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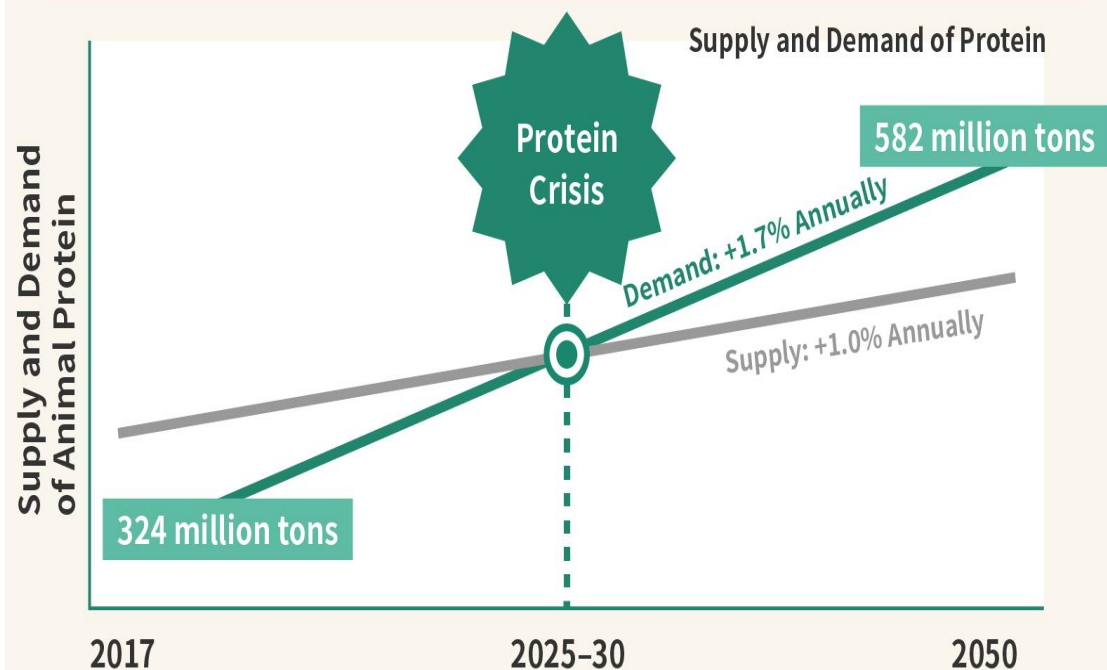
Seaweed-Protein research in the Sultanate of Oman: Current research and future potential

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Protein Crisis — Protein Demand Exceeding Supply



<https://regional.fish/en/>

RISING GLOBAL PROTEIN DEMAND

- Global protein demand projected to increase 70% by 2050
 - Population: 9.7 billion people (UN, 2019)
 - Rising living standards
- Food security challenges: sustainable alternatives urgently needed

SEAWEEDS AS PROTEIN SOURCES

- **High protein content:**
 - *Porphyra spp.*: up to **47% protein (db)**
 - *Ulva spp.*: up to **35% protein (db)**
 - *Macrocystis pyrifera*: ~**24% protein (db)**
- **Superior productivity:**
 - Seaweed: **0.7–9.9 t protein/ha**
 - Soybean: **1.1–1.5 t protein/ha**
 - Alfalfa: **1.2–3.3 t protein/ha**

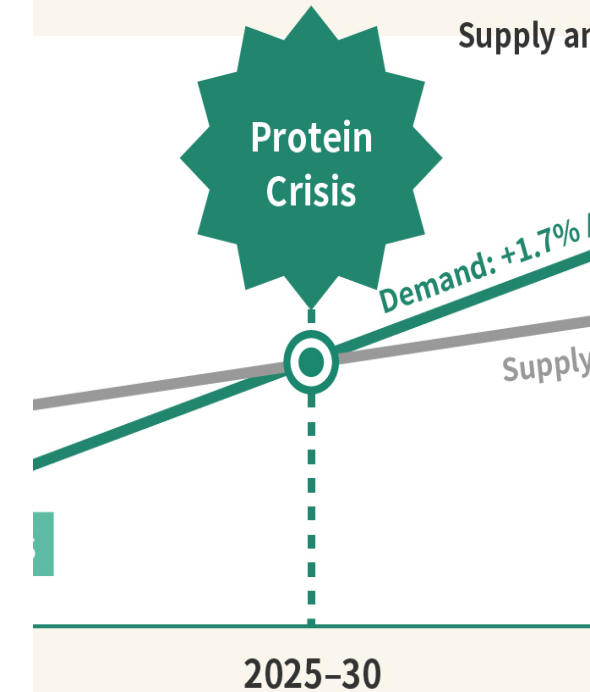


<https://www.unsw.edu.au/newsroom/news/2016/11/underwater-health-check-shows-kelp-forests-are-declining-around->



<https://farmtario.com/crops/dlf-sowing-the-seeds-of-increased-alfalfa-breeding-with-corteva-aquisition/>

Protein Demand Exceeds Supply



<https://www.tradeindia.com/products/soybean-seeds-c6053601.html>



SUSTAINABILITY ADVANTAGES

- No arable land, freshwater, or synthetic fertilizers required
- **90% fewer GHG emissions** vs. beef protein
- **Zero irrigation water** (vs. soybean: 1,800 L/kg protein)
- Mitigates pressure on decreasing arable land (**-0.3% annually**)



OPPORTUNITIES WITH *HYPNEA BRYOIDES*

- Found abundantly in **Omani seas** (~17% protein db)
- Dual-product potential: **protein + carrageenan**
- Global seaweed market: **\$16.6B (2020) → \$25.5B (2028)**
- Under-researched protein properties = strong R&D opportunity



