IDENTIFICATION OF YELLOW CULTURED PEARLS FROM THE BLACK-LIPPED OYSTER *PINCTADA MARGARITIFERA*

By Shane Elen

Although the *Pinctada margaritifera* oyster usually is associated with the black pearls cultured in French Polynesia, it also can produce attractive large yellow cultured pearls, among other colors. An absorption feature at 700 nm can be used to separate these yellow cultured pearls from their more common counterparts produced in the South Seas by the *Pinctada maxima*. This absorption feature previously has been attributed to the presence of black pigments, and has been reported as an identifying characteristic of black cultured pearls from the *P. margaritifera*. An additional absorption feature in the UV region, between 330 and 385 nm, is indicative of natural yellow color in cultured pearls from the *P. margaritifera*.

Until the late 1990s, strands of large cultured pearls typically were marketed in single colors of white, yellow, gray, or black (Federman, 1999). The white and yellow colors originated from the *Pinctada maxima* oyster, while the gray and black came from the *Pinctada margaritifera*. However, the *P. margaritifera* can produce cultured pearls of many other colors (see, e.g., figure 1). The introduction and growing popularity of strands of multi-colored cultured pearls was a bonus for cultivators of pearls from the *P. margaritifera* oyster, as many of the pastel colors previously had been considered unusable (Federman, 1998a). Multi-colored strands marketed today may include a mix of cultured pearls from the *P. maxima* and *P. margaritifera* (Federman, 1998b) or consist only of cultured pearls that originate from the *P. margaritifera*. The latter may include several in the following yellow hue range: yellow, greenish yellow, brownish yellow, or grayish yellow. This makes some of them difficult to distinguish from similar-color cultured pearls from the *P. maxima*.

Identification of the mollusk species in which a pearl was cultured is becoming an important issue in the industry. Until recently, it was relatively easy to identify freshwater, South Sea, "Tahitian," or Akoya cultured pearls just by size, shape, and color. Today, however, there is considerable overlap in these once distinctive characteristics from one type of cultured pearl to another. Yet guidelines for quality grading cultured pearls often vary with the mollusk species. For example, the acceptable nacre thickness for the export of black cultured pearls from Tahiti is 0.6 mm (scheduled to change to 0.8 mm on July 31, 2002; "Pearl thickness controls…", 2001). This would be exceptional for an Akoya cultured pearl (grown in the *Pinctada fucata martensii*), as it would require a culturing period of about

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See end of article for Acknowledgments.

GEMS & GEMOLOGY, Vol. 38, No. 1, pp. 66–72

Figure 1. As multi-colored cultured pearls have become increasingly popular, a broad range of colors from the P. margaritifera*—including various yellow hues—have arrived in the marketplace. The strand on the left, ranging from 12 to 15 mm in diameter, is courtesy of Pacific Pebbles, Beverly Hills, California. The* P. margaritifera *strand on the right, 8 to 11 mm, and the 15 × 17.82 mm loose cultured pearl on the right are courtesy of King's Ransom, Sausalito, California. The 14 mm loose cultured pearl on the left is courtesy of Assael International. Photo © Harold & Erica Van Pelt.*

four years based on the average annual deposition rate of the nacre for this species. Identification of the mother oyster is also important for the detection of treatments, such as the separation of a dyed black Akoya cultured pearl from a natural-color black *Pteria sterna* cultured pearl. Both may be similar in size, shape, and color, but this author has observed that only the latter exhibits a strong fluorescence emission at 620 nm.

The present study investigates the importance of specific absorption features in yellow cultured pearls from the *P. margaritifera* for confirming both the origin of the mother oyster and whether the coloration is natural. It also demonstrates the need for additional testing to verify natural origin of the black coloration when examining gray or black cultured pearls from the *P. margaritifera*.

BACKGROUND

A striking characteristic of the *P. margaritifera* shell is the presence of white nacre surrounded by black to dark green nacre on the interior periphery of the shell. This "black lip" enables the oyster to produce beautiful black and gray cultured pearls. In some *P. margaritifera* oysters, a layer of yellow nacre can occur and may be visible between the central white and peripheral black nacre (figure 2). When yellow coloration is present, it may not always be visible on the interior of the shell but is only revealed when the exterior surface is polished. Other *P. margaritifera* do not display the characteristic dark green or black peripheral nacre but exhibit yellow nacre in their place (N. Sims, pers. comm., 2001), or (rarely) they exhibit only white nacre (S. Akamatsu, pers. comm., 2001).

