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Reflective and Structural Characteristics of Natural Pearl

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ABSTRACT

In this study, we analyzed the reflective and structural nature of natural freshwater pearls that originated from Sabah, Malaysia. Seven color pearls from brightest to darkest ones were examined and analyzed by UV-Vis spectroscopic and electron microscopic techniques. Results showed that the UV-Vis spectrum of black shows that reflection occurs at 530-540 nm, 600-610 nm,660 nm, and 690 nm which are reflective of green, yellow, and red. However, it mainly differs from other color spectrums as it shows great absorption at wavelengths 270-300 nm. Meanwhile, white pearl reflects most of the visible color at wavelength 400 nm, 450-470 nm, 550 nm, 600-630 nm, and 665 nm which represent all colors possessed by the visible spectrum. FESEM studies show the formation of tablet structures in smooth layers transition between vaterite and aragonite in black pearl. The structural arrangement of its layers is closer and there are many big circular spots on the copper pearl. Besides, the pearl's surface looks a bit rough. The layer of aragonite platelets in hexagonal shape gives the pearl's prismatic layer in pinkish pearl. Meanwhile, The arrangement of vaterite layers looks smooth and the layers of the stack are arranged in parallel in white pearl. The different morphology of pearl reflects the different colors as well.

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1. INTRODUCTION

A pearl is a lustrous, hard object formed in the soft tissue of a living shelled mollusk or another animal, such as fossil conulariids. A mollusk's shell is a pearl that is made of calcium carbonate (mostly aragonite or a combination of aragonite and calcite) in a minute with crystalline form [1]. The ideal pearl is perfectly round and smooth, but baroque pearls come in a variety of shapes. Natural pearls of the highest quality have been prized as gemstones and items of beauty for decades. Because of its very high price, pearls have become a metaphor for something rare, fine, and admirable by humans nowadays. It has many beautiful and eye-catching colors such as white, pink, silver, cream, brown, green, and more [2, 3]. The most valuable pearls which are natural pearls occur spontaneously in the wild world but it is extremely rare. It also formed without human intervention. Cultured or farmed pearls from pearls oysters and freshwater mussels make up the majority of those currently sold. Imitation pearls are also widely sold in inexpensive jewelry, but the quality of this type is too low and poor [4-6].

The transparent layers of pearls reflect, refract and diffract light, giving them their distinct luster. The finer the luster, the thinner and more numerous the layers in the pearl. The overlapping of successive layers in pearls produces iridescence, which breaks up light falling on the surface [7]. Pearls can also be colored yellow, green, blue, brown, pink, purple, or black (especially cultured freshwater pearls). Pearls with a metallic mirror-like luster are the finest. In addition, pearls may dissolve in vinegar since they are mainly made of calcium carbonate. Since the crystals react with the acetic acid in the vinegar to form calcium acetate and carbon dioxide, calcium carbonate is susceptible to even a weak acid solution [8, 9]. Pearls have been used for adornment for about 6000 years. Pearls do not require any processing because they are natural, shows full gloss, and have an attractive luster in their natural state.

A natural pearl's build-up typically consists of a brown center zone made up of calcium carbonate (mostly calcite, but occasionally aragonite) and a yellowish to white outer zone made up of nacre (tabular aragonite). The presence of organic-rich calcium carbonate implies the formation of juvenile mantle tissue during the early stages of pearl growth [10]. Living cells that have been displaced and have a well-defined role may continue to function in their new position, resulting in a cyst, an injury that can cause such displacement. The shell's delicate rim is exposed, making it vulnerable to harm and injury [11]. Predators and parasites such as worm larvae can all induce traumatic attacks and lesions that separate some exterior mantle tissue cells from their layer. These cells may survive and create a tiny pocket in the mantle's conjunctive tissue, where they continue to release calcium carbonate, their natural product. The pocket is known as a pearl sac, and it expands over time as a result of cell division [12, 13]. Calcium carbonate is secreted by juvenile mantle tissue cells from the inner surface of the pearl sac, depending on their developmental stage. The exterior mantle cells of the pearl sac eventually give rise to tabular aragonite.

