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Effect of Structure Parameters and Wavelength on the Casein Concentration Detected by the Method of Scattered Transmitted Ratio

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Abstract

The objectives of this study were to investigate the effect on the casein concentration detected by the method of scattered transmitted ratio (STR) at different structure parameters and wavelength. Detection experiments were performed at four kinds of testing devices and five kinds' different wavelength lasers. All measurements had good reproducibility. Both structure parameters and wavelength had a significant effect on the measured effective concentration of the casein. The design of four different structure of the testing device was measured and analyzed. And the structure parameter of the testing device was determined in this paper. Compared measured value with standard value, it was determined by more effective wavelength. The accuracy of the method of scattered transmitted ratio, evaluated through the correlation coefficient (R) and the root mean square error of prediction (RMSEP) for five kinds different wavelength lasers. Overall, the results of this study suggest that the suitable structure parameter was experimented for testing devices.

Keywords: *casein concentration, structure parameters, scattered transmitted ratio, laser wavelength*

1. Introduction

Rapid and direct determination of casein is of great interest and has brought numerous attentions. Currently, there are lots of methods to measure the milk ingredients. The chemical analysis is still the elementary method. However this method is off-line by nature, expensive, time-cost and labor consuming, and inefficient, it has been partially replaced by rapid methods such as near-infrared spectroscopy analysis method and the ultrasonic method, etc. The dynamic light scattering method is most prevalent nowadays and more precise [1-3]. Dynamic light scattering as an important means of studying polymer molecular structure can directly determine the parameters of macromolecules in solution such as diffusion coefficient, particle size and distribution, and has the advantages of no interference with the sample, informative, simple and fast, it also has played an important role in the characterization of protein structure, analysis of aggregate processes and interactions [4-7].

However, sensor structure parameters have direct impacts to detection accuracy on the device [8]. The sensor was mainly including sample room and sample pool in casein concentration detection system [9]. Through light scattering experiments of casein

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samples, related parameters of the sensor device were analyzed in this paper. And structural parameters of the sensor had determined for the design of casein concentration detection system. These analyses can improve the precision of the testing instrument and provide data support for sensor design.

2. Casein composition detection system

In order to eliminate the effect of the light source power fluctuation, the ratio of the scattered light intensity $I_{\perp}$ to the transmitted light intensity $I_{//}$, called scattered–transmitted ratio (STR)[10]. $I_{//}$ represents the intensity of the transmitted light. And $I_{\perp}$ represents the intensity of the scattered light which is perpendicular to the incident light.

3.1. Structure of detection system

In order to achieve the detection of casein, casein colloids are homogenized before detection to guarantee that casein colloids evenly distribute in the solution during light scattering test. Based on the above theoretical analysis, the experimental equipment which can analyze casein is designed, and the experimental equipment schematic diagram is shown in Figure 1. Through the analysis of different angles, and considering the installation techniques of experimental equipment, we install the photoelectric sensors at 0° and 90° position to detect the scattering light intensity after fixed-wavelength laser across the sample. Thermostatic device keep at 37 degree Celsius to maintain the detected temperature of casein samples. In the following, data processing is used.

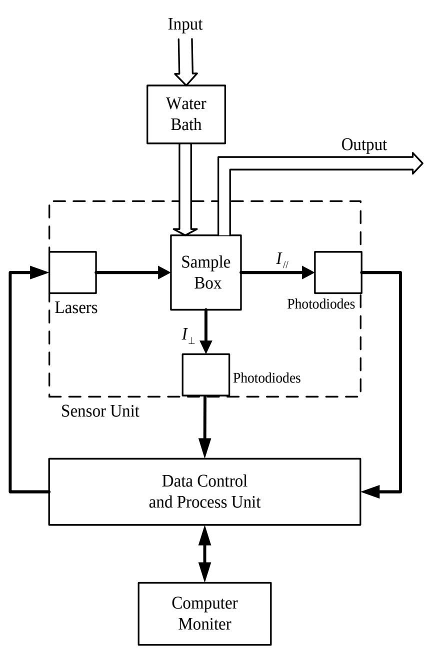


Figure 1. Principle diagram of component analysis of experiment equipment

In order to determine the relation of the structure of the sensor unit and scattering light, three different sizes sensor units of the shell and the sample were designed. Sensor measurement unit structure is shown in Figure 2.

