Hybrid Workshop on

Developing novel Blue biorefineries from aquatic resources

Organized by

CEVA

10 Day | 09 Month | 25 Year

13h00 - 16h15 Icelandic time UTC+0

15h00 - 18h15 Paris time UTC +2

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WELCOME

Joint event

CIRCALGAE

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Co-funded by the European Union

Workshop

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Microalgae as a Source for Commercial Fucoxanthin

Oran Ayalon, Algalíf

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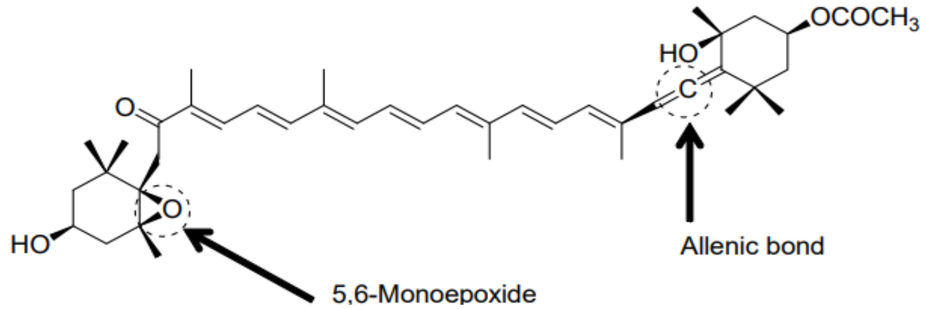
Algalif in a nutshell:

- Privately owned Icelandic biotechnological company.
- Founded 2012
- Largest producer of natural Astaxanthin
- State-of-the-art production plant with an array of tubular photo-bio-reactors.
- Advanced control system incorporating AI.
- Highly trained professional and diverse team.

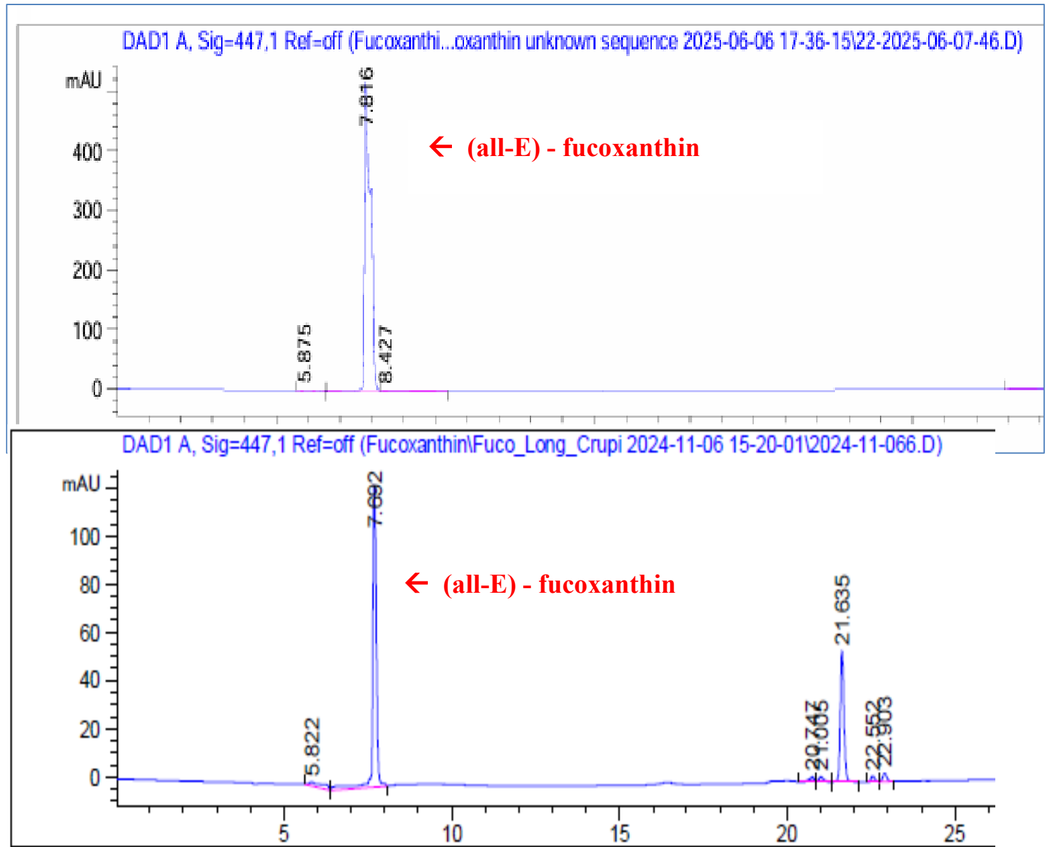
Fucoanthin:

- Most abundant carotenoid in nature (accounts to about 10% of carotenoids mass).
- Golden brown pigment.
- Xanthophyll, which contains two functional groups.
- Highly unsaturated and forms isomers: all-E, 9 or 9'Z, 13 or 13'Z.
- Confers unique health benefits.