The various combinations of nacre color and strong overtones exhibited by the *P. margaritifera* result in a wide variety of cultured pearl colors, many of them subdued or pastel in nature. Whether natural or cultured, natural-color gray and black

Figure 2. Although the nacre in most P. margaritifera *shells is black or dark green on the periphery and white in the center, some exhibit the unusual combination of nacre coloration shown here, which progresses from white to yellow to black. Photo courtesy of Shigeru Akamatsu.*

Figure 3. This group of 11.5–12.0 mm cultured pearls, all from the P. margaritifera*, illustrates some of the colors tested in this study. Photo by Maha Tannous.*

pearls from this oyster exhibit a characteristic absorption at 700 nm (Komatsu and Akamatsu, 1978). This feature, which has been observed only in the *P. margaritifera* (Miyoshi et al., 1987), is often accompanied by two other absorption features, at 405 and 495 nm; however, the 700 nm feature is typically the most prominent of the three. The feature at 405 nm, also known as the Soret band (Britton, 1983), is characteristic of porphyrins (Iwahashi and Akamatsu, 1993). Porphyrins are naturally occurring tetrapyrole pigments, commonly referred to as the "pigments of life"; they are among the most highly fluorescent compounds in nature (Guilbault, 1990; Milgrom, 1997).

The feature at 700 nm has been attributed to black pigmentation present in the *P. margaritifera* (Coeroli, 1993). Several attempts have been made to identify the origin of the 700 nm absorption and the black pigmentation in this mollusk (Miyoshi et al., 1987; Blanc and Jabbour, 1988), but none has been conclusive. Efforts to consistently identify the presence of melanin in *P. margaritifera* have not been successful (Blanc and Jabbour, 1988), because *melanin* (a term used to describe naturally occurring insoluble polymeric materials that can result in red, yellow, brown, or black coloration) does not define a specific chemical structure (Britton, 1983). It has been suggested that a combination of eumelanin and phaeomelanin (certain classes of melanins) might be present (Caseiro, 1993), or that an "unusual" type of melanin might be the cause (F. Blanc, pers. comm., 2001).

Due to the demand for gray and black pearls, some cultured pearls are treated with black dye or silver salts, or they are irradiated to produce similar colors (Goebel and Dirlam, 1989). These treatments do not produce an absorption feature at 700 nm, so its presence is used frequently to verify natural black coloration (Kennedy et al., 1994). However, this test is unreliable, because it assumes that the treatment was not applied to an off-color cultured pearl originating from the *P. margaritifera*. Although the Tahitian government has strict controls on the quality of exported cultured pearls, there are other sources of *P. margaritifera* cultured pearls outside of French Polynesia that are not necessarily subject to the same rigorous standards ("Fiji's 1st harvest . . .," 2001).

A recent study of yellow cultured pearls from the gold-lipped *P. maxima* demonstrated that an absorption feature in the ultraviolet region between 330 and 385 nm could be used as evidence of natural color (Elen, 2001). This characteristic also may apply to similar-color cultured pearls originating from the *P. margaritifera*. Currently there are no reports of treatments used to improve yellow colors from off-colored white and yellow *P. margaritifera* cultured pearls. However, treatments used for the cultured pearls from the gold-lipped *P. maxima* (Elen, 2001) could also be applied to cultured pearls from the *P. margaritifera*.

MATERIALS AND METHODS

A total of 29 yellow cultured pearls, ranging from 10.1 to 14.8 mm in diameter, were characterized for this study. All were represented as natural color, from the *P. margaritifera*. The colors included light and medium yellow as well as light to dark yellow modified by green, brown, or gray (see, e.g., figure 3). Ten undrilled samples were obtained directly from sources in French Polynesia, and the remaining 19 drilled samples were provided by reputable suppliers of cultured *P. margaritifera* pearls (see "Acknowledgments"). Only two shell samples of *P. margaritifera* exhibiting yellow nacre on their interior surface were available for the study. Light and medium yellow nacre samples from these two shells were tested *in situ*.

Two white and two black *P. margaritifera* cultured pearls, as well as two *in situ* white nacre samples from a *P. margaritifera* shell, were studied for comparison with the two yellow *P. margaritifera* nacre samples.

Inspection of all the *P. margaritifera* cultured pearls using a binocular gemological microscope revealed no visual evidence of color treatment.

For each sample, reflectance spectra were collected from 250 to 800 nm using a Hitachi 4001

UV-Vis spectrophotometer, and fluorescence observations were made using a UVP model B100 AP long-wave ultraviolet lamp. The reflectance spectra were compared with data for similarly colored samples of nacre and cultured pearls obtained from *P. maxima* oysters for a previous study, as reported by Elen (2001).

