Chapter 12
The Optical Characteristics of Cultured Akoya Pearl Are Influenced by Both Donor and Recipient Oysters

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Abstract The characteristics of a cultured pearl are influenced by two kinds of pearl oysters. One is the donor pearl oyster, which provides a small piece of mantle to be transplanted, and the other is the recipient pearl oyster, in which the pearl nucleus and a small piece of mantle are transplanted. Generally, the brightness, luster, and color of pearls are affected by the donor oyster, while the thickness of nacre is affected by the recipient oyster. Previously, we have indicated that the sex of recipient pearl oyster directly affects the quality of pearl, and the optical characteristics measured by FT-IR (Fourier transform infrared spectroscopy) of pearl produced from male and female pearl oysters significantly differ (Iwai et al. Aquaculture 437:333–338, 2015). Moreover, using the various strains of Akoya pearl oyster as recipient and the same donor oyster, the produced Akoya pearl had different spectra for each strain. Also, besides the culture of the Akoya pearl oyster, the transplantation also produced different optically characterized pearls by breeding them in various environments. These results suggested that the optical characteristics underlying pearl quality are not only the influence by donor oyster but also the sex, the strain, and the breeding conditions of recipient oyster.

Keywords Cultured pearl · Optic characteristic · FT-IR

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12.1 Introduction

The technique of producing pearls in the body of Akoya pearl oyster by transplantation is a biotechnology developed in Japan that skillfully utilized the biomineralization ability of oysters (Southgate and Lucas 2008; Wada 1999). The characteristics of a cultured pearl are influenced by two kinds of pearl oysters. One is the donor pearl oyster, which provides a small piece of mantle to be transplanted; the other is the recipient pearl oyster, in which the pearl nucleus and a small piece of mantle are transplanted to produce a pearl. Generally, the brightness, luster, and color of pearls are affected by the donor oyster, while the thickness of nacre is affected by the recipient oyster (Wada and Komaru 1996). Only the recipient oyster is required to have good growth rate and disease-resistance trait; hence, the effect of recipient oysters on the quality of produced pearls has been underestimated.

In transplantation, the pearl nucleus and a small piece of mantle were transplanted into the gonads of recipient pearl oyster. The sex and state of gonads affect the characteristics and quality of cultured pearl. In our previous study, we have clearly indicated that the sex of recipient pearl oyster directly affects the quality of pearl, and the optical characteristics measured by FT-IR of pearl produced from male and female pearl oysters significantly differed (Iwai et al. 2015). These results showed that the optical characteristics and quality of pearls have strong influence not only by donor oysters but also by recipient oysters. Moreover, it is also known that the characteristics and quality of pearls are affected by the difference of pearl cultivation area in general. In this study, we measured the FT-IR spectra of the pearls produced with various recipient and donor strain combinations and pearls cultured in various culture area and, then based on these characteristics, clustered and investigated what kind of factors influence the quality of pearls.

12.2 Materials and Methods

12.2.1 Akoya Pearl Oysters

Akoya pearl oysters, *Pinctada fucata*, were obtained from K, S, U, and M pearl farmers. The strains “U-H” and “U-T” were two types of Akoya pearl oyster strains produced by U pearl farmer. The strain “M-H” was one of several strains produced by M pearl farmer.

12.2.2 Pearl Culture

Various conditions, such as transplantation date and harvest date, in pearl culture used in each test are described in each figure legend. The method of pearl culture used for this study was generally in accordance with the method that the pearl farmer carried out.
12.2.3 Fourier Transform Infrared Spectroscopy and Data Analysis

The methods in this study were described previously (Iwai et al. 2015). Briefly, a Fourier transform infrared (FT-IR) ALPHA Platinum ATR spectrometer (Bruker Optics, Germany) was used to acquire spectral data of the pearl surface. A spectral resolution of 4 cm\(^{-1}\) was applied, and 64 scans were co-added and averaged for each spectrum. Transmission/absorption FT-IR spectra were collected, and data from 400 to 4000 wavenumbers were stored on a computer while purging the instrument continuously with dry air to reduce water vapor absorption. Ward’s algorithm was used for hierarchical clustering as described previously (Helm et al. 1991). The hierarchical clustering was performed with the cluster analysis module of OPUS 7.2 software (Bruker Optics, Germany). Hierarchical cluster analysis was used to objectively assess clustering of the FT-IR vector-normalized spectra obtained from the different culture site or recipient and donor combination.

12.3 Results

12.3.1 The Cultured Pearls from Various Culture Sites

In order to evaluate the characteristics of cultured pearls, ten culture areas mainly carrying pearl culture in Uwa Sea, Ehime Prefecture, Japan, were selected (Fig. 12.1a). Nine months after transplantation at various culture areas, the pearls were collected and analyzed by FT-IR spectrometry (Fig. 12.1b, c). However, visual evaluation of the quality of these pearls was difficult. Accordingly, we examined the differences between the pearls from various culture area based on the optical properties of the pearl surface using the FT-IR spectrometer (Fig. 12.1c). By performing hierarchical cluster analysis with FT-IR spectrometry, these pearls were classified into two clusters. When comparing this result with the actual culture area, the culture pearls were separated into a north area and a south area. These results indicated that the optical characteristics of pearls from various culture areas were significantly different. Furthermore, the optical characteristics of each pearl were determined according to the culture area of Akoya pearl oyster.

