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Rapid identification of pearl powder from *Hyriopsis cumingii* by Tri-step infrared spectroscopy combined with computer vision technology

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ABSTRACT

Pearl powder, an important raw material in cosmetics and Chinese patent medicines, is commonly uneven in quality and frequently adulterated with low-cost shell powder in the market. The aim of this study is to establish an adequate approach based on Tri-step infrared spectroscopy with enhancing resolution combined with chemometrics for qualitative identification of pearl powder originated from three different quality grades of pearls and quantitative prediction of the proportions of shell powder adulterated in pearl powder. Additionally, computer vision technology (E-eyes) can investigate the color difference among different pearl powders and make it traceable to the pearl quality trait–visual color categories. Though the different grades of pearl powder or adulterated pearl powder have almost identical IR spectra, SD-IR peak intensity at about 861 cm^{-1} (ν_2 band) exhibited regular enhancement with the increasing quality grade of pearls, while the 1082 cm^{-1} (ν_1 band), 712 cm^{-1} and 699 cm^{-1} (ν_4 band) were just the reverse. Contrastly, only the peak intensity at 862 cm^{-1} was enhanced regularly with the increasing concentration of shell powder. Thus, the bands in the ranges of (1550–1350 cm^{-1}, 730–680 cm^{-1}) and (830–880 cm^{-1}, 690–725 cm^{-1}) could be exclusive ranges to discriminate three distinct pearl powders and identify adulteration, respectively. For massive sample analysis, a qualitative classification model and a quantitative prediction model based on IR spectra was established successfully by principal component analysis (PCA) and partial least squares (PLS), respectively. The developed method demonstrated great potential for pearl powder quality control and authenticity identification in a direct, holistic manner.

1. Introduction

Pearl is a kind of natural biocomposite and it requires several years of growth to achieve their unique sphericity and luster, resulting from biomineralization of calcium carbonate, matrix proteins and other organic matrixes [1,2]. Generally, the majority of freshwater pearls have luster and the inorganic component of these lustrous pearls is constituted by aragonite crystal and these pearls are regarded as aragonite pearls [3]. The vast majority of pearls found today in the market are cultured. Moreover, only a small number of mollusks species are used for large-scale commercial cultivation [4]. In China, freshwater cultured pearls are generally gestated in *Hyriopsis cumingii*. *Hyriopsis cumingii*, a member of freshwater pearl mussels, is the most economically important mussel species in China (Naiad of the Unionidae family) [5]. In the world market, China produces 95% of freshwater pearls and 95% of freshwater pearls are produced from *H. cumingii*. As the best for producing high quality pearls, *H. cumingii* is widely cultivated in China [6,7].

Pearl powder is made from bivalve mollusks (such as *Pteria martensii* (Dunker), *Hyriopsis cumingii* (Lea), *Cristaria plicata* (Leach), etc.) by the physical grinding method [8]. A number of studies have indicated that pearl contains over 25 organic salts and 10 amino acids, providing a rich source of organic calcium, selenium, zinc, and other trace metal elements. Pearl powder makes the ingredients more bioavailable. It replenishes the calcium deficit within a short period of time, as well as supplies some trace metal elements and thereby improve the immune system [9,10]. Therefore, pearl powder is also popular for use in Chinese medicines and as raw materials in cosmetics.

However, so far, there is no exact and unified quality grading standards for pearl powder. Even the freshwater cultured pearls gestated in the same mussel have diverse qualities due to the different growth environment [11]. The quality of cultured pearls is influenced by environmental factors such as water quality parameters at the culture site and food availability, as well as non-environmental factors such as