Anti-oxidant, anti-obesity, anti-inflammatory properties



Chemical structure of fucoxanthin (Din et al., 2022. Foods 11: 2235.)



Sources of Fucoxanthin

- Found predominantly in marine microalgae and **brown seaweeds**, which are traditional in Japanese cuisine: Wakame, Kombu, Hijiki

- Characteristic pigment that defines **diatoms and golden-brown microalgae**.

Microalgae as a better source of Fucoxanthin

High fucoxanthin concentration(~ 1%)

Grow and reproduce fast.
Vegetative reproduction

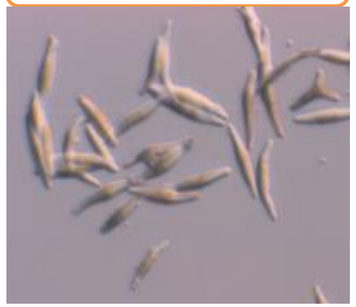
Grow under controlled conditions

Available all year round

Clean and pure

Harvesting friendly to the environment

Microalgae



Seaweeds

Low fucoxanthin concentration (~ 0.01%)

Grow slower; differentiate into organs; Gametophytes

Grow under uncontrolled conditions at sea

Seasonal

Accumulate contaminants such as Arsenic and Iodine

Harvesting destroys the seabed

Relatively low costs high efficiency

Relatively high costs low efficiency

Phaeodactylum vs. *Isochrysis*

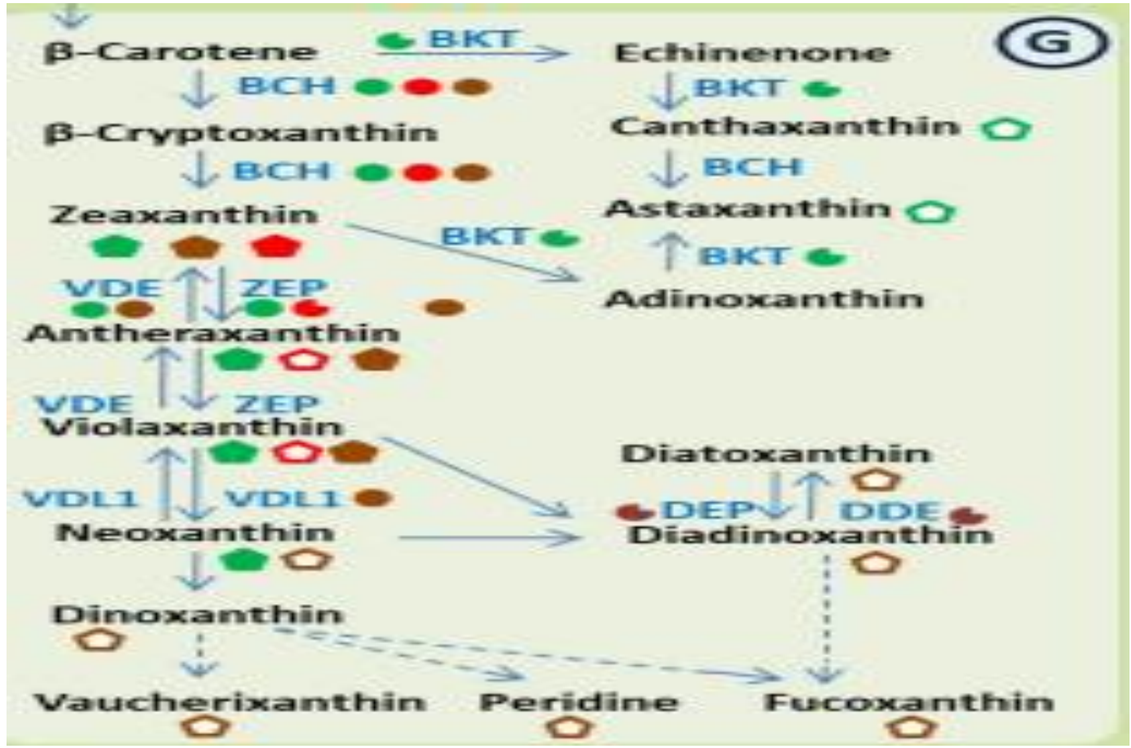
	Phaeodactylum	Isochrysis
Fucoxanthin concentration (w/w)	0.7 – 1.5 %	1 – 2.8 %
Cell wall	Rigid cell wall	No cell wall
Lipid profile	Less PUFA (30–40%) predominantly EPA	More PUFA (40-55%) predominantly DHA
Extraction method and efficacy	Organic solvents. Green extraction less efficient.	Green extraction (SCF-CO2)
Organoleptics effect	Intense	mild
Regulation	Already approved as a NDI	Extract approved in cosmetics

