JOINT INNOVATION PROJECT – 2024/25

Final Report

Reducing Impact of Heavy Metals in Seaweed to Address Barriers of Growth

Alaska Fisheries Development Foundation

Category: Innovations in Processing – Stabilization, Blanching, Pre-processing before Drying or Freezing, Product Development

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Project Location: KSMSC, Kodiak, AK | Wildsource, Kodiak, AK

Reducing Impact of Heavy Metals in Seaweed to Address Barriers of Growth

I. Executive Summary

This project, a collaboration between **Four Corner Foods, LLC** and **Sun'Aq Tribal Enterprises**, addresses a primary barrier to the growth of the Alaskan mariculture industry: the naturally high levels of heavy metals and iodine in seaweed. While seaweed is nutritionally dense, regulatory limits on daily intake for components like lead, arsenic, cadmium, and iodine often restrict its marketability and consumption.

To process freshly harvested seaweed into a form – either fresh, frozen or dehydrated, it requires a choice of preparation steps, before seaweed would be safe for consumption. This study compared various processing techniques to identify "best practices" for reducing these levels. For seaweed in a fresh or frozen form, results demonstrate that **hot water blanching** is significantly more effective than steam blanching. Specifically, hot water blanching reduced iodine by **87% to 94%** and heavy metals by **30% to 50%**. These reductions allow for a dramatic increase in the amount of seaweed that can be safely consumed daily. For seaweed in a dehydrated form the results demonstrate that applying a preceding step of Hot water blanching or no preceding step, remains a choice due to varying impacts of iodine and heavy metal reduction or concentration.

II. Introduction

The Alaskan seaweed industry faces a challenge: high concentrations of heavy metals (Lead, Arsenic, Cadmium, Mercury) and iodine can limit human consumption due to Recommended Daily Allowance (RDA) regulations. Lowering these levels through processing directly increases the allowable daily consumption, which drives economic growth and higher utilization of harvested seaweed. This project focuses on identifying processing methods that "leach" these undesirable components while maintaining product quality.

Phase 1 Hypothesis: Thermal processing (blanching) will leach these elements into the water/steam phase, reducing their concentration in the final tissue.

> **Phase 1 Objective:** To determine which blanching method (Hot Water vs. Steam) provides the highest reduction while maintaining product integrity.

Phase 2 Hypothesis: Dehydrated seaweed will result in lower amounts of these elements when preceded by Blanching, which leaches these elements.

Phase 2 Objective: To compare final element results (Dehydrated vs Blanched/Dehydrated) for higher consumption allowance.

III. Methodology

The research was conducted in two phases using primarily two key species, obtained locally in Kodiak, Alaska: **Kombu** (*Saccharina Latissima*) and **Wakame** (*Alaria Marginata*). Raw samples were tested for baseline concentrations of As, Cd, Pb, Hg, and I.

- **Phase 1 (Blanching):** Evaluate Hot Water vs. Steam blanching for leaching soluble contaminants.
  - **Hot Water Blanching:** Submerging raw seaweed in hot water at 195 F-205 F for 90 seconds.
  - **Steam Blanching:** Exposing raw seaweed to hot steam at 212 F for 90 seconds.
- **Phase 2 (Dehydration Study):** Analyze the effects of air-drying seaweed both with and without the optimized blanching process to quantify final contaminant concentrations in dried products.
  - **Blanched/Dehydrated:** Submerging raw seaweed in hot water at 195 F - 205 F for 90 seconds. Followed by drying: 160 F for 3 hours + 120 F for 5 hours.
  - **Dehydrated:** Drying: 160 F for 3 hours + 120 F for 5 hours.

IV. Results and Data Analysis

1. Phase 1 Reduction Efficiency Comparison between Hot Water and Steam Blanching Processes

<u>The trials clearly identified hot water blanching as the superior method for reducing target contaminants</u>. However, for some heavy metals like Lead, there was no reduction (in fact, there was concentration) with the blanching process. Heaviest reduction was in iodine levels, followed by arsenic levels when a blanching process is utilized.

Table 1: Summary

Component	Hot Water Blanching (% Reduction)	Steam Blanching (% Reduction)
Iodine	87% to 94%	16% to 60%
Heavy Metals (As, Cd)	30% to 56%	15% to 20%
Heavy Metals (Pb)	40% to 50% Increase	3% to 200% increase

Table 2: Iodine reduction comparison Hot Water vs Steam Blanching

Iodine in ppb					
Kombu	Washed	Hot Water Blanched	% Reduction	Steam Blanched	% Reduction
T1	83580.2	2793.4	96.7%	4366.4	94.8%
T2	97375.5	7688.2	92.1%	89198.9	8.4%
T3	113587.8	12384.9	89.1%	86823	23.6%
T4	32444.2	845.6	97.4%		
Average	81746.925	5928.025	**93.8%**	60129.43333	**16.0%**
Wakame	Washed	Hot Water Blanched	% Reduction	Steam Blanched	% Reduction
T5	25699.9	2229.7	91.3%	14884.3	42.1%
T6	23119.4	2689.7	88.4%	4030.4	82.6%
T7	15608.5	2285	85.4%	4827.7	69.1%
T8	28714	4448.6	84.5%		
Average	23285.45	2913.25	**87.4%**	7914.133333	**64.6%**

Table 3: Arsenic reduction comparison Hot Water vs Steam Blanching

Arsenic in ppb					
Kombu	Washed	Hot Water Blanched	% Reduction	Steam Blanched	% Reduction

T1	2541.4	1255.8	50.6%	2175.1	14.4%
T2	2438.4	1397.8	42.7%	3273.4	-34.2%
T3	3087.5	1596.2	48.3%	3459.3	-12.0%
T4	2310.8	1599.2	30.8%		
Average			**43.1%**		**-10.6%**
Wakame	Washed	Hot Water Blanched	% Reduction	Steam Blanched	% Reduction
T5	3359.4	1448	56.9%	3353.5	0.2%
T6	2564.2	1302.3	49.2%	1974	23.0%
T7	4008.9	1518.9	62.1%	2220.4	44.6%
T8	3201.4	1308.3	59.1%		
Average			**56.8%**		**22.6%**

