해조류 바이오연료 생산공정 설계 동향

- INTRODUCTION -

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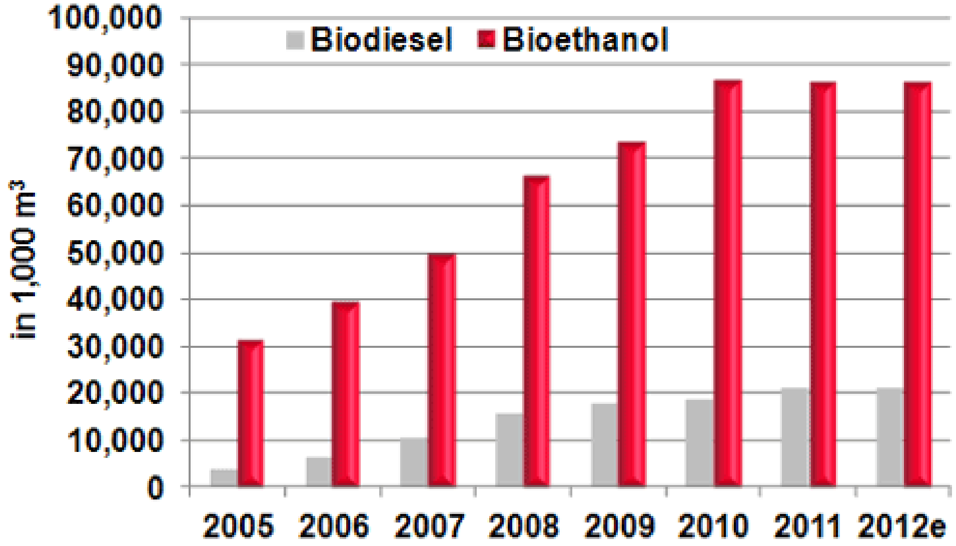
Importance of Bio-energy

- Growing demand for energy, fuel, materials and chemicals (growing market)
- Finite availability of fossil fuel resources (continued price rises)
- Overdependence of many countries on imported resources (national security)
- Reality of climate change and need to reduce greenhouse gases (keep warming below 2°C or GHGs concentration below 450-ppm CO_2 equivalent (UNCCC, 2010))
- The primary goal of the international energy agency is to reduce energy-related CO_2 emissions below 50% while renewables provide 40% of the primary energy supply by 2050

World biofuel production

- World biofuel production is growing fast and bioethanol is playing a major role amongst all other biofuels. The production of bioethanol for fuel applications has been increased from 13 billion gal In 2007 to 23.4 billion gal In 2011 (RFA, 2014).



World Bioethanol and Biodiesel production from 2005 to 2012 (Source: F.O.Licht)

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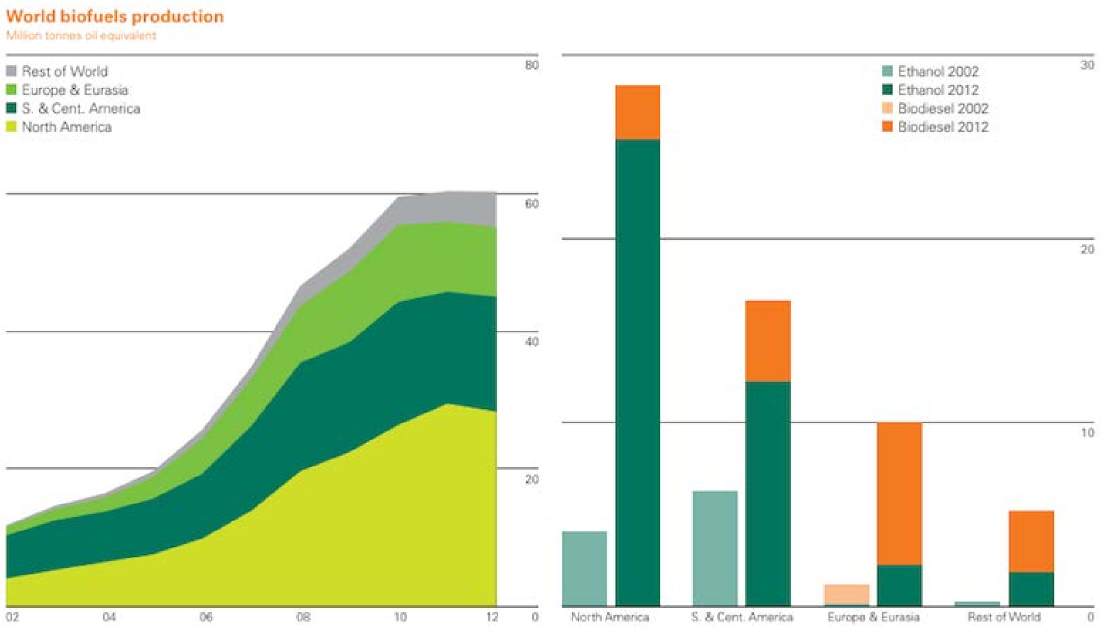