Isochrysis offers higher fucoxanthin and milder smell / taste, making it ideal for consumer products

Fucoanthin physiologic functions and biosynthesis:

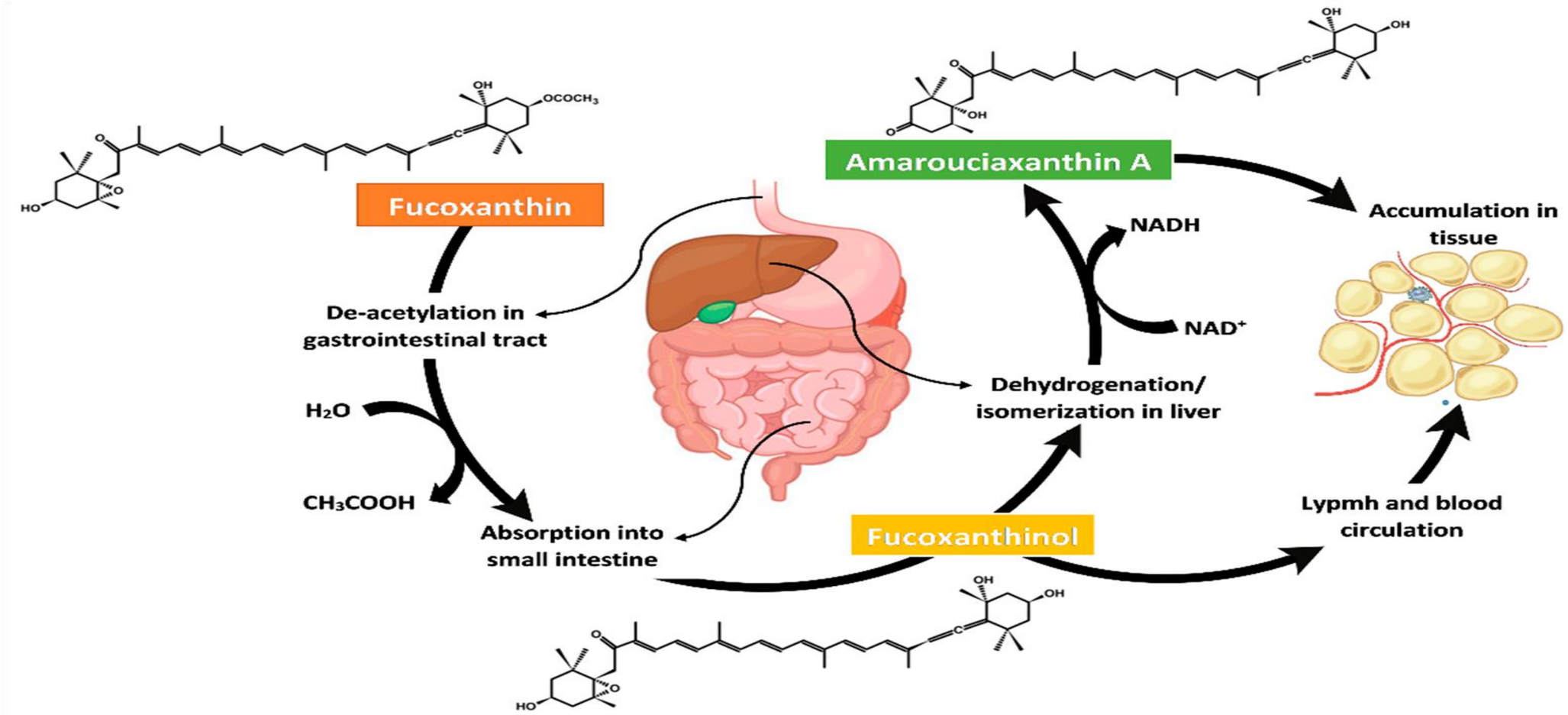
- Integral to the light-harvesting complex in algae.
- Forms complexes with Chlorophyll a, c, and apoproteins (FPC).
- Facilitates electron transfer from the thylakoid membrane.
- FPCs absorb light in the 390–580 nm range, classified into:
  - 2 blue, 2 green, and 3 red groups.
- Protects photosynthetic machinery from oxidative damage under high light intensity.