Table 4: Lead reduction comparison Hot Water vs Steam Blanching

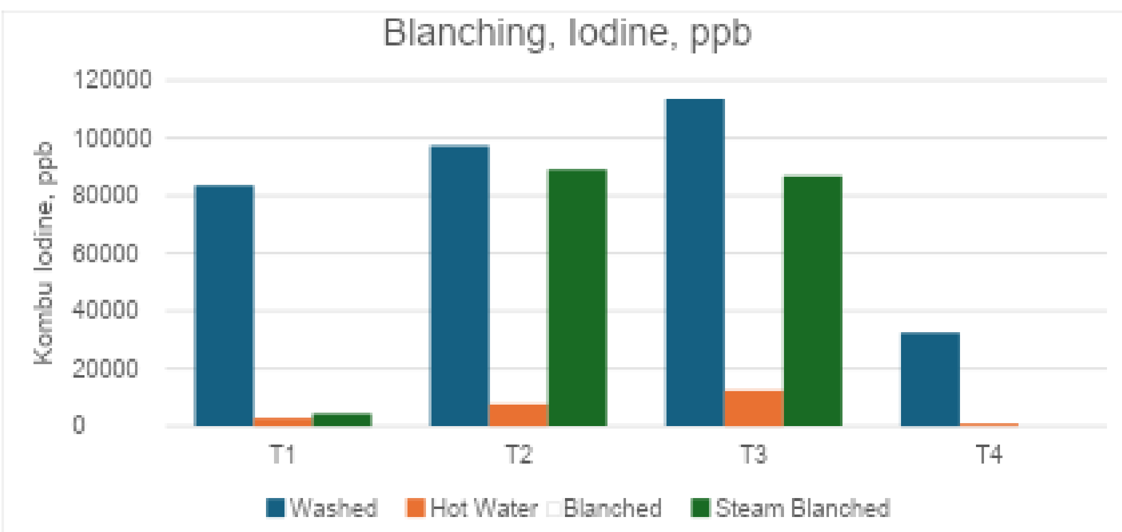
Lead in ppb					
Kombu	Washed	Hot Water Blanched	% Reduction	Steam Blanched	% Reduction
T1	5.7	15.2	-166.7%	18.9	-231.6%
T2	5.9	12	-103.4%	22.1	-274.6%
T3	9.8	11.1	-13.3%	17.6	-79.6%
T4	38.8	9.7	75.0%		
Average			**-52.1%**		**-195.2%**
Wakame	Washed	Hot Water Blanched	% Reduction	Steam Blanched	% Reduction
T5	9.5	22	-131.6%	10.5	-10.5%
T6	7	15.5	-121.4%	8.1	-15.7%
T7	18.8	13.9	26.1%	15.8	16.0%
T8	22.2	11	50.5%		
Average			**-44.1%**		**-3.4%**

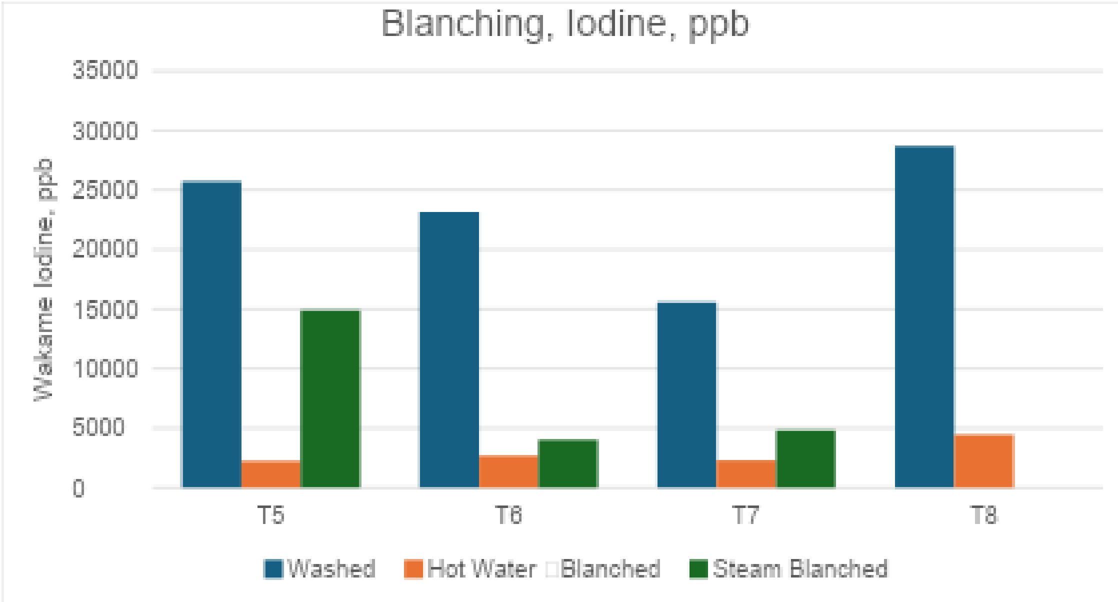
Table 5: Cadmium reduction comparison Hot Water vs Steam Blanching