World biofuel production increase from 2002 to 2012 (www. businessinsider.com).

Biomass

- Biomass is the only source of renewable liquid fuels.
- Three generations of biomass have been studied so far in literature.

Biomass Feedstock

First generation biomass
Sugar/Starch Crops:
e.g. sugar cane / corn
Oil Crops: e.g. rapeseed, soybean

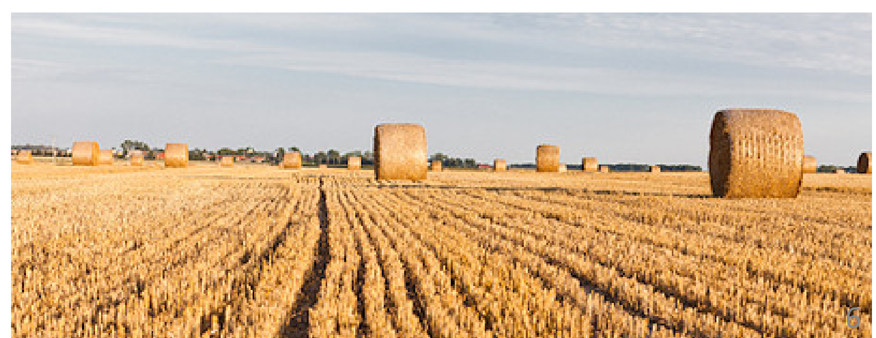
Biomass

- 1st generation biomass has a food vs. fuel issue.
- 2nd generation biomass requires extensive arable land.

Biomass Feedstock

Second generation biomass

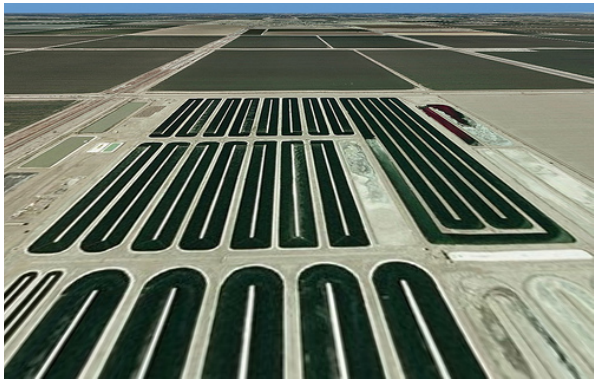
Lignocellulosic Biomass: e.g. forestry & agricultural wastes



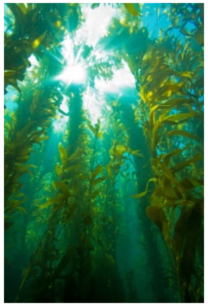
Biomass

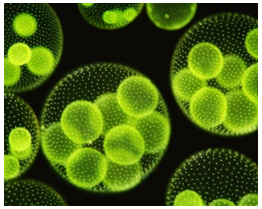
- 3rd generation biomass includes micro- and macroalgae.
- Micro- and macroalgae are gaining worldwide attention as biomass feedstock.

Biomass Feedstock



Third Generation biomass:
Macroalgae
Microalgae





Biomass

- 3^{rd} generation biomass has advantages over 1^{st} and 2^{nd} generation biomasses.
- Especially macroalgae have great potential in Korea as biomass feedstock.

