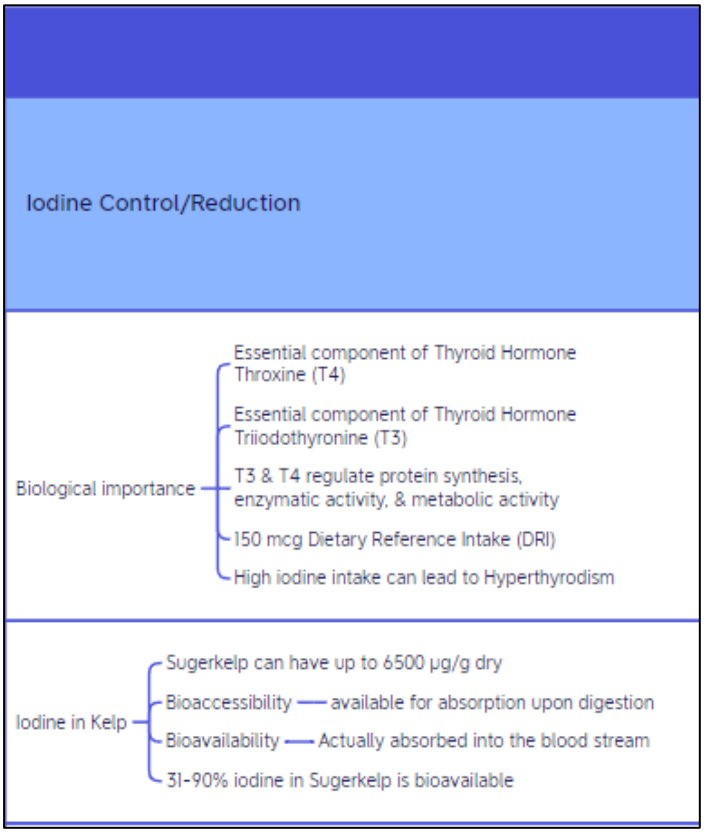
- The effort was reduced even further and became the easiest and most efficient method studied. This also tracks with PAA inducing the highest iodine release from the sugar kelp.
- It is possible that the acid in combination with antimicrobial properties worked to efficiently loosen the bio-fouling.

Recommendations for Future Research:

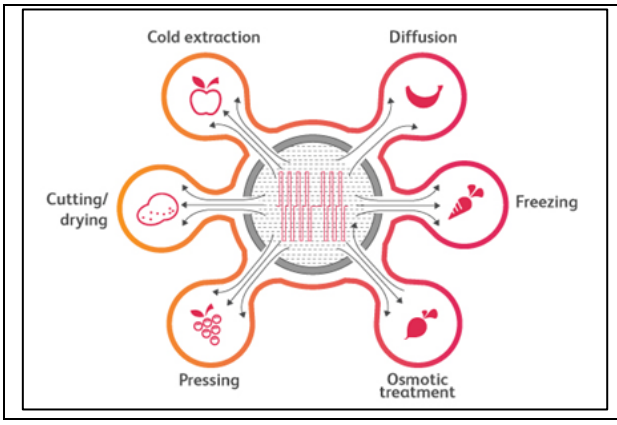
- Test larger, more developed bio-fouling
- Different types of bio-fouling
- Mechanical agitation in a flume or wash tank
- Varying time soaking in the wash water

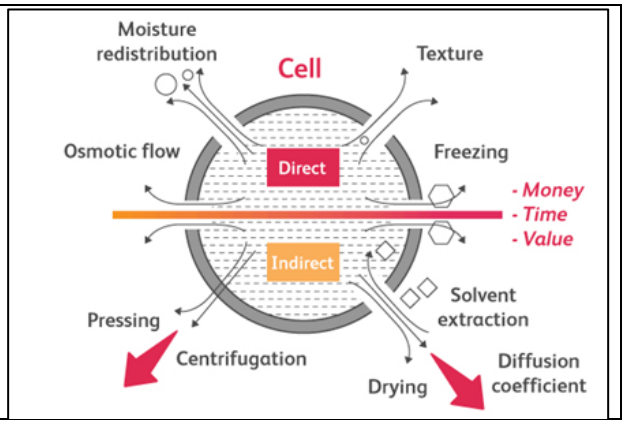
Addendum: Literature Summaries

Iodine Control/Reduction:



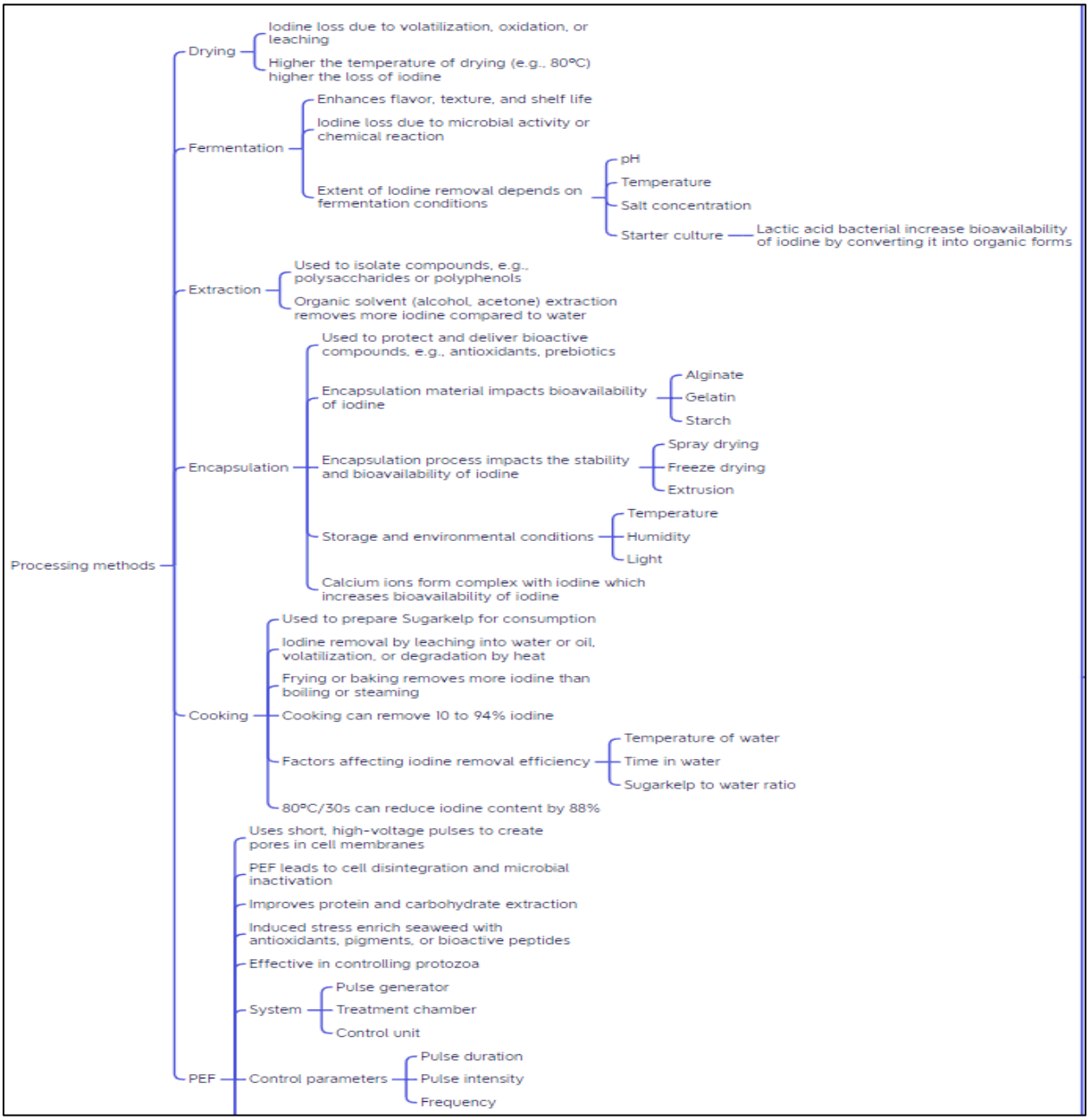
Pulsed electric fields (PEF)