Cadmium in ppb					

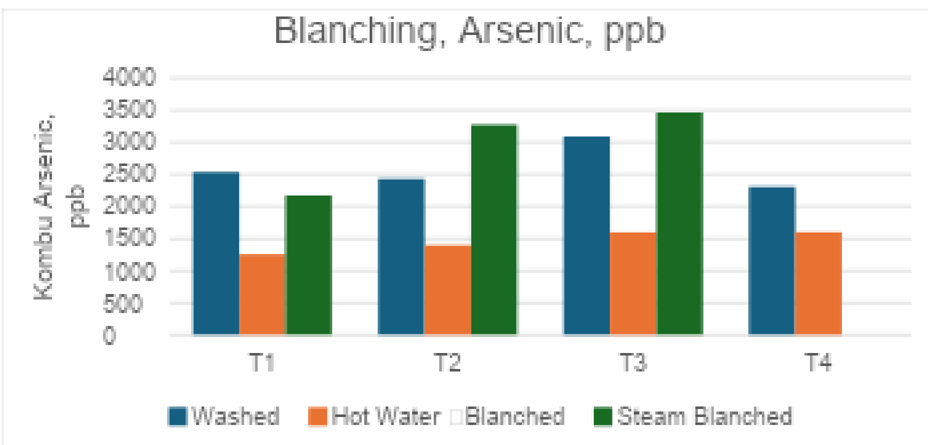
Kombu	Washed	Hot Water Blanched	% Reduction	Steam Blanched	% Reduction
T1	139.2	126.1	9.4%	192.8	-38.5%
T2	139.7			261	-86.8%
T3	222.8	201.4	9.6%	196.3	11.9%
T4	277.3	205.3	26.0%		
Average			**15.0%**		**-37.8%**
Wakame	Washed	Hot Water Blanched	% Reduction	Steam Blanched	% Reduction
T5	46.5	41.8	10.1%	62.8	-35.1%
T6	36.4	35.9	1.4%	58.7	-61.3%
T7	118.7	49.9	58.0%	83.6	29.6%
T8	78.7	39.6	49.7%		
Average			**29.8%**		**-22.2%**

