The Objective Conditions Study and Optimization of Digital Imaging System on Color Measurement Case with Jadeite

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The objective conditions study and optimization of digital imaging system on color measurement: Case with jadeite

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Abstract The application of digital imaging to color measurement is more and more extensive, which also provides new ideas for gemology. In this paper, the single-factor experiment method and orthogonal experiment design are used to study the influence parameters of the digital imaging system (DIS) on gem color measurement. Among them, the illuminance has the most significant impact on the measurement results, followed by the exposure time, and the change of the measurement distance has an insignificant impact on the results; through range analysis and analysis of variance, the most suitable measurement parameters for red jadeite are 1600lx, 12500ms, 25cm.

Introduction

The current methods for evaluating the color of gems include color chips (Munsell, Gem-dialogue), colorimetric stones, ultraviolet-visible spectrophotometers, and spectrophotometers. Among them, the color chips and the colorimetric stones are used to directly help the eyes to make judgments¹. These methods are mainly based on the subjective evaluation of the color by the operator, so it takes a lot of time and money to train professional graders. UV-Vis spectrophotometers can provide accurate absorption spectra from which color calculations can be made^{2,3}; however, the complex conversion process has hindered their development in gemstone color measurement; hand-held spectrophotometers, as the mainstream gem color measurement tool at present, has been used to measure the color of jadeite green⁴, jadeite red^{5,6}, turquoise⁷, peridot^{8,9}, amethyst¹⁰, chrysoprase^{11,12}, and extensive gemstone chromatography studies. Because of its convenient operation and reliable data, this tool has already been favored by researchers. But there are also limitations: 1. The size of the gemstone is smaller than the smallest aperture that can be measured by the device, which will lead to significant errors caused by the background. 2. The reading color method is uniform color reading and it's hard to distinguish and study color-striped gems.

Furthermore, the use of contact measurement in some precious materials like gems may cause unavoidable damage. With the development of color measurement technology in various research fields, such as reproduction and protection of artwork¹³, remote sensing mapping¹⁴, and dental medicine¹⁵, non-contact color measurement is widely used. In food science, many experiments and studies have been conducted on quality control¹⁶. In the fields of geoscience, the non-contact color measurement method is also widely used to classify and sort ores based on colors and textures^{17,18}; Oestreich et al. analyzed the composition content of minerals based on digital images¹⁹; Chatterjee et al. used artificial neural networks to effectively predict the attributes of calcium oxide, alumina, and silica in limestone²⁰. Gozalo Diaz et al. analyzed the defects of contact color measurement in obtaining the color of human tissues and organs, and proposed a non-contact color measurement scheme²¹; Yang et al. analyzed that computer vision after color correction can be more commonly used²²; In the study of the color of Dunhuang murals, Wan proposed to use the self-made Dunhuang color charts and Color Checker color chips to make ICC feature files to correct the errors generated between different digital cameras, so that the digital protection and dissemination of Dunhuang murals can receive strong

technical support²³; In our other work, experiments by Zhang et al. compared computer vision system and traditional hand-held spectrophotometer for the measurement and evaluation of various colors of jadeite, then judged the applicability by experts panel which makes the color matching subjective²⁴; Therefore, in gemology, a digital imaging as one of the non-contact methods can provide researchers with new ideas. In the above-mentioned measurement method, a non-contact measuring device-a spectroradiometer or camera- is used to obtain accurate measurement results under the condition of an external light source. However, in previous studies, the researchers did not discuss the influence of the changes in the measurement conditions on the experimental results, which will lead to this method not being replicated and applied to future studies.

Gem-quality jadeite is mainly from Burma and Guatemala, which is produced in Jadeitite and has beautiful and durable properties^{25,26}. Harlow et al. believe that jadeite is a complex fibrous aggregate of minerals²⁷, which gives itself a beautiful, varied appearance, also the reason why it is loved by Chinese people. It is usually colorless and translucent without other impurities. The cause of the color of jadeite can be divided into two types: primary color and secondary color^{6,28}; The green of jadeite is the primary color; and the red and yellow is the secondary color, which is caused by exogenous geological activities, and usually produced when impurities, such as water-containing iron oxide, are infiltrated along the cracks and the grain boundaries that are not tightly bound. According to comparative experiments, Wang et al. recognized that the D65 standard light source (representing the average daylight with a color temperature of 6504K) is the most suitable light source for evaluating Jadeite green²⁹; Pan et al., Guo, Li believe that D65 light source is suitable to evaluate the red color of jadeite, tourmaline, and ruby respectively^{6,30,31}. The color of jadeite is the most important indicator of value, so it is important to accurately measure and display its color.

