Seaweed Industry in China

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July 2nd, 2018 Beijing

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Table of Contents

1. Summary

China represents world seaweed industry and its development in terms of total cultivated production and consumption market. Fujian and Shandong provinces contribute 42% and 32% of the total annual cultivated seaweed. Among 7 main popular cultivated seaweed species in China, Kelp (*Saccharina (Laminaria) Japonica)* has been accounting for majority of the total annual production in China, 98% in 1950s and still 68% nearly 1.5 million tons (dried weight) today.

China national government has been encouraging and supporting seaweed industry since early of 1950s. Today, seaweed cultivation and its industrial processing are under pressure of historical strict environment protection regulations concerning coastal marine ecology, total biomass, water pollution and conflicts to other offshore industries.

Kelp seedling, cultivation, food processing and market have been developed smoothly from few hundred tons to an industrialized industry today. However, this industry still appears plain, labor intensive, less mechanical operation but still more manual work. Seedling companies are countable in both north and south. Many large and small companies in north and countless families' operation units in south are competing on kelp farming and processing business.

Kelp industrial processing industry started from 1950s mainly for producing iodine. During 1980s – 1990s, hundreds of factories competed on this business. Under pressure of sourcing kelp raw materials, freshwater sources, water pollution, environment protection regulations and its serious enforcement, this industry suffered through tough restructure process and lots of factories were shut down. Today, some of survived factories or companies grow into national or world leading players, not only scale of factories and quantity of alginates production, but also quality of products and world class up-to-date innovative R&Ds and new products.

Benefit from continuous contribution from 4-5 generations Chinese scientists, researchers and professors, both fundamental and application R&D works on seaweed have achieved visible successes. National and provincial science & technology funds and seaweed industry have been keeping investing seaweed R&D projects, not only to help seedling, cultivation and food processing business sectors, but also to help alginates and seaweed bioactive substances industry development and applications of these products.

Kelp food consumption took 80-98% of annual cultivated kelp during 1950s-early 1990s. From mid of 1990s to mid of 2000s, alginates industry competed 60% cultivated kelp raw materials while other 40% went for food. After year of 2005, market demands for kelp food and aquaculture feed increased gradually and steadily, taking 60% and 20% respectively. Alginates industry in China has to invest abroad for outsourcing kelp raw materials in other foreign countries.

Not many but some leading industry players and R&D organizations could be important contacts and/or cooperation partners within seaweed industry.

Based on understanding about mutual and common interests on seaweed industry between Norway and China, a sorted expects could be valuable for Norwegian seaweed aquaculture business sector and its related R&D community in Norway. Seaweed industry in Norway needs to strategically figure out **whether to export cultivated and harvested kelp raw materials to China for alginates and/or food industry, or, to cultivate, harvest and process it into kelp food and/or alginates in Norway first and then export it to China**. In addition, issues like possibility of export kelp food products, kelp food products innovative development, possibilities of having private companies' investments from China for joint venture kelp farm, joint venture kelp food and/or industrial processing factories in Norway, joint R&D cooperation on water treatment and pollution management, etc., will be discussed and clarified as well.

2. Overview

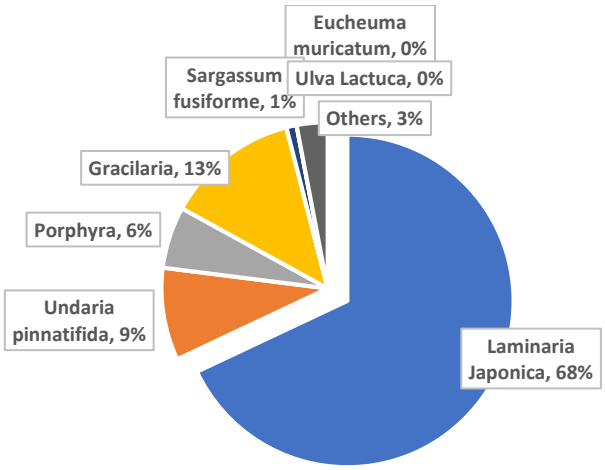
2.1 Total production

In China, the total algae production is mainly contributed from 7 cultivated species. According to statistical data published by China national fishery & aquaculture authority, total cultivated seaweed production was around **2.1 million tons (dried weight) in 2015,** taking 93% of total annual algae production (including wild-catch macroalgae and cultivated microalgae) in China.

Of the total annual cultivated & harvested seaweed production, kelp, *Saccharina (Laminaria)* japonica was 1.4 million tons taking 68% of total annual production. *Gracilaria spp* was around 270,000 tons. Wakame took 193,000 tons and *Porphyra spp* took 116,000 tons. The annual productions of Hijiki (*Sargassum fusiforme)*, Guso (*Eucheuma muricatum*) and sea lettuces (*Ulva Lactuca/Enteromorpha prolifra*) are small. As a fact, China annually harvests and consumes 75,000 tons many other species of seaweed including other various green seaweeds, red seaweeds and microalgae.

In addition to China local 2.25 million tons (dried weight) annual algae production, China also annually and globally sources around 100,000 tons (dried weight) seaweeds. 90% of it is brown seaweeds mainly from Chile and Peru. Most of it is taken by alginates industry. Some went to fertilizer business. A tiny percentage goes for food. Other 10% imported seaweed mainly is *Eucheuma spp* that mostly goes to carrageenan processing industry but a tiny quantity consumed as food directly.

The 7 main cultivated seaweed species and production proportions in China, 2015



2.2 Main cultivated species

All following 7 main seaweed species are cultivated in seawater along China coastal line from north to south. Technology & technics for seedling and cultivation have been developed and operated for decades already, and it is quite matured and easy for all seaweed farming companies to handle in annual and daily practices.

All these cultivated seaweeds are traditionally sun-dried and/or salted consumed as food directly. Kelp, Wakame, Higiki, *Porphyra spp* and sea lettuce are normally processed into large variety of food products by seafood processing companies. Seaweed food products made by kelp, wakame, *Porphyra spp* and Hijiki are exported to Japan as well. Kelp, Wakame and *Gracilaria spp* are popular sourced as feed for abalone and sea cucumber aquaculture. Kelp and Guso are widely used as raw materials for alginates, fertilizer and carrageenan industries.