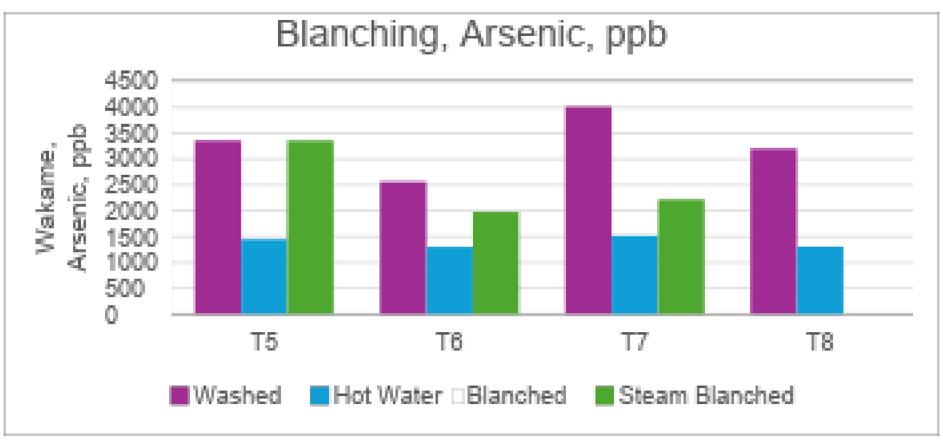
Graphs 1 - Iodine



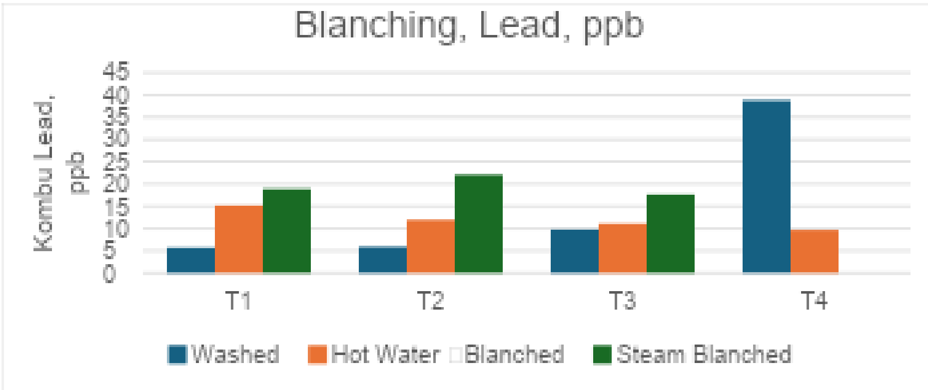


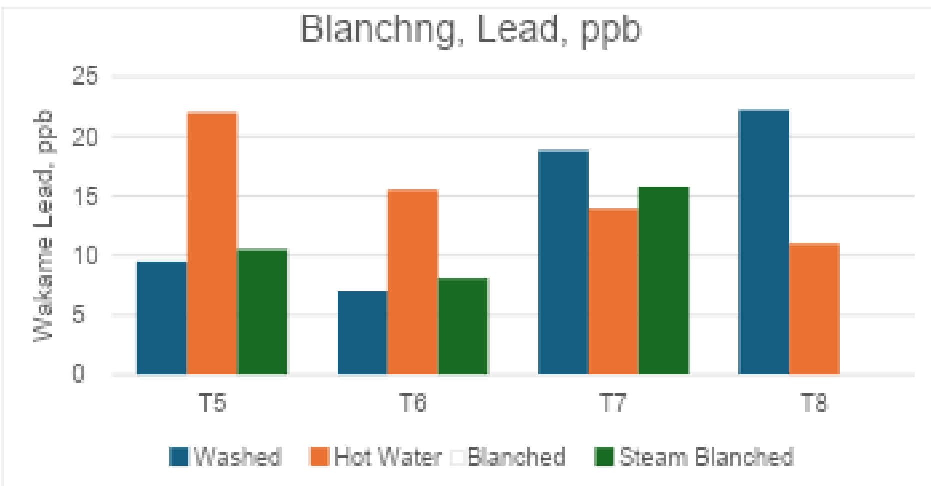
Graphs 2 - Arsenic



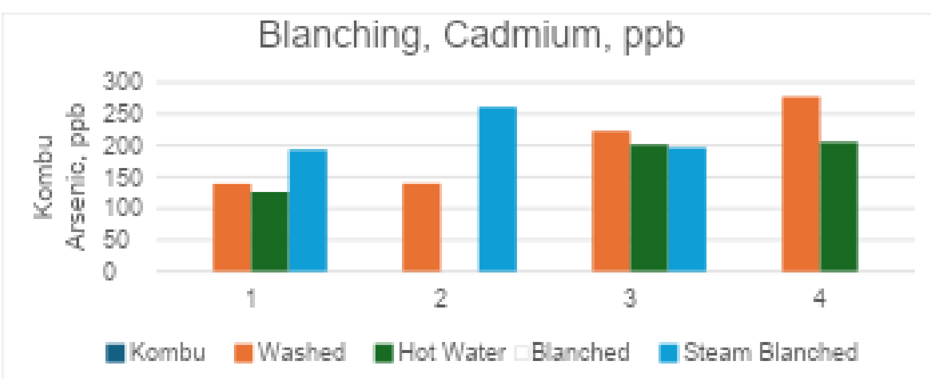


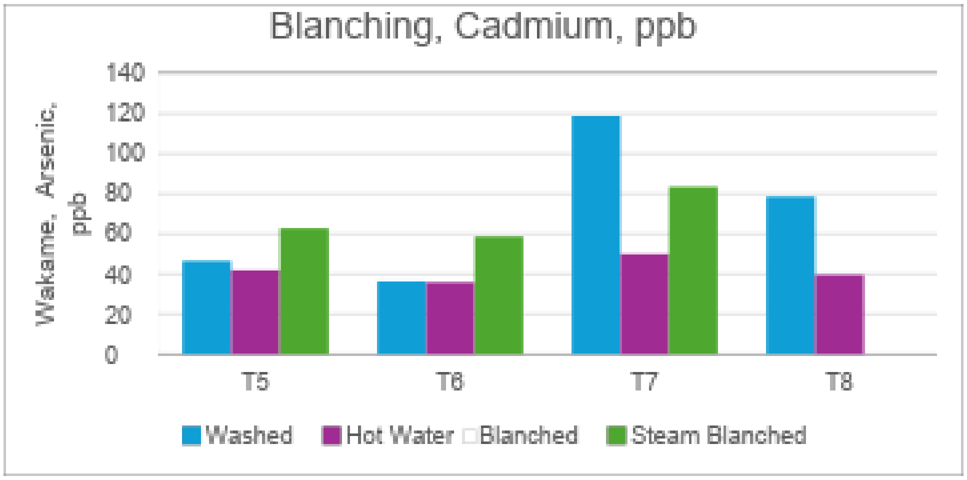
Graphs 3 - Lead





Graphs 4 – Cadmium





2. **Phase 2 (Dehydration Study):** Comparison of dehydrated samples with and without a preceding blanching process.

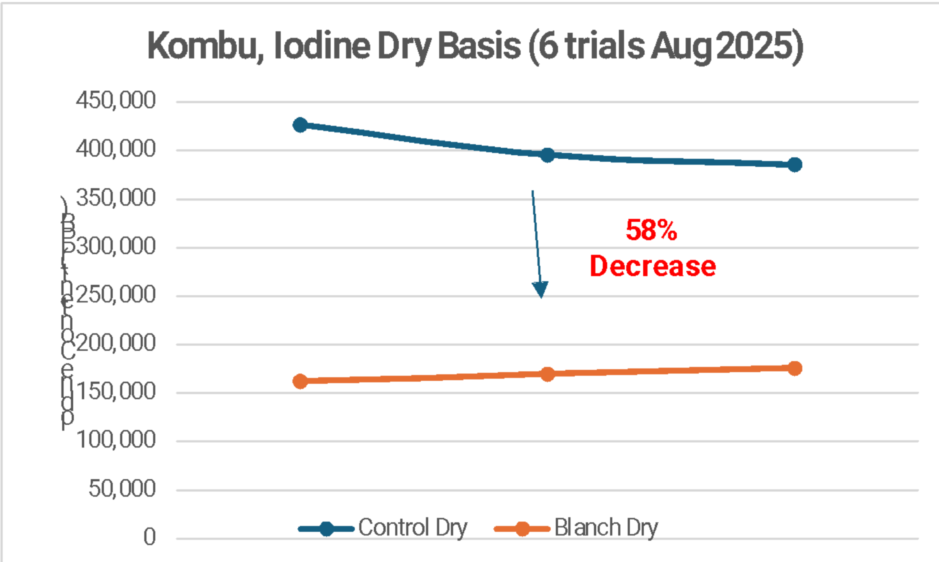
For Arsenic and Iodine, the trials demonstrated that blanching with hot water before dehydration resulted in lower levels than regular dehydrated samples (with no preceding blanching step). However, for Lead levels, there was an increase in blanched dehydrated samples vs the regular dehydrated samples.

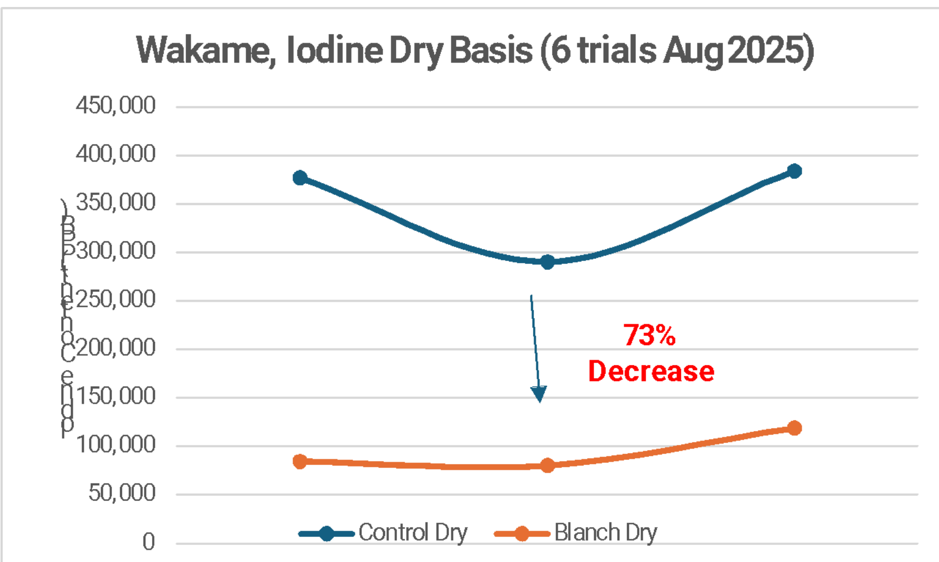
A key finding was that blanching results in a loss of solids (Leaching of solids in the blanch water) and thus results in a higher drying ratio. See Table 7/8 and Graphs 7.