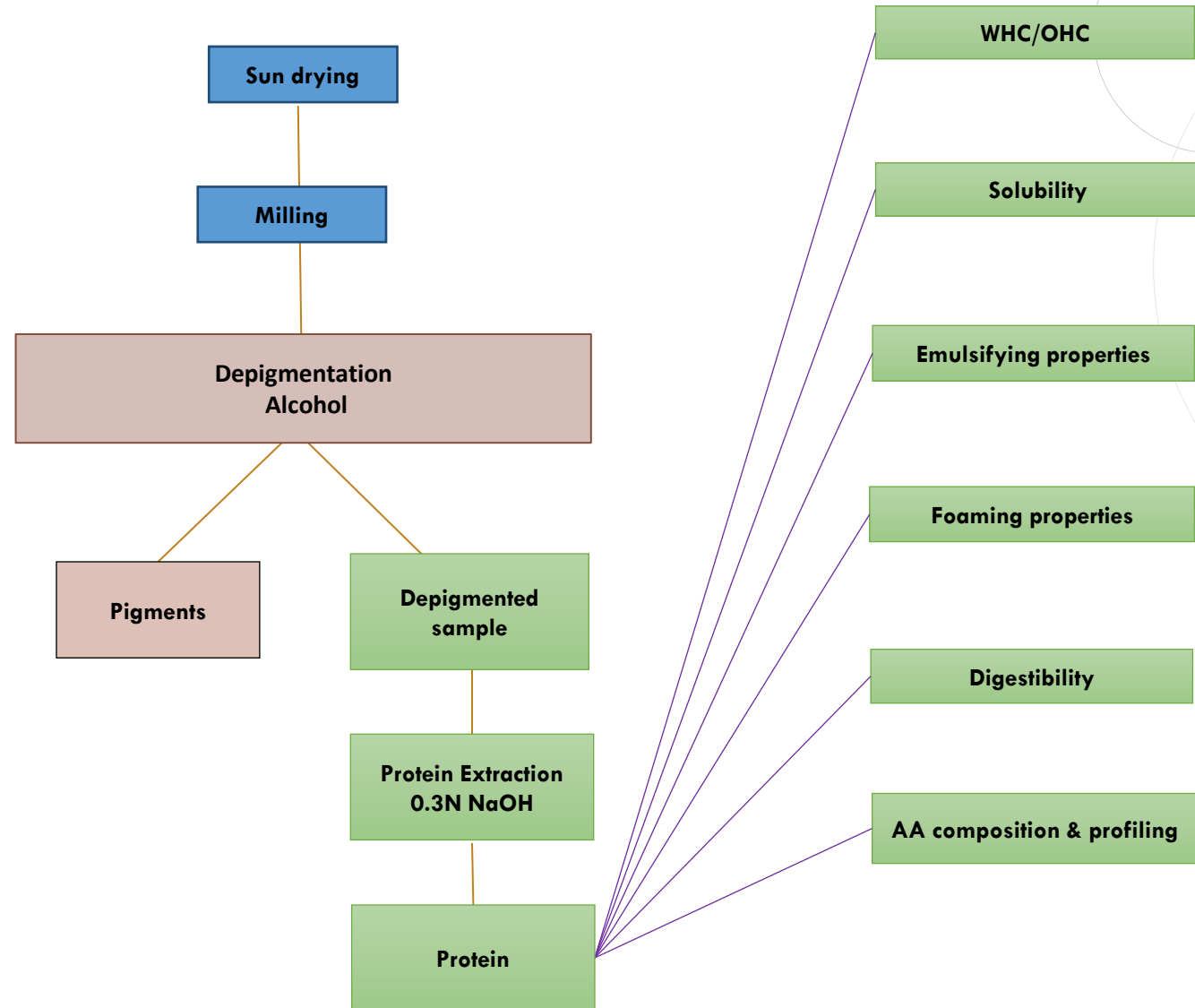
OBJECTIVES

- Characterize the protein composition of *Hypnea bryoides* collected from Omani seas
- Evaluate functional properties (solubility, emulsification, water/oil holding) of *H. bryoides* proteins
- Evaluate protein quality (amino acid profile, digestibility)
- Find the optimized conditions to maximize protein extraction

https://www.theportugalnews.com/news/2026-02-24/portuguese-biotechnology-reinvents-food-with-the-support-of-compete-2030/976871#google_vignette