Biosynthesis Pathway
Fucoxanthin is a **xanthophyll** derived from **β-carotene**.
Two hypothesized pathways:
Violaxanthin → Neoxanthin → Diadinoxanthin or Fucoxanthin
Enzymes involved (e.g., **VDL**) are still under investigation.
(Gupta et al., 2021. Frontiers in Bioscience-Landmark, 26(6), 171–190).



Understanding these traits and biosynthetic steps enables selection and induction of high-yield fucoxanthin strains or mutants

Fucoxanthin Absorption & Metabolism



Absorption, metabolism and tissue distribution of fucoxanthin. Amarouciaxanthin A is concentrated mainly in the liver. Fucoxanthinol is concentrated in White Adipose Tissue (Din et al., 2022. Foods 11: 2235)

Pharmacokinetics of Fucoxanthin

Administered dose	Cmax of metabolites	AUC 24h	Bioavialability
2 – 8 mg per day	0.5 – 2.5 μg/ml within 4-6 h’	10 – 50 μg / ml	0.5 – 3 %

Serum Half Life	Adipose Tissue half life
0.92 – 1.23 days	2.76 – 4.81 days

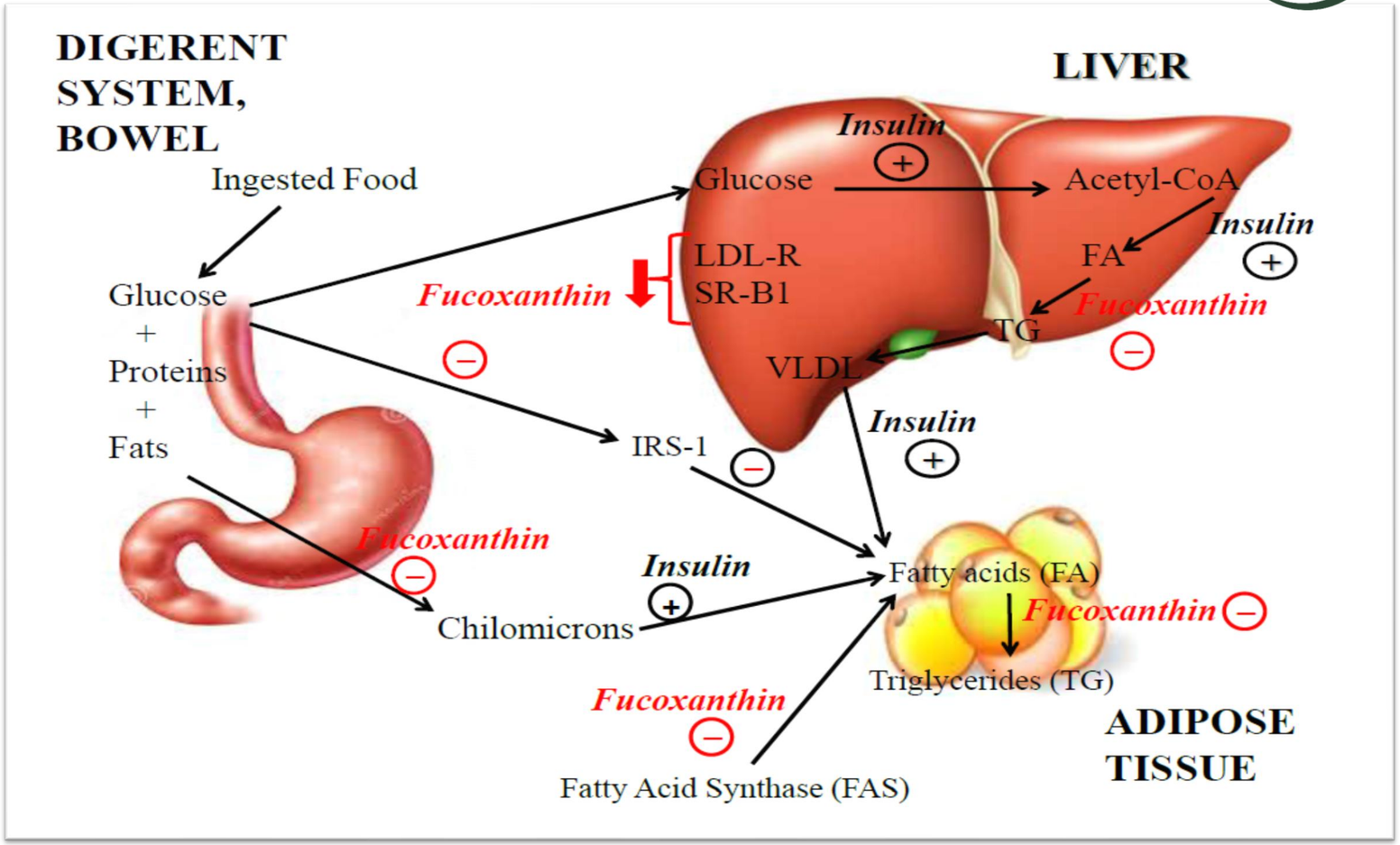
Enhanced bioavailability of fucoxanthin in humans