Pearl is an organic gem that is produced only from shellfish mollusks. Thus, make it a typical biomineralization material. Nacre, which is also known as the mother of pearl, is a composite material composed of inorganic, Calcium Carbonates plates in an aragonite structure that is connected by a framework of organic molecules which is similar to the native structure of bone. Polysaccharides, acidic proteins, glycoproteins, proteoglycans, and chitin make up this matrix [14-17]. Despite being present in only a small amount, the organic components of pearls play an important role in biomineralization by controlling orientation and shape during crystal formation, stabilizing high energetic polymorphs, and enhancing physical and chemical properties [18, 19]. Therefore, as a result of these factors, biocomposites have promising applications in a variety of fields, including medical research, nanotechnology, materials science, and biomimetic engineering. $CaCO_3$ has also demonstrated good biocompatibility. It is less stable and dissolves more quickly than calcium phosphate ($CaHPO_4$) [20]. Therefore, we make further studies of natural pearl formation using microscopic and spectroscopic methods to gain more understanding of the natural phenomena of this lustrous object.

2. METHODOLOGY

Freshwater pearls were acquired from the market. The pearl was originated from Sabah, northern Borneo of Malaysia. The pearls were then washed with isopropanol and sorted from brightest to the darkest color assigned; white, cream, yellow, copper, pinkish, dark green, and dark. We then characterize the morphology, micro, and nano-structure as well as their composition of bio-vaterite in aragonitic pearls, and to study the inter-phase relationship between both polymorphs using a scientific method which is UV-Visible spectroscopy under Reflection mode and Field Emission Scanning Electron Microscope (FESEM). UV-Vis reflection spectra of pearl were examined by UV-Vis spectroscopy brand HITACHI U-3900/3900H equipped with spectrophotometer in the range of 200 to 800 nm as shown in Figure 1.

Figure 1. UV-Vis spectrometer

3. RESULTS AND DISCUSSIONS

The result of reflection on natural white color pearl in Figure 2 shows that it reflects most of the visible color at wavelength 400 nm, 450-470 nm, 550 nm, 600-630 nm, and 665 nm which represent all color possesses by visible spectrum, which are violet, indigo, green, yellow, orange, and red. Therefore this result shows that all those reflective colors are then superimposed and combined to become one bright white color.