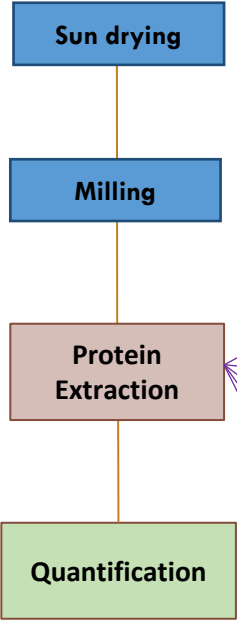
METHODOLOGY





OPTIMIZATION 1

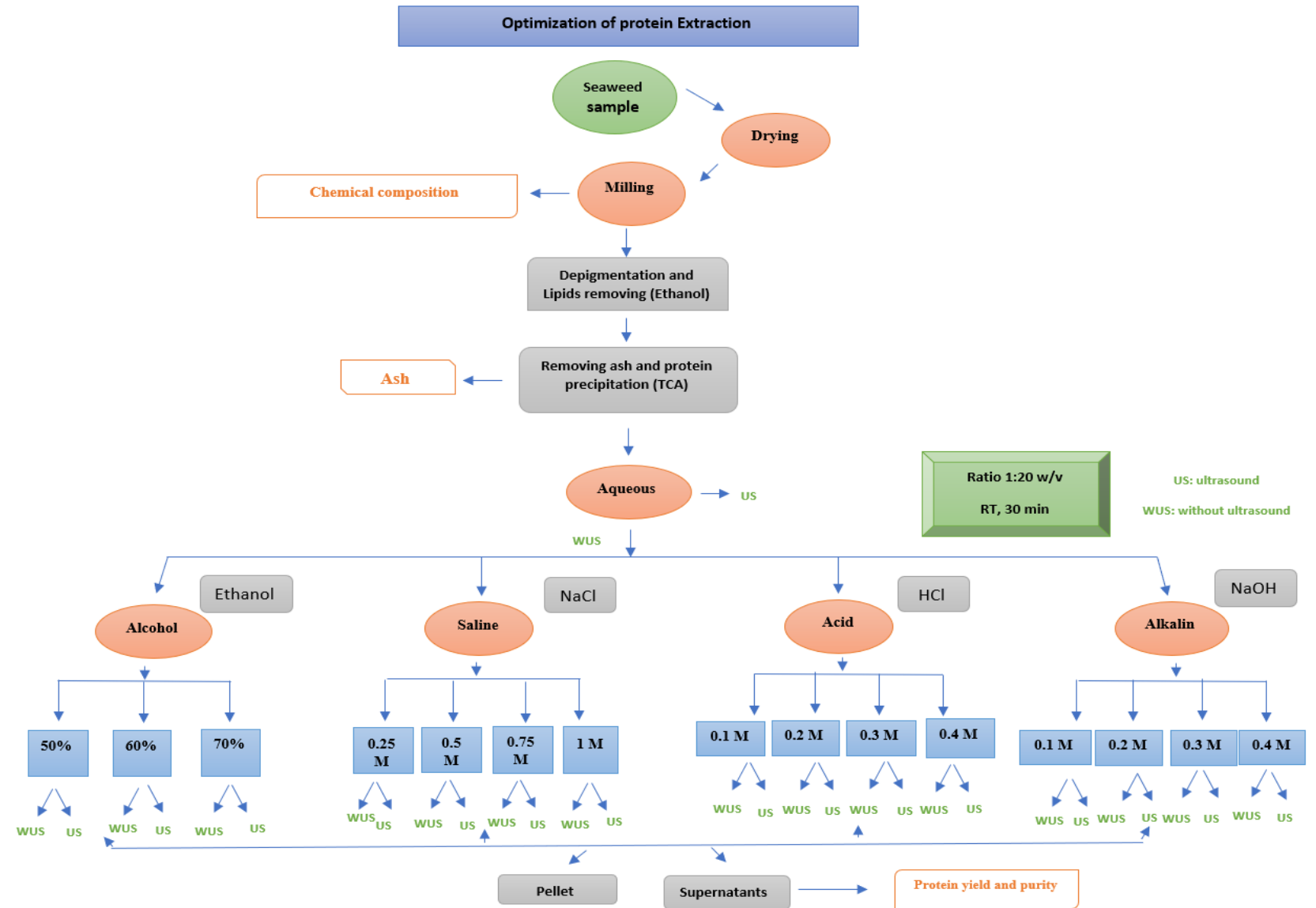
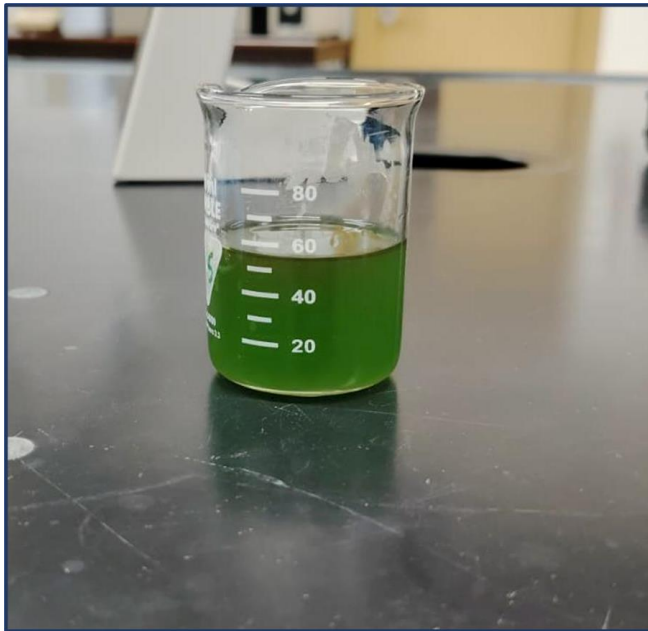
Three factors: solvent, application of pre-treatment (ultrasound bath), and incubation temperature, were examined for their effects on protein yield and extract purity.



Solvent Type	Ultrasound Application	Incubation Temperature
Water	Applied	4°C
		Room Temperature
	Not Applied	40°C
		4°C
0.1M NaOH	Applied	Room temperature
		40°C
	Not Applied	4°C
		Room temperature
0.1M HCl	Applied	40°C
		4°C
	Not Applied	Room temperature
		40°C
0.5M NaCl	Applied	4°C
		Room temperature
	Not Applied	40°C
		4°C
70% Ethanol	Applied	Room temperature
		40°C
	Not Applied	4°C
		Room temperature
		40°C



OPTIMIZATION 2





RESULTS





PROXIMATE COMPOSITION

- High in protein and carbohydrates
- Low in Ash and fat

Composition	Content in (%) in the recent study
Moisture	12.28± 0.09
Ash	11.87 ± 0.05
Fat	1.01± 0.07
Protein	19.48± 0.07
Carbohydrate	67.57±0.00

2011 study

10.94±0.8 %

39.04±1.1 %

3.38±0.1 %

15.93±0.8 %

41.65±0.4 %



YIELD



Sample name	Yield of crude protein (%)	Purity of extracted protein (%)	References
<i>Hypnea bryoides</i>	31 ± 0.35	88.5 ± 0.71	Our study
<i>Kappaphycus alvarezii</i>	43	62.3 ± 1.62	Kumar et al. (2014)
<i>Hypnea charoides</i>	46.3 ± 0.61	83.1 ± 0.94	Wong and Cheung (2001)
<i>Hypnea japonica</i>	45.4 ± 0.23	85.0 ± 0.38	Wong and Cheung (2001)