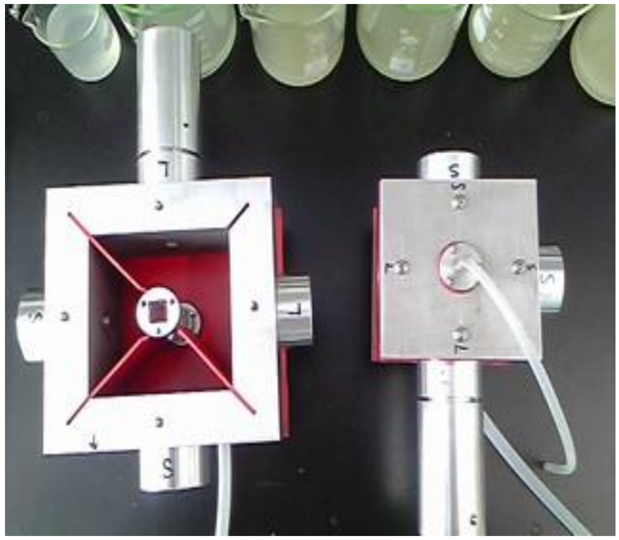


Figure 2. Sensor Unit

And these sample room and sample pool were combined according to four different combinations that is shown in Table 1.

Table 1. Four different combinations testing devices (mm)

Unit	Sample room size	Sample pool size
1	SR: 90×90 SP: 40×40	7×7
2	SR: 170×170 SP:120×120	10×10
3	SR: 130×130 SP:80×80	10×10
4	SR: 90×90 SP:40×40	5×5
* where, SR is the length of sample room, SP is the length of sample pool		

3.2. Light intensity detection unit

Because there were the scattered light $I_{\perp}$ and transmitted light $I_{//}$ need to measure, there would install two way photovoltaic detectors at 90°and 180° direct. It is commonly adopted photovoltaic detector including photovoltaic cells and photoelectric diode. And photovoltaic cells have some advantages, such as detection area is larger and wide range of wavelengths can be detected. So we use photovoltaic cells as photoelectric sensor components. Its model is S5061-02, its output range of 0 V to 0.57 V.

In order to convert weak light signals to identify the signals for system, a photoelectric conversion and signal amplification circuit is crucial with linearity and high stability for the whole testing system. It directly affects the measurement precision, sensitivity and stability of the whole system [11]. In view of the above requirements, design the following light intensity detection unit circuit.

3.1.1 Light intensity signal amplification circuit: Photovoltaic cells in under the condition of light action, it will be generated by the current increases with the increase of light intensity. When the intensity of light measured is constant, photovoltaic cells can be regarded as constant current source. The preamplifier circuit is used to make the light signal can be identified, and the identification signal also has high resolution and large measuring range. It can reduce the system noise and improve the detection accuracy.

Preamplifier input is the output of the photovoltaic cells. Through current/voltage (I/V) conversion of operational amplifier, preamplifier output is proportional to the intensity of light. Because the circuit working in the way of short circuit, it can reduce the effects of PN junction of forward current, and make the photovoltaic cells to get the best signal-to-noise ratio. So amplified signal intensity is proportional to the light of the photovoltaic cells detection. Design of the preamplifier circuit was shown in Figure 3.