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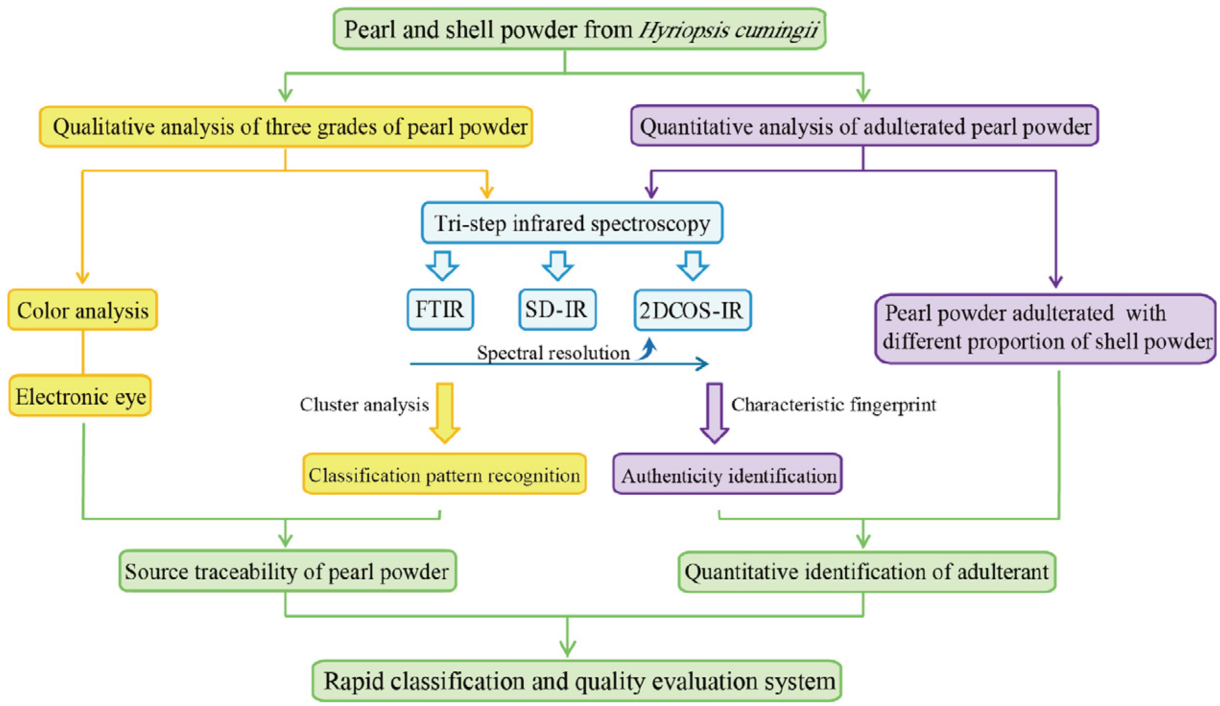

Fig. 1. The scheme of experimental design.

grafting techniques, host oyster condition, saibo influences and husbandry techniques [12]. Different quality levels of raw materials will affect the quality of pearl powder. Moreover, it is well known that the micro morphology and chemical composition of shell powder are similar to those of pearl powder, which all of them including calcium carbonate (aragonite, about 95 wt%), organic matrix like protein and polysaccharide (about 5 wt%) [3,13–15]. Unfortunately, pearl powder adulterated with low-cost shell powder is occurring frequently in the Chinese market. Given that no established test standard of quality grading and authentication, it would be essential to develop a new promising approach for identifying pearl powder originated from different quality grades of pearls and authenticity identification.

Electronic eye, a computer vision technology converting the image into digital image, uses the image sensor instead of the human eye to collect images of objects, and use computer simulation criterion to identify the image avoiding the subjective deviation of human eye [16]. Since pearl powder usually has similar color, it is difficult to distinguish the color difference and the visual color of pearl raw materials by the naked eye. In this work, we used electronic eye to discriminate different pearl powder, obtain visualize information on different samples and make it traceable to the pearl quality trait–visual color categories. Thus, adopted the computer vision technology on the pearl powder from different sources, it could provide the color information for better traceability and more comprehensive characterization of them.

Tri-step infrared spectroscopy, a technique consists of Fourier transform infrared spectroscopy (FT-IR), second derivative infrared spectroscopy (SD-IR), and two-dimensional correlation infrared spectroscopy (2DCOS-IR) can not only reveal the main constituents in sample but also distinguish the varieties and contents of chemical constituents in highly similar matrices [17,18]. FT-IR is a rapid, non-destructive and easy to handle molecular spectroscopic method with high signal-to-

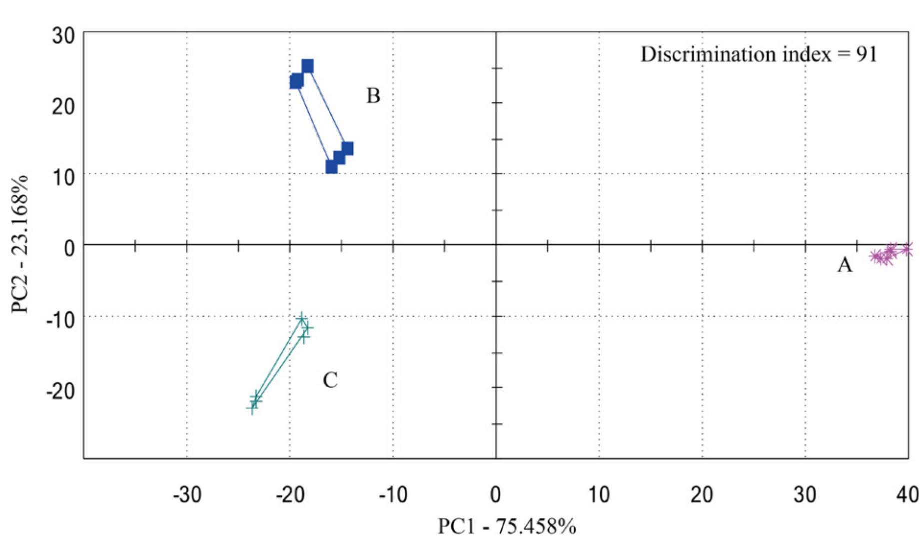

Fig. 2. Color map of three pearl powders originated from the grade A, B and C (quality decreases from A to C) pearl based on principal component analysis (PCA).