RESULTS: UV-Vis REFLECTANCE SPECTRA AND ULTRAVIOLET FLUORESCENCE

Both yellow *P. margaritifera* nacre samples exhibited a broad absorption from 330 to 460 nm that was composed of two features: one in the UV region between 330 and 385 nm, and the other in the visible from 385 to 460 nm. Only the medium-yellow nacre sample exhibited an additional weak absorption at 700 nm (figure 4 and table 1). This sample fluoresced a moderate greenish brown, and the very light yellow shell nacre fluoresced a light yellow. The white *P. margaritifera* shell samples had no absorption features in the 330–460 nm region or at 495 or 700 nm; they fluoresced a strong very light yellow.

As indicated in table 1, the vast majority of the *P. margaritifera* cultured pearls tested exhibited a medium to strong absorption feature at 700 nm (figures 5 and 6); the exceptions were the two white samples and three very light yellow ones. Two of the very light yellow samples exhibited a weak absorption shoulder at 700 nm, and one did not show the feature at all. Sixteen of the 29 yellow samples also revealed a medium to strong 495 nm absorption feature, and another eight showed a weak feature at 495 nm. The fluorescence of all these samples ranged from light yellow or light brown to greenish yellow, greenish brown, or reddish brown.

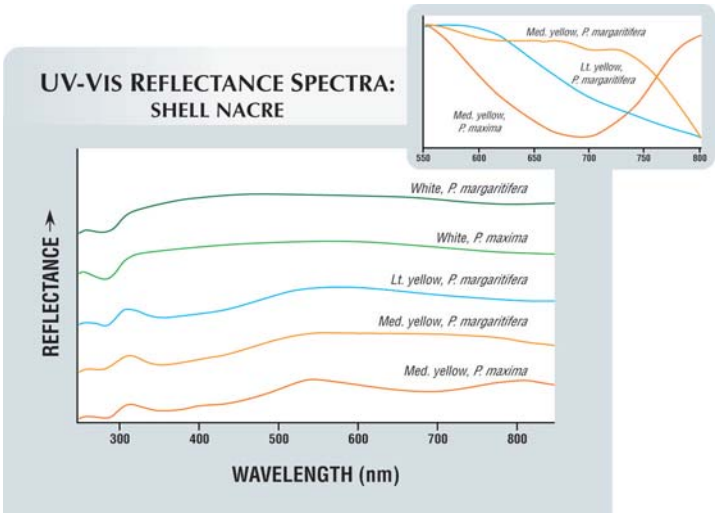

Figure 4. These reflectance spectra are for white and yellow nacre samples taken from the shells of P. margaritifera *and* P. maxima. *The spectra for respective colors are similar in the 330 to 550 nm region, but often differ from 550 to 800 nm. The inset vertically expands this region to illustrate how the weak absorption feature at 700 nm exhibited by the darker* P. margaritifera *sample is distinctly different from the broad absorption often seen in the* P. maxima *samples.*

TABLE 1. Comparison of color, fluorescence, and absorption features in yellow, white, and black *P. margaritifera* cultured pearls and nacre.

			Absorption features (nm) ¼ no. of samples					
P. margaritifera samples[a]	Long-wave UV fluorescence	Total no. of samples	330–385	385–460	330–430 or 330–460	405	495	700
Light to medium yellow and greenish yellow	Moderate to strong greenish brown, greenish yellow, light brown, and light yellow	16	16	16	0	0	12	16
Light to dark grayish and brownish yellow	Weak to strong yellow, brown, greenish brown, and reddish brown	9	0	0	9	9	9	9
Very light yellow	Moderate to strong yellow	4	4	1	0	0	3	3
White	Strong light yellow	2	0	0	0	0	0	0
Black	Moderate reddish brown	2	0	0	2	2	2	2
White shell nacre	Strong very light yellow	2	0	0	0	0	0	0
Yellow shell nacre	Light yellow and moderate green-brown	2	2	2	0	0	0	1

[a] *All samples are cultured pearls unless designated "nacre."*

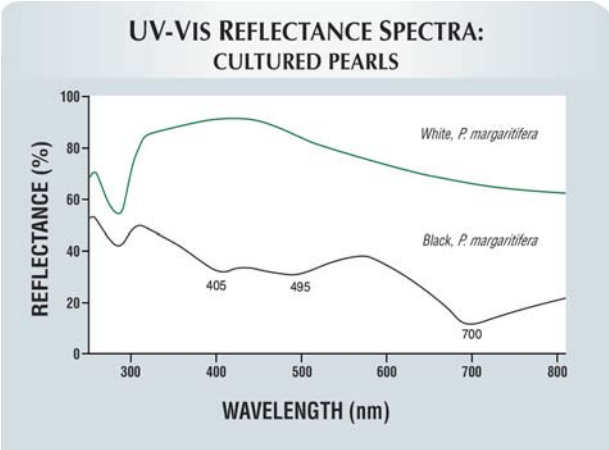

Figure 5. Reflectance spectra are shown here for white and black cultured pearls from the P. margaritifera. *The absorption features measured for the black sample at 405, 495, and 700 nm are characteristic of black cultured pearls from this species.*