WHC/OHC

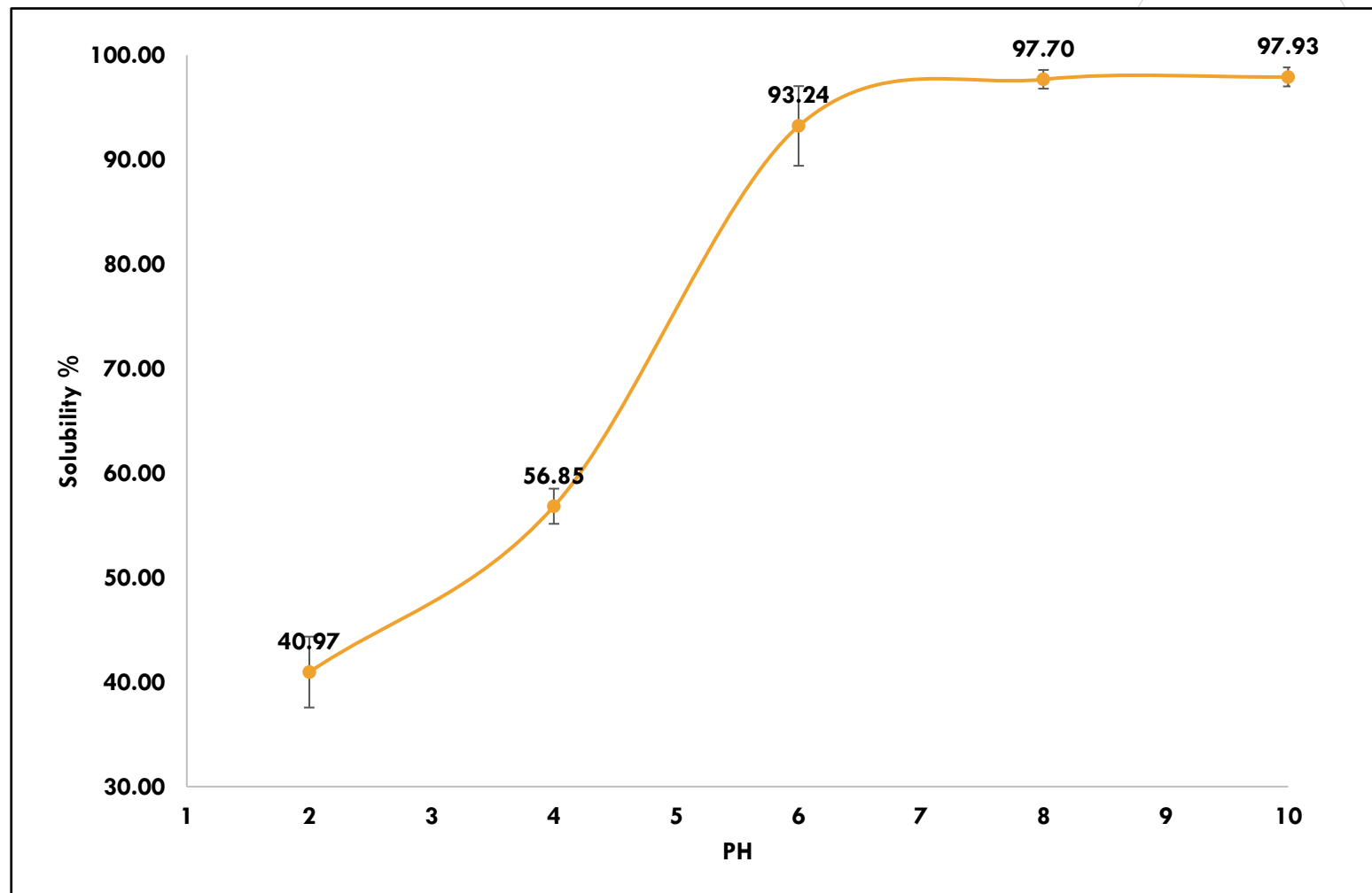
- Both high
- WHC as high as most of the reported results
- OHC: the highest ever reported

Sample name	WHC (water/g protein)	OHC (oil/g protein)	References
<i>Hypnea bryodies</i>	9.61 ± 0.15 g	13.56 ± 0.26	Our study
<i>Himanthalia elongata</i>	10.27 ± 0.09	8.1 ± 0.07	Garcia-Vaquero et al. (2017)
<i>Ulva lactuca</i>	8.68 ± 0.50	0.650.03	Wong and Cheung (2000)
<i>Spirulina platensis</i>	2.25	5.80	Bleakley and Hayes (2021)
<i>Isochrysis galbana</i>	0.47	3.16	Bleakley and Hayes (2021)
<i>Hypnea charoides</i>	10.9 ± 0.30	0.95 ± 0.04	Wong and Cheung (2000)
<i>Hypnea japonica</i>	11.8 ± 0.05	0.82 ± 0.01	Wong and Cheung (2000)