China national fishery & aquaculture authority has been recording these species production data since 1950s. Annual seedlings data for kelp and *Porphyra spp* are recorded in the statistic yearbook as well.

Main seaweed species and production (dried weight), 2015 China

Unit: metric ton; Dried weight

Category	Chinese name	Common name	*Latin name*	Sample	Production
Brown algae	海带	Kelp	*Saccharina (Laminaria) Japonica*		1,411,000
	裙带菜	Wakame	*Undaria pinnatifida*		192,500
	羊栖菜	Hijiki	*Sargassum fusiforme*		9,300
Red algae	紫菜	Porphyra	*Porphyra yezoensis*		116,000
		Porphyra	*Porphyra haitanensis*		
	江蓠	*Gracilaria*	*Gracilaria verrucose / confervoides & Gracilaria tenuistipitata*		270,000
	麒麟菜	Guso	*Eucheuma muricatum*		5,000
Green algae	苔菜	Sea lettuces	*Ulva Lactuca / Enteromorpha prolifra*		100

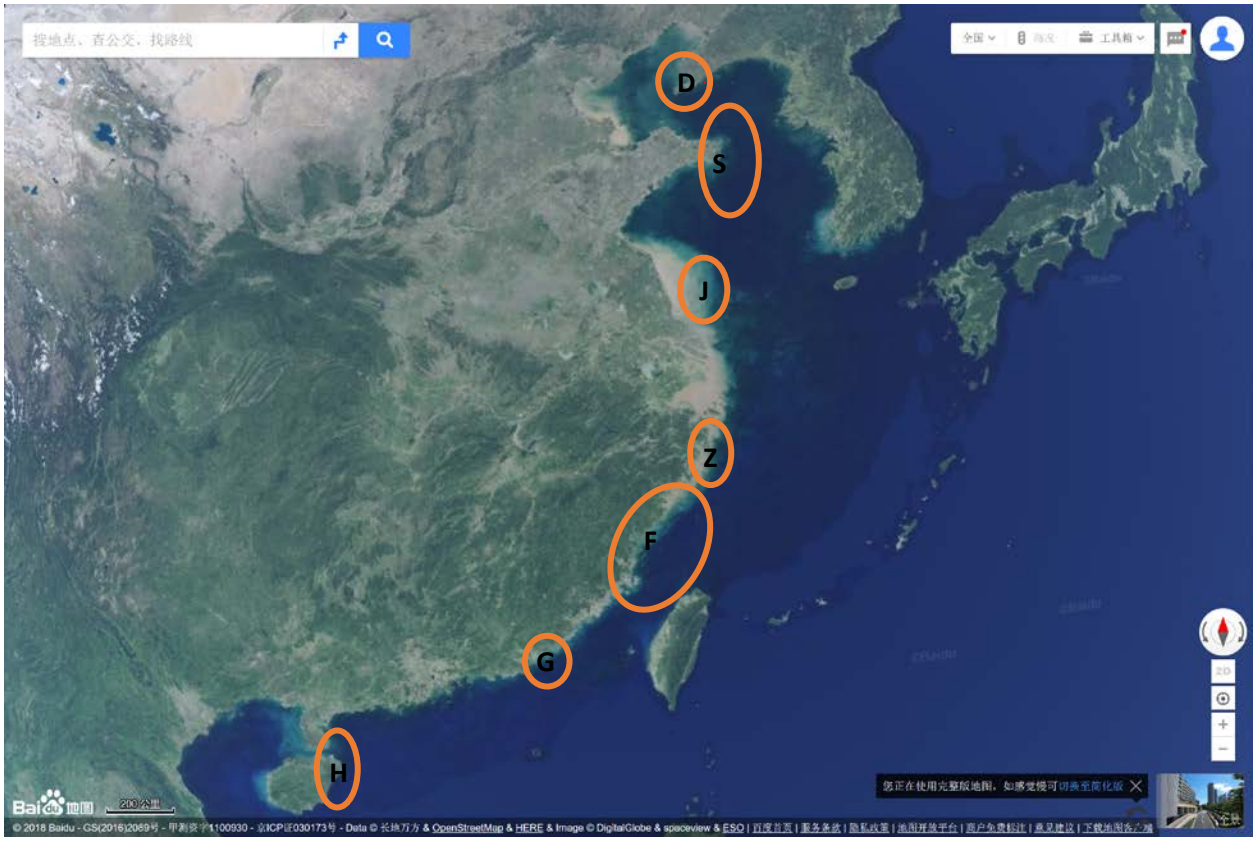
China fishery & aquaculture statistic data, 2015

2.3 Main cultivation regions

Since China started kelp farming in the early of 1950s, Dalian region in northeast China used to be the leading area. During the past 70 years development, kelp seedling and cultivation has been being spreading from northern coast to south till Fujian province in southeast coast.

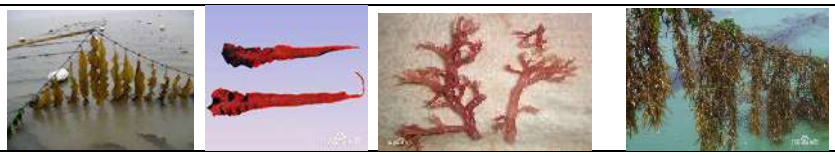
Nowadays, Fujian province turns into the first position, taking 43% of total annual cultivated seaweed production and 46% of annual cultivated kelp production, while Shandong province in north coast takes the second leading position, taking 32% of total annual cultivated seaweed production and 40% of annual cultivated kelp production.

The main seaweed farming regions in China are circled and marked on the map as below.



Main seaweed farming regions in China D: Dalian, S: Shandong, J: Jiangsu, Z: Zhejiang, F: Fujian, G: Guangdong, H: Hainan

The main seaweed farming regions and main cultivated seaweed species in each region are summarized in following table.

Main regions	**Main cultivated species**
Dalian	
Shandong	
Jiangsu	
Zhejiang	
Fujian	

Guangdong	  
Hainan	 

2.4 Policy and regulation

Since 1950s till mid of 2010s, Chinese national government and provincial government have always been encouraged seaweed industry development supported by policy, finance & funds, onshore & offshore farming areas, freshwater resources, etc.

