Journal of Applied Phycology (2006) 18: 259–267
DOI: 10.1007/s10811-006-9025-y

Farming of the giant kelp *Macrocystis pyrifera* in southern Chile for development of novel food products

Alfonso Gutierrez[1], Tomás Correa[1], Verónica Muñoz[1], Alejandro Santibañez[2], Roberto Marcos[3], Carlos Cáceres[4] & Alejandro H. Buschmann[1,*]
[1]*i∼mar, Universidad de Los Lagos, Camino Chinquihue km 6, Puerto Montt, Chile;* [2]*Departamento de Gobierno y Empresas, Universidad de Los Lagos, Casilla 557, Puerto Montt, Chile;* [3]*Productos del Pacífico, S.A. de C.V., Ensenada, México;* [4]*Consultora Los Lagos, Población Varmontt Nr. 4, Puerto Varas, Chile*

*Author for correspondence: e-mail: abuschma@ulagos.cl; fax: +56 65 322418

Key words: Macrocystis pyrifera, farming, food products, Chile

Abstract

This study explores the potential cultivation of the giant kelp *Macrocystis pyrifera* (L.) C.A. Agardh in southern Chile, for the development of novel food products. The study demonstrates the importance of considering the collection site of the parent sporophytes for successful cultivation. This study also shows that the ropes must be seeded with 10,000 to 40,000 spores ml^{-1}, depending on the culture method used. We also demonstrated that under environmental conditions in southern Chile, the seeded ropes must be put at sea at the latest during autumn (April) in order to reach the harvesting season in December. However, several other management aspects must be considered to improve the quality of the product. Our final estimation indicates that over 14.4 $kg\,m^{-1}$ of rope (fresh weight) can be produced and from this total production, over 70% can reach the quality to produce different food products that are already being introduced in oriental countries. The remaining 30% can be used for abalone feeding and is also available for the organic fertilizer industry located in Chile.

Introduction

California kelp beds started to be harvested as a source of potash during the first decade of the 20th century and commercial interest in the giant kelp *Macrocystis pyrifera* expanded significantly between the 1970s and 1980s (Neushul, 1987; Druehl et al., 1988). This interest was primarily for the production of alginates, but also to produce biomass as a feedstock for methane production as a consequence of the energy crisis at that time (North et al., 1982; Gerard, 1987; Neushul & Harger, 1987). Nevertheless, *M. pyrifera* commercial cultivation for methane production was never a reality. At present, the supply of *M. pyrifera* biomass for the alginate industry relies exclusively on restoration practices and management of natural beds to obtain a sustainable production (North, 1979; McPeak & Barilotti, 1993; Vásquez & McPeak, 1999). After the energy crisis and because of the low price of alginates, farming research on *Macrocystis* declined sharply.

On the other hand, other brown algal species began to be commercially cultivated in Japan, China and Korea, mainly for human consumption (Tseng, 1987; Kaneko, 1999; Hanisak, 1998) while kelp-farming attempts for this purpose have also proved technically feasible in other regions (e.g. Druehl et al., 1988; Kain, 1991; Merril & Gillingham, 1991). Interestingly, the demand for brown algae is also increasing due to the introduction of new uses such as fertilizers, cultivation for bioremediation purposes, and abalone as well as sea urchin feeding among others (Petrell et al., 1993; Vásquez & Vega, 1999; Buschmann et al., 2001c; Ugarte & Sharp, 2001; Chopin et al., 2001). In Chile, despite the commercial importance of various algal species, aquaculture is still limited to the red alga *Gracilaria chilensis* (Buschmann et al., 2001b).

In Chile, Abalone and sea urchin cultures, organic fertilizer production and novel seafoods have created a new niche market for the giant kelp *Macrocystis pyrifera*. Increased harvesting is already causing some deterioration of different kelp populations (Vásquez & Vega, 1999). Considerable information on *Macrocystis* cultivation has been published in the past (North, 1979). However, some basic knowledge necessary to run a successful commercial activity is still lacking, especially with regard to the different environmental conditions and complex morphological and reproduction variability between populations, that can have important commercial consequences.