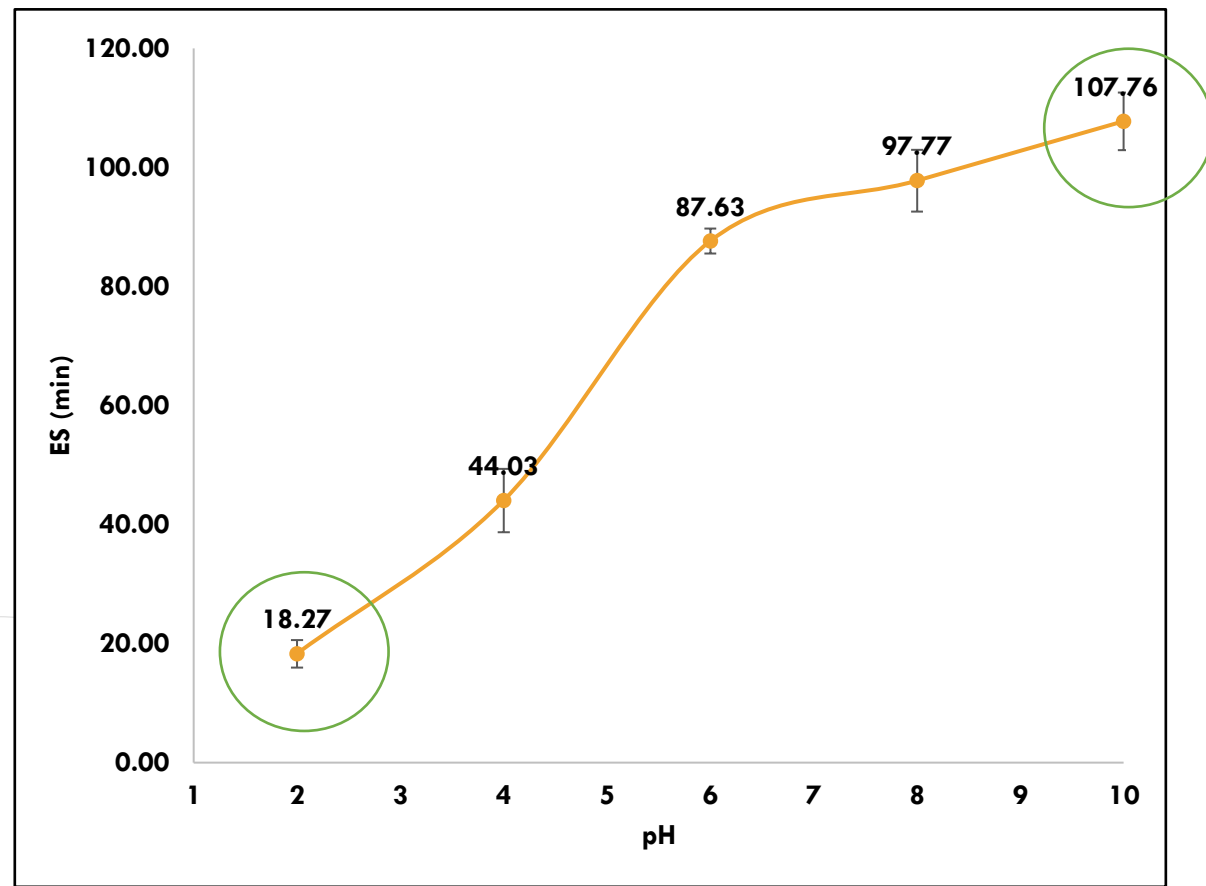
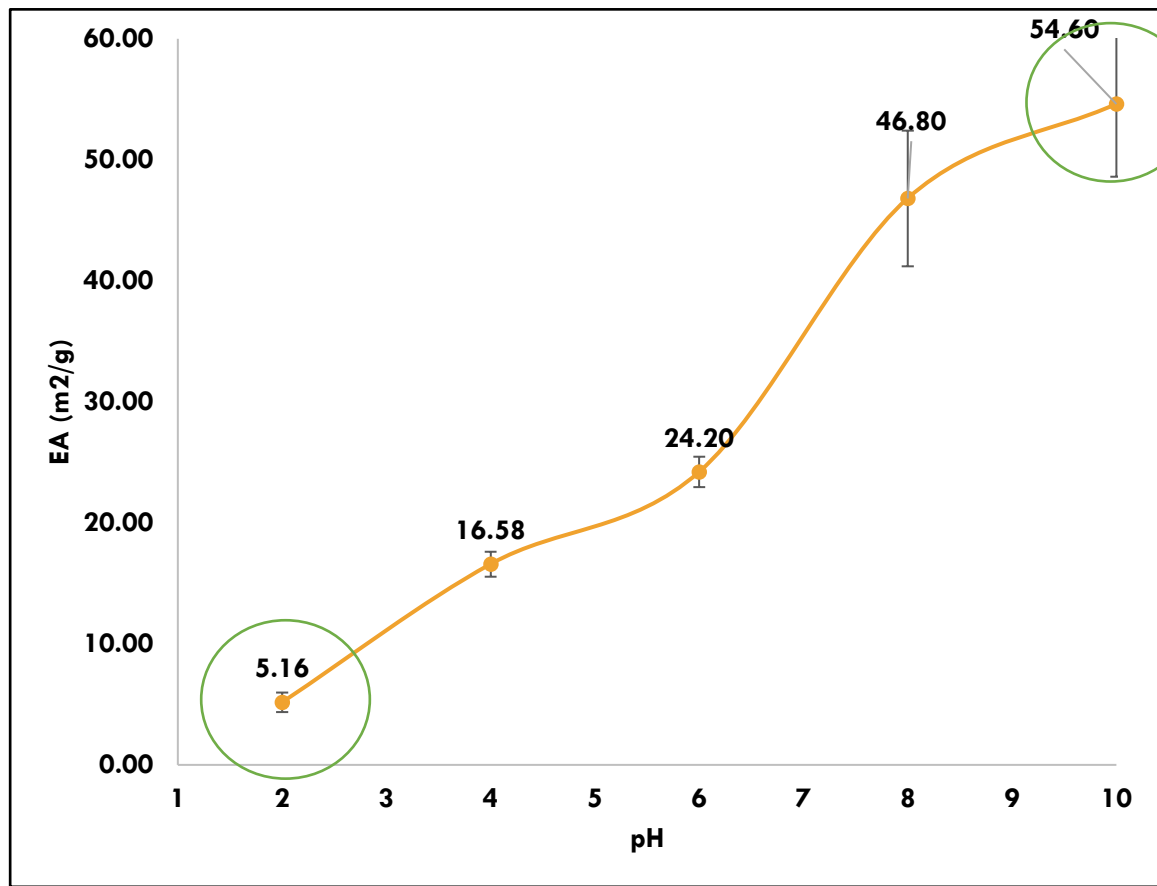
SOLUBILITY

