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Cultivation and utilization of *Undaria pinnatifida* (wakame) as food

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Abstract

A brief review is presented concerning wakame, *Undaria pinnatifida*, one of the most popular seaweeds used for food in Japan. Although it has been cultivated since about 1940, full-scale cultivation occurred after 1955. As methods for providing 'seed stock' and of processing the harvested sporophytes progressed, the yield increased rapidly. The main areas of cultivation are in Japan (e.g. Sanriku, Naruto), Korea and China, while 'wild' *U. pinnatifida* has been introduced into France, New Zealand and Australia. The total world yield of wakame exceeds 500 000 t fresh weight. Cultivated and harvested *Undaria* is boiled and salted (thus becoming green) and refrigerated; in the factory, it is removed its foreign matter and salt and dried. After checking for quality, the product is packaged in forms convenient for cooking and eating.

Introduction

Wakame, *Undaria pinnatifida* (Harvey) Suringar (Phaeophyta:Laminariales), is a seaweed with alternating gametophytic and sporophytic generations that were described by Kanda (1936). In occurs on the rocky shores in the temperate zones of the Far East, including most of Japan (except eastern Hokkaido and Okinawa prefectures). There are two forms: *distans* in the Sanriku area, and *typica* elsewhere. Wakame from protected waters differs from that in more open waters (Taniguchi *et al.*, 1981).

Preparations such as wakame soup and seaweed salad have increased in popularity because of the high fibre and low joule content of this seaweed. The increased demand led to the importation of wakame into Japan from Korea and China. As boiled *Undaria* turns green, this has led to consumer preference for all wakame products be green.

The processing of wakame requires numerous steps from the basic resource to the finished product. This paper reviews the production features and discuss the problems and future of a wakame industry.

History of cultivation

Cultivation of *Undaria pinnatifida* was first studied at Dalian, northeast China, by Youshiro Ohtsuki who patented cultivation techniques for wakame and for kombu (*Laminaria japonica* Areschoug) in 1943. After World War II, Sudo (1948) studied tank cultivation, but Ohtsuki's patent prevented cultivation from becoming widespread until 1955, when several enterprising fishermen began cultivating it on ropes. In 1957, Kurogi and Akiyama published an important paper on the ecology and cultivation of this species. After 1955, owing in part to promotional measures, wakame cultivation spread to various places in Japan, especially in the Sanriku and Naruto areas. Shortly thereafter, commercial cultivation, based on Japanese procedures, began in Korea and China.

History of wakame processing

In addition to improved methods of cultivation, concurrent improvements in processing techniques have been very important in leading to increased consumption of wakame. Previous methods of processing consisted mainly of sun-drying (suboshi wakame) and ash-drying (haiboshi wakame) (Table 1). The process for boiled, salted wakame was developed in the 1960s, and almost all cultivated *Undaria* is now processed in this way. This product is superior in color, taste, stability and convenience.

Distribution of wakame

Undaria pinnatifida was distributed in Japan, Korea and China (Chensan Island in Zhoushan Archilpelago). As a result of cultivation, the species has become more widely distributed in China. In addition, because of the transport of gametophytes attached to oyster shells or being contained in seawater used for ballast, *U. pinnatifida* is now found in France (Pérez *et al.*, 1981, 1984; Floc'h *et al.*, 1991), New Zealand (Hay, 1987, 1988, 1990) and Tasmania (Sanderson, 1990).

In Japan, there is large-scale cultivation in the Sanriku area (forma *distans*, for the most part) and Naruto (forma *typica*). With yields of over 300 000 t fresh weight per annum, Korea is the major producer of wakame. The main cultivation fields are on the south coast, around Wando, and on the east coast, around Pusan. Almost all the wakame cultivated in Korea is boiled and salted, and large quantities are exported to Japan. In China, *U. pinnatifida* is cultivated around Dalian and Qingdao. All of the harvest is boiled, salted and exported to Japan. The amount of wakame produced in China is increasing.

Methods of cultivation

The methods of *Undaria* cultivation are well described in the literature (Akiyama 1965, Akiyama & Matsuoka 1986). The seeding process, which occurs in spring and summer when spores are released from sporophylls, is distinguished from

Table 1. Processes of manufacturing various products of wakame in Japan.

