Valorisation of Purple Non-Sulphur Bacteria Biomass from Anaerobic Treatment of Fuel Synthesis Process Wastewater to Aquaculture Feed

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CORFU 2022

June 16, 2022

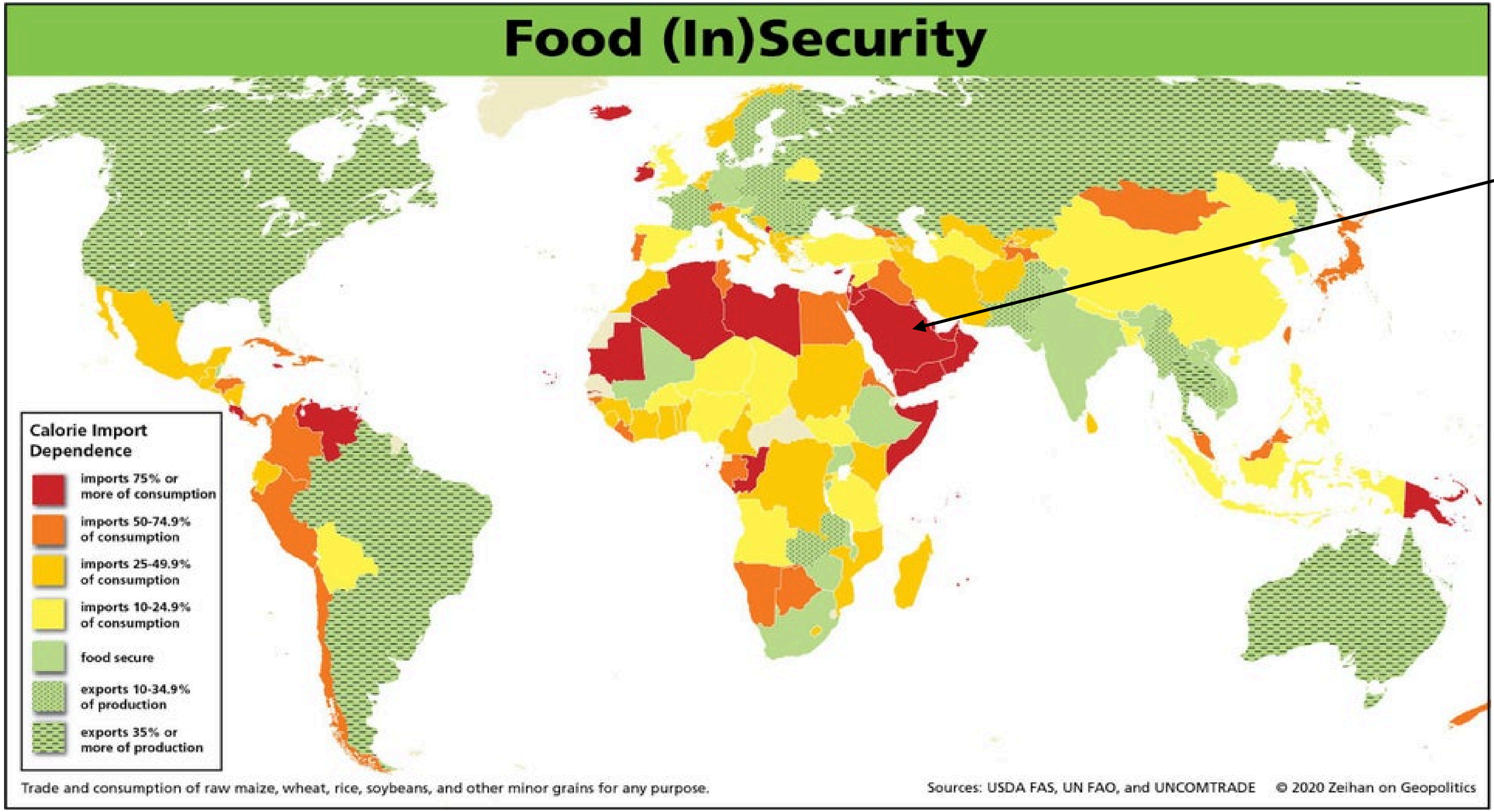
OUTLINE

- Background
- Research gap and objectives
- Methodology
- Analytical methods
- Results
- Conclusion
- References