In this paper, we use one single factor method to study how the circumstances of the digital imaging system influence the color measurement and ColorChecker calibration to objectively verify the feasibility of DIS. Based on the Orthogonal Design, the analysis of variance (ANOVA) was used to explore the suitable measurement parameters.

A total of 24 Burmese jadeites are selected in this article, of which six are red, eight are orange and six are yellow. The color varies from red to yellow in steps and the color distribution is even when observed by the naked eye. The shapes are droplet, flat, and oval, with an average diameter of 7-10mm (Fig.1). All of the samples are gem-quality and polished, purchased from the jade market in Sihui, Guangdong Province, China.

Figure 1. Part of the jadeite samples used in this paper

Result and discussion

Influence of Illuminance The 24 pieces of jadeite samples were tested in 1100 – 2900lx (interval=200lx) respectively (Measurement Distance:25cm, Exposure Time:12000 μ s); The China national standard GB/T 26189-2010 “Lighting of Indoor Workplaces” suggests that the maintained illuminance (the lowest average illuminance on the work surface) of indoor jewelry manufacture and precious gemstone operation should be 1500lx³².

Figure 2. The highly positive correlation between illuminance and colorimetric coordinate a^* and b^*

The correlations between colorimetric coordinate a^*b^* and illuminance is shown in Fig.2. The increment of b^* is more than a^* with the increase of illuminance, with a fitting coefficient of 0.013($R^2=0.998$) and 0.007($R^2=0.997$) respectively.

As shown in Fig.3(a), with the gradual increase of illuminance, the lightness L^* of jadeite increases significantly and the mean lightness change from 1100 to 2900lx is 27.81, which is the same as the observation by the naked eye. By comparing the lightness of jadeite with different hues, it is found that the lightness of yellow jadeite ($h^\circ \in (80,110)$) has a greater change, besides, it is found that there is a high positive correlation between colorimetric coordinate b^*_{1100lx} and the change of lightness from 1100 to 2500lx ($R^2=0.859$)(Fig.3b), which indicates that the lightness L^* of jadeite with a higher colorimetric coordinate b^* is more sensitive to the illuminance change. So those samples with a yellowish hue show a greater lightness change as the illuminance change (Fig.3b #55 compares with #61).

Figure 3. (a) With the rise of illuminance, the lightness L^* of jadeite increases. Each box represents the distribution of the lightness of all samples at the same illuminance level. (b) A highly positive correlation between $\Delta L^*_{1100-2500lx}$ and color coordinate b^*_{1100lx} . The color boxes are the simulated color of the sample under 1100 and 2500lx.

Fig.4(a) shows that the chroma C^* of jadeite positively correlates to the illuminance within the range from 1100lx to 2900lx. The mean value of chroma change from 1100 to 2900lx is 22.29 that indicating the jadeite color will be vivid as the illuminance gets higher, which is consistent with the perception that colorfulness rises as illuminance grows in rational range³³. As shown in Fig.4(b), a positive correlation was found between colorimetric coordinate b^*_{1100lx} and $\Delta C^*_{1100-2500lx}$ ($R^2=0.761$), combined with the result of Fig.2 and Fig.3, the rises in illuminance will lead to an increase in lightness L^* , while the colorimetric coordinate b^* is positive with the change of lightness, so the chroma C^* of samples with a higher b^* is more sensitive with the change of illuminance(Fig4.(b) #61 compares with #67)

Figure 4. (a) With the rise of illuminance, the chroma of jadeite increases; (b) A moderate positive correlation between $\Delta C^*_{1100-2500lx}$ and color coordinate b^*_{1100lx}

The mean hue h° changes(max-min) is 3.12 which indicates jadeite color hue turns to yellow tones as the illuminance gets higher, which corresponds to the Bezold-Brücke hue shift that perceptual changes in hue when the intensity of a stimulus increases or decreases^{34,35}. By comparing jadeite with different hue angle variations, the samples were divided into 3 groups. As shown in Fig.5, it shows that the sample whose hue angle ranges from 35° to 50° has a significant rise (red box), because the increase of lightness will expand the wavelength range of yellow light, thereby shifting red to yellow.