Name	Process	Quality
Suboshi wakame	Raw resource – sun-drying	Brownish green High frequency foreign materials Poor storage quality
Haiboshi wakame	Raw resource – mixed with ash – sun-drying – washed – sun-drying	Fresh green High frequency foreign materials Poor storage quality
Salted wakame	Raw resource – salted – dehydrated – mid-rib removed – visual selection – packaging	Brownish green
Boiled and salted wakame	Raw resoure – boiled – cooled – salted dehydrated – mid-rib removed – visual selection – packaging	Fresh green
Dried cut wakame	Boiled and salted wakame – sifted – washed – dehydrated – cut – washed – dehydrated – salt removed – dried through a rolling dryer – mechanical selection – final visual check – metal detection – packaging	Fresh green Low frequency foreign materials Good storage quality

the cultivation process. In Japan, wakame is harvested from February to May.

Cultivation bigins with seed strings on which zoospores have settled and gametophytes have developed. Normally during summer, the surface-water temperatures in Japan are too warm for gametogenesis to occur. If temperatures become too warm, then many gametophytes die. Therefore, the seed string is kept cool by being lowered below the summer thermocline (as in Sanriku) or by culturing in special aquaria (in Naruto) during summer. Under these conditions, gametogenesis and the formation of small sporelings occur in summer and early autumn. In autumn, as sea-surface temperatures decline, the seed string is attached in various ways to long lines which are suspended close to the sea surface, where the crop of *Undaria* sporophytes developed. After approximately four months, the *Undaria* plants become about 2 m in length.

Methods of processing

(1) Primary treatment immediately after harvesting

The tops and bottoms of the *Undaria* are trimmed at harvest, and the thallus is briefly blanched in sea water (rarely in fresh water); this changes its color from brown to bright green. The color change results from a change in chlorophyll-related enzymes, and is regulated by time and temperature of blanching. The color change occurs above 65 °C, but if the wakame is heated at too high a temperature for too long, chlorophyll is degraded to phaeophytin and the color changes to brown. Failure in the boiling process frequently leads to *Undaria* turning brown during storage. After blanching, *Undaria* is cooled, mixed with salt and preserved overnight in a highly-saturated salt water solution. The salted blades are then drained and allowed to dehydrate for several days, after which the mid-ribs are removed. The blade portions are further dehydrated before being checked for quality and packed into polyvinyl packages, which are stored at −20 °C.

(2) Relationship between the boiling process and quality

Because of consumer preference for bright-green wakame, we investigated the relationship between blanching temperature and color. We used *Undaria* cultivated at Toni Bay, Sanriku. The thalli were heated to various temperatures and for various times, and the results are summarised in Fig. 1 which show color changes with temperature and time for different months. Below 50 °C, wakame did not change color; between 60° and 70 °C, the thalli become brownish-green, and fresh green above 80 °C. The thalli were somewhat brownish when blanched at 95 °C for 90 s and especially so after 300 s. This suggests that short periods of heating (30–60 s) between 80° and 95 °C are best for attaining an ideal color for processed wakame. Changes in pigment composition after treatment and following storage are shown in Table 2.

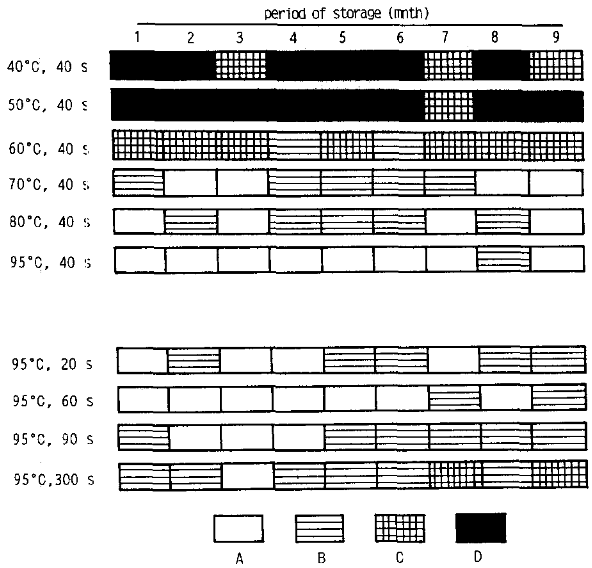

Fig. 1. Relationship between the color of *Undaria pinnatifida* and the temperature and duration of blanching. The rectangles show the degree of color (A: fresh green – D: brown) of boiled and salted *Undaria* by monthly visual check following storage at −20 °C.