Background: Water stress in the Middle East

12 of the 17 most water-stressed countries globally are in the MENA region (Water Resources Institute, 2019)

Background: Food security in the Middle East



Around 90% of food available in the GCC is imported (World Bank, 2021)

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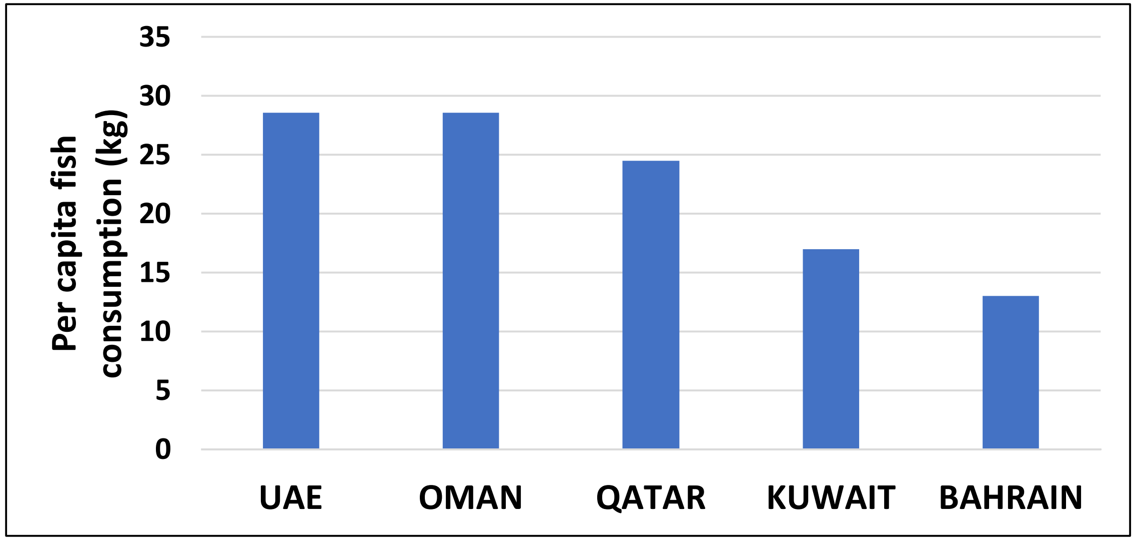
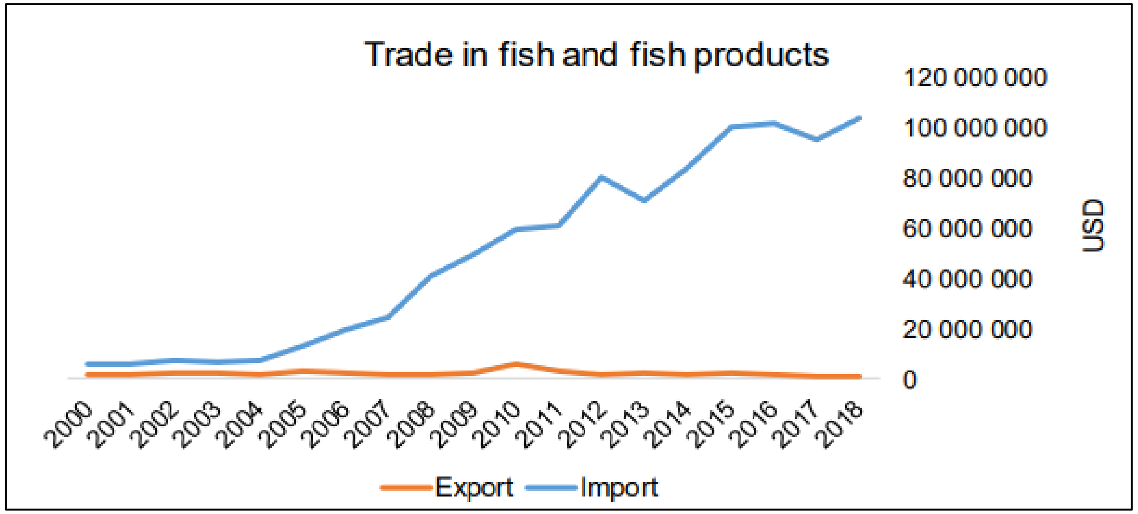
Background: Fish as a historical and major protein source in the Middle East