Biomass Feedstock

First generation biomass
Sugar/Starch Crops:
e.g. sugar cane / corn
Oil Crops: e.g. rapeseed, soybean

Second generation biomass
Lignocellulosic Biomass:
e.g. forestry & agricultural wastes

Third Generation biomass:
Macroalgae
Microalgae

Classification	Land Plants		Marin Plants
	Crop Based (1st Generetaion)	Wood Based (2nd generation)	Macro algae (3^{rd} generation)
Harvest cycle	1~2 times/Year	1 Times/8 year	4~6 Times/Year
CO_2 Fixation Ability (Ton/ha)	5-10	4.6	36.7
Manufacturing Process	Simple	Complex(Lignin Removal)	Simple(No lignin)
Disadvantage	Food-Related	Forest Damage	None
Cultivation Environment	Sun Light, CO_2, Fertilizer, Water, Land	Sun Light, CO_2, Fertilizer, Water, Land	Sun Light, CO_2, Sea Water

Biomass

- Like other biomass, there are two ways of biomass conversion to energy.
- Biochemical conversion is appropriate for macroalgae and thus has been studied relatively extensively.

Biomass Feedstock

First generation biomass
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Oil Crops: e.g. rapeseed, soybean

Second generation biomass
Lignocellulosic Biomass:
e.g. forestry & agricultural wastes

Third Generation biomass:
Macroalgae
Microalgae

Conversion Technologies

Thermochemical conversion: *e.g. pyrolysis, gasification, etc.*

Biochemical conversion: *e.g. fermentation, anearobic digestion, etc.*

Product Stream

Energy: *e.g. heat, electricity*

Fuels: *e.g. biodiesel, bioethanol, biogas*

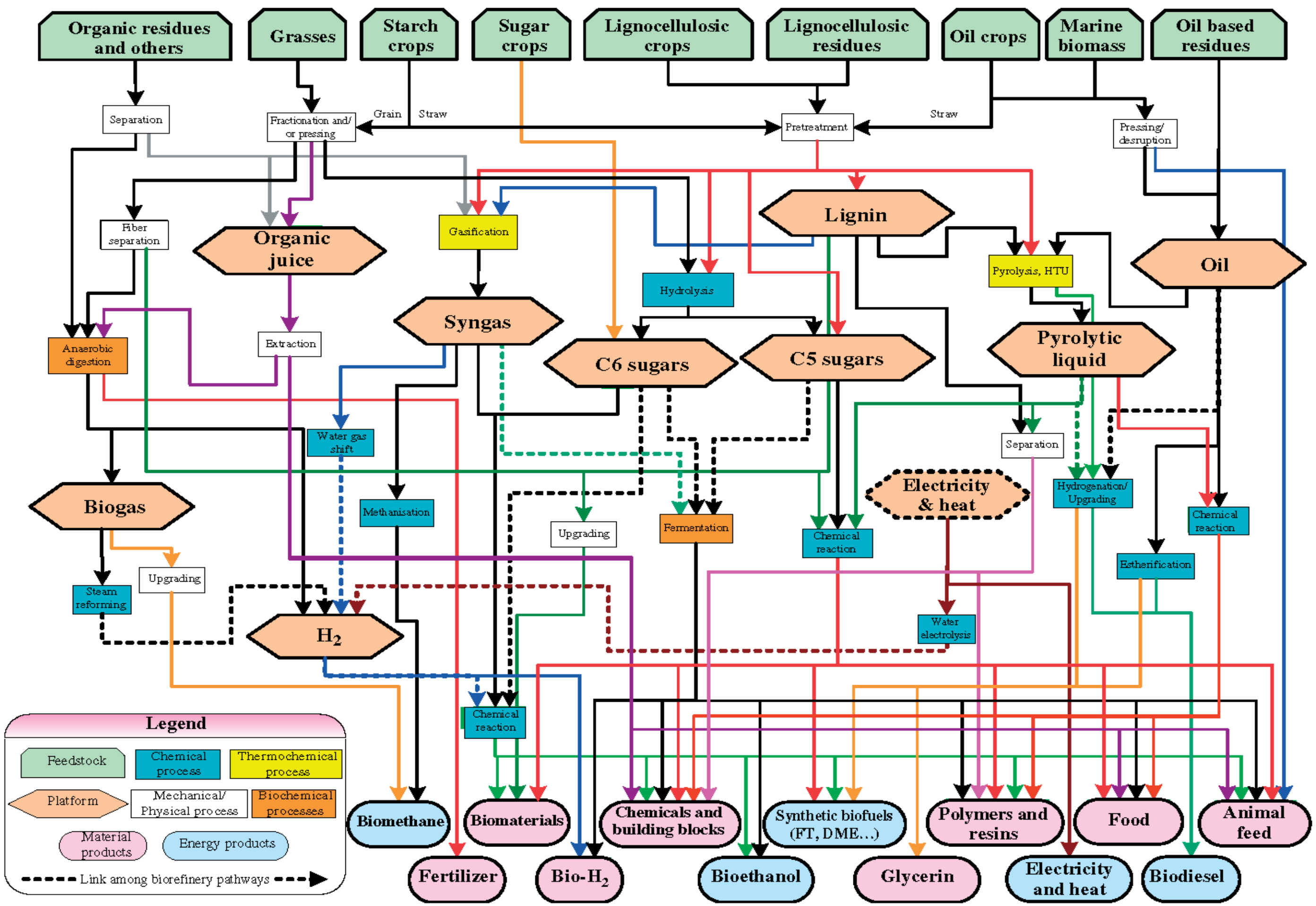
Chemicals: *e.g. bulk, intermediate, final*

