Green Extraction of Astaxanthin from Atlantic Shrimp by-products

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1. Introduction

- Shrimp processing by-product can make up > 50wt% of harvested material.
- Represents
  - loss of profit as by-product is a source of bioactive materials (proteins, carotenoids and lipids) and biomaterials (chitin and minerals),
  - an environmental/ economic burden
- Overall objective of this study is to develop sustainable, green processes to extract high yield and quality bioactives (astaxanthin/lipids), leaving toxic-free solid (for further material development).
- In this study, we use fish oil (sustainably extracted from salmon offal) in a solvent-based process to extract astaxanthin.

2. Methodology

2.1. Fish oil extraction

- In previous work, we developed two green processes to extract fish oil from finfish processing offal (bones, trimmings, guts etc.) [1,2]
- The fish oil extracted is used as a solvent to extract astaxanthin and tested over a range of ratios of oil: residue, temperatures and time
- Both "wet" and freeze-dried (FD) shrimp residues were used as feedstocks.

2.2. Astaxanthin extraction using fish oil

- Shrimp residue was mixed with fish oil and the following parameters varied:
  - ratios of oil: waste of 3:1,6:1, 9:1 v/w
  - temperature of 50, 60, 70 °C
  - time of 1, 2, 3 h
- Samples were then pressed/centrifuged to separate the oil from shrimp solids (Fig. 1).

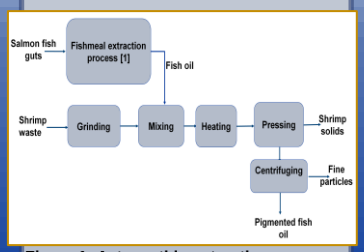

Figure 1: Astaxanthin extraction process using fish oil

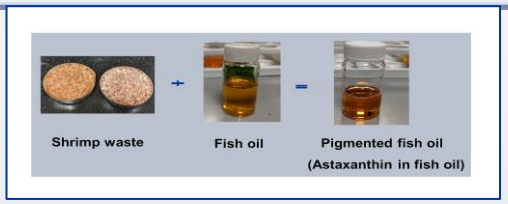

Figure 2: Wet & FD shrimp residue, and fish oil & pigmented fish oil

2.3. Validation of process

- To validate and establish the experimental procedure, sunflower oil (which has been studied earlier) was used; and the results were compared to the literature [3,4] (Table 1).

3. Results

3.1. Validation

- Astaxanthin yield with sunflower oil (128.58 µg/g $_{waste}$,dry basis) to FD shrimp residue at 4:1 (v/w), 70 °C over 2 h was much higher [3] (Table 1).
- Yield for "wet" shrimp residue was 27.82 µg of astaxanthin/g $_{wet\ waste}$ at 2:1 v/w, 70 °C over 2 h. This value was in agreement with the literature in [4] (Table 1).

Table 1: Comparison of astaxanthin yields using sunflower oil with the literature

	Ratio of 4:1 (v/w), 70 °C over 2 h	
	This work	**[3]**
	FD shrimp residue	Cooked/dried shrimp residue
Astaxanthin yield, µg/g$_{waste}$, dry basis	128.58± 10.40	1.66 × 10^{-4}
	Ratio of 2:1 (v/w), 70 °C over 2 h	
	This work	**[4]**
	Wet shrimp residue	Wet shrimp residue
Astaxanthin yield, µg/g$_{waste}$, wet basis	27.82.± 3.14	26.3

3.2. Astaxanthin extraction using fish oil

Table 2 shows astaxanthin yields recovered from wet and FD shrimp residues at 50 °C and 60 °C over various ratios (3:1,6:1,9:1 v/w) and times (1, 2 h).

Table 2: Astaxanthin yields using fish oil at various conditions

	Temperature, °C	Time, h	Ratio, v/w	Astaxanthin yield, µg/g$_{waste}$, wet basis
Wet shrimp residue	50	1	6	7.79± 0.02
	50	2	3	8.69± 3.13
	60	1	3	5.56± 0.25
	60	1	9	24.69± 10.30
FD shrimp residue	50	1	6	89.05± 14.09
	50	2	3	54.13± 27.33
	60	1	3	84.48± 10.62
	60	1	9	114.13± 10.52

3.3. Moisture effect on astaxanthin yield

- Astaxanthin yields (µg/g $_{waste}$,dry basis) extracted for "wet" and FD shrimp residues were tested to determine the impact of drying. FD showed higher extraction at 123.45 µg/g $_{waste}$, dry basis while wet was 96.91 µg/g $_{waste}$, dry basis (Fig. 3).

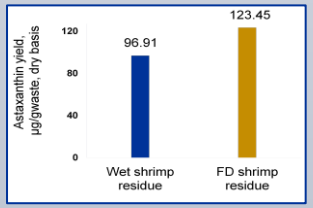

Figure 3: Moisture effect on astaxanthin yield at 70 °C, 3 v/w and 3 hours

3.4. Comparison of fish oil efficiency with ethanol in Soxhlet

- Astaxanthin yield (µg/g $_{waste}$,dry basis) extracted for FD shrimp residue at 9:1 v/w, 60 °C and 3 h was compared to Soxhlet efficiency using ethanol (gives maximum extraction).
- Fish oil was able to extract 70.5% of astaxanthin recovered using ethanol (Fig. 4). Note ethanol is expensive and Soxhlet is run at boiling point.

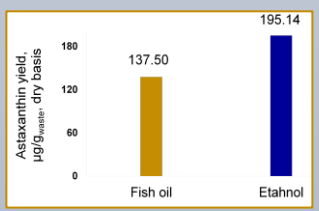

Figure 4: Comparison of fish oil efficiency with ethanol

4. Conclusions and Outlook

- Waste fish oil was as effective as "traditional" solvent (e.g., ethanol) representing a low cost and sustainable alternative to traditional solvents
- Water inhibits extraction yield, BUT subsequent work in our lab indicates that freeze drying may impact "quality". Thus. we must balance quality and yield.
- The next step will be to explore supercritical CO_2 extraction by adding fish oil as a co-solvent.
  - ❑ **Question:** Can we improve yield/quality and decrease GHG emissions through CO_2 re-use?

5. References

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