Imports - Top 10 Products (Value)

			USD
1st	Shrimps, prawns	frozen HS 0306.17	16 211 000
2nd	Tunas, skipjack, bonito	prepared or preserved; whole or in pieces HS 1604.14	12 624 000
3rd	Pacific salmon	fresh or chilled; excluding fillets, livers and roes HS 0302.13	9 697 000
4th	Shrimps, prawns	frozen; cold-water species HS 0306.16	5 450 000
5th	Flat fish	frozen; excluding fillets, livers and roes HS 0303.39	4 224 000
6th	Seabass	fresh or chilled; excluding fillets, livers and roes HS 0302.84	4 199 000
7th	Catfish	frozen fillets HS 0304.62	3 917 000
8th	Fish, other than species in 0302	fresh or chilled; excluding fillets, livers and roes HS 0302.89	3 624 000
9th	Oysters	live, fresh or chilled HS 0307.11	3 230 000
10th	Shrimps, prawns	dried, smoked, salted or in brine	2 084 000

Exports - Top 10 Products (Value)

			USD
1st	Fish, other than species in 0302	fresh or chilled; excluding fillets, livers and roes HS 0302.89	550 000
2nd	Crustaceans, other than species in 0306	dried, smoked, salted or in brine, flours, meals, pellets HS 0306.99	106 000
3rd	Fish, other than species in 1604	prepared or preserved; whole or in pieces HS 1604.19	79 000

FAO, 2018

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Background: Global aquaculture feed gap

527% increase

AQUACULTURE

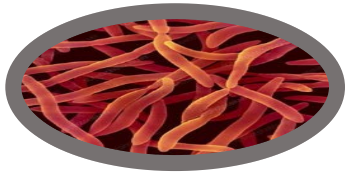
CAPTURE

14% increase

FAO, 2020; Jason A. 2021

Background: SCP as alternative protein source

Purple non-sulphur bacteria (PNSB)



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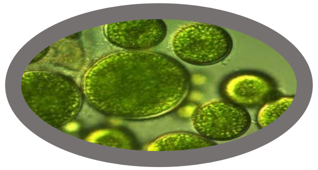
Algae



Yeast

Bacteria

Metabolic versatility	Higher cell protein content	Ability to withstand harsh conditions	Ease of selectivity in mixed-culture
Ability to treat wide array of wastewater sources	Preference for anaerobic and microaerobic conditions	Higher rate of multiplication	Presence of biomolecules valuable for aquaculture feed

Research Gap & Objectives

To date, most studies examining SCP production via PNSB have utilized agricultural-based wastewater due to its richness in organics and nutrients. However, such sources are limited in the GCC.

With the region being the global hub for Oil and Natural gas, this study examines the feasibility of utilizing an abundant waste source- Fuel Synthesis Process Water (FSPW) for SCP resource recovery.

This study evaluates the efficiency of **PNSB-based anaerobic wastewater treatment**, **the volarization of PNSB biomass for valuable bioproducts**, and **preliminary FSPW/biomass quality assessment**.

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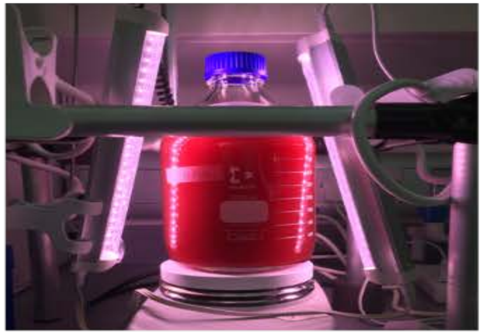
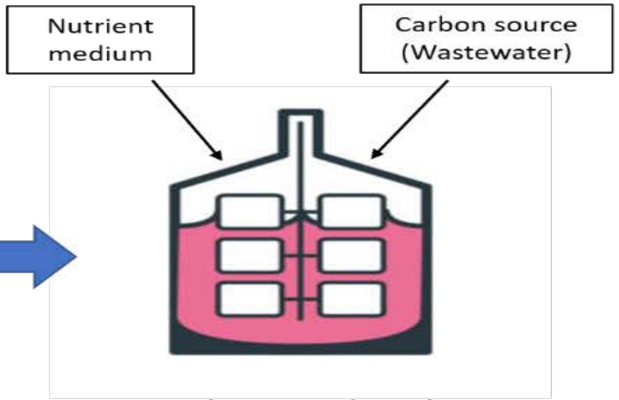
Methodology: Laboratory Flowchart