Figure 5. The correlation between three groups of jadeites with different hue angles h° and illuminance (group1 $h^\circ \in (35, 50)$; group2 $h^\circ \in (55, 70)$; group3 $h^\circ \in (80, 100)$)

The main effect of illuminance on reading the color of jadeite is to improve the lightness, chroma, and shift red to yellow, however, excessive illuminance will cause the obtained photos to be overexposed (Fig5. Yellow box) and read unreal data.

Figure 6. The lightness histogram of jadeite with different hue angles under different illuminance levels. All the lightness histograms were exported from PhotoShop2020.

The yellow jadeite is dominant by the colorimetric coordinate b^* , so its lightness and chroma show a higher sensitiveness to the change of illuminance; combined with lightness histogram, when the illuminance reaches 2500lx and above, the lightness histogram of the yellow jadeite is occupied by the high lightness area (Fig.6 red circle) when the histogram of red and orange jadeite shows a good uniformity, which means there is loss of color data in the yellow sample and causes the reading of unreal color. Therefore, the optimal parameters for the measurement of jadeite with different hues (red-orange-yellow) should be discussed separately.

Influence of Exposure Time (E.T) The 14 jadeite samples were tested in 10500-13500 μ s (interval=500 μ s; 1500lx, 25cm) respectively. As shown in Fig.7(a), the lightness L^* of jadeite is increasing with the increase of E.T. The mean lightness change from 10500 to 13500 μ s is 14.11, which corresponds to the objective fact that the luminous flux of the camera is increased. Fig.7(b) shows the Chroma C^* gets higher as the E.T increases, the mean value of Chroma difference between 10500 and 13500 μ s is 8.9. By analyzing with samples (#23 and #52), the higher $C^*_{10500\mu s}$ and $L^*_{10500\mu s}$ (the Chroma and Lightness in initial E.T value) it is, the more ΔC^* and ΔL^* will be. The E.T have little influence on the Hue h° of samples, with a mean change $\overline{\Delta h^\circ_{max-min}}=1.37$, those jadeites with lower hue angle show a relatively greater sensitiveness than those higher (Fig.7(c)). According to the similar trend of $L^* C^* h^\circ$ caused by illuminance and exposure time, the interactive influence between them is considered in the orthogonal experiment subsequently.

Figure 7. (a) A highly positive correlation between E.T with Lightness L^* of Jadeite; (b) The Chroma C^* is increasing when the E.T increase; (c) The variation of hue angle h° of jadeites which are divided into three groups based on hue angles.

Influence of Measurement Distance Under the conditions of 1500lx and 12000 μ s, the 14 samples were tested in 20-35 cm (interval=5cm) respectively. The mean change $\overline{\Delta L^*} = 0.273$, $\overline{\Delta C^*} = 0.326$, $\overline{\Delta h^\circ} = 0.383$, which illustrates the influence of M.D is smaller than the illuminance and exposure time. Since the size and shape of jadeite in the market are very variable, the stability of the color measurement test can be simulated by changing the measurement distance. According to the results, it can be found that the digital image system can provide good stability under the set lighting and background conditions.

Optimal Parameter for Jadeite-red by DIS Six red jadeites from the tested samples were chosen for this chapter. According to the pre-test shown in Fig.8, three levels for each factor were selected for the subsequent orthogonal experiment. The color difference was used here to measure the degree of applicability of the combination of test parameters, the smaller the $\overline{\Delta E_{00}}$, the better the combination.

Figure 8. The pre-test result for the orthogonal design, which shows the selected 3 levels for each factor with a black box. ΔE_{00} is the color difference between data from DIS and data from photo calibration calculated by equation (9). The box is the range for the subsequent Orthogonal Design, the reason for the selected levels is based on the lowest ΔE_{00} and China national standard GB/T 26189-2010 "Lighting of Indoor Workplaces" and GB/T 23885-2009 "Jadeite grading". From top to bottom: Exposure Time, Measurement Distance, Illuminance.