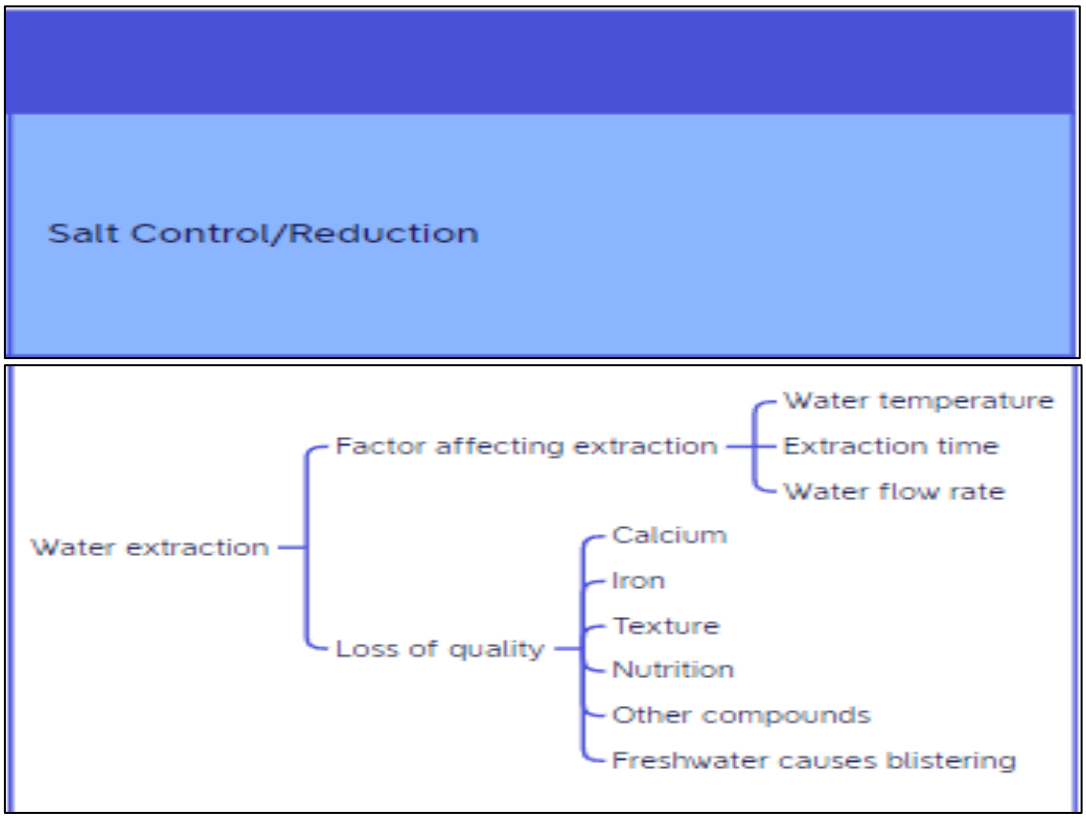
I

odine Control/Reduction, continued:



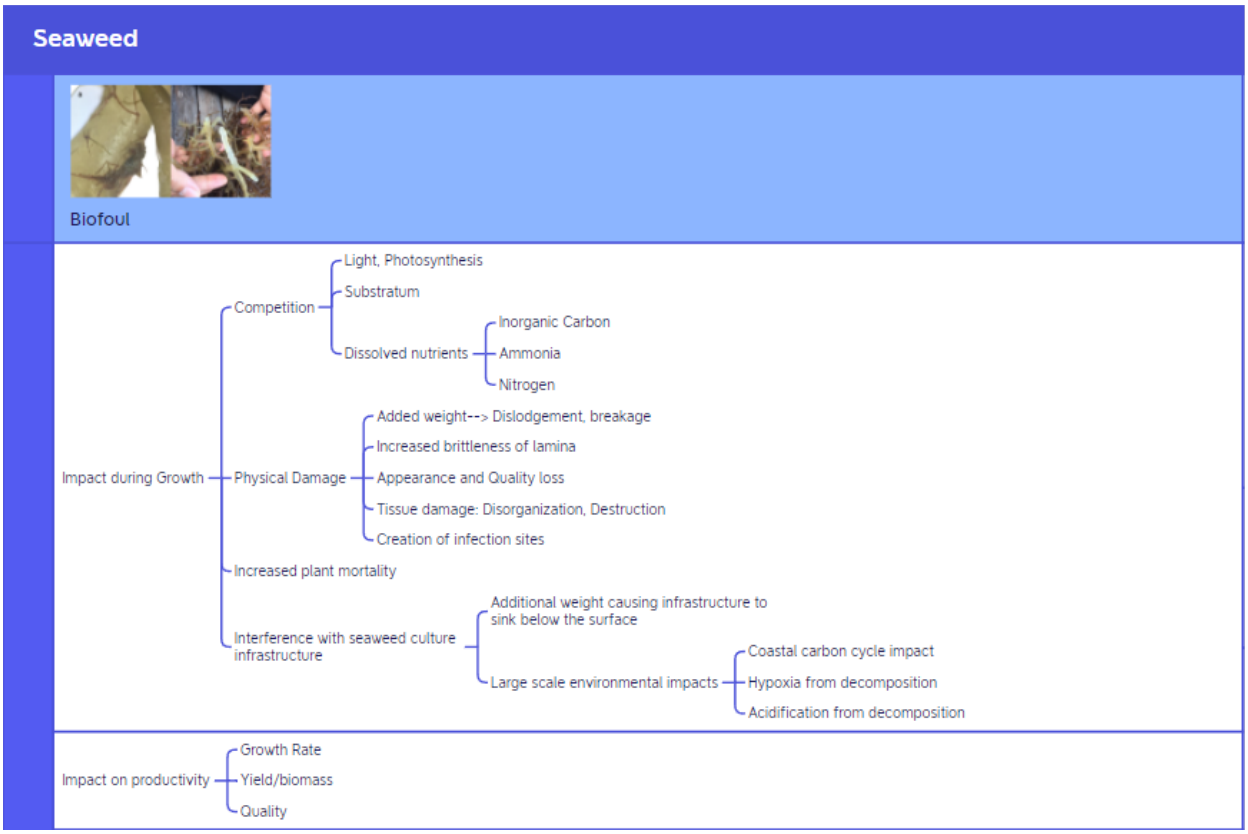
Salt and Iodine Control, Bio-foul Reduction, and Storage of Fresh Sugar Kelp - June 2023

Salt Reduction:

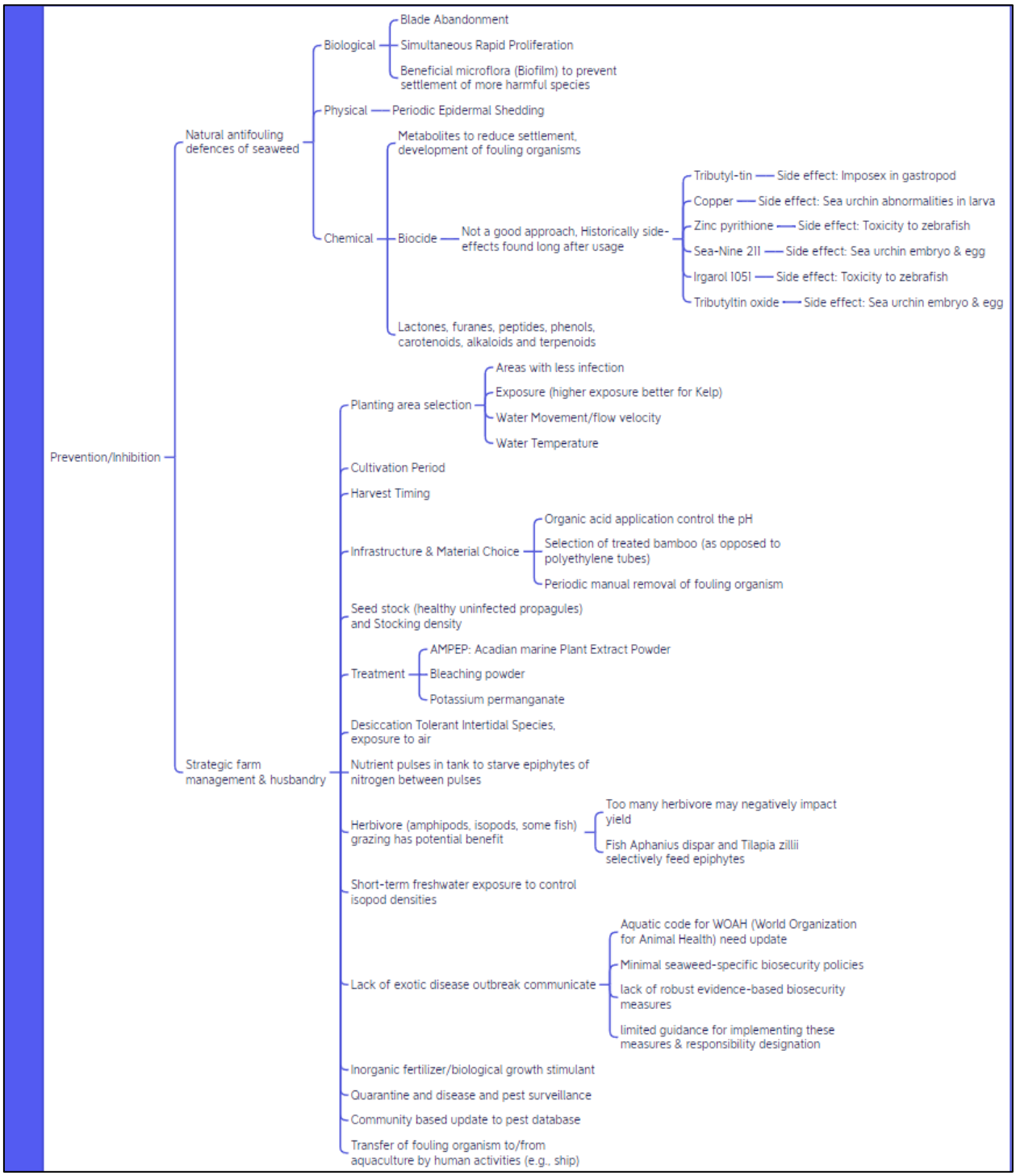


Salt and Iodine Control, Bio-foul Reduction, and Storage of Fresh Sugar Kelp - June 2023

Bio-foul:



Bio-foul,continued:



Salt and Iodine Control, Bio-foul Reduction, and Storage of Fresh Sugar Kelp - June 2023

Details on sugar kelp used for Salt and Iodine Control and Bio-foul Reduction studies:
Fresh sugar kelp was harvested on the morning of May 17th from a farm site in Groton, CT. The sugar kelp was from 2 different seed sources, including Groton and Montauk. Water temp was 55°F and air temp ranged from 60 to 65F during harvest, with 10-13 mph winds and sun. Harvest started at 8am into 55-gallon barrels with vented lids. Due to the difficulty of harvest in high winds, whole plants (including holdfasts) were harvested rather than the food-industry standard of blades only. The barrels were delivered to shore by 9:30am, where they sat unrefrigerated in direct sunlight until 11:00am, when the kelp was transferred into vented MACX bins in a refrigerated van set to 36 degrees Fahrenheit. The kelp arrived at Western Mass Food Processing Center at 1:30pm. Product was received and placed into refrigerated storage (target 36F) for cooling prior to processing.

Details on sugar kelp used for Storage study:
Fresh sugar kelp was harvested on the morning of May 25th from a farm site in Groton, CT. Water and air temps were not recorded. Kelp was harvested into 55-gallon barrels with vented lids, and landed at 9:30am where it was transferred immediately into vented RPC totes on ice inside an insulated bulk fish tote. Sugar kelp was delivered to Western Mass Food Processing Center at 12:15pm, where it was received and placed into refrigerated storage for cooling prior to re-packaging.