Table 2. Ratio of the absorbance at 410 nm/430 nm for *U. pinnatifida* following storage at − 20 °C. Chlorophyll and phaeophytin show peaks at 430 nm and 410 nm, respectively.

Temp. (°C)	Time (s)	Period of storage (month)		
		4	6	9
40	40	0.98	0.96	0.93
50	40	0.94	0.93	0.93
60	40	0.88	0.89	1.02
70	40	0.88	0.91	0.96
80	40	0.87	0.89	0.92
95	40	0.86	0.86	0.89
95	20	0.86	0.87	0.87
95	60	0.88	0.88	0.88
95	90	0.89	0.89	0.88
95	300	0.92	0.94	0.93

(3) Processing dried, cut wakame

In this process, the boiled and salted product is washed, chopped, desalted and dried at the factory. We use mechanical drying because the final product rehydrates quickly. However, large quantities of *Undaria* are processed through a rolling dryer, as this results in an end product comprised of small, easily-packed pieces (Iwasaki & Sato 1984). Less than 10% of the moisture is retained, which is good for product-stability during storage.

A major problem in quality control is the quantity of foreign materials included with the harvested seaweed. We use various processes to clean the harvests, including washing machines, sifters, metal detectors, blowers and electronic procedures. Unless the harvested material is cleaned, a manufacturer can expect about 1000 foreign bodies per ton of dried wakame. After cleaning the incidence of foreign bodies per ton is reduced to about 50. There is a final visual check as the product passes on conveyor belts before being packaged.

Variety of wakame products

There is a wide variety of *Undaria* products available in the Japanese market. These include salted wakame, dried cut wakame, wakame soup, seaweed salad, pre-cooked wakame to go over rice and so forth. Wakame is eaten in restaurants, fast food shops and in instant noodles. Other products, for example, powdered wakame and seaweed-based snacks, are being developed. These products are beginning to be exported to Europe and America. The value of the Japanese market alone is estimated to exceed 50 billion ¥ ($US 400 million). Consumer demand, especially for convenient chopped, dried wakame is tending to increase.

Future of wakame as food

The quality of *Undaria* products is judged by the seaweed's thickness and hardness (factors determined during cultivation), color, stability during storage and absence of foreign substances, among other things. We need constantly to monitor new products, from cultivation through to their use by consumers.

During cultivation there are problems with several types of diseases caused by fungi and parasitic copepods that affect the quality of finished *Undaria* products. Diseases such as Nanpusei Anaaki sho, Hantensei Sakikusare sho (Ishikawa & Saga, 1989) and *Olpidiopsis* disease (Akiyama, 1977) are among those reported. Ishikawa and Saga (1990) discuss developments of strains resistant to these diseases. Although there are studies of cultivating *Undaria* in new fields (Ishikawa *et al.*, 1992) and of crossbreeding (Migita, 1967; Shinmura, 1985; Hara & Akiyama, 1985), there is little published information on the genetic characteristics of *Undaria*.

In the primary treatment, we are changing from a burner system to a boiler system to maintain more stable temperatures. We must also investigate the effect that fluctuations in pH have on the product, the influence of various ionic concentrations on the product and conditions of storage. Furthermore, the mid-ribs are still removed by hand, and the development of mechanical means for this is an urgent priority. In the secondary treatment, techniques for washing, drying and selecting are changing rapidly and the final check for quality is now done automatically.

Undaria pinnatifida is a traditional food in Japan. The amount consumed has increased significantly as a result of progress in techniques of cultivation and treatment and through the development of new products. It is clear that high-quality products will be available in future, and accordingly the development of culturing, processing and new products must proceed rapidly.

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