Table 1. Orthogonal Design

Num	Illuminance (A)	E.T (B)	A×B	A×B	M.D	Error	$\overline{\Sigma \Delta E_{00}}$
1	1500	11500	1	1	20	1	2.46
2	1500	11500	2	2	30	3	2.79
3	1500	12000	1	3	30	2	2.03
4	1500	12000	3	1	25	3	2.06
5	1500	12500	2	3	25	1	1.31
6	1500	12500	3	2	20	2	1.28
7	1600	11500	1	3	25	3	1.57
8	1600	11500	3	1	30	2	1.33
9	1600	12000	2	2	25	2	1.03
10	1600	12000	3	3	20	1	1.06
11	1600	12500	1	2	30	1	0.73
12	1600	12500	2	1	20	3	0.73
13	1700	11500	2	3	20	2	0.91
14	1700	11500	3	2	25	1	0.94
15	1700	12000	1	2	20	3	1.45
16	1700	12000	2	1	30	1	1.48
17	1700	12500	1	1	25	2	1.63
18	1700	12500	3	3	30	3	1.64
K ₁	11.93	10	9.87	9.69	7.89	7.98	T=26.43
K ₂	6.45	9.11	8.25	8.22	8.54	8.21	
K ₃	8.05	7.32	8.31	8.52	10	10.24	
k ₁	3.98	3.33	3.29	3.23	2.63	2.66	
k ₂	2.15	3.04	2.75	2.74	2.85	2.74	
k ₃	2.68	2.44	2.77	2.84	3.33	3.41	
R _j	1.83	0.89	0.54	0.49	0.70	0.75	

Note: K_i is the sum of the color difference ΔE of the same level of the column; k_i is the mean of K_i; R_j is the Range

As is shown in Table1, L₁₈(3⁶) is selected for the 3-level 3-factor experiment with 2 interactions(A×B). According to the result of range analysis, R₁>R₂>R₃ indicates the order of degree of influence of the experimental factors on the result: Illuminance>Exposure Time>Measurement Distance. For the result of illuminance, because it is based on the average color difference ΔE_{00} – the smaller it is, the better the result is- k₂<k₃<k₁ represents the most suitable level is 1600lx. And so on the best measurement distance is 25cm, and exposure time is 12500ms.

ANOVA can help distinguish between data fluctuations caused by changes in experimental conditions and data fluctuations caused by experimental errors. Again, the results of the ANOVA can further verify the conclusions of the above range analysis. The SS_T indicates the sum of squared deviations where n represents the total number of experiments, y_i represents the result of each experiment, and SS_T is calculated by:

$$SS_T = \sum_{i=1}^n (y_i - \bar{y})^2 = \sum_{i=1}^n y_i^2 - \frac{1}{n} \left(\sum_{i=1}^n y_i \right)^2 \quad (1)$$

The sum of squared deviations of each column SS_j as:

$$SS_j = \frac{r}{n} \left(\sum_{i=1}^r K_i^2 \right) - \frac{T^2}{n} \quad (2)$$

Where T is the sum of $\overline{\Sigma \Delta E_{00}}$.

The degrees of freedom of each factor f_A and the total degrees of freedom f_{total} are calculated as follows:

$$f_A = m - 1 \quad (3)$$

$$f_{total} = n - 1 \quad (4)$$

Where m represents the number of levels.

According to the sum of square deviations of each factor V_A , the statistic F value can be calculated as:

$$V_A = \frac{S_A}{f_A} \quad (5)$$

$$F_A = \frac{V_A}{V_{MS}} = \frac{\frac{S_A}{f_A}}{\frac{S_{MS}}{f_{MS}}} \quad (6)$$

Table 2. Analysis of variance

Factors	S_A	f_A	V_A	F	F Distribution	Sig
Illuminance (A)	2.64	2	1.32	18.0	$F_{0.10}(2,6)=3.11$	***
E.T (B)	0.62	2	0.31	4.2	$F_{0.05}(2,6)=4.46$	*
A×B	0.48	4	0.12	1.6	$F_{0.01}(2,6)=8.65$	-
M.D	0.2	2	0.1	1.4		-
Error	0.516	7	0.0737			
Total	4.467	17				

Note: Compare the F value with the F distribution. If F is greater than $F_{0.01}(2,6)$, the result is very significant (***), greater than $F_{0.05}(2,6)$ is significant (**), greater than $F_{0.10}(2,6)$ represents to have some influence, otherwise deemed to have no significant impact.