Comparison: Humans vs. Rodents

- Similar pharmacokinetic curves over time.
- Only fucoxanthinol detected in human plasma.
- Human oral dose was 15% of rodent dose.
- Yet, CMAX was 33% higher and AUC was 46% higher in humans.

Fucoxanthin's Role in Fat Metabolism

- Lowers lipid levels by down-regulating:
  - **LDL** (Low-Density Lipoprotein) receptor and **SR-B1** (Scavenger receptor class B member 1), reducing triglyceride and cholesterol uptake in the liver.
  - Inhibits glucose absorption in fat cells by reducing phosphorylation of **IRS-1** (insulin receptor substrate 1).
- Modulates lipid metabolism genes:
  - Decreases expression of **FAS** (fatty acid synthase) and **ACC** (Acetyl-CoA carboxylase), leading to lower triglyceride synthesis.
  - Enhances activity of enzymes that regulate cholesterol.



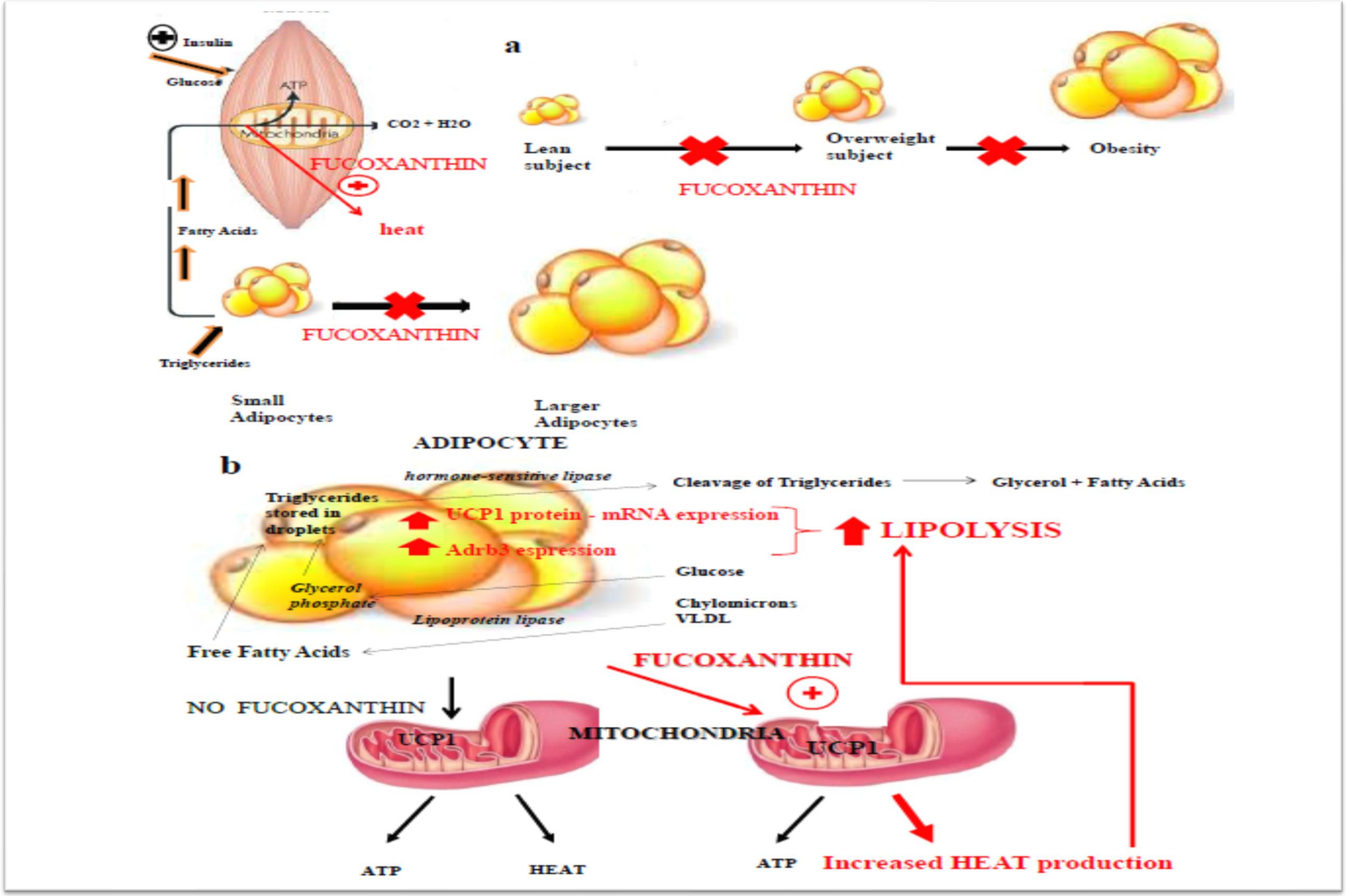
(Gammone & D'Orazio 2015. Mar. Drugs 13: 2196