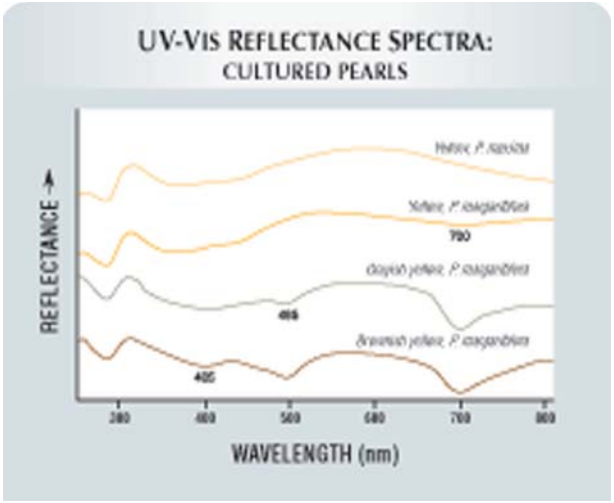

Figure 6. Reflectance spectra for yellow, grayish yellow, and brownish yellow cultured pearls from P. margaritifera *are compared here with the spectrum for a yellow cultured pearl from* P. maxima. *Note the similarity in absorption features in the UV region between 330 and 460 nm for the "pure" yellow samples, as compared to the grayish and brownish yellow samples. All three* P. margaritifera *samples exhibit the absorption feature at 700 nm, which is absent from the yellow* P. maxima *sample and also the white* P. margaritifera *sample shown in figure 5.*

Of 20 yellow and greenish yellow *P. margaritifera* cultured pearl samples, 17 exhibited a broad absorption from 330 to 460 nm that comprised two features (figure 6), similar to those observed in the yellow nacre samples (figure 4). The other three in this group, which were very light yellow, only exhibited a weak absorption in the 330–385 nm region. The nine remaining samples, which were brownish or grayish yellow, exhibited a single broad absorption feature from 330 to 430 nm, or 330 to 460 nm, with a maximum centered at 405 nm (figure 6).

The two black *P. margaritifera* cultured pearls used as reference samples exhibited strong absorptions at 405, 495, and 700 nm, as well as the broad absorption from 330 to 430 nm. These features are similar to those observed in some of the grayish and brownish yellow samples; however, the black coloration results in a much stronger overall absorption (figure 5). The spectra of the two white cultured pearls were similar to those of the two white nacre samples, in that no absorption features were noted between 330 and 700 nm (figures 4 and 5). The black cultured pearls exhibited a characteristic reddish brown fluorescence, and the white samples fluoresced a strong very light yellow.

DISCUSSION

Two distinct reflectance curve patterns were observed for the yellow *P. margaritifera* cultured pearls tested in this study. They are defined by different reflectance characteristics in the ultraviolet-to-blue region of the spectrum (figure 6). The first was typical for the yellow and greenish yellow samples: a broad absorption between 330 and 460 nm that consisted of two absorption features—from 330 to 385 nm and from 385 to 460 nm. The

TABLE 2. Summary of color and absorption features for cultured pearls from the *P. margaritifera* and *P. maxima*.

Species	Color	Presence of absorption features (nm)					
		330–385	385–460	330–430 or 330–460	405	495	700
P. margaritifera	White	No	No	No	No	No	No
P. margaritifera	Yellow and greenish yellow	Yes	Yes	No	No	Frequent	Common
P. margaritifera	Brownish and grayish yellow	No	No	Yes	Yes	Yes	Yes
P. maxima	White	No	No	No	No	No	No
P. maxima	Yellow	Yes	Yes	No	No	No	No

second distinct pattern was exhibited by samples with a grayish or brownish yellow color: a single broad absorption feature from 330 to 430 nm, with a maximum centered at 405 nm. A third pattern showed a single broad absorption from 330 to 460 nm, also with a maximum centered at 405 nm, but it appears to be an intermediate pattern between the other two (figure 6).