After year of 2015, national government started industry restructure under pressure of serious environment and ecology issues, e.g. air and water pollution and disorder competitions on any natural resources. The offshore seaweed farming and its industrial processing industry are facing re-layout and restructuring as well in the coming years. National fishery & aquaculture authority planned and predicted that China aquaculture industry will move into stable and slow increase period. The whole aquaculture industry will shift its focuses from quantity, value and fast increase to quality, safety and sustainability.

The offshore kelp farming areas will be re-layout too, considering conflicts to other industries along coastal areas. Water pollution from other industries has been challenging kelp farming industry for years, concerning heavy metal and chemicals affecting to kelp food safety. Kelp food pre-treatment workshops/factories will be upgraded. Investment on water treatment facilities are mandatory demanded and strictly supervised & inspected by all levels environment protection authorities.

The kelp industrial processing factories will face historical strict supervision & inspection on approval and accessing fresh water resources for industry utilization. To access to sufficient kelp raw materials has been being a painful challenge for years to this industry concerning its sustainable development.

Hereafter, this report will focus on kelp (*Saccharina (Laminaria) japonica)* considering its importance in China seaweed industry and relevance to seaweed industry in Norway today.

3. Kelp (*Saccharina (Laminaria) japonica*)

3.1 Seedling, cultivation and food processing

Kelp cultivation in commercial scale in China started from early of 1950s mainly to match demand on food and/or iodine for preventing goiter disease (iodine deficiency disorder, IDD) spreading out in China. After late 1980s, kelp cultivation scale increased tremendously driven by seaweed industrial processing industry development and aquaculture development.

Today, kelp dominates and represents algae industry in China. Here after, taking it as an example to describe the whole value chain of kelp industry - seedling, cultivation, food & alginates processing, utilization, R&D and market, etc.

3.1.1 Seedling

During past 70 years, R&D on kelp seedling gained progresses. Today, it is getting matured after decades operating practices and experiences. Professional seedling companies can supply as many as kelp farming industry's annual demand. In 2015, totally **33.7 billion** kelp seedlings were supplied to kelp farming industry in China.

4-5 generations of scientists and researchers working for various research institutes and universities based in Qingdao, Dalian, Yantai & Weihai, have devoted and contributed on its benchmarking R&D work.

According to kelp seedling industry, diseases happened from time to time, but it is not a vital issue during seedling season. To keep water temperature below 8 °C is important. In case of disease happened, a common treatment method is to speed up water flow and wash seeds curtains.

The facilities and equipment applied in kelp seedling operation is very plain without any high-tech. Sand-filter and/or ozone water treatment system, cooling water temperature to below 8 °C, wood, bamboo, (Manila) coir rope, vinylon rope, ceiling and window light control, etc., are common materials used in seedling workshops.


(Manila) coir rope


Coir rope curtain, Shandong


Vinylon rope curtain, Fujian


Wood, Bamboo and ropes


Preparation


Ceiling light control seedling room

In Shandong northeast coastal regions, most kelp cultivation companies have established its own kelp seedling facilities and built sufficient seedling capacities to guarantee their own and any other kelp farming companies' annual demand.

Seedling season in Shandong starts from mid/late August till early/mid of October during the same year.

In Fujian province, most kelp seedling & seeds business is carried out and supplied by around 13 key professional kelp seedling companies mainly spreading along its coastal regions, e.g. Xiapu, Putian and Lianjiang. The total seedling capacity in Fujian province is much over than demand by kelp farmers in Fujian and Guangdong, and almost 1/3 of kelp seeds are supplied from Fujian to Shandong and Dalian in north coastal regions.

Seedling season in Fujian starts from mid/late September till mid of November.

3.1.2 Cultivation

In Shandong and Dalian, kelp seedlings are transferred from land-based seedling workshops to offshore facility started from early of October to early of November. After 20-40 days temporary cultivation in offshore farming facility, normally during late November and early December, small young kelp need to be removed from seedling coir rope and grip it to offshore cultivation rope.

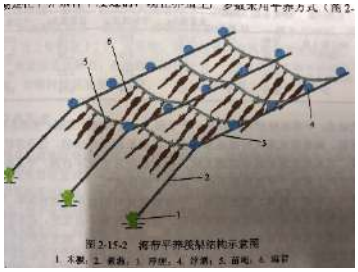
In Fujian province, to move seedlings from workshop to offshore farming area normally started from late November to December. Small young kelp will be griped to offshore rope in during late December-early January.

Preparing seedlings ropes before transferring to offshore kelp farm, Late October in Rongcheng Shandong province

Remove young kelp from seedling rope and grip it to cultivation rope, early December, in RongCheng Shandong

Some Chinese companies have tried to introduce griper machine/tool for kelp seedling operation. However, it is still not perfect yet and kelp farming industry still choose manual work so far.

Different offshore kelp farm layout models have been practically operated in Shandong and Dalian for years. After years' operating tests and experiences, a typical offshore kelp farm layout shown as below is commonly applied in both north and south coastal regions today.



Layout model of offshore kelp farm, Shandong

In Shandong and Dalian in north coastal region, kelp cultivation is carried out in offshore open seawater areas. Water quality is normally good. Most kelp farms are operated by companies. And, most of such companies-owned and operated kelp farms are operated in large scale, 50,000 – 100,000 'Mu' (3,500 – 6,700 hectares) are common scale for each company.

A typical offshore kelp farm in RongCheng Shandong

Common equipment & tools are shown in following picture. It started from straw ropes and bamboo floats during 1950s - 1960s. During 1970s – 1980s, coir ropes and glass floats are commonly used. After 1990s, coir rope, nylon rope and plastic floats are widely used till today.
Working boats is small wooden and/or fiberglass (FRP) boats equipped with engine.

A display of kelp farming history in China

Offshore kelp farming rope

Floats and cages

Plastic Floats

Offshore kelp farm and daily working boats

In Shandong and Dalian, cultivated kelp can grow up to 4-6 meters before harvest.

In south coastal region of Fujian province, almost all offshore kelp cultivation activities are carried out by individual family business units. The investment is incomparable to companies' operation in north. Too many

kelp farms are inside gulfs/bays. Water quality is very bad as a fact. All kelp farmers use any kind of cheap but very polluted foam or leather materials as floats. Offshore kelp farming ropes are same as ropes used in north.

Not many but some kelp farms are established in offshore open sea areas as well. Its layout, ropes and floats are same as it is in Shandong and Dalian.