✅ **Supports healthy lipid profile**
✅ **Reduces fat accumulation**
✅ **Improves metabolic balance**

Fucoxanthin’s Role in Fat Tissue Regulation

- Activates thermogenesis by up-regulating:
  - Uncoupling Protein-1 (UCP-1)
  - β3-Adrenergic Receptor (Adrb3)
- These effects occur primarily in White Adipose Tissue (WAT). Results in:
  - Enhanced fat oxidation
  - Increased lipolysis
  - Boosted heat production (thermogenesis)

✅ **Supports weight management**
✅ **Promotes metabolic activation in fat tissue**



(Gammone & D’Orazio 2015. Mar. Drugs 13: 2196)

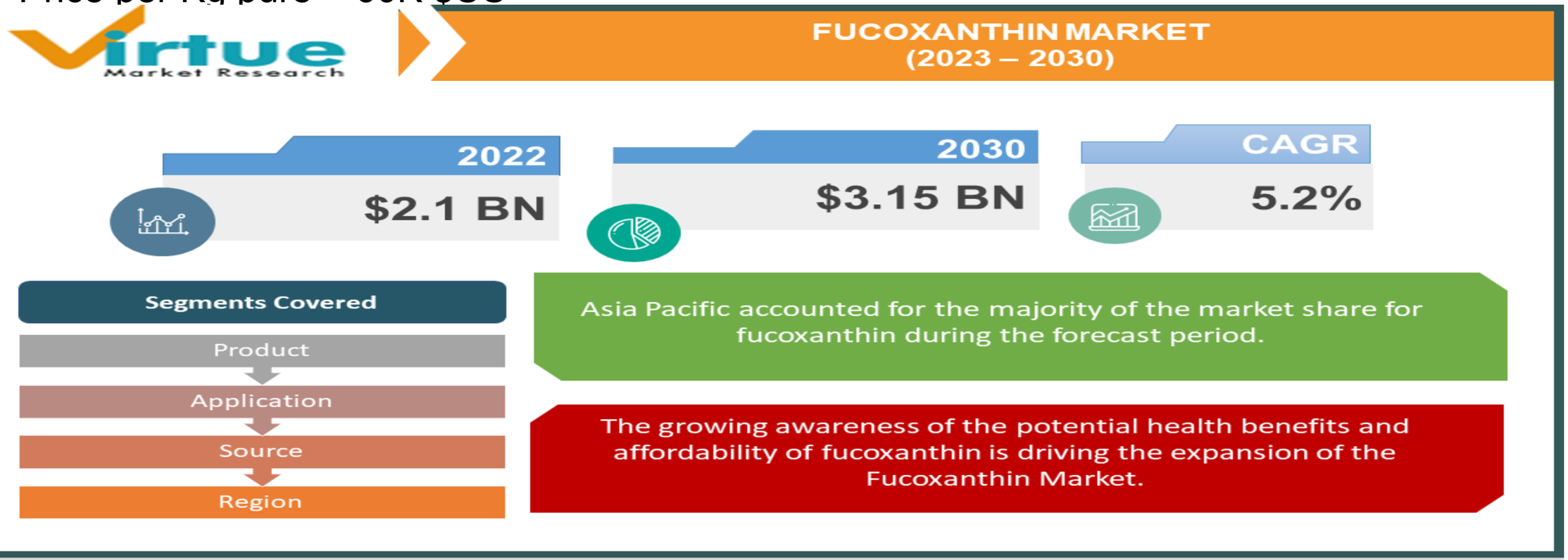
Other important health benefits

Beyond its role in fat metabolism, fucoxanthin has demonstrated the following effects in clinical and animal studies:

- 🛡️ Antioxidant protection: Shields organs and tissues from oxidative stress.
- 🧠 Neuroprotection: Supports brain health and cognitive function.
- 🔥 Anti-inflammatory: Reduces inflammation across various systems.
- 🌞 Skin & DNA defense: Protects against UVB-induced damage.
- ⏳ Anti-aging & longevity: Promotes lifespan extension (e.g., in C. elegans) via gene regulation.
- 🧬 Anti-cancer potential: Induces apoptosis in tumor cells.
- 🧪 Reproductive health: Enhances spermatogenesis and male fertility.
- 😊 Mental wellness: Alleviates symptoms of depression and anxiety.

Fucoxanthin Market

- The most abundant , but least consumed carotenoid
- Sold as an active ingredient in dietary supplements, functional foods, cosmetics and medicines.
- Current estimates of the global yearly market varies – 120 M up to 2.1 B.
- Currently, >99% is sourced from seaweeds
- Price per Kg pure ~ 60K $US



Limits to reaching its true market potential.