Materials: *e.g. polymers*

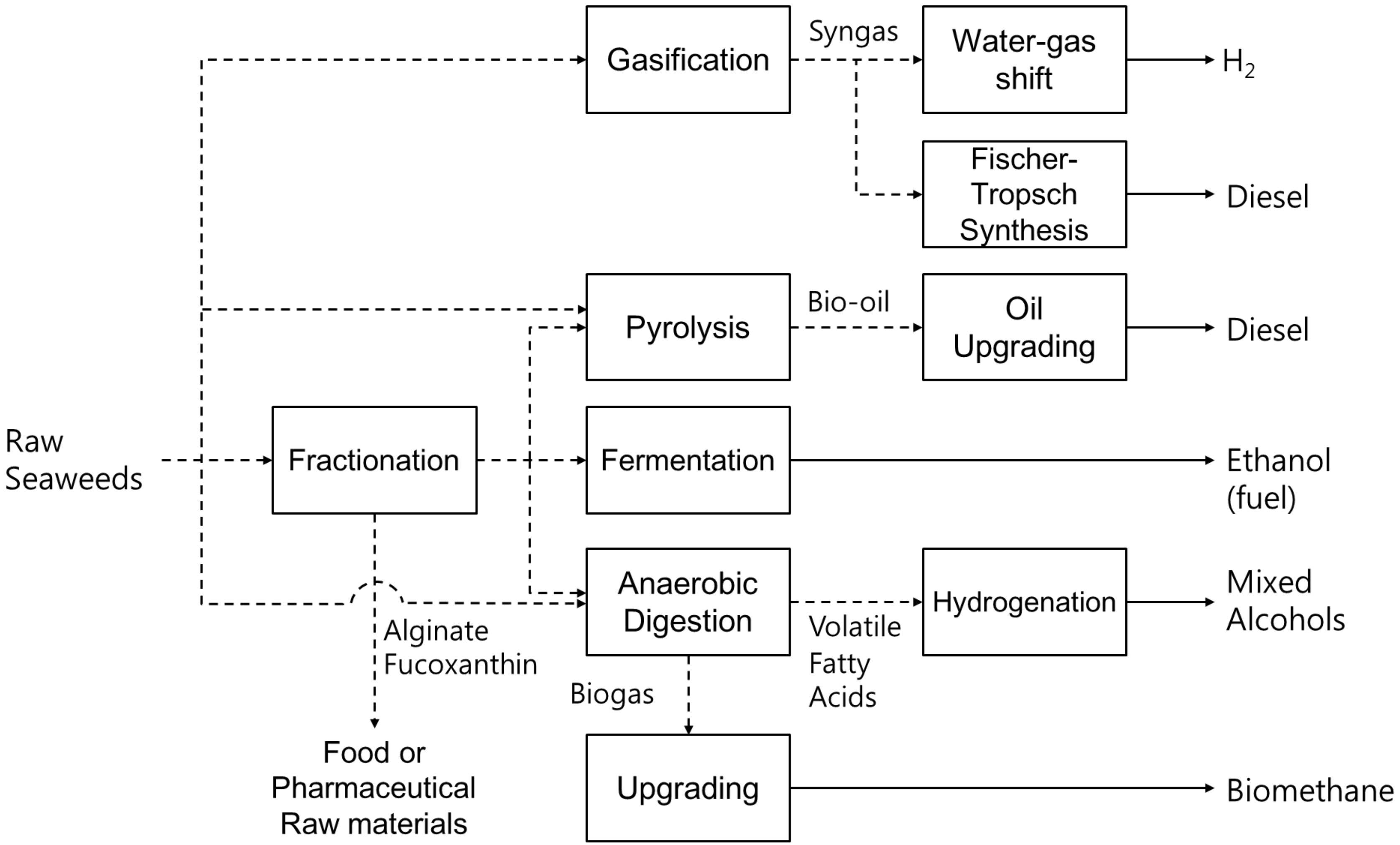
Brief history of seaweed biomass research