Considering this new market scenario, the potential impact on natural populations and the lack of biological knowledge necessary to produce a high quality product, this paper deals with the cultivation of *M. pyrifera* in southern Chile. Specifically, the effect of the origin of the parental plants on the survival and growth of young sporophytes cultivated on ropes was tested, in both hatchery and field conditions. Finally, a pilot cultivation was established to determine the potential yields of *M. pyrifera* in southern Chile and we describe some of the food products developed.

Materials and methods

Study sites

Fertile sporophylls of *Macrocystis pyrifera* were collected at six localities in southern Chile: Metri (41°35′S; 72°42′W), Pargua (41°47′S; 73°25′W), Calbuco (41°46′S; 73°08′W), Pucatrihue (40°33′S; 73°43′W), Bahía Mansa (40°34′S; 73°44′W) and Curaco de Velez (42°26′S; 73°35′W) (Figure 1). Site selection was based on the presence of abundant kelp populations and different water movement conditions. The plants were collected by scuba divers and transported, within 6 h, on ice to the seaweed culture laboratory in Metri. All field cultivation experiments were carried out in Metri and the pilot culture in Calbuco (Figure 1).

Cultivation of different populations

The sporophylls collected in Metri, Pargua, Calbuco, Pucatrihue and Bahía Mansa, were washed under tap water and UV treated filtered seawater (0.2 μm) containing commercial iodine (0.5% for 10 s), packed in filter paper, covered with aluminum foil and stored at 15 °C (Figure 2A). After 12 h, 10 to 15 sporophylls were placed in 20 L sterile plastic containers filled with filtered (0.2 μm) and autoclaved seawater (Figure 2B). Sporulation started in all cases after 25 to 35 min and, after 1 h the sporophylls were removed and the water was filtered with a 100 μm mesh. Eight PVC cylinders covered with a 1.5 mm nylon rope were introduced into each of the 20 L containers to allow for spore settlement (Figure 2B). After 12 h, the eight PVC cylinders were removed and placed in a 30 L glass tank filled with autoclaved, filtered, and Provasoli enriched seawater (McLachlan, 1973; Figure 2B). Culture was carried out at a photon flux density of 30–40 μmol m^{-2} s^{-1}; a temperature of 9–10°C; a salinity of 30% and a pH of 7.8–7.9. Photoperiod was 16:8 (L:D) during the first week; 14:10 (L:D) during the second week; 12:12 (L:D) during the third week and 10:14 (L:D) thereafter (following a previously determined protocol; Buschmann unpublished results). After 44 days, 3 cm pieces of rope were randomly cut off and plant density (number of sporophytes fronds per cm of rope fragment) estimated under a stereomicroscope. Furthermore, the maximum lengths of the juvenile sporophytic fronds were determined using an ocular micrometer. The data were statistically analyzed by a one-way ANOVA after logarithmic transformation to ensure the normality and homocedasticity of the data. If significant differences were detected between treatments, a Tukey *a posteriori*-test (according to Steel and Torrie, 1985) was performed. As the data were obtained from independent tanks, seeded from independent plants and comparisons between times were not considered, no pseudoreplication exists (*sensu* Hurlbert, 1984).

After 60 days in the hatchery (September), seeded ropes were attached to a 3 m long horizontal supporting rope (18 mm diameter) in groups of three placed at 2 m depth (Figure 3) in Metri (Figure 1). Three seeded ropes were used for each one of the five original populations. Plant density and length of the different *Macrocystis pyrifera* populations were estimated, after one and two months in the field, by random sampling of 5 cm seeded rope sections under a stereomicroscope. All data were analyzed as above.

Pilot study

Parent sporophytes were collected in Curaco de Velez (Figure 1) and seeded on ropes following the same methods and culture conditions described above. The ropes were seeded in mid January and were brought to the Calbuco culture site (Figure 1) in March. The initial culture conditions of the sporophytes in the field were