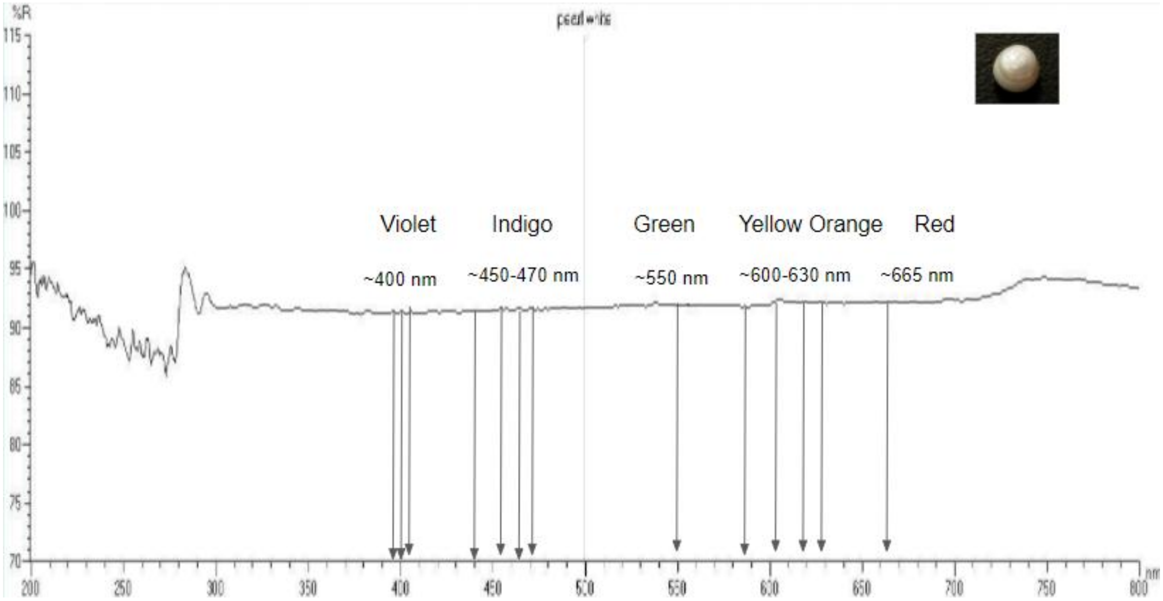

Figure 2. UV-Vis spectra of white pearl

On the other hand in Figure 3, the UV-Vis spectrum of black shows that reflection occurs at 530-540 nm, 600-610 nm,660 nm, and 690 nm which possessed reflective of green, yellow, and red. However, it mainly differs from other color spectrums as it shows great absorption at wavelength ~270-300 nm.

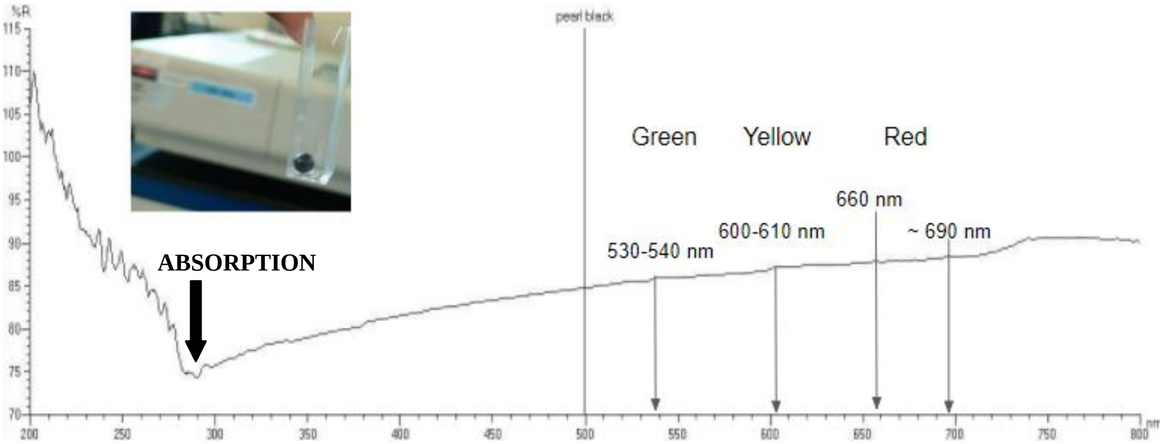

Figure 3. UV-Vis spectra of black pearl

The arrangement of the $CaCO_3$ crystal polymorphs on the pearl's nacre surface structure through 5K to 10K magnification under FESEM is shown in Figure 4. From the scanned images, we can clearly see the arrangement of prismatic layers that stack on layers of nacre tablets with the aragonite crystal structure (orthorhombic shape) and also circular spots on the crystal surface that could be classified as vaterite tablets [21, 22]. The stacks of the crystal tablets that form prismatic layers show that pearl nacre's surface doesn't all flat. The circular spots that could be seen from this magnification were growing nacre tablets. The tablets won't get in contact with each other until they grow up bigger and change shape from spherical to polygonal. Aragonite is less stable than calcite. Thus, aragonite and vaterite structures were confirmed in freshwater pearl.