Table 6: Summary Dehydration Study

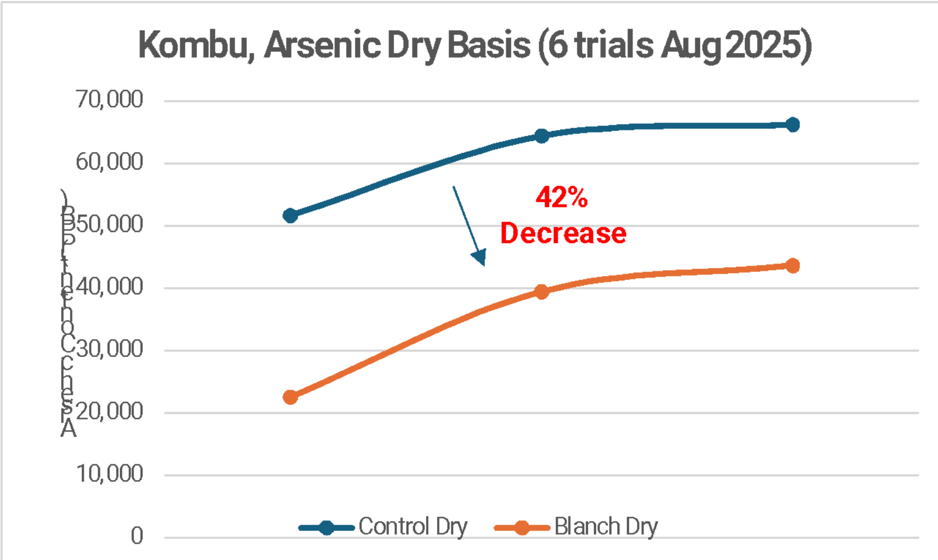
Component	**Reduction with Blanching before Dehydration**
Iodine	58% to 73%
Heavy Metals (Arsenic)	42% to 46%
Heavy Metals (Pb)	98% to 278% Increase

Graphs 5 – Iodine


Kombu, Iodine Dry Basis (6 trials Aug 2025)
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
58%
Decrease
Control Dry
Blanch Dry


Wakame, Iodine Dry Basis (6 trials Aug 2025)
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
73%
Decrease
Control Dry
Blanch Dry