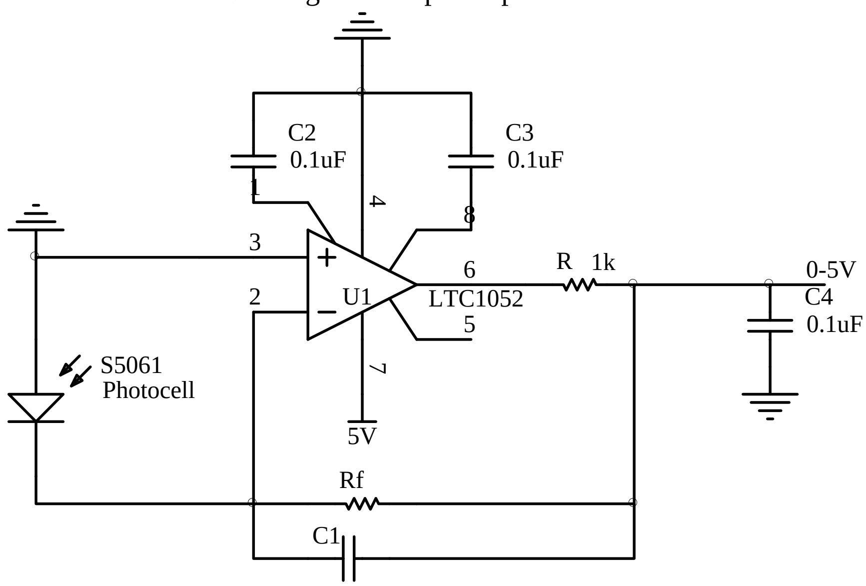


Figure 3. Preamplifier circuit of photocell

As Figure 3 shows that the greater the feedback resistance Rf, the higher I/V conversion efficiency. But it should attention that the feedback resistance Rf should be to choose according to the actual situation.

To guarantee the stability of the I/V conversion amplifying circuit, resistance R adopted precision resistance which has smaller temperature coefficient in the circuit. The Output voltage of amplifier circuit is from 0 to 5 V.

3.1.2. Voltage frequency (V/F) conversion circuit: In the voltage frequency (V/F) conversion circuit, preamplifier output voltage was converted into frequency signal. Frequency signal has a stronger anti-jamming ability, through the single chip microcomputer to frequency signal acquisition, light intensity can more accurate to be measured. Design of the voltage frequency conversion circuit was shown in Figure 4.

The voltage frequency (V/F) conversion circuit consists of a low noise zero-drift OP amp (LTC 1052), a dual Precision Instrumentation Switched Capacitor Building Block (LTC 1042) and other components. Through the voltage frequency (V/F) conversion circuit, voltage signal of the preamplifier can be converted frequency signal from 0~5V to 1Hz~1.2MHz. frequency signal would complete the data processing in subsequent unit.

3.2.3. Data processing unit: Data processing unit chose PIC18F47J53 to finish data processing function. PIC18F47J53 has multipath signal capture unit, used in the detection of frequency signal, facilitate the expansion of the follow-up study requirements. It integrated full-Speed USB 2.0, data communication be used in this design. Through USB, measurement system can be connected with the computer to complete data communications and the other related work. And it also can provide convenient power source. The interface of the microprocessor was shown in Figure 5.