1. (U.S.A.) Marine Biomass Energy Program (1968 – 1990)
   – Focused on methane production and offshore cultivation
2. (Japan) Tokyo Gas & NEDO (2005 – 2007)
   – Focused on electricity generation from seaweed-derived methane
3. (EU) BioMara (2009 – 2015)
   – Focused on fuels (ethanol & methane) from macroalgae and cultivation
4. (Korea) Aquatic Biomass Research
   – Holistic approach for utilizing macroalgae for energy and high-value chemicals
5. (EU) MacroFuel (2016 – 2019)
   – Subsequent project of BioMara

Biorefinery network (IEA Bioenergy task 42)



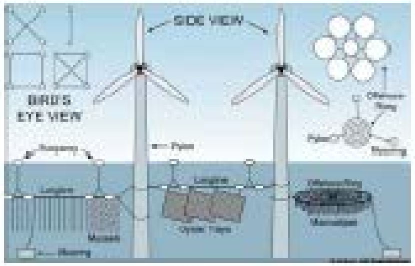
Conversion pathways for seaweed biomass feedstock under consideration



Seaweed resource and cultivation

❖ Seaweeds are cultivated naturally and artificially. High yield artificial cultivation technologies are required to be developed to have higher biomass production and lower selling prices.

System	Yield	Production Cost
	$\frac{Dry\ ton}{ha.\,year}$	$\frac{\$}{dry\ ton}$
Macrocystis, nearshore	83	25
Gracilaria/Laminaria rope farm (offshore)	59	112
Gracilaria/Ulva, tidal flat farm	30	21
Sargassum, floating cultivation	47	25



Developments in seaweed cultivation and collection.

Seaweed resource and cultivation

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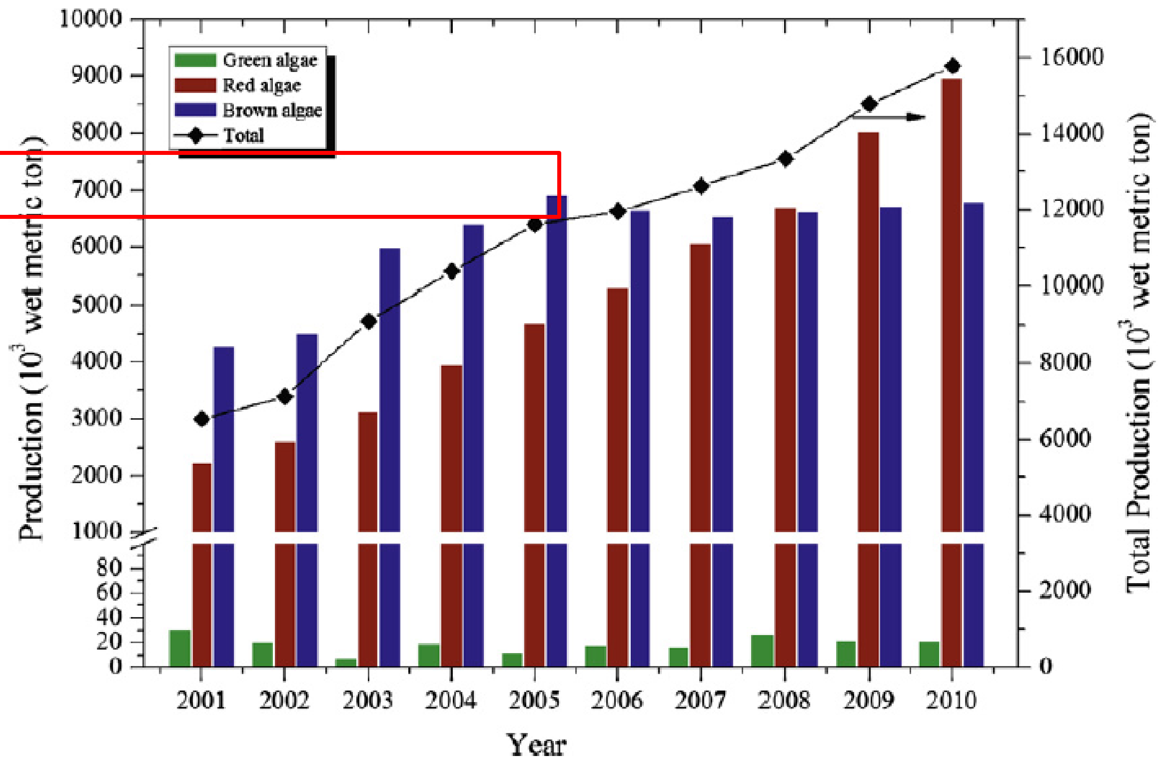