Graphs 6 - Arsenic



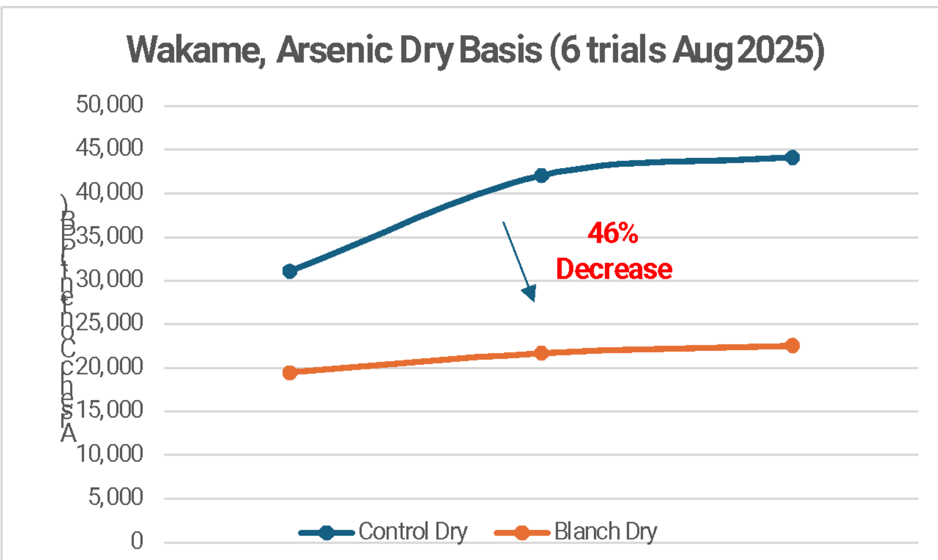


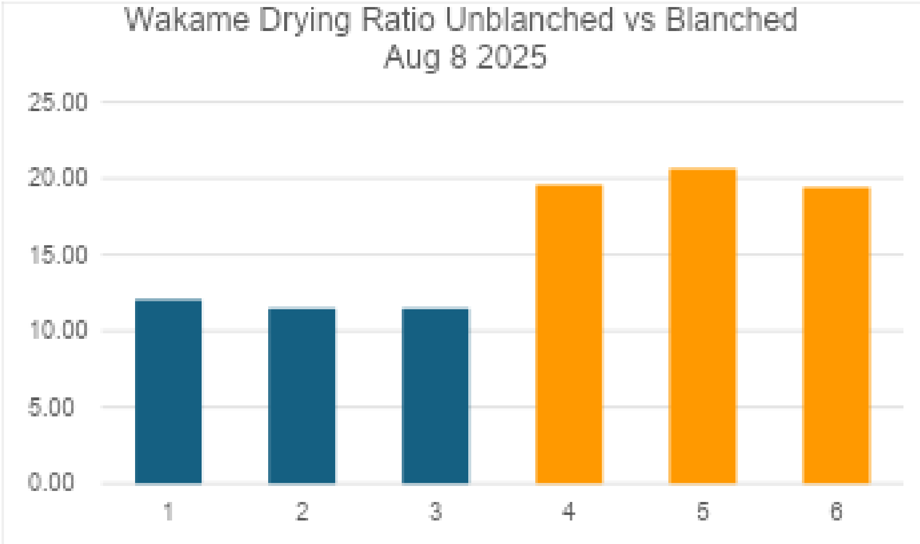
Table 7: Drying Ratio Summary

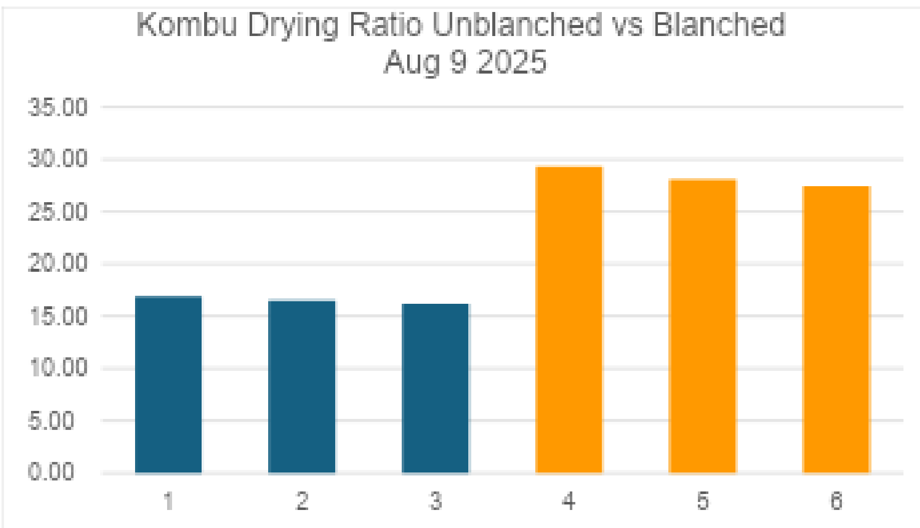
Product	**Drying Ratio Unblanched** (Wet weight/Dry weight)	**Drying Ratio Blanched** (Wet weight/Dry weight)
Kombu	16 to 17	27 to 30
Wakame	11 to 15	19 to 24

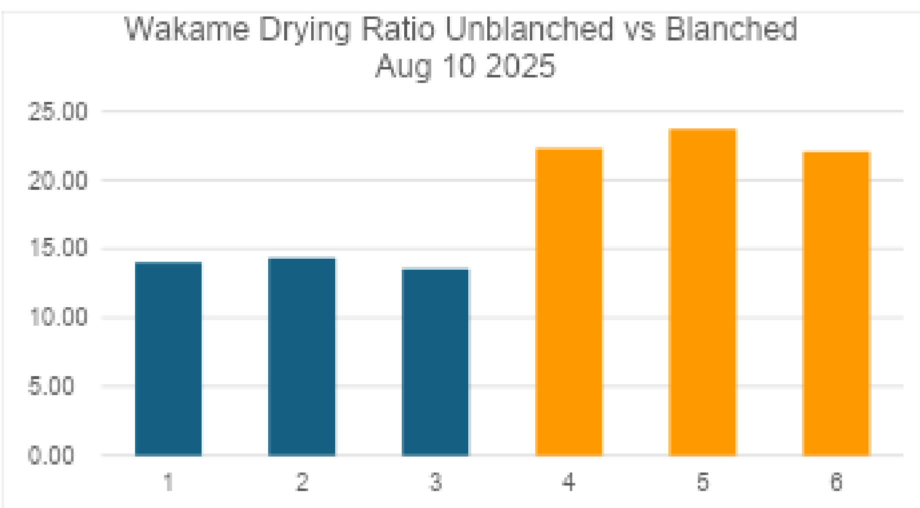
Table 8: Drying Ratio Comparison with and without Blanching

	Product Name	Sample Name	Process	Washed Weight (lbs.)	Wash and HW Blanch Weight (lbs.)	Dry Wt, lb	Drying Ratio Wet Wt/Dry Wt	Blanched Product Temp. (F	Notes
8/8/2025	Wakame, Ribbon Kelp, Alaria Marginata	W080825T1	Unblanched	4.040	N/A	0.336	12.02		
		W080825T2	Unblanched	3.710	N/A	0.324	11.47		
		W080825T3	Unblanched	4.060	N/A	0.354	11.48		
		W080825T4	Blanched	4.69	5.210	0.266	19.58	198	Water 205F, 90 Sec + Cold Water rinse
		W080825T5	Blanched	4.41	4.910	0.238	20.63	199	Water 205F, 90 Sec + Cold Water rinse
		W080825T6	Blanched	4.75	5.170	0.266	19.41	195	Water 205F, 90 Sec + Cold Water rinse
8/9/2025	Kombu, Sugar Kelp, Saccharina Latissima	K080925T7	Unblanched	4.84	N/A	0.287	16.89		
		K080925T8	Unblanched	4.43	N/A	0.269	16.48		
		K080925T9	Unblanched	4.56	N/A	0.282	16.18		
		K080925T10	Blanched	4.08	4.000	0.137	29.30	204	Water 205F, 90 Sec + Cold Water rinse
		K080925T11	Blanched	4.09	4.350	0.155	28.12	201.5	Water 205F, 90 Sec + Cold Water rinse
		K080925T12	Blanched	3.77	3.760	0.137	27.44	202.4	Water 205F, 90 Sec + Cold Water rinse
8/10/2025	Wakame, Ribbon Kelp, Alaria Marginata	W081025T13	Unblanched	4.88	N/A	0.348	14.03		
		W081025T14	Unblanched	4.99	N/A	0.348	14.34		
		W081025T15	Unblanched	4.86	N/A	0.359	13.53		
		W081025T16	Blanched	5.88	6.310	0.283	22.29	204	Water 205F, 90 Sec + Cold Water rinse
		W081025T17	Blanched	5.96	6.510	0.274	23.72	203	Water 205F, 90 Sec + Cold Water rinse
		W081025T18	Blanched	5.73	6.200	0.281	22.06	201	Water 205F, 90 Sec + Cold Water rinse