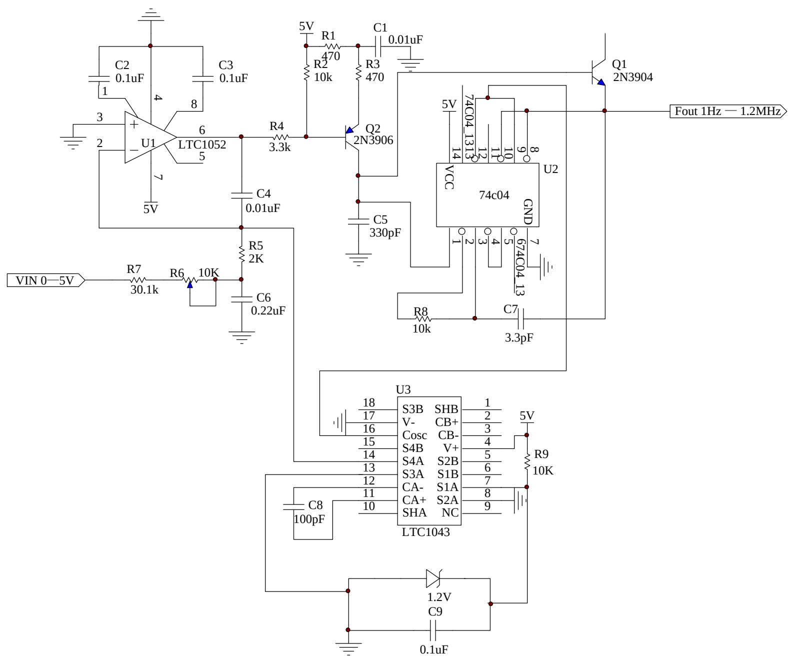


Figure 4. V/F transmit circuit

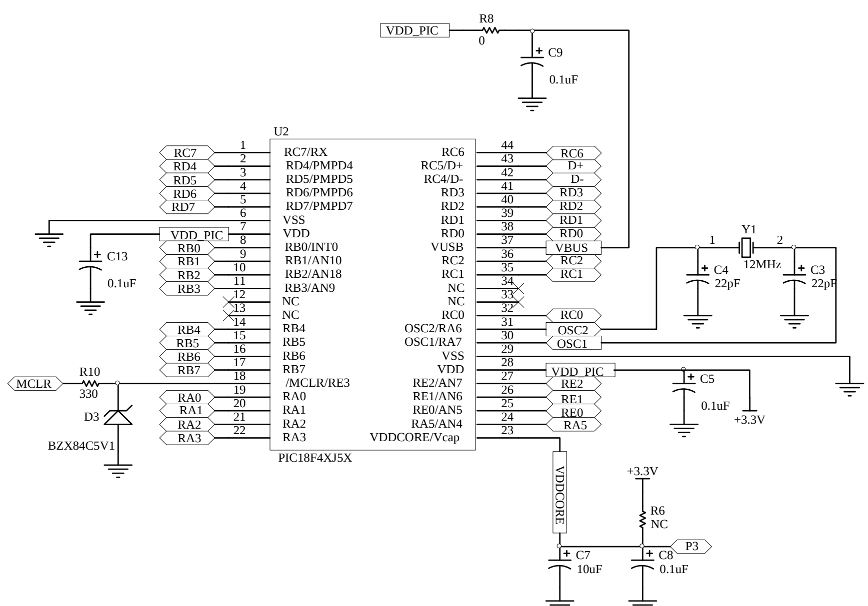


Figure 5. Main unit of measurement circuit

4. Experiment

4.1 Experiment instrument and sample

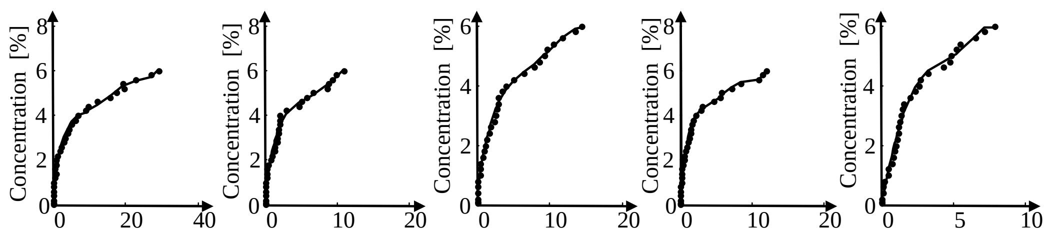
1. Optical power meter: The TQ8210 is a handheld optical power meter which can be combined with ADVANTEST. The TQ8210 has such features as built-in response compensation, thereby ensuring high accuracy even when measurement range and sensor are changed. Q82014A is optical sensor that wavelength range is 400nm to 1100nm.

2. Lasers: Choice of wavelength including 650nm, 780nm, 830nm, 850nm, 980nm.

3. Casein: Sigma C-5890. Solvent use 0.1 mol/L of sodium carbonate solution

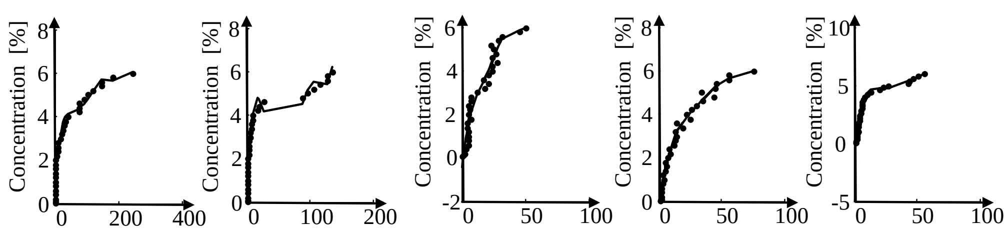
4.2. Evaluation of testing device

In order to improve test accuracy, the relation curve of casein concentration and STR through was used by the least square principle to complete. This experiment improves measurement precision by averaging the testing values of repeated measurements. There were five kinds of lasers, such as 650nm, 780nm, 830nm, 850nm, 980nm, which were selected as experimental light source. Curve of casein concentration and STR of four testing devices were shown as Figure 6, Figure 7, Figure 8 and Figure 9.