- Low at low pH
- High at neutral and high pH



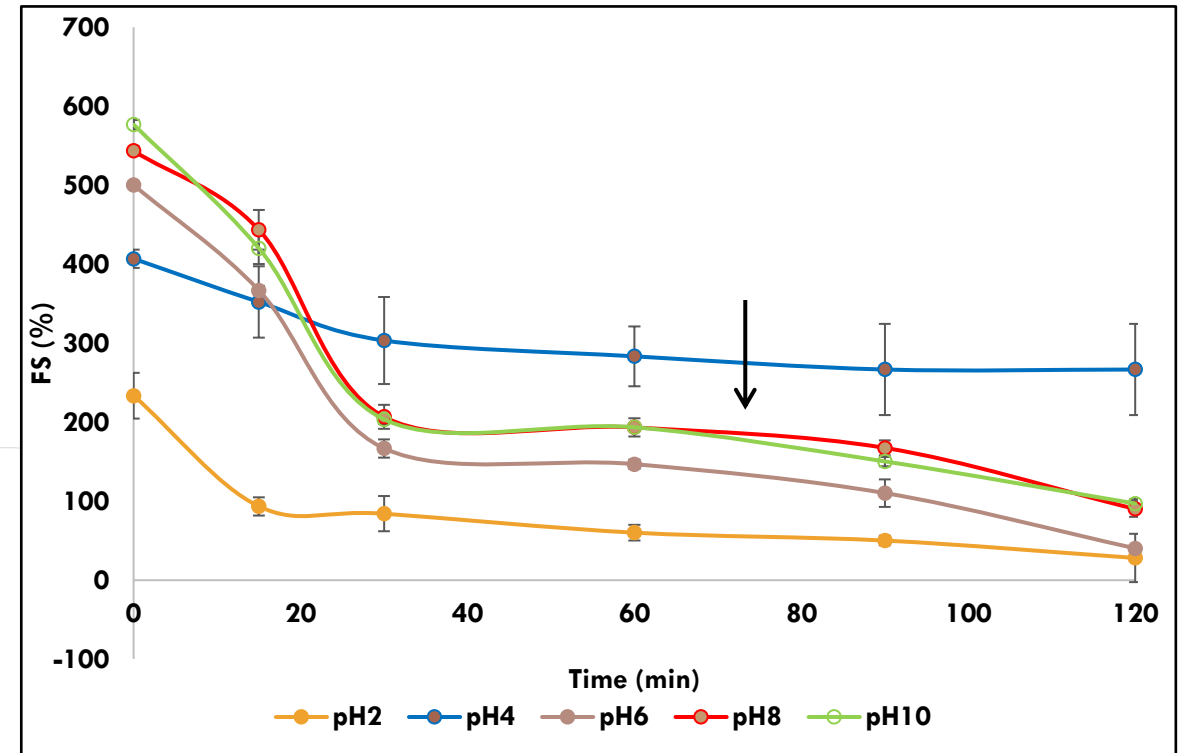
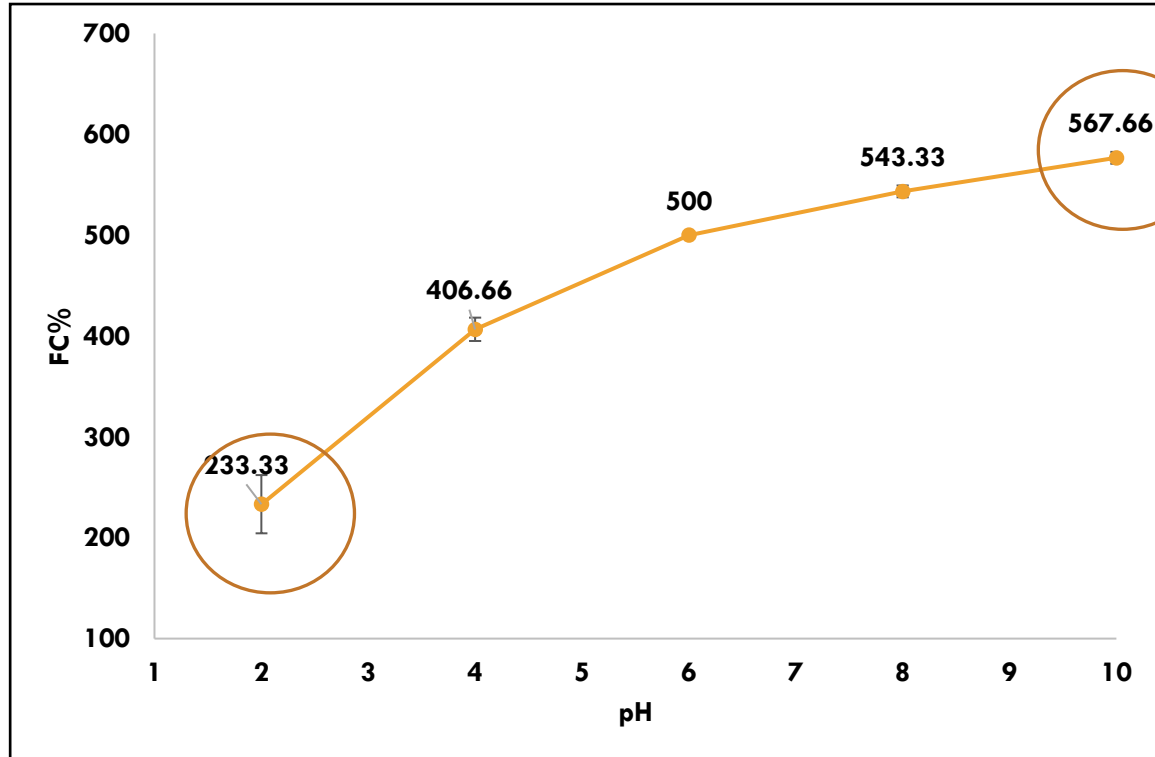


EMULSIFYING ACTIVITY AND STABILITY





FOAMING CAPACITY AND STABILITY





DIGESTIBILITY

- Relatively low compared with the reported data

Sample name	Digestibility (%)	References
<i>Hypnea bryoides</i>	62.62±3.29	Our study
<i>Porphyra columbina</i>	74.33±3.0	Cian et al. (2014)
<i>Hypnea charoides</i>	88.7±0.70	Wong & Cheung (2001)
<i>Hypnea japonica</i>	88.9 ± 1.40	Wong & Cheung (2001)
<i>Ulva lactuca</i>	85.7 ± 1.90	Wong & Cheung (2001)



AMINO ACIDS PROFILE

- High in polar amino acids and especially negatively charged amino acids.
- Good amount of essential amino acids