Graphs 7 - Drying Ratio Comparisons


Wakame Drying Ratio Unblanched vs Blanched
Aug 8 2025
25.00
20.00
15.00
10.00
5.00
0.00
1
2
3
4
5
6


Kombu Drying Ratio Unblanched vs Blanched
Aug 9 2025
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
1
2
3
4
5
6


Wakame Drying Ratio Unblanched vs Blanched
Aug 10 2025
25.00
20.00
15.00
10.00
5.00
0.00
1
2
3
4
5
6

3. Consumption Amounts - Impact on Safe Daily Intake

Table below demonstrates that iodine levels are generally the governing factor for consumption amounts that require labeling and compliance i.e. consumption amounts on both wet and dry products will reach its limit per the iodine content in it before the other heavy metal factors like lead and arsenic become limiting factors.

By reducing iodine levels, the amount of seaweed a person can safely eat within the 150-microgram daily limit increases substantially.

The reduction in iodine is particularly important. Because iodine levels are so high in raw Kombu, a consumer could only safely eat less than 2 grams per day of fresh seaweed. After hot water blanching, that limit jumps to over 25 grams, making the product much more attractive to health-conscious consumers and regulators.

Recommended Daily Allowances (RDAs) are set by scientific bodies and claims on consumption amounts based on the RDAs, are regulated by FDA for food and dietary supplement products.

For this exercise, to demonstrate consumption limits;

RDA limits used for lead = 0.5 microgram per day (per prop 65)

RDA limit for iodine = 150 microgram per day

Limit for Total Arsenic = 105 microgram per day

Note: Arsenic Limit exercise for this study, outlined below;

1. While no official RDA exists for Arsenic, EPA sets safe consumption limit of 0.3 microgram/Kg of body weight/day for inorganic arsenic.
2. In most seaweed species with the exception of Hijiki, it is generally accepted that inorganic arsenic is under 1% of total arsenic.
3. For the purposes of this study a conservative number of 20% inorganic arsenic is applied as a percent of total arsenic.
4. Assuming 70 Kg as accepted body weight for calculation; total arsenic consumption = (0.3 x 70)/(0.2) = 105 microgram per day.
5. The above exercise for Arsenic is intended as an example only and these assumptions and corresponding limits can be changed or adjusted per the user's justification.

Considering Iodine levels, Arsenic levels and Lead levels present in the test samples, the following Table represents the daily consumption amounts.

Table 9: Consumption amount limits on Wet Basis

Wet Basis										
Treatment	Product	Lead	Arsenic	Iodine	Lead	Arsenic	Iodine	Lead	Arsenic	Iodine
		ppb			Limit, microgram/Day			Daily Amount, grams		
Control	Kombu	9.0	5931.0	81746.0	0.5	105	150	55.56	17.70	1.83
HW Blanch	Kombu	12.0	2591.0	5928.0	0.5	105	150	41.67	40.52	25.30
Control	Wakame	7.0	3418.0	23285.0	0.5	105	150	71.43	30.72	6.44
HW Blanch	Wakame	8.3	842.0	2913.0	0.5	105	150	60.00	124.70	51.49

Table 10: Consumption amount limits on Dry Basis

Dry Basis										
Treatment	Product	Lead	Arsenic	Iodine	Lead	Arsenic	Iodine	Lead	Arsenic	Iodine
		ppb			Limit, microgram/Day			Daily Amount, grams		
Control	Kombu	93.3	60723.3	402253.0	0.5	105	150	5.36	1.73	0.37
HW Blanch	Kombu	185.0	35139.0	168747.0	0.5	105	150	2.70	2.99	0.89
Control	Wakame	41.7	39057.0	350187.0	0.5	105	150	12.00	2.69	0.43
HW Blanch	Wakame	159.0	21200.0	94143.0	0.5	105	150	3.14	4.95	1.59

V. Discussion

1. Analysis results of Heavy metals (Lead, Arsenic, Cadmium, Mercury) and Iodine showed variability in measurement with some inconsistent results. Multiple samples were sent to mitigate this variability. (Sample preparation, like pureeing the product or grinding before analytical measurements are known vectors to introduce variability and must be standardized by laboratory for consistency). For

future trials a larger sampling frequency can be used for greater consistency in measurement. However, there were sufficient samples to draw the conclusions for this study purposes.

2. Since seaweed harvest is mostly limited to a few months annually, fresh seaweed upon harvest, requires a stabilization process like freezing or dehydration for safe consumption availability during the entire year.
   a. For ‘Wet’ consumption, seaweed can be consumed either fresh harvested (limited to a few days of shelf life) or in frozen packaged form (where it can be stored in a freezer for a shelf life of 1-2 years).
   b. Other forms of ‘Wet’ food consumption and stabilization can be pickling or salting process and in some cases fermentation.
   c. For ‘Dry’ consumption, seaweed would go through a dehydration process to stabilize the product and then packaged in moisture barrier package for ambient storage (shelf life 1-2 years).
3. Prior to the above stabilization processes, the processor has a choice to apply preceding process steps like washing, chopping, blanching etc.
4. The most significant process unit operation is blanching, which can bring about a change in the physical properties of the seaweed, where there are heat related physical changes (like change in color) and a leaching or concentration of elements and compounds. Hence this is an influential choice that processors must consider during their stabilization process, as it impacts the final levels of these substances, present in their ‘finished’ wet or dry product.
   a. An added nuance is that blanching before dehydration results in a lower yield (i.e. a higher drying ratio).
5. In this study, the focus was on Heavy Metals and Iodine, since these are present in higher levels in seaweed compared to other land based food products.
6. Iodine levels are high in both species studied here – Saccharina Latissima (Alaskan Kombu) and Alaria Marginata (Alaskan Wakame), harvested from Kodiak Island, Alaska. Amongst the Heavy metals and Iodine levels, the Iodine levels have a greater impact on the consumption of the finished products i.e. for a particular amount consumed, these stabilized seaweed products will reach the allowable iodine levels limit before reaching the Heavy Metals limit (mainly for Lead and Arsenic). Other heavy metals like Cadmium and Mercury are at even lower amounts.
7. The portion size of consumption is governed by daily limits established by scientific bodies and regulated by FDA, based on maximum levels allowed for certain elements.