12.3.2 The Cultured Pearls from Combination of Donor and Recipient Pearl Oysters

In order to investigate how the characteristics of pearls change by combination of donor and recipient oysters, pearls were produced using three kinds of Akoya pearl oyster strains as donors and two kinds as recipients (Fig. 12.2a). Unlike pearls produced by various culture area, pearls differed greatly in appearance. Pearls using
Fig. 12.1 The cultured pearls from various culture sites. The pearls were cultured by the following conditions: transplantation date, July 20, 2014; harvest date, Feb 23, 2015–Mar 6, 2015; pearl nucleus size, 6.67 mm at single transplantation; donor oyster, Akoya pearl oyster strain-K; recipient oyster, Akoya pearl oyster strain-S; transplantation was operated by single pearl farmer. (a) A map showing the point where pearls were cultivated. (b) A picture of the cultured pearls. (c) Dendrogram of a hierarchical cluster analysis showing objective spectral diversity in pearls from various culture sites. Cluster analysis was performed with vector-normalized spectra. The spectral distances were calculated with Pearson’s correlation coefficient, and Ward’s algorithm was used for hierarchical clustering. Hierarchical clustering is a statistical data analysis procedure for the classification of similar objects into North-Area and South-Area groups. The name of each sample is as follows; taking “A-7T,” for example, “A” indicates the cultured area shown in (a, b), “7” means a serial number of the obtained pearl, and “T” is the initial of Tounen in Japanese and means that the cultivated period is within 1 year.
Donor

Recipient

Fig. 12.2 The cultured pearls from combination of donor and recipient pearl oyster. The pearls were cultured by the following conditions: transplantation date, July 2–3, 2015; harvest date, Jan 19, 2016; pearl nucleus size, 6.67 mm at single transplantation were operated by single pearl farmer. (a) A picture of the cultured pearl. (b) Dendrogram of a hierarchical cluster analysis showing objective spectral diversity in pearls from combination of donor and recipient pearl oyster. Cluster analysis was performed with vector-normalized spectra. The spectral distances were calculated with Pearson’s correlation coefficient, and Ward’s algorithm was used for hierarchical clustering. Hierarchical clustering is a statistical data analysis procedure for the classification of similar objects into strain “U-T” and “U-H” as recipient pearl oyster groups.
Akoya pearl oyster strain “M-H” as a donor clearly produced white pearls compared to the other four pearls, irrespective of using the Akoya pearl oyster strain “U-H” or “U-T” as recipient. Accordingly, we examined the differences between the pearls from various combinations of donor and recipient oysters based on the optical properties of the pearl surface using the FT-IR spectrometer (Fig. 12.2b). By performing hierarchical cluster analysis with FT-IR spectrometry, these pearls were classified into two clusters. These two clusters were highly dependent on the recipient strain. These results suggested that the effect on the optical characteristics of pearls was stronger in recipients than in donor.

12.4 Discussion

What is the factor that affects the quality of pearls which has been the great attention of pearl culture farmers and researchers since the beginning of pearl culture? From various experiments and experience of pearl farmers, it was known that the donor’s characteristics have a great influence on the quality of pearls, and research on donors has been actively conducted in recent research (Fujimura and Komaru 2017; Odawara et al. 2017). However, the recipient oysters that actually produce the pearl were considered to affect only the size of the pearl, such as the thickness of the nacre, and attention has not been paid to recipient oysters. Our study revealed that the sex of the recipient oysters affects not only the thickness of the pearl nacre but also the optical characteristics and quality of the pearl (Iwai et al. 2015). Therefore, in this study, we investigated the influence of donor and recipient on pearls, which is a factor influencing the optical characteristics of pearls. As a result, it was revealed that the influence of the recipient on the optical characteristics of the pearl surface by the FT-IR is larger than that of the donor which has been conventionally mentioned. It was suggested that in order to further improve quality in the future pearl culture, it was necessary to carry out seedling production and selective breeding of pearl oyster as a recipient with consideration of the influence on the quality of pearls. Moreover, the quality of pearls was also known to be strongly influenced by the pearl culture area. However, there were not many cases comparing pearls with different pearl culture environments. In this study, comparison of produced pearls was possible according to Akoya pearl oysters, which was transplanted under the same condition and was bred in each culture area, and the optical characteristics of pearls using FT-IR could be evaluated objectively. As a result of the comparison, the pearls produced in each culture area of Uwa Sea had two different optical characteristics, and it was able to distinguish from the north area and the south area clearly. These results are consistent with the actual impression of the pearl culture farmer, and it became clear that the method of distinguishing pearls by FT-IR is useful. It is necessary to investigate in detail what kind of environmental factors in breeding culture areas are affecting the optical characteristics of pearls. We investigate various factors on the quality and optical characteristics of culture pearls, and we could contribute to the improvement of pearl quality by investigating the influence.
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