Mixed culture dominated by PNSB

UPSTREAM PROCESSING



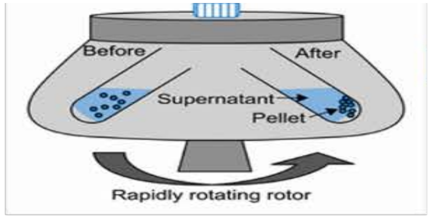
Inoculum Preparation



Biomass Production Photobioreactor

DOWNSTREAM PROCESSING

Biomass Harvesting
(centrifugation)



Biomass Processing
(Drying & homogenization)

Heavy metal screening

Biomass characterization
(Protein, lipid, Co-enzyme Q10,& Fiber)

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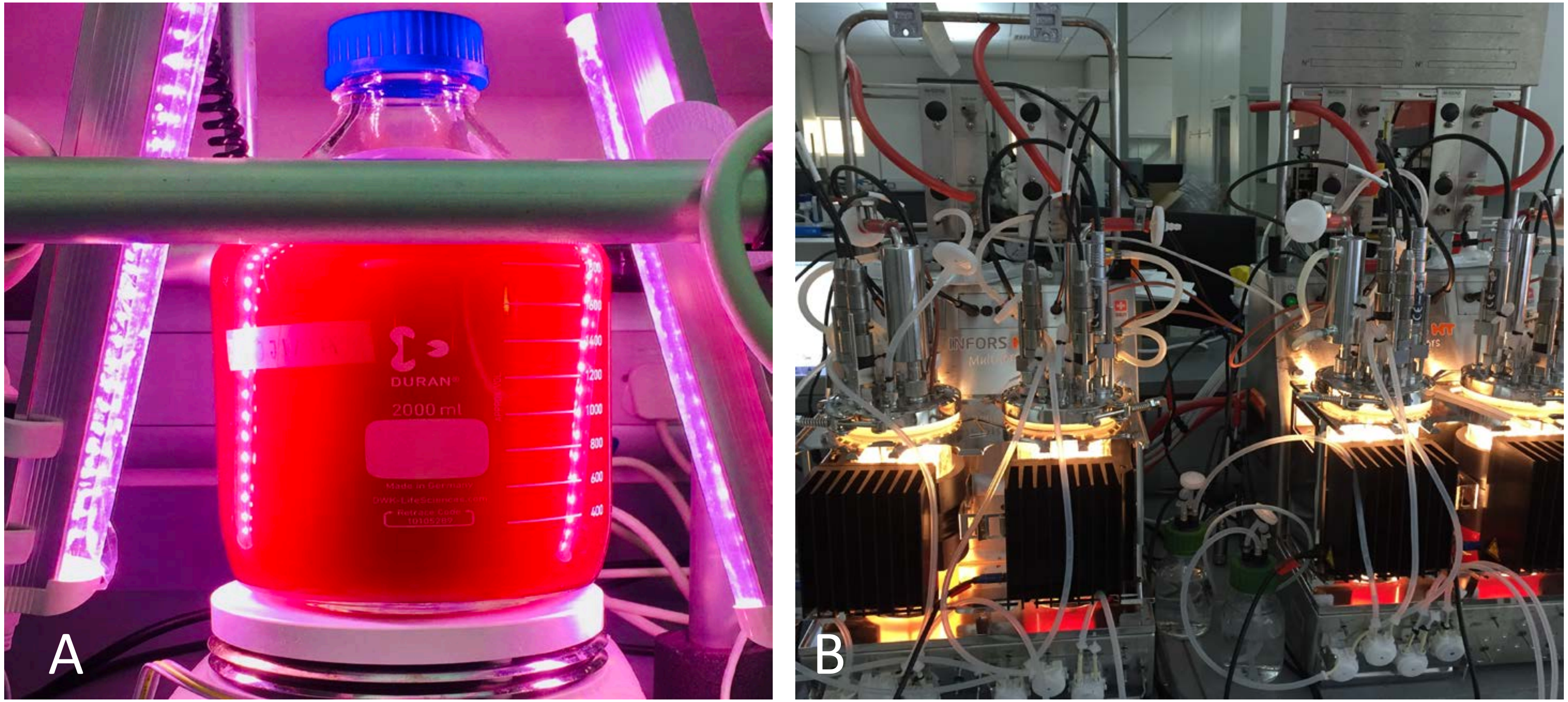
Methodology: Experimental Design