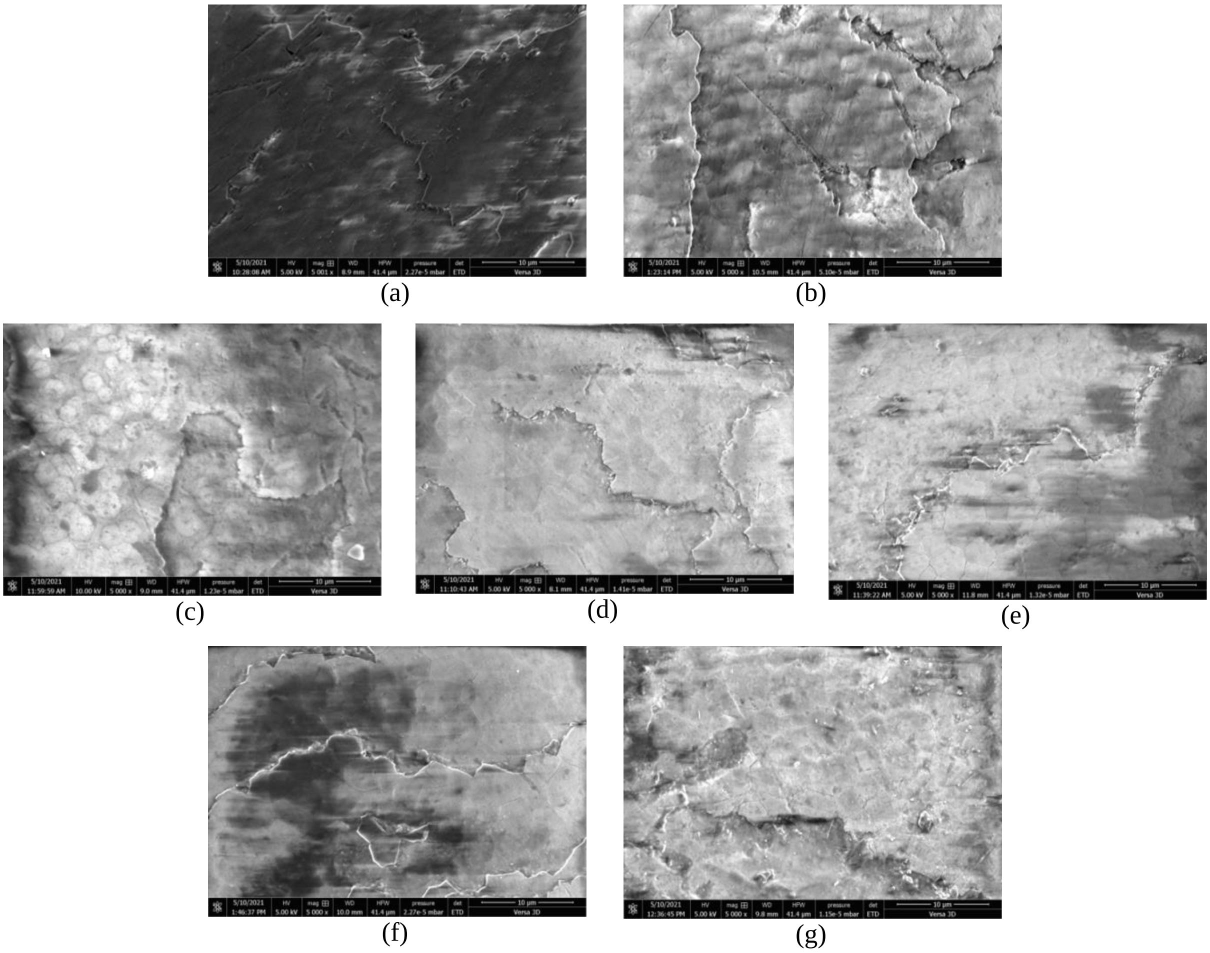

Figure 4. FESEM images for (a) Black (b) Cream (c) Copper (d) Dark Green (e) Pinkish (f) White and (g) Yellow colours of freshwater pearls.

Tablet structures show smooth layers transition between vaterite and aragonite in black, It shows stack layers of vaterite tablets with the rough bumpy surface in cream pearl. The structural arrangement of its layers is closer and there are many big circular spots on the copper pearl. Besides, the pearl's surface looks a bit rough. The layer of aragonite platelets in hexagonal shape gives the pearl's prismatic layer in pinkish pearl. Meanwhile, The arrangement of vaterite layers looks smooth and the layers of the stack are arranged in parallel in white pearl.

4. CONCLUSION

In this study, we had observed a clear picture of different colours of pearl occurring due to different morphology and stacking between vaterite and aragonite layers formed at pearl nacre. UV-Vis reflection spectrum shows that white pearl reflects most of the visible colour from violet, indigo, green, yellow, orange, and red representing white colour as seen by our eyes while black pearl showing great absorption occur at range 270-300 nm which demand vanishing of a certain colour. This study shows the close relation between surface morphology reflective wavelength and absorption of light as well.

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