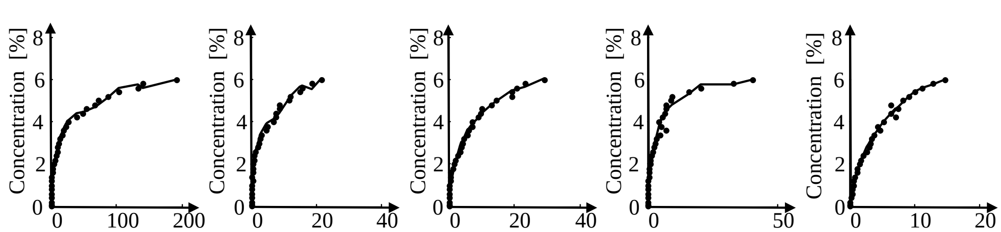
(a) 650nm STR (b) 780nm STR (c) 830nm STR (d) 850nm STR (e) 980nm STR

Figure 6. Curve of relation of casein concentration and STR for 1# device



(a) 650nm STR (b) 780nm STR (c) 830nm STR (d) 850nm STR (e) 980nm STR

Figure 7. Curve of relation of casein concentration and STR for 2# device



(a) 650nm STR (b) 780nm STR (c) 830nm STR (d) 850nm STR (e) 980nm STR

Figure 8. Curve of relation of casein concentration and STR for 3# device

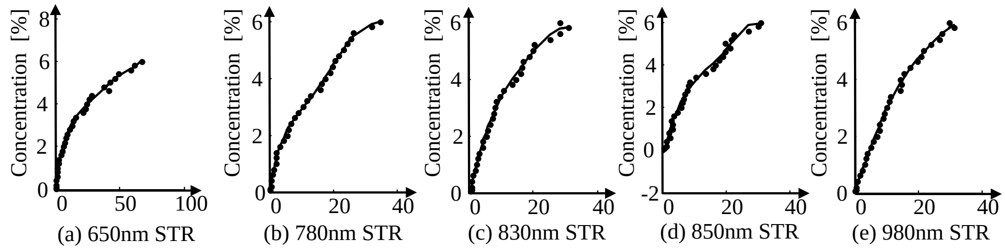


Figure 9. Curve of relation of casein concentration and STR for 4# device

By above four figures of the original data, when laser wavelength was fixed, this is correlation between curve of casein concentration and STR using the different testing device. The concentration of casein has the same trend as STR. The STR rises with the increase of the concentration of the casein solution. The experiment device can all be a solution to measure the concentration of than scattered through, which can be used to test solution concentration. Experiment data show that different structure size parameters of testing device also have differences in the same wavelength. When the same size testing device were be scattered in different wavelength laser, fitting curves are also different. In order to be able to achieve a more accurate concentration measure, parameters matching testing device is important. In comparison, the 4# testing device fitting effect was better than other testing devices.

5. Analysis the influences of concentration measurement in different wavelengths

According to this curve, it can fast detect casein concentration in any an unknown concentration of casein solution. Firstly, we are preparing casein solution for experiment. And casein concentration was determined by the Kjeldahl method as described by GB/T5413.1-1997(National Standard of P. R. China), and the factor 6.38 was used to convert the nitrogen values to casein. Measurement result would for testing standard values. Because of the best fitting effect of 4# testing device, the subsequent experiments would use it. Measurement results and analysis are shown in Table 2.

Table 2. casein concentration in different wavelength using method of STR

	Standard value	measured value				
		650nm	780nm	830nm	850nm	980nm
1	0.5008	0.4901	0.5896	0.3857	0.4240	0.4924
2	1.5009	1.4101	1.2715	1.6674	1.3113	1.8263
3	2.5095	2.4503	2.3091	2.7716	2.3775	2.8300
4	3.5143	3.7892	3.7191	3.2404	3.6288	3.7252
5	4.5087	4.5176	4.8471	4.7044	4.7636	4.5684
6	5.5107	5.4353	5.7971	5.8179	5.2763	5.8149
R		0.9974	0.9961	0.9941	0.9930	0.9973
RMSEP		0.0548	0.1046	0.1012	0.0788	0.0769

Compared measured value with standard value, the values of the correlation coefficient (R) and the root mean square error of prediction were relatively ideal. The values of correlation coefficient (R) of between measured values with standard values are above 0.99. There were significant correlations between measured values with standard values.

6. Conclusions

In this paper, using the method of scattered–transmitted ratio to measure casein concentration, it is critically important to find suitable structure parameters and wavelength.

Through experiments and analysis, that suitable testing device was identified, whose use as a testing device resulted in casein concentration experiment at five different wavelength lasers. The values of correlation coefficient (R) of between measured values with standard values are above 0.99.

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