(A) Setup for preliminary study (diluted FSPW); (B) Setup for main experiment (undiluted FSPW)

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Methodology: Analytical methods

Parameters	Analytical Method/Instrument
COD	Hatch digestion reactor method
pH, dissolved oxygen, and temperature	Hamilton probe sensors
Optical density	Shimadzu UV-3600 plus and TECAN Spark
TOC, IC, and TN	Shimadzu TOC analyzer
Volatile fatty acids and anions	Ion chromatography
TSS/VSS/Fiber	APA Standards method
Heavy metals	ICP-OES
Zeta potential/Particle size	Zetasizer Nano ZS
Metagenomics	Qiagen extraction kit and Ion S5 next generation sequencing system
Protein/Lipid/Carbohydrate content	Modified Lowry method/Bligh&Dyer/Anthrone
Pigments and Co-enzyme	Spectrophotometric methods

Results: FSPW physicochemical characteristics

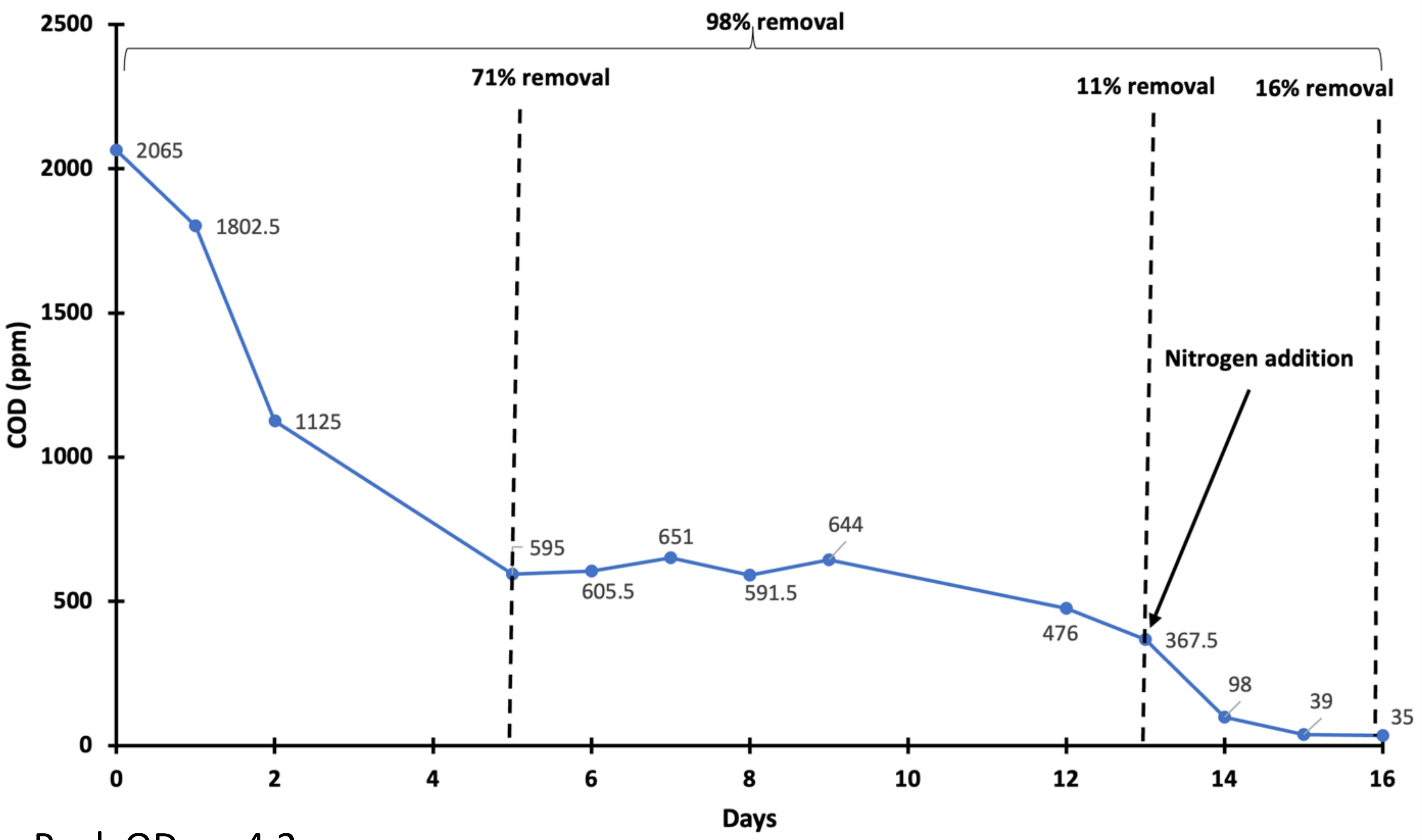
Characteristics	Concentration
pH	3.48±0.12
Electrical conductivity	191.6±0.14 μS/cm
Total dissolved solids	123 mg/L
COD	10,338±790 mg/L
Total organic carbon (TOC)	2,794±214 mg/L
Acetate	1,420±46 mg/L
Butyrate	373±17 mg/L
Iso-butyrate	1,493±127 mg/L
Propionate	318±21 mg/L
Valerate	283±13 mg/L
Formate	34±0.60 mg/L
Iso-valerate	46±0.01 mg/L
Characterized VFA fraction of TOC	1,953 mg/L