The two features between 330 and 460 nm observed in 17 of the *P. margaritifera* yellow cultured pearls and yellow shell material are consistent with similar absorption features observed in *P. maxima* natural-color yellow cultured pearls and yellow nacre (figures 4 and 6) as part of a previous study (Elen, 2001). Specifically, the 330–385 nm feature was found in natural-color yellow—but not treated-color yellow—cultured pearls from the *P. maxima*. It appears likely that the same zoochrome (a naturally occurring pigment molecule found in the animal kingdom; Needham, 1974) may be responsible for the yellow coloration in both the *P. margaritifera* and *P. maxima*. Therefore, the presence of this UV absorption feature in the spectra of yellow pearls from the *P. margaritifera* should indicate natural yellow coloration. Approximately one-third of the yellow *P. margaritifera* cultured pearls tested did not exhibit this feature; however, these samples tended to be brownish or grayish yellow rather than "pure" yellow or greenish yellow (figure 6).

The fact that two very light yellow *P. margaritifera* samples—one nacre and one cultured pearl—did not exhibit an absorption feature at 700 nm indicates that some yellow cultured pearls from this oyster do not show this feature. If this absorption is due to black pigmentation, as claimed in the literature, then its appearance in the (darker) medium yellow shell sample is not entirely unexpected. In the nacre samples tested, the yellow coloration lies between the white and black nacre layers, but is not defined by a distinct boundary. The light yellow region occurs closer to the white layer, and the medium yellow region is closer to the black layer. It is, therefore, very likely that the medium yellow nacre sample incorporated some black pigmentation, which may be responsible for the 700 nm absorption. This is contradicted somewhat by the fact that some of the light yellow cultured pearls tested exhibited quite strong 700 nm absorption features. Further work is required to determine the pigments responsible for the yellow and black coloration and, especially, whether the absorption at 700 nm is directly or indirectly associated with either of these pigments.

The combination of yellow and black nacre also may be responsible for producing a dark greenish black—rather than black—nacre at the periphery of the shell in some *P. margaritifera*.

A review of the data collected for yellow *P. maxima* cultured pearls in a previous study (Elen, 2001) shows that about 20% of those samples exhibited a very broad absorption feature with a maximum occurring either at 695 or 720 nm (figure 4). This absorption is extremely broad, unlike the 700 nm feature observed in the *P. margaritifera* samples (figure 4 inset and 6). The fluorescence observed for the yellow, orangy yellow, and greenish yellow *P. maxima* samples in that same study is similar to the reaction seen in the present study for *P. margaritifera* samples of similar color. It would appear that fluorescence criteria used in the previous study for separating natural- from treated-color *P. maxima* cultured pearls also might be applicable to *P. margaritifera* samples in this hue range.

CONCLUSIONS

The UV-Vis reflectance spectrum of a yellow cultured pearl can establish that it was produced by a *P. margaritifera* oyster and, in conjunction with fluorescence reactions, indicate whether the color is natural or was produced by treatment. Specifically, those yellow cultured pearls that exhibit an absorption feature at 700 nm, often accompanied by one at 495 nm, can be positively identified as originating from the *P. margaritifera* (see table 2, for a comparison to cultured pearls from *P. maxima*). However, the absence of these features does not necessarily exclude *P. margaritifera* as the source. Another absorption feature in the UV region, between 330 and 385 nm—when accompanied by light yellow, greenish yellow, greenish brown, or light brown long-wave UV fluorescence—is also indicative of natural yellow coloration.

The feature at 700 nm has been reported previously as evidence of natural color in natural or cultured gray to black pearls from the *P. margaritifera*. However, there is always the possibility that an off-color gray or yellow *P. margaritifera* cultured pearl might be treated to produce a black color. Therefore, in the absence of other tests, the presence of an absorption at 700 nm should be used only to provide proof of origin from the *P. margaritifera*, and not as proof of natural black color.

ACKNOWLEDGMENTS: The author thanks the following for providing samples of shells and cultured pearls for this study: Robert Wan of Robert Wan Pearls, Papeete, Tahiti; Martin Coeroli of Perles de Tahiti, Papeete; and GIA Education, Carlsbad. Several people also provided constructive comments: Shigeru Akamatsu of K. Mikimoto & Co., Tokyo; Ken Scarratt of the AGTA Gemological Testing Center, New York; Dr. Lore Kiefert of the SSEF Swiss Gemmological Institute, Basel, Switzerland; Dr. Françoise Blanc of the Université Montpellier, Montpellier, France; and Neil Sims of Black Pearls Inc., Kona, Hawaii. Neil Barron of the Richard T. Liddicoat Library and Information Center, Carlsbad, was very helpful in searching the literature.

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