Working boats are steel framed, filling foam materials and wood appearance, equipped with engine.

			
Under construction working boat	*Family operating unit*	*Kelp farm, foam materials floats and appearance of seawater*	*Kelp farm and appearance of seawater*

In Fujian province, farmed kelp can grow up to 3-4 meters before harvest. In some years, sea water temperature increase before normal harvest season and kelp starts rotting and broken.

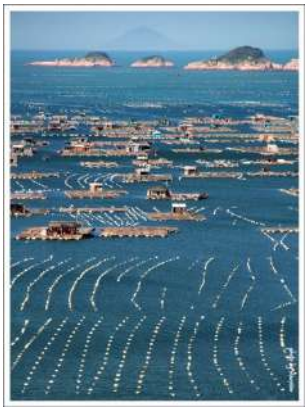
Kelp starts rotting before harvest. Mid of March in Xiapu Fujian province

3.1.3 Polyculture

Started from mid of 1980s, kelp farming companies in Shandong and Dalian have been operating integrated aquaculture hanging scallop cages in offshore kelp farm.

After mid of 1990s, due to severe diseases spread out on scallop, most kelp farms shift scallop to abalone and sea cucumber. Some kelp farms also set up fin-fish farming cages in kelp farming areas.

Kelp and abalone offshore farm, Shandong



Kelp, abalone and fin-fish offshore farm, Fujian

Steel poles for sun-drying kelp and cages for abalone farming beside dock, Shandong

Today, abalone is farmed in kelp farm in both north and south in Shandong, Dalian and Fujian.
A common operation practice started from recent past years. The farmed abalone are transported from Fujian to Shandong and Dalian keeping it in kelp farms during summer. Farmed abalone are transported from Shandong and Dalian to Fujian putting it in kelp farms during winter.

3.1.4 Harvest

In Shandong and Dalian, cultivated kelp harvest season normally starts from mid of May till end of June.
In Fujian province, it normally starts from end of March and lasts till early of June.

To harvest cultivated kelp is still a labor-intensive work and almost no harvesting machine is applied in, neither in Shandong & Dalian nor in Fujian.

The demand on seasonal workers during kelp harvest season has been being an issue year by year. Many of harvesting workers are farmers, temporarily hired from inland countryside. Knife is the only tool. Workers cut cultivated kelp rope and lift kelp together with rope on boat.

Harvest kelp with rope together, Fujian

Kelp harvesting work appears low tech. The transport boat is very plain in both north and south shown in following pictures. Wooden boats are still commonly used today. In Fujian, local kelp farmers invented a very simple wooden boat filling with foams inside boat skeleton. It works efficiently carrying and transporting 8-10 tons kelp each time.

Kelp harvest wooden boat, Fujian

Kelp harvest boat, Shandong

3.1.5 Transport & logistics

In Fujian province, kelp farms normally close to seashore. Farmers use above mentioned wooden boat and transportation boat shown as below to transport kelp directly to land or to sun-drying bamboo poles areas on intertidal zone.

Kelp harvest and transportation boats, Fujian

In Shandong and Dalian, kelp farms normally spreading out to huge areas towards offshore. Small wood boats are commonly used for workers to cut and carry kelp. Then, many small wood boats will be hauled by medium sized fishing boats and/or transportation boats returning back to pier.

Transport from kelp farm to pier, Shandong

Transport from kelp farm to pier, Shandong

Cranes beside pier lift harvested kelp on small and plain tractors, and then transport kelp to either beach, field, any other places for making sun-dried kelp or processing workshops for pre-treatment processing. Some pre-treatment workshops are just beside or nearby piers, but some are located in inland areas, 5-8 km away from piers.

Transport from pier to pre-treatment plants by small plain tractor, Shandong

3.1.6 Pre-treatment

This processing process mainly to wash and boil harvested kelp in mass quantity. Product from this process is boiled and salted, clean and green color kelp packed in big bags. Then, it is transported to cold storages (-18°C) in other kelp food processing factories/workshops. Kelp food companies will produce further for making large variety of kelp food products.

Launching into pre-treatment processing lines, Shandong

Washing and bioling in pre-treatment processing lines, Shandong

After pre-treatment products, salted in bulk sacks, Shandong

Kelp pre-treatment processing demands large quantity of fresh water and causes environment concerns. Today, all such kelp pre-treatment workshops/factories are mandatory demanded to invest water-treatment facilities.

This pre-treatment process relies on seasonal workers as well.

3.1.7 Processing food products

Sun-dried kelp

Sun-dried kelp has been being a common food product in both north and south for decades in China. During harvest season, kelp is put everywhere, along sand beach and stone coast, hanging on steel or bamboo poles, shelves, nets, on the road, in agriculture field and any piece of open land in village.

Beach and field sun-dried kelp used to be efficient and common way to get dried kelp used for either food or raw materials for alginate industry. However, quality of such products is low mixed sand and straw often, and even stones sometimes. Price is normally low then. To get better quality products for better prices, more and more farmers use bamboo and steel poles, shelves, fiber cloth and nets etc., during harvest season in both north and south.

Beach sun-dried kelp, Shandong

Field sun-dried kelp on fiber cloth sheet, Shandong

Sun-dried kelp on road in village, Shandong

Steel towers prepared for sun-drying kelp, Shandong

Bamboo poles prepared for sun-drying kelp, Fujian

Setting up bamboo poles prepared for sun-drying kelp, Fujian

Bamboo poles sun-drying kelp, Fujian

Shelves sun-drying kelp, Fujian

Sun-dried kelp used to be a common and traditional product being sold in whole China, even being visible in far northwest inland part of China in Muslim and Tibetan regions. Today, competed by seafood processing industry, abalone and sea cucumber aquaculture industry, only less than 20% of annual harvested kelp production goes to sun-dried process.

Seafood factories processed kelp food products

In Shandong and Dalian, around 60-70% of total annual harvested kelp are produced into food products. And, of these kelp for food, more than 80% goes through pre-treatment processing and further food processing process.
In Fujian, only 40% of annual harvested kelp goes for food. Of this, half of it goes through pre-treatment and further processing process, and half goes for sun-dried.

Food & seafood processing companies produce large variety of kelp food products, e.g. dried, semi-dried, wet, salted and non-salted, seasoning products in flavors, sliced, tied, small and large pieces, different kelp parts, kelp-sauce, kelp-noodle, kelp soup-mate, branding packages and HoReCa packages, etc.