Results: FSPW heavy metal profile

Heavy metals	Concentration in FSPW(mg/L)	WEPA drinking water permissible limit (mg/L)	WEPA industrial effluent permissible limit (mg/L)
Nutritionally Undesirable Metals			
As	Undetected	0.01-0.05	0.25
Cd	Undetected	0.003	0.03
Hg	Undetected	0.001	0.005
Pb	Undetected	0.01	0.2
Tl	Undetected	-	-
Nutritionally Desirable Metals			
Co	0.2 ± 0.0	-	-
Cr	Undetected	0.05	0.1
Cu	Undetected	2	0.5
Fe	0.65 ± 0.07	<1	2.0
Mn	0.9 ± 0.06	0.5	1.0
Mo	Undetected	-	-
Ni	Undetected	0.02	0.2-6.4
Se	Undetected	0.01	
Zn	0.7 ± 0.1	5	1.0

Water Environment Partnership Asia (WEPA), 2013

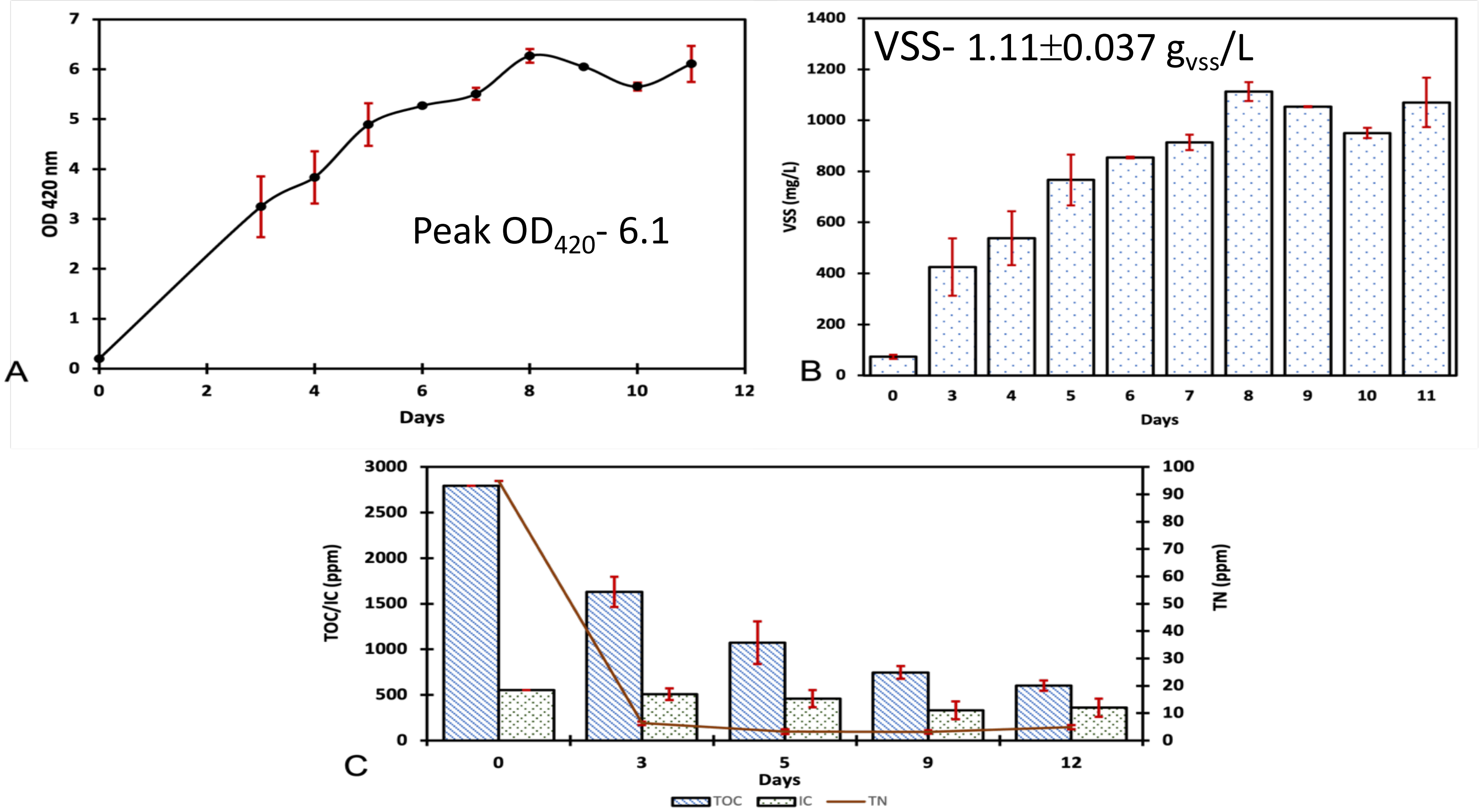
Results: PNSB's efficiency in diluted FSPW (5X)