Amino acids		Concentration (PPM)
Essential amino acids	Phenylalanine	23.19±1.98
	Tryptophan	nd
	Leucine	26.31±0.43
	Isoleucine	11.15±1.19
	Methionine	3.374±0.40
	Histidine	8.25±1.67
	Lysine	23.84±0.87
	Valine	22.26±1.13
	Threonine	25.28±1.67
Non-essential amino acids	Alanine	21.83±0.49
	Glutamic acid	51.43±1.95
	Aspartic acid	38.68±1.11
	Glycine	28.59±1.36
	Serine	27.07±0.82
	Glutamine	20.26±0.03
	Asparagine	6.71±0.05
	Cysteine	nd
	Tyrosine	18.64±0.48
	Arginine	25.61±0.59
	Proline	25.01±1.82
Total amino acids		398.14
Essential amino acids		35%
Non-essential amino acids		65%



OPTIMIZATION 1

- ❖ Increasing the temperature increased the yield. The significance varied.
- ❖ Use of Ultrasound didn't enhance extraction significantly.
- ❖ Alkaline and acid treatments had the highest extraction efficiency.

Solvent Type	Ultrasound Application	Incubation Temperature	Protein Yield (%)
Water	Applied	4°C	17.8
		Room Temperature	18.4
		40°C	20.3
	Not Applied	4°C	15.8
		Room temperature	15.8
		40°C	18.8
0.1M NaOH	Applied	4°C	16.6
		Room temperature	18.4
		40°C	31.5
	Not Applied	4°C	19.0
		Room temperature	25.3
		40°C	43.8
0.1M HCl	Applied	4°C	10.3
		Room temperature	17.3
		40°C	60.0
	Not Applied	4°C	11.8
		Room temperature	29.4
		40°C	48.5
0.5M NaCl	Applied	4°C	16.3
		Room temperature	16.9
		40°C	18.1
	Not Applied	4°C	18.4
		Room temperature	21.2
		40°C	22.6
70% Ethanol	Applied	4°C	16.9
		Room temperature	18.8
		40°C	17.4
	Not Applied	4°C	10.8
		Room temperature	14.5
		40°C	16.5



EFFECT OF SALT

- ❖ Salt was extracted alongside proteins.
- ❖ This affected the nature of the extraction condition.

Extraction Conditions (Solvent, Incubation Temperature)	Amount of Inorganic Material in the Dried Extract (%)	Estimated Total Extracted Inorganic Materials from the Original Quantity (%)
Deionized water, 4°C	60.76 ± 2.9	51.34
Deionized water, room temperature	63.28 ± 2.4	58.95
Deionized water, 40°C	46.44 ± 3.2	61.44



EFFECT OF HEAT

- ❖ Coagulation was observed in the samples extracted at 40 °C.
- ❖ This is attributed to the solubilization of carrageenan.



Coagulation due to the extraction at 40 degrees Celsius



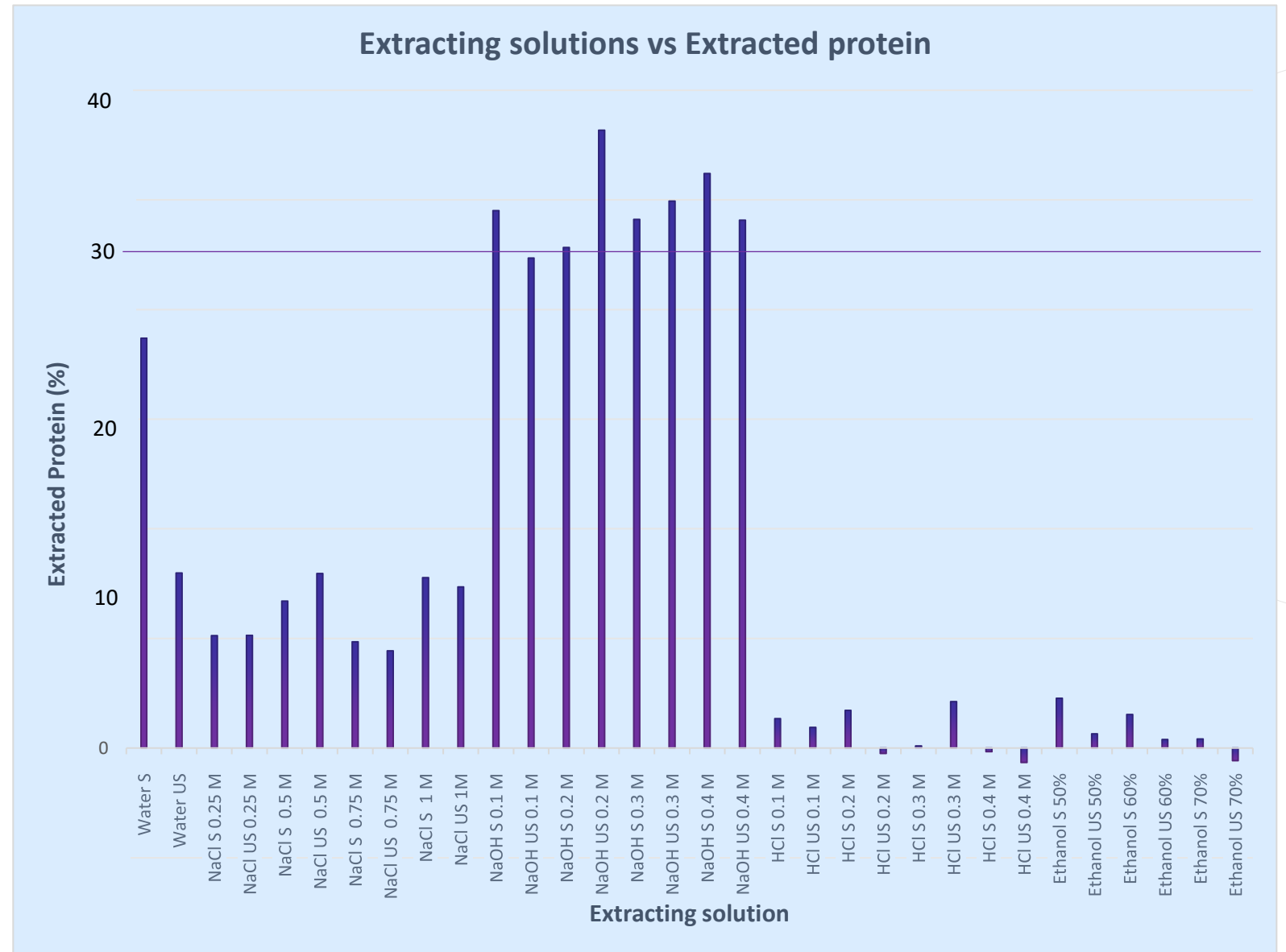
OPTIMIZATION 2

Improvements:

- ❖ Addition of a desalting step through the use of 10%TCA.
- ❖ Perform extraction at room temperature.