⚠ Inconsistent raw material quality and supply

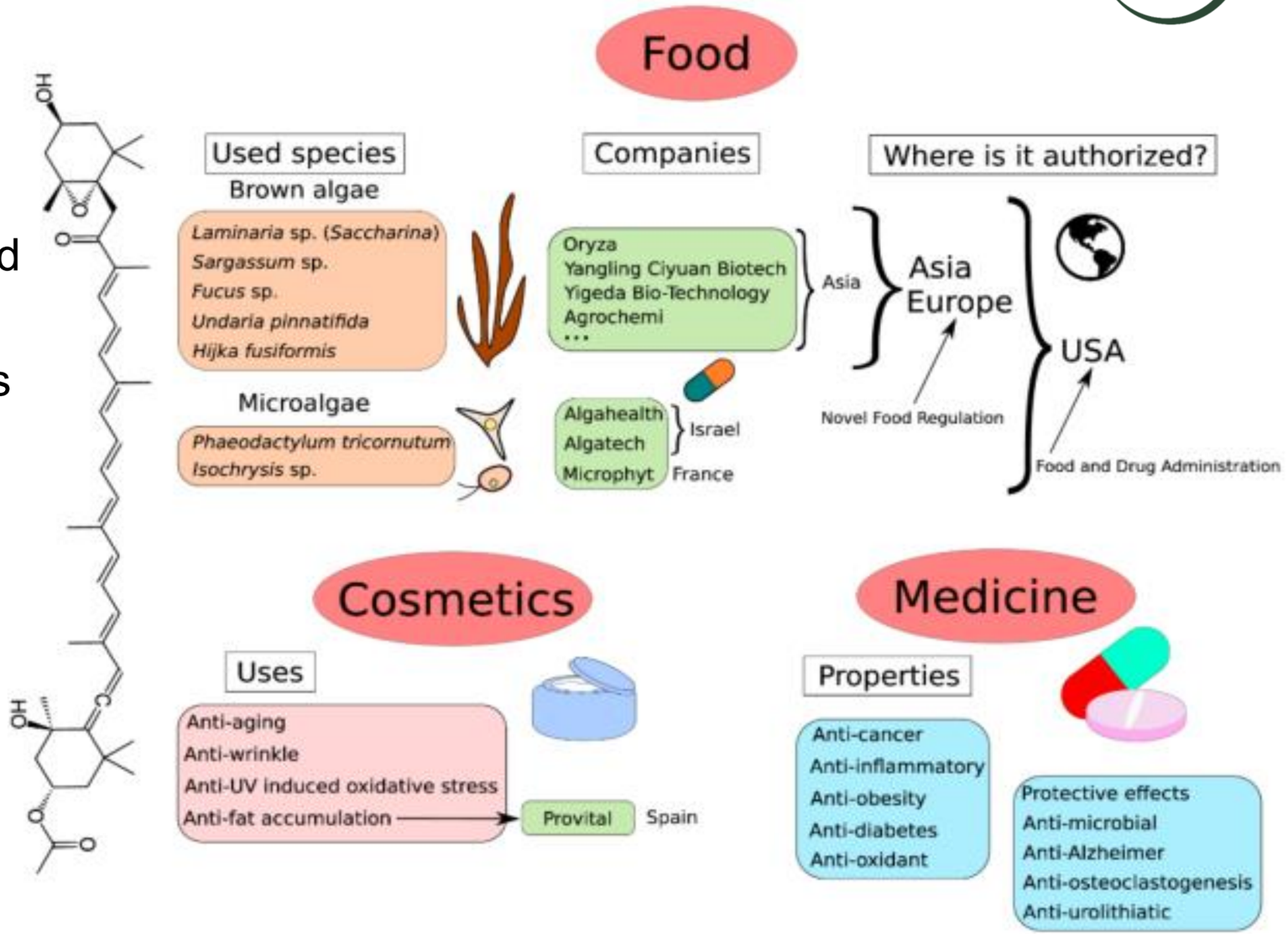
💰 High extraction and production costs

🔬 Limited investment in R&D

📜 Regulatory challenges across regions

🧠 Low consumer awareness

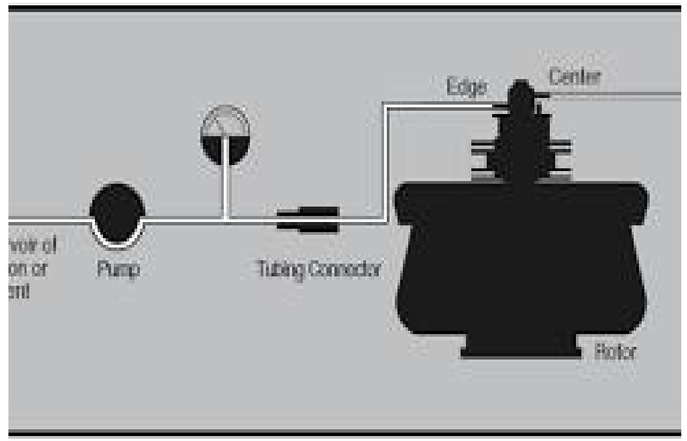
💊 Competition from pharmaceutical alternatives



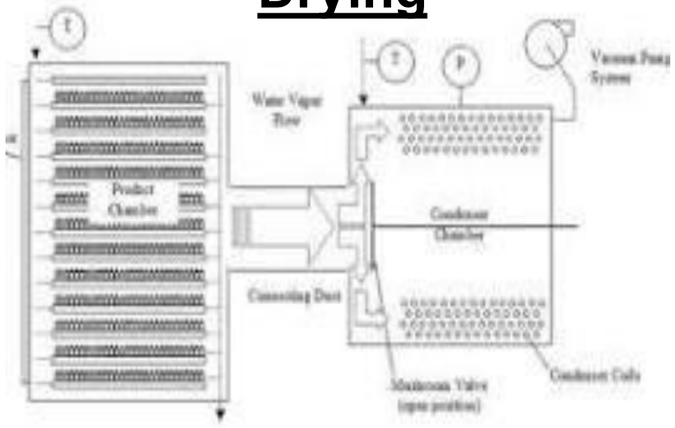
Applications and current market of fucoxanthin in food, cosmetics and medicine (Pajot et al., 2022. Mar. Drugs 20: 222)

General production process

Inoculum → **Large scale cultivation** → **Harvest**



Drying → **Extraction** → **Product**



Key Takeaways on Fucoxanthin

- Unique chemical structure delivers potent health benefits, especially for obesity and metabolic syndrome.
- Physiologic role in algae enables agro-technical and genetic optimization for enhanced production.
- Upon ingestion, fucoxanthin is converted to fucoxanthinol and amarouciaxanthin A, with fucoxanthinol being the dominant metabolite in tissues.
- In humans, fucoxanthin shows higher bioavailability and slower metabolism than in other species.
- Microalgae offer a cleaner, more efficient source of fucoxanthin compared to seaweeds.
- The global market potential for fucoxanthin remains largely untapped.

Thank you!

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