8. The limits of consumption Tables in the section of ‘Impact on Safe Daily Intake’, above, are developed utilizing the FDA guidelines and other scientific publications. This is for calculation purposes and can be adjusted if other interpretations of daily limits are applied by the user. Hence the ‘Daily Amounts’ are presented above as a result of the measured levels in the seaweed species tested and the interpretation of the Limits per Day.
9. Tables 9 and 10, demonstrate that a blanching process step, applied before either Wet or Dry stabilization process, allows for increased consumption of both Kombu and Wakame. Each species reaches the limit of allowable iodine consumption amount, before the other Heavy Metals reach their allowable consumption limits. Hence the maximum recommended daily consumption amount needed for labeling the product would be governed by the iodine levels, as shown in the example above.
10. An important criteria for Dry product is the yield of dried product from the wet raw material used. Due to blanching and an exchange of solids leaching into the blanch water, there will be a lower dry product yield when blanching is applied vs no blanching. Hence the processor has a choice to achieve a higher yielding dry product with higher levels of iodine (and correspondingly a lower consumption limit) or a lower yielding dry product with lower levels of iodine (and correspondingly a higher daily consumption amount, for greater marketability).
11. A further nuance to the marketability of the product is the custom application in various foods, as an ingredient, where the daily limits can now be applied to the usage levels, to determine labeling compliance.

VI. Conclusions

The study concludes that **hot water blanching** is the most effective industry best practice for reducing heavy metals (like Arsenic) and iodine. While steam blanching is common for food safety, it does not provide enough "leaching" to significantly improve the reduction of target compounds, for safe consumption limits for seaweed. Adopting hot water blanching allows processors to offer products that can be consumed in much larger portions while remaining within safety guidelines. This highlights the massive market potential opened by proper processing.

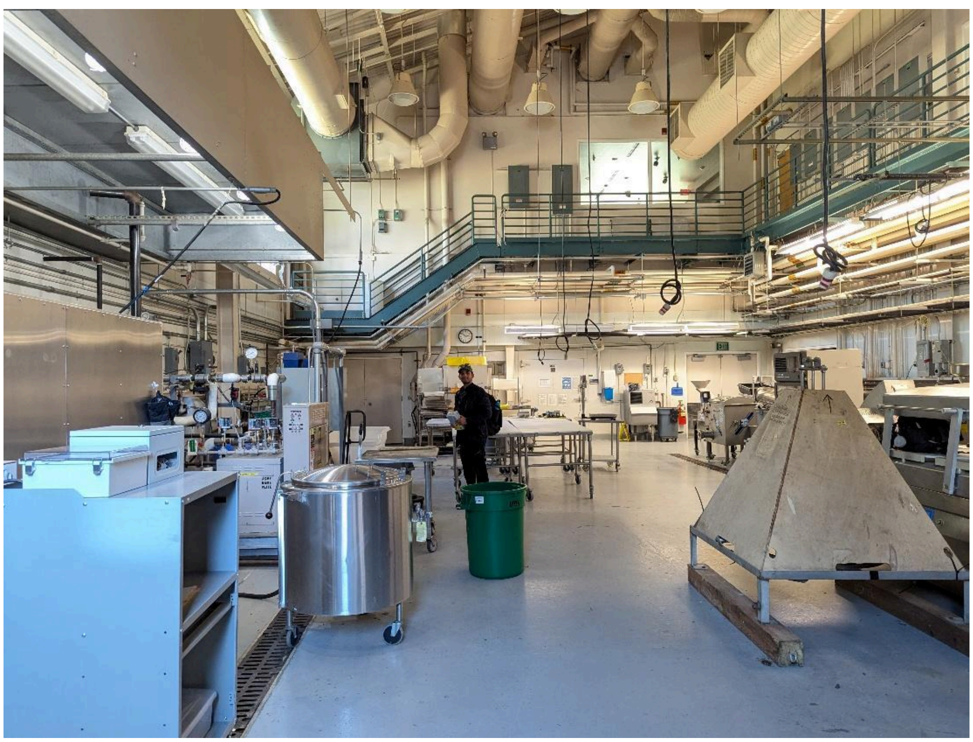
Dehydration of seaweed with a preceding step of blanching also results in lower levels iodine and arsenic.

Some elements, like Lead and cadmium did not show a reduction (and were concentrated) by applying the blanching process. However, even with the concentration, the levels of these elements are still lower than impactful limits governed by iodine levels.

VII. Next Steps

1. **Repeatability and Laboratory Consistency**: Expanded study to establish repeatability and reduction in laboratory analysis variability.
2. **Establish Best Practices:** Publish specific temperature and time recommendations for Alaskan seaweed processors.
3. **Dehydration Trials:** Further trials on the economics of the drying process considering the impact of yield with utilization of blanching processes vs control of no blanching, can be studied for business impact and pricing.
4. **Industry Outreach:** Share findings with tribal communities and commercial partners to improve the quality and safety of seaweed products globally.

Pictures

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