Table 3. Interactive influence between illuminance and E.T

	A1	A2	A3
B1	1.98	1.54	2
B2	1.64	0.99	1.54
B3	1.41	0.82	1.64

According to the results of the ANOVA(Table 2), the conclusions of the range analysis can be verified. The order of the degree of factors that influence the DIS is Illuminance (A)>Exposure Time(B)>A×B>Measurement Distance. Illumination has a very significant influence on the DIS, and the k_2 level is the best; the effect of exposure time is significant, and the result shows that the k_3 level is the best; the effect of measurement distance is not obvious, and the level with the lowest color difference k_1 can still be selected for the result; the interaction between illuminance and exposure time is not obvious, according to the analysis of the interactive influence, it is found that the A2B3 combination is the best level(Table 3), which corresponds to 1600lx, 12500ms; finally, the optimal parameter level combination for the red jadeite color reading by the DIS is 1600lx, 12,500ms, and

25cm. In the future, more test samples can be added to modify the optimized measurement conditions, and based on this basis, measurement parameters can be obtained for other colors of jadeite.

Conclusion

DIS is a non-contact color measurement system that could help researchers better study unevenly distributed colored gems. The system includes circumstance factors such as light source intensity (illuminance), exposure time, measurement distance, etc., which will affect the color reading of jadeite. Under the single factor experiment method: 1. The influence of illuminance is mainly to improve the lightness and chroma of jadeite, those with a higher hue angle are more sensitive to changes in illuminance, and others with a lower hue angle will shift to yellow. 2. The effect of exposure time is mainly to increase the luminous flux, thereby improving the lightness and chroma of jadeite, and the overall change trend is consistent with the change in illuminance; 3. The DIS shows good stability on the change of measurement distance, which is used to simulate the measurement on jadeites with different sizes and shapes.

Based on the results of single-factor experiments, a three factors three levels orthogonal experiment with two interactive effects was designed. The order of the degree of influence obtained by range analysis and ANOVA is illuminance, exposure time, measurement distance (from high to low). Combined with the result, the optimal color measurement parameters of jadeite-red for DIS are 1600lx, 12500ms, 25cm; this provides a new case and theoretical support for the future application of DIS on reading the color of gemstones and the establishment of a gem-color database.

Methods

Color Space The CIE (International Commission de l'Éclairage) 1976 $L^*a^*b^*$ uniform color space has been widely used in the color evaluation of various colored gemstones; compared to the CIE1931 color space, the geometric distance between two given colors is inconsistent with human visual perception³⁶. CIE1976 $L^*a^*b^*$ uniform color space has two advantages: (1) good color uniformity and (2) conform to the subjective law that the visual color difference in the yellow-blue direction is bigger than that in the red-green direction. This color system comprises color coordinates a^* , b^* and Lightness L^* . Chroma C^* and Hue angle h° can be calculated based on a^* and b^* :

$$C^* = \sqrt{a^{*2} + b^{*2}} \quad (7)$$

$$h^\circ = \arctan\left(\frac{b^*}{a^*}\right) \quad (8)$$

Color Difference Formula To explore the optimal parameter combination of the Digital Image System (DIS) for measuring jadeite, this paper chooses the CIE DE2000 formula to analyze the results of the measured samples. The DE2000 formula is experimentally obtained based on the color difference formulas such as CIE LAB and CIE 94, which is more accurate and more computational:

$$\Delta E_{00} = \left[\left(\frac{\Delta L'}{K_L S_L} \right)^2 + \left(\frac{\Delta C'}{K_C S_C} \right)^2 + \left(\frac{\Delta H'}{K_H S_H} \right)^2 + R_T \left(\frac{\Delta C'}{K_C S_C} \right)^2 \left(\frac{\Delta H'}{K_H S_H} \right)^2 \right] \quad (9)$$

where $\Delta L'$, $\Delta C'$, $\Delta H'$ represent the difference in lightness, chroma, and hue angle respectively (between the DIS data and photo calibrated data). The weight functions S_L , S_C , and S_H are used to calibrate the uniformity of the color space, and the function R_T is used to correct the deflection of the

color tolerance ellipse in the blue area; the Parameters K_L, K_C, K_H are to correct the experimental conditions, in gemology, where the parameter combination is usually set as (1:1:1) to provide better perceptibility.

The color difference is calculated at the “colortell.com” (developed by ColorTell Tech CO., LTD, Beijing, China) color management website by importing digital imaging system data (samples) and calibrated photo data (standards), after which the color data is calculated by the equation(9).