Some new products, such as kelp noodle, kelp sauce, the new invented cutting product, snacks, etc., are learnt from Japan and Taiwan during recent past years. So far, only few Chinese companies can produce the new cutting products.

Wet slice, piece and tie, HoReCa packaging

Dried brand packaging, supermarket

Semi-dried salted slice, tie and sheet, supermarket or local wet market

Dried brand packaging

Wet brand packaging

Japanese new invented slice cutting, dried and semi-dried, brand packaging

Japanese style dried brand packaging

Japanese invented kelp-noodle, brand packaging

Seasoning wet kelp salad, brand packaging

Dried young pieces, brand packaging

Dried kelp soup mate, brand packaging

Sun-dried kelp slices, plain packaging, supermarket or wholesale market

Japanese style kelp sauce

Sun-dried kelp, supermarket, wholesale market and local community wet market

Kelp snacks food

3.1.8 Processing facilities and machines

Same as seafood processing factories, kelp processing factories are normally divided into sections of cold storages for pre-treated raw materials and finished products, processing workshops and processing lines equipped by different machines for making various products and packaging, e.g. dried, semi-dried, wet, seasoning and snacks products.

All processing equipment and machines are made by food grade stainless steel. Common visible machines and tools are washing tanks or tunnels, large kitchen cookers, hydroextractors, cutting and slicing machines, heating & drying tunnels, cooling fans, heavy metal sensors/detectors, weighting instruments, auto-feeding/packing machines, automatic and manual vacuum packing machines, special tailor-made kelp noodle making machines, etc.

Most kelp food processing machines are designed by kelp processing factories and/or workshops, and are tailor-made by kitchen tools & equipment producers. Auto-feeding/packing machines and weighting instruments can be sourced from professional industrial producers.

Many seafood & food processing companies in China have HACCP certificate. However, it is not situation for almost all kelp food processing factories/workshops.

Taking photo is not allowed during visiting kelp food processing factories/workshops. In general, all equipment, tools, machines, instruments & devices can be found in the international food/seafood processing machinery exhibition in Qingdao. http://www.china-spjx.com.cn/#

3.1.9 Storage & conservation

In processing factories, dried kelp products are normally stored in low temperature (0-4°C) cold storage. Shelf life could be 24 months or even further longer. Semi-dried, wet, salted or non-salted, seasoning kelp products are normally stored in cold storage (below -18°C). Shelf life could be 18-24 months.

In wholesale markets and local community wet markets, sun-dried kelp products are put in normal temperature through all four seasons in a year. Salted semi-dried and seasoning kelp products are put in cold storage during summer, but leave it in normal temperature in other three seasons.

Most consumers simply put sun-dried and salted semi-dried kelp products in normal temperature. Some families put semi-dried and seasoning kelp products into refrigerator.

3.1.10 Sales & distribution channels

Kelp food products are sold in whole China through wholesale markets, supermarkets, local community wet/morning markets and E-commerce business channels.

Wholesale markets network have been built throughout China since mid of 1980s, encouraged and supported by ministry of agriculture. Most of it have been established outskirt cities or nearby. It plays prominent role to trade all kind of agriculture and aquatic products including kelp in mass quantity with relatively low profit prices. Large scale B2B trades are main businesses, where B2C retailing businesses take place as well. However, its facilities, working environment, hygiene condition, traceability, products quality & safety, un-transparent prices, bargaining behavior and tax dogging, etc., shows challenges as negative facts. Started from recent past years, many municipal governments plan to either close such markets or move it to places further far away from cities but close to countryside.

Local community wet markets or morning markets are like wholesale markets but in small scale retailing businesses. Working environment, food quality & safety and hygiene condition are same negative facts. But residents enjoy its relative low price and convenience.

Most brand packaging products are normally sold through supermarkets. Prices are a bit high but quality and safety are much better than wholesale and local wet markets. It is right channel and place for newly invented kelp products, new packages and brands.

E-commerce grows fast and get popular in China. China has been keeping building and improving efficient and secure online payment and credit system during recent past years. Prices are transparent and more competitive comparing to traditional sales and distribution channels. And, thanks to still cheap enough labor cost in China that gives opportunity to build competitive and efficient delivery business sector for E-commerce businesses. It makes business from Online to Offline (O2O) possible. It supports B2B, B2C and even C2C business models. All these infrastructural developments do encourage consumers to do online shopping more and more. It does helps consumers to build online shopping habit, and it is getting more and more. It is obviously a good platform for all kind of kelp products, newly invented cutting products, traditional and new packages and brands, etc.

Kelp food products on Alibaba webpage

Many large-scale kelp companies involved in almost whole value chain of kelp business. They have invested on kelp seedling, cultivation, pre-treatment, food processing, storage, distribution and retailing channels, both traditional ways and online stores.

In addition, there are countless distributors to carry out wholesaling, distributing and retailing national wide in whole China, from coastal city to far remote desert Gobi market.

3.2 Kelp utilization as feed

In the beginning of commercialized kelp cultivation in 1950s in China, most of annual cultivated kelp production were directly consumed as food, while some amount went to iodine industry. During late 1980s, 1990s and before 2005, around 80% of annual cultivated kelp were utilized by alginate industry, 20% went to food business sector. After year of 2005, it turned to 20% for alginate, 80% for food. And then, more and more cultivated kelp gradually used as feed for abalone and sea cucumber aquaculture.

Today, in Shandong and Dalian, 30-40% of annual cultivated kelp production is directly used as feed for abalone and sea cucumber aquaculture. Around 60-70% of total annual harvested kelp are produced into food products. In Fujian, more than 60% of annual cultivated kelp is directly used as feed for abalone and sea cucumber farming. Comparing to kelp cultivated in Shandong and Dalian, sea water is warmer in Fujian. Cultivated kelp grows faster but a certain number of production accumulates less contents of nutrition. Quality is not actually suitable for food but good enough for feed.