Peak OD_{420}- 4.2

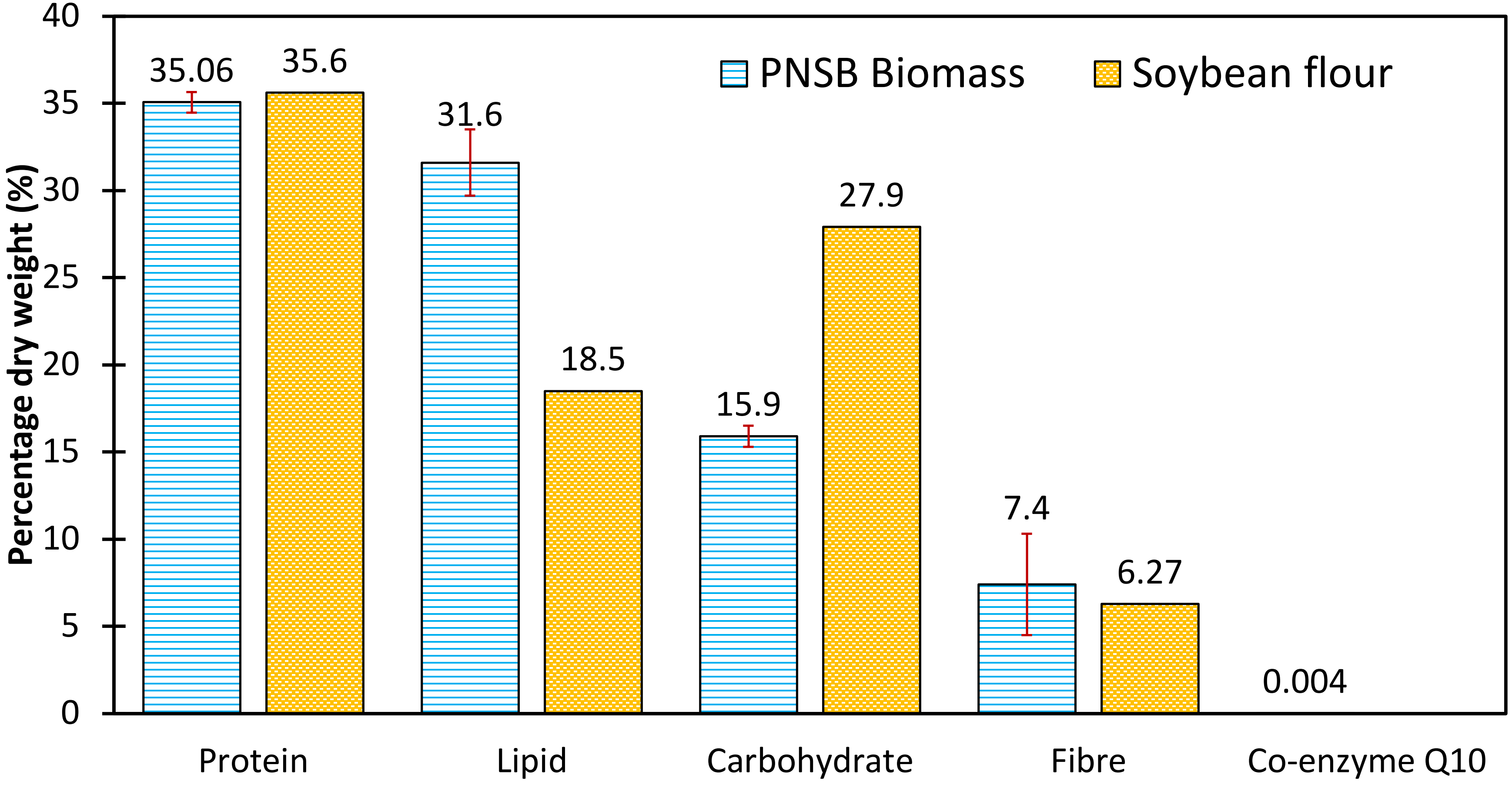
VSS- 740±14 mg/L

Results: PNSB's efficiency in undiluted FSPW



NH_4^+-N removal efficiency - 29.5 mg/L/day

Results: SCP recovery from PNSB Biomass



Similar protein content has been reported in aquafeed protein sources like soybean, squid liver paste, and commercial aquafeed (Ayba et al., 2012 and FAO 1997)

Results: Heavy metal profile of PNSB biomass

Metal	Concentration in Dry Biomass (mg/kg)
Nutritionally Undesirable Metals	
As	Undetected
Cd	Undetected
Hg	Undetected
Pb	Undetected
Tl	Undetected
Nutritionally Desirable Metals	
Co	33±0.0
Cr	71.5±0.0
Cu	86.2±0.05
Fe	1,298±0.0
Mn	518.8±0.5
Mo	2.75±0.07
Ni	49.5±<0.01
Zn	152.2±0.2

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Conclusion

- Anaerobic treatment of FSPW with PNSB proved to be very effective, as high COD and nitrogen removal were observed.
- Recovered PNSB biomass had protein content similar to mainstream aquafeed protein sources.
- PNSB biomass also contained valuable bioproducts like lipids, carbohydrates, and co-enzyme Q10.
- Nitrogen proved to be a limiting nutrient.
- Further studies to are required to optimize culturing conditions for enhanced protein and high-value amino acid content.

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Acknowledgement

- The authors would like to acknowledge the Qatar National Research Fund (grant MME01-0910-190029) and Shell Research and Technology Centre for their financial and technical support, respectively.

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