Digital Imaging System (DIS) The color of jadeite was measured by the Digital imaging system under the same Munsell N7 background (Fig.9). The images were captured by using a Mako G-507C industrial camera (Allied Vision Technologies, Stadtroda, Germany) equipped with a CMOS-type Sony IMX264 sensor with a size of type 2/3. The resolution of the camera is 2464(horizontal) $\times$ 2056(vertical), it has a global shutter, a 50 mm focal length, and an aperture factor of 1.4. The dome lampshade is a type of shadowless dome light source with a color temperature of 6500 K, which is positioned 10cm above the sample. To better read the color of the sample, a special diffuse reflection material is used inside the lampshade. so that the light can be evenly irradiated on the surface of the sample. A Konica Minolta CL-200 Color Illuminometer (Tokyo, Japan) served to measure the environmental illuminance of the measuring position.

Figure 9. The DIS experimental device

The color reading was processed by the CKVisionBuilder V3.0 software (developed by Shenzhen CKVision Machine Vision Technology Co., Ltd., Shenzhen, China). The color conversion algorithm is encapsulated in the supporting CKVisionSDK 3.0. The user can select different types of tools to read the color of the specified area in the picture, and the software can convert the RGB value of the selected area to the $L^*a^*b^*$ value. Three areas were chosen to calculate the average color parameters for each sample.

All the jadeite samples were well polished and showed a high quality "glassy luster" because of their high refractive index (1.66). To prevent the influence of surface reflection on color measurement, we excluded the reflective areas from the color reading, selected three uniformly colored locations in the measuring area, measured the color, and took the average value as the test result (Fig.10). Some samples containing black or white mineral inclusions were excluded from the measuring area.

Figure10. The reflective area with strong reflection and inclusion in the measuring area should be avoided during the color reading process.

Photograph Calibration The Nikon Z5 (Nikon, Tokyo, Japan) equipped with a CMOS-type sensor is used to take photos of X-rite Color Checker Passport (X-rite, Shanghai, China Fig.11) (Fig.11) and jadeite samples under the standard D65 light source, and all the samples are placed at the Munsell N7 neutral grey background.

X-rite Color Checker Passport contains a set of three-Color Checker photography targets³⁷, a desktop camera calibration application, and an Adobe Photoshop Lightroom camera calibration plug-in to create a DNG profile that reflects specific camera, lens, and lighting conditions to process the calibration of the RAW photo and restore the true color of the jadeite. Each photo was processed in Photoshop 2020, using the established environment DNG feature file for correction (Fig.12), operation steps as follow:

1. Take the picture of ColorChecker and samples under the set circumstance, the output format is RAW.
2. Import the picture including ColorChecker into “ColorChecker Camera Calibration” (developed by X-rite, Shanghai, China) to create a DNG profile.
3. Open picture of samples through Photoshop2020, then set the DNG profile as the configuration file.

Figure 11. X-rite Colorchecker passport

Figure 12. The pictures of the sample (RAW and Calibrated) were placed on the Munsell N7 value scale.

Single Factor Experiment This paper applied the single factor experiment method to test the three main influencing factors of the DIS (Illuminance, Exposure Time (E.T), Measurement Distance (M.D)). While one of the factors is regarded as a variable, the other two factors are regarded as constants, for example, when testing the influence of Illuminance, the experimental conditions were set as 1. Illuminance: 1100lx, 1300lx, 1500lx, 1700lx, 1900lx, 2100lx, 2300lx, 2500lx, 2700lx, 2900lx; 2. Exposure Time: 12000 μ s; 3. Measurement Distance: 25cm. To explore the influence of variables on the experimental results.

Orthogonal Experiment Design An $L_{18}(3^6)$ Orthogonal table was selected for this paper, with 3 factors 3 levels, and 2 interactives. A blank column was set to consider the error. And the average color difference of each combination of experimental conditions is assigned to determine the feasibility of the experimental result. The ANOVA was set to investigate the degree of influence of experimental conditions on experimental results.

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Author contributions

Writer of manuscript, Z.L; Methodology and conceptualization, Z.L, Y.G; Operator of the experiment, Z.L; Owner of samples, Y.S; Data visualization and edition, Z.L, Y.S, B.Y. All authors have read and agreed to the version of the manuscript.

Competing interests

The authors declare no conflict of interest.

Data availability

Data underlying the results presented in this paper are not publicly available at this time but may be obtained from the authors upon reasonable request.

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