As a fact, kelp food business sector still can offer higher prices and guarantee to get demanded cultivated kelp annually. Abalone and sea cucumber farming industry has to use partly kelp and partly other seaweeds as feed, e.g. Wakame (*Undaria spp*), Hijiki (*Sargassumm spp*), JiangLi (*Gracilaria spp*), etc., due to shortage of kelp

supply. According to researchers and abalone farmers, live and fresh kelp and wakame are best feed for abalone and sea cucumber. Live and fresh *sargassum, gracilaria* or any other green seaweed are subsidies when it is out of season for kelp and wakame.

Live gracilaria feed in abalone cage, late October, Shandong

3.3 Alginates and bioactive substances applications

Seaweed industrial processing industry was established in 1950s mainly producing iodine, while the whole country was facing serious goiter (iodine deficiency) disease. Today, most iodine producers stop using kelp but find other ways to produce iodine due to much more competitive cost/price.

Seaweed alginate industry started from mid of 1980s while China fishery & aquaculture industry was looking for more industrial utilization on cultivated kelp. During that period till 2005, cultivated kelp production has been keeping fast increasing year by year. Kelp food consumption was relatively stable but market demand on alginate products was attractively increasing. Gradually, Chinese alginates processing industry utilized more and more annual cultivated kelp and reached to a peak nearly 80% during late of 1990s, and more than 80 alginate factories were established in China mainly distributed in Shandong and Fujian provinces. However, accompany to further increase of kelp food market demand, abalone and sea cucumber aquaculture developed fast as well, and it took 15-20% of annual cultivated kelp in China. After 2005 till today, alginate industry was squeezed very much, always struggling for getting sufficient kelp raw materials. Its market share on kelp raw material has been decreasing from 80% in 1990s to 20% during year of 2000-2010. Many alginate factories were shut down and not many are survived. However, some alginate factories have grown steadily till today. Some of them have invested heavily on outsourcing kelp raw materials from other foreign countries, e.g. Chile, Peru, USA, Australia and South Africa. Imported main species are *Lessonia flavicans, Lessonia nigrescens, Macrocystis pyrofera* and *Ecklonia maxima* for producing alginates, *Ascophyllum nodosum* for producing seaweed fertilizer. The annual imported seaweed is around 100,000 -150,000 tons (dried weight) estimated by alginate industry.

Today, some Chinese kelp industrial processing companies have grown successfully in terms of investment scale, R&D and technology level, variety of products and its annual production, quality and international certificates of products, competitiveness in Chinese and global markets and strong financial status, etc.

Iodine used to be the main product from kelp industrial processing industry. However, this business is completely defeated by other iodine industry, only 6 kelp industrial processing factories continuously produce iodine but only less than 200 tons annual production in total. Today, they focus on producing alginates, alginic acid, mannitol, sorbitol, fucoidan, food ingredients, functional food and other kelp bioactive substances. All these products are actively and widely applied in large variety of food and functional food products, textile products, pharmaceutical bio stimulants, medical materials, cosmetics and fertilizer/soil conditioner, etc.

BrightMoon Seaweed Group Co., Ltd. - A case study
BrightMoon is one of the global leading alginate producing companies located in Qingdao city. Its products, applications and R&D trend represents status of alginate industry in China today. An up-to-date State Key Lab on seaweed bioactive substances, http://www.skl-bass.com/ is invested and established inside this company.

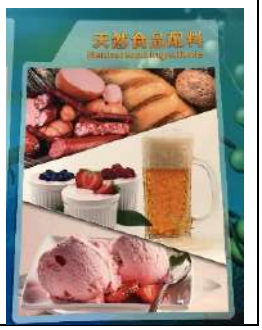
3.3.1 Alginates and applications

Alginates are main products from kelp industrial processing industry. Its wide and popular applications are described in following text.

BrightMoon produces a series certified alginates product listed in following table. And, these products are widely applied in many other products/industries in China already. This company is the No.1 in the world in terms of total annual alginates production. However, BrightMoon is still looking for R&D and business cooperation with other world leading players to further improve its Propylene Glycol Alginate (PGA) product.

Products and certificates	Grade	Applications	
Sodium alginate	Food	Bionic food shaping, jelly food molding, meat products, dairy products, beverage, frozen food, flour products, baked products, sauce and condiment, dental impressions	
	Pharm	Pharmaceutical excipient, e.g. inhibitors, adhesive, suspending agent, thickening agent, microcapsule material, film-forming material	
	Low molecule	Pharmaceutical excipient, e.g. functional food, healthcare food,	

		ink-jet printing, cosmetics	
	Textile	For different reactive printing styles and fibric For chemical fiber fibric printing Improve water holding, dye yield and soft feeling	
Propylene Glycol Alginate (PGA)	Food	Dairy products, beverage, flour products, baked products	
	Food	Beer forming stabilizer	
Potassium alginate	Food	dental impressions, industrial welding rods, beer clarification	
Alginic acid	Pharmaceutical	API, e.g. gastric drug, cardio cerebrovascular drug, nephropathy drug, targeting drug, pharmaceutical excipient, e.g. disintegrating agent	
Calcium alginate	Food	Flour product, e.g. thickening, strengthening	
Ammonium alginate	Food	Thickening agent for food and cosmetics	

3.3.2 Functional sugar alcohol

Products	Grade	Applications	
Mannitol	Medical	anti-hypertensive agent, diuretic, dehydration agent, laxative, pharmaceutical excipient and filler, preparation of mannitol hexa-nicotinate, dibro-mannitol	  
	Food	Sweeteners and anti-sticking agent applied in chewing gum beverage candy baked food other food healthcare products	
	Chemical and others	Toothpaste humectant Mannitol polyurethane Liquid electrolyte in electrolytic capacitor Microbial culture medium	
Solid sorbitol	Food	Sugar free food Healthcare products Pet food Aquatic products Sandwich biscuit, chewing gum	
	Pharmaceutical	Sorbitol injection Iron sorbitol injection Compound amino acid injection Pharmaceutical excipient, e.g. Anti-crystallization agent Cryoprotective agent Stabilizer of Chinese traditional medicine preparation	
Liquid sorbitol	Food	Candy Cake	

		Biscuit Aquatic products Beverage Ice cream Jelly Jam	
	Daily chemical	Toothpaste Cosmetics Cigarette	
	Others	Pharmaceutical industry Chemical industry Textile industry Leather industry Papermaking industry	

3.3.3 Composite seaweed functional food ingredients

The extracted bioactive substances, e.g. fucoidan, alginates, iodine, fucoxanthin, phlorotannin, water soluble dietary fibers, etc. are produced into functional food ingredients. For instance, thickening, suspension, emulsifying, water locking, gel, absorption, sustained release functions to improve elasticity, toughness, water retention and product structure for good taste.