World production of farmed macroalgae from 2001 to 2010. Adjusted from FAO (2012a) (Jung et al., 2013).

Seaweed resource and cultivation

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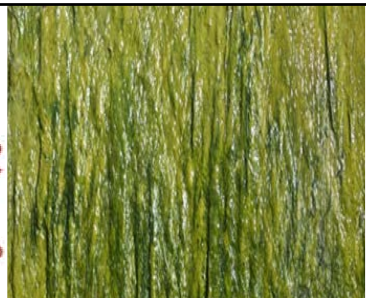
Species	Group	Production ton wet	% of total
L. japonica	Brown algae	5,146,883	32.61
E. spp.	Red algae	3,489,388	22.1
K. alvarezii	Red algae	1,875,277	11.88
U. pinnatifida	Brown algae	1,537,339	9.74
G. verrucosab	Red algae	1,152,108	7.30
P. spp.	Red algae	1,072,350	6.79
G. spp.	Red algae	565,366	3.58
P. tenera	Red algae	564,234	3.57

Species	Group	Production ton wet	% of total
E. denticulatum	Red algae	258,612	1.64
S. fusiforme	Brown algae	78,210	0.50
Phaeophyceae	Brown algae	21,747	0.14
E. clathrata	Green algae	11,150	0.07
M. nitidum	Green algae	4,531	0.03
C. spp.	Green algae	4,309	0.03
C. fragile	Green algae	1,394	0.01
G. amansii	Red algae	1,200	0.01
Total		15,784,098	100.00

World production of macroalgae (FAO, 2012)

Macroalgae

 Red algae	 Green algae	 Brown algae
Carrageenan	Starch	Laminaran
Agar	Cellulose	Mannitol
Cellulose		Alginate
Lignin		Fucoidan
		Cellulose

Laminaran → Linear polysaccharide of β(1,3)-D-glucose

Mannitol → Sugar alcohol derived from mannose

Alginate → Major structural component made of β-D-Mannuronic acid and α-L-Guluronic acid

Fucoidan → Sulphated polysaccharide containing l-fucose and sulphate ester groups

Cellulose → Linear chain of β(1→4) linked D-glucose

Brown Algae

❖ Chemical Composition of Brown Algae (*Laminaria Japonica*)

Proximate analysis	dry basis, % w/w
Ash	26
Volatile Solids (VS)	74
Protein	12
Lipids	2
Mannitol	12
Laminarin	14
Alginates	23
Cellulose	6
Fucoidin	5
Component	% wet basis
Water	88
Total solids	12
Heating Value	MJ/kg, dry basis
HHV	13.2
LHV	12.1

Elemental analysis	dry basis, % w/w
C	34.6
H	4.7
O	31.2
N	2.4
S	1
Minerals (Average for L. Japonica)	**mg/100g dry**
Ca	552.5
Na	3111
K	8515
Mg	757
I	410
Fe	29
Mn	0.4
Se	0.4
Cu	0.2
Zn	0.13