Results:

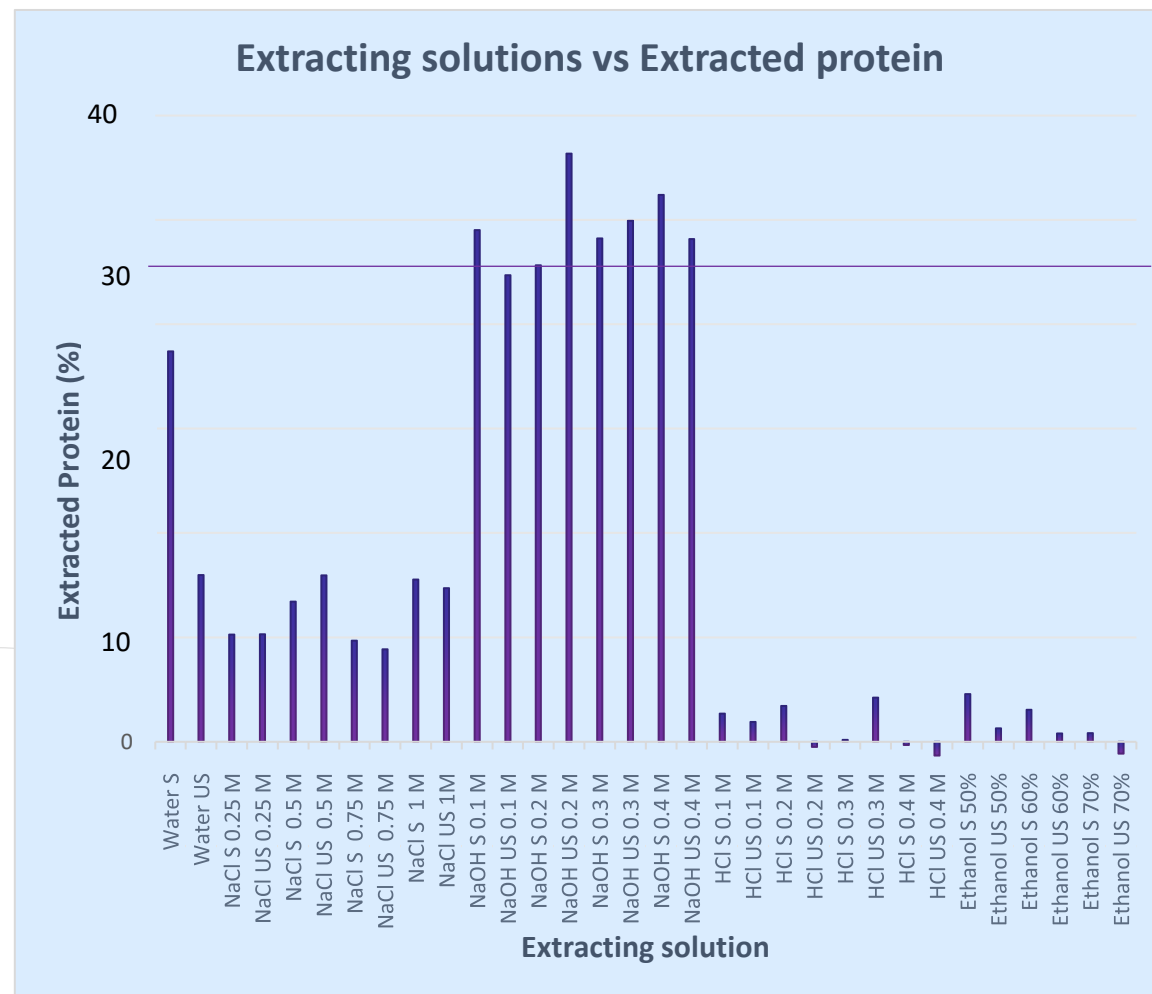
- ❖ Disappearance of acid and alcohol soluble proteins





COMPARISON

Solvent Type	Ultrasound Application	Incubation Temperature	Protein Yield (%)
Water	Applied	4°C	17.8
		Room Temperature	18.4
	Not Applied	4°C	15.8
		Room temperature	15.8
0.1M NaOH	Applied	4°C	16.6
		Room temperature	18.4
	Not Applied	4°C	19.0
		Room temperature	25.3
0.1M HCl	Applied	4°C	10.3
		Room temperature	17.3
	Not Applied	4°C	11.8
		Room temperature	29.4
0.5% NaCl	Applied	4°C	16.3
		Room temperature	16.9
	Not Applied	4°C	18.4
		Room temperature	21.2
70% Ethanol	Applied	4°C	16.9
		Room temperature	18.8
	Not Applied	4°C	10.8
		Room temperature	14.5





CONCLUSION



<https://www.cbsnews.com/news/seaweed-farming-and-its-surprising-benefits/>

- *Hypnea bryoides* protein contains different classes of protein and requires different solutions to maximize yield.
- Sequential extraction that involves acidic extraction is very important to achieve high yield.
- Functional properties: strong oil-holding, optimal solubility, emulsifying, and foaming at pH 8–10; unique foaming stability at pH 4.
- Moderate digestibility is likely influenced by phenolics and carbohydrates.
- Nutritional profile: 35% essential amino acids; methionine & cysteine are limiting.



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THANK YOU



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