Popular functional ingredients are applied in flour products, baked products, dairy products, jelly food products, meat products (sausage and ham), juice, yogurt, beer and soy sauce, etc.

3.3.4 Functional food

Functional food products are mainly directly use seaweed, e.g. ferment jelly food, ferment powder/meal made noodle.

Kelp jelly food and kelp noodle

3.3.5 Cosmetics

Different skin care cream, moisture and facial mask products made by alginates are visible and sold in Chinese market. It is a joint venture R&D and commercial business together with Korean cosmetics company.

Skin care and facial mask products

3.3.6 Marine biomedical materials

BrightMoon has been keeping investing R&D in this field and made quite a lot of breakthrough progresses. All products listed in following table have been being commercially applied in China. A strong R&D team, with many abroad study background PhD and post doctor degrees researchers led by a Chinese scientist returning from UK, is dedicated on R&D projects in this field.

products	Applications
Alginate fiber	Healthcare, facial mask, fire protective cloth, static proof cloth, home decoration, sanitary napkin
Alginate sterile dressing	To provide moist condition to accelerate wound healing, especially for refractory chronic wound
Alginate non-woven fiber	Gauze/carbasus for healing wound
Alginate band-aid and woundplast	to accelerate wound healing and to reduce scar
Medicative scar paster	To avoid pain by dry scar, applying to C-section scar, surgical scar, hypertrophic scar, burn and scald scar
X-ray detectable yam	To be woven with cotton yam to produce X-ray detectable gauze; to be thermally or ultrasonically bonded to medical fibric

3.3.7 Fertilizer

Seaweed fertilizer is BrightMoon's another important product. The seaweed raw material is imported *Ascophyllum nodosum.* BrightMoon can produce more than 100 different fertilizer products for vegetables, fruits trees and flowers. So far, the proved effect specially works on apple trees.

	
Imported seaweed, Ascophyllum nodosum	*BrightMoon's fertilizer products*

This company keeps looking for *Ascophyllum nodosum raw materials from foreign countries including Norway.*

3.4 R&D competence and resource

Since 1950s, 4-5 generations scientists, professors and researchers have been contributing on R&D work for kelp selection, breeding, cultivar, seedling, commercialized cultivation, bioactive substances and its applications.

Most important research institutes, universities and key labs are in north China, mainly based in Qingdao and Dalian.

Some researchers and professors cooperate in connection to relevant joint R&D projects, which are financed and/or coordinated by government at national level, provincial level and/or municipal city level.

It is common that Chinese researchers and professors work closely within kelp seedling and cultivation industry during past decades. Many kelp farming companies are in Shandong and Dalian, north coast regions in China. Both researchers and companies benefit on such geographic advantage. Kelp companies also rely on up-to-date R&D progresses and companies always show interests to researchers and professors. And, they are normally willing and welcome professors and researchers to use kelp companies as a research stations. Some kelp companies have such field research stations for different research teams from different research institutes and/or universities. Some these type field research stations carry out important national level R&D projects financed by ministries and/or national R&D funds. Master students, PhD students and post doctors work in such stations often. Researchers and professors keep long term close and friendly relationships with kelp companies' owners. All kelp seedling, farming and processing companies in Shandong, Dalian and Fujian rely on these researcher and professors.

Following research institutes, universities and labs are important R&D resources to support kelp farming and processing industry in China.

Institute of Oceanology, China Academy of Sciences (IOCAS), Qingdao
http://www.qdio.cas.cn/

IOCAS has been keeping doing kelp R&D work since 1950s. 5 generations researchers have been keeping working on kelp R&D projects. This institute represents fundamental R&D level.

It is under administration of China Academy of Sciences (CAS), and get R&D funds mainly from CAS as well. In addition, it is also common and often to get funds from Ministry of Science & Technology, the State Natural Science Fund, the State 863 Program, the State 974 Program, and funds from Shandong provincial government.

IOCAS actively keeps communication with international algae organizations. Its researchers are members and/or have connections to international algae organizations and/or sub-organizations based on species and/or regions. Its researchers are common and often participate and present in algae events, publish academic articles, leading and coordinating regional algae cooperation in East Asia and Southeast Asia.

Yellow Sea Fisheries Research Institute (YSFRI), Qingdao
http://www.ysfri.ac.cn/

YSFRI is a professional application R&D institute with focus on marine aquaculture industry. Many researchers work even more close to marine aquaculture industry including kelp companies.

It is under administration of Ministry of Agriculture, and undertakes R&D projects mainly financed by ministry of agriculture. In addition, it also carries out projects financed by other funds same as IOCAS.

YSFRI keeps active international communication, researcher exchange project and presence to international algae events. Especially, it has been keeping more than 25 years long term close relationships with the Institute of Marine Research in Bergen and Bergen University. This special relationship was build based on the

Norwegian government donated 'Beidou' fisheries research vessel in 1983 after the Norwegian Prime Minister visited China and had a successful meeting with Chinese leader Deng Xiaoping.

China Ocean University (COU), Qingdao
http://www.ouc.edu.cn/

COU is the most well-known and important university mainly major in ocean and marine aquaculture.

Some professors work closely to kelp companies. They also get projects financed by national and provincial levels.

COU's alumni network within marine aquaculture industry in China turns into its outstanding competitive and intangible asset today.

COU keeps active international communication and presence.

Dalian Ocean University (DOU), Dalian
http://www.dlou.edu.cn/

DOU used to be Dalian Fishery College with advantage major in marine aquaculture before mid of 1990s. Quite a lot of excellent professors are specialized on kelp, wakame and shell fish aquaculture. DOU has close connections with professors and researchers in Japan.

Yantai Marine Research Institute, Yantai

This research institute is under administration of Shandong provincial government founded in 1950s. It contributed a lot directly and closely to marine aquaculture industry in Shandong province, especially in Yantai & Weihai regions where marine aquaculture industry is intensively located in. Good relationships and professional network within kelp farming industry are their competitive advantages.

State Key Laboratory of Seaweed Bioactive Substances, Qingdao
http://www.skl-bass.com

This lab is funded by BrightMoon company and is established inside the company. It is professional with R&D focuses on seaweed bioactive substances and its widely applications in various industries.

Its research teams are led by young PhD and post doctor degrees researchers who have studied in top level universities in China and universities abroad. During recent years, they have made progresses on new alginate fiber, non-woven fiber and its applications in new products. Quite a lot of medical materials, new anti-fire cloth and anti-static cloth, steriling dressing, band-aid, sanitary napkin, woundplast, etc.

3.5 Key players

Main kelp seedling, faming and food processing companies

China has many kelp seedling, farming and food processing companies in Shandong, Dalian and Fujian, in addition to countless kelp farming family operation units in Fujian. Some companies listed as below are in RongCheng region in Shandong province. These are leading players within this industry.

HaiZhiBao Ocean Science & Technology Co., Ltd. RongCheng Shandong
http://hzb.chinaaquatic.cn

XunShan Group Co., Ltd. Rongcheng Shandong
http://www.xunshangroup.com

LiDao Oceanic Technology Co., Ltd. RongCheng Shandong
http://www.shizaobao.cn

GaoLv Seaweed Group Co., Ltd. RongCheng Shandong
http://www.sdgaolv.com/en/index

Main alginates and bioactive substances industrial processing companies

Companies in this business sector has been reducing a lot. Not many are survived today. Most leading players are in Qingdao region.

It is heavy assets investment on industrial processing facilities, machines and equipment. Normally, it is not allowed to take photos during visiting these factories. However, some facilities are visible in these companies' websites.

BrightMoon Seaweed Group Co., Ltd. Qingdao
http://www.bmsg.com

JieJing Group Co., Ltd. RiZhao
www.china-jiejing.com/index.html

JuDaYang Ocean Algae Industry Co., Ltd Qingdao
http://www.judayang.com/#page1

3.6 Mutual interests and potential cooperation between Norway and China

Norway has started studying alginate since more than 100 years ago. Its commercial and industrialized alginate business has lasted more than 80 years, but dominated by only one company – Protan AS / FMC BioPolymr AS. Alginate industry in Norway is almost completely rely on natural beds of *Saccharina (Laminaria) digitate in the beginning and then hyperborea* (sugar kelp) that accounts for about 90% of the total annual harvested seaweed in Norway today.

A small amount of *Ascophyllum nodosum* is utilized as feed/fodder and bio-stimulants/fertilizer. The business has been carrying out by only one company – Algae AS/Valagro Group.

A tiny quantity of *Ulva spp* is manually harvested by some small companies and produce it into food products.

During recent past years, more and more small companies have shown interests of exploring kelp cultivation and processing businesses. However, the fact of the current small-scale kelp cultivation and its tiny harvested output tells seaweed aquaculture in Norway is still in very early stage - scientific study, strategic development plan, certificate regulatory and discussion among industry, local communities and fisheries authority.

Based on recent years communication and dialogues between Norway and China in connection to kelp farming, food processing, industrial processing and utilizations business sectors, following interests could be valuable reference for both sides to understand to each other.

	Norwegian interests towards China	Chinese interests towards Norway
Species		Researchers look for introducing *S. (L.) hyperborea / digitate* from Norway to China
Seedling	Know-how details – facility, equipment, layout, rope, water quality and temperature control, light control, disease control, sand filter water treatment facility,	Water cooling system, technology and technics
	Technic of griping kelp seedlings from seedling ropes to offshore farming ropes	
	Contacts of Chinese experts or experienced skillful technicians	
	Onsite training in Norway	
Cultivation	Offshore facility, equipment, mooring layout, ropes	To further develop polyculture / integrated aquaculture together
	Know-how details – sea water currents and ropes directions of layout,	To invest joint venture kelp farm in Norway
	Chinese experts or experienced skillful technicians	
	Onsite training in Norway	
Harvesting		To develop mechanical harvesting machines together
Pre-treatment	Know-how details – water temperature, time of boiling cooling, salting and dehydration	Waste water treatment and nutrition separation and purification
Processing	To study and understand kelp food products for China/Asia market	
	Tailor designed and made facility, equipment, auto or mechanical machines	
	To study *Porphyria spp* food products and its processing machines for developing kelp products	
	Storage for sorted products – dried, semi-dried, salted and non-salted, seasoning with and without liquid sauces	
Food market	Possibility of exporting/selling in Chinese/Asian market	
	Market study on importing, distribution and retailing businesses, and E-commerce	
	Market study on Chinese consumers – gender, age, geography, income, consuming tradition, habit, etc.	
	Business partner(s)	
	To export kelp food products	
Alginates & bioactive substances	Facilities, equipment, machines, layout	To buy kelp raw materials, *Ascophyllum nodosum and S. (L.) hyperborea* from Norway to China
	Technology for producing alginates, alginic acid and other bioactive substances	To further develop PGA products together with Norwegian scientist(s)
	Sales channels / customer networks in different applications industries	To develop seaweed fodder products together for cattle and pig
Common interests		
Networking	Personnel exchange – professors & researchers, university students, professional and experienced technicians	
	Business network – visiting, meeting, sharing information to each other	
	R&D network - visiting, meeting, sharing information to each other	
Cooperation	R&D and trade	

Acknowledgement

A special gratitude is sincerely expressed to Professor Delin Duan, a Chinese seaweed scientist working in IOCAS. Supported by his expertise and network within Chinese seaweed industry, Innovation Norway China accessed to up-to-date knowledge and professional information sources, visiting and meeting researchers, professors and industry people in Shandong and Fujian provinces in connection to whole value chain of kelp industry.

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- GaoLv Seaweed Group Co., Ltd., Shandong
- BrightMoon Seaweed Group Co., Ltd., Qingdao
- Dalian Kowa Food Co., Ltd., Dalian
- JieJing Group Co., Ltd., Shandong
- Institute of Oceanology, China Academy of Sciences, Qingdao
- China Ocean University, Qingdao
- Yellow Sea Fisheries Research Institute, Qingdao
- Zhoushan Ocean University, Zhejiang
- Shanghai International Food Machinery Exhibition, Shanghai
- Asia-Pacific Aquaculture & Fujian International Seafood and Aquaculture Exhibition, Fuzhou
- Qingdao International Food/Seafood Processing Machinery Exhibition, Qingdao