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Study on Water-Induced Ultra-Weak Luminescence Value of Wheat Kernels

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Abstract

The wheat kernels were processed by moistened in water. The spontaneous and water-induced luminescence data (photon counts) were noted with an ultra-weak luminescence (UWL) detector. The following was the features of the data analyzed by the statistical parameters of the spontaneous luminescence and the fitting curves of the water-induced luminescence. The results show that the UWL intensity rises with the moistened time prolonged. It is concluded that the intensity depends on the moistened time mainly. If the moistened kernels owned a more porous structure, in the initial phase of imbibition, a higher UWL emission would be noted. Consequently, the further quantitative research of the relevant could lead a novel testing method about the wheat's activity and quality.

Keywords: *wheat kernels, ultra-weak luminescence, moistened, exponential function*

1. Introduction

Wheat is the important grain reserves varieties in China. It was reported that with the storage time longer, the quality of wheat will deteriorate, which may affect people's health seriously [1]. At present, the test methods of wheat quality are mainly sensory judgment method and biochemical testing method. However, because of the technical limitations and the personnel quality, these methods are subjective, complex operation and high cost [2-4]. Therefore, it is necessary to explore a novel security, non-destructive and rapid novel detection method.

It was reported that the UWL in organisms is discovered by Russian cell biologists A.G.Gurwitsh [5], and it was reported that Colli who is from Italian used a photomultiplier tube to detect some plants germinal UWL phenomenon, the UWL belongs to biophotonics [6]. The research of biophotonics shows that the UWL is not only a common biophysical phenomenon of living organisms, but also a reaction of life activity status. It provides important information on the organism metabolism and the energy conversion, and it is highly sensitive to the subtle changes in the internal of the system and the impact of the external environment. When the biological is in adversity, such as disease, injury, changes in the external environment and so on, the biophotons emission will be changed significantly [7-10].

As we all know, the main factors that affect the wheat quality index are temperature, microorganism and pests. The difference quality would take on the main performance in physical structure, chemical composition and other physiological indexes and so on. The change of these indexes eventually reflected in weakened vitality. Li Fu-Jun and Zhang Xin-hua [11] research showed that the UWL intensity reflect the size of the sample vitality in a certain extent. At present, UWL has already been applied in plant anti-stress researches have been reported [12-15], detection characters of seed mouldy [16], assaying R gene responses [17], monitoring environmental pollution [18], and determining germination capacity and vigour [19-21]. In the report [14], the delay UWL of the maize are investigated under various NaCl concentration. The results shows that with the increase of NaCl, the UWL intensity decreased, and the decrease speed increased following with the increase of NaCl concentration. The study reveals that the spectral analysis of the UWL is a useful tool for studying plant response to salt stress. The report [16] is about the characters of moldy seed. Its result shows that the UWL of

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moldy rice enhances with the increase of sample temperature and weight in whole, while weakens along with the length of detect time, and scales up with the moldy degree and proportion. The report [21] shows that the UWL intensity and the vigour (germination rate) of rough rice are vary with the irradiation doses and storage time. Therefore, the research of the UWL characters of wheat kernels may have a useful value for exploring new detection method of food quality.

The cell membrane of the wheat seed changed largely in the process of mature and dry. Seed contracts when seed drying, and the cell wall highly distorts. Nucleus and mitochondrion present irregular state and membrane has been damaged to various degrees. All of these changes will significantly diminish seed activity. The degree of hydration of the membrane increase when the seed absorbing water. A variety of membrane repairs itself, and returns to normal quickly, the metabolic activity instantaneous enhance. This process is very short. Membrane repairs itself slowly and even it cannot be repaired to the normal status when the seeds deteriorating seriously and then absorbing water again.

In the present paper, we suppose that the UWL can be also modified by the structural change and damage to wheat grains as a result of their moisture treatment. Therefore, the purpose of this study is measurement of the UWL from imbibing wheat grains moistened previously in water for several given periods of time and then dry in free air and of the UWL from wheat kernels.

2. Materials and Methods

2.1. Materials

The experimental material is Zhengmai 9023 wheat kernels. Wheat kernels are purchased from a village in Zhengzhou, located in the middle of China. The wheat is an indigenous plant and belongs to Monocotyledon class, Poales, Gramineae. The materials include “old samples” (cropped in June 2010) and “new samples” (cropped in June 2011).

Three 5.00±0.02 g portions of uniform size without scars grain are chosen for the study. Two samples of both types of grain are then soaked in distilled water for 2 hours (called group 2 hours) or 4 hours (called group 4hours). The wet grains are next spread on sheets of paper and dry in the air to the mass they had before soaking. The error is less than 0.5%. One set of two different samples which has not been soaked is used as control material (called group 0 hours). All the samples are placed in the sealed bag until the measurements of the UWL are taken.

2.2. Instrument

The UWL of the samples is measured by the apparatus BPCL-ZL-TGC UWL detector equipped with a photomultiplier, which is purchased from a company in Beijing. The detection scheme is shown in Figure 1. The apparatus is responsive to photons in the wavelength region from 380nm to 650nm. To obtain more accurate results, a semiconductor electric refrigeration unit is used. Operating voltage of the photomultiplier is set to 1036V.

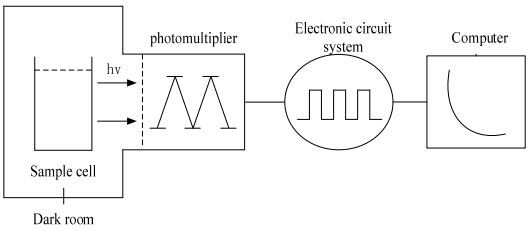

Figure 1. The Biological UWL Detector Principle

The measured sample in the sample cup is put into sample cell in a dark room. The dark room is in front of the photomultiplier. The photomultiplier records incoming photons, and turns optical signals into electrical signals. Then electrical signal inputs an electronic circuit system for processing. The computer is used to record the measurement data, and the software is used to control the whole measuring process.

The detector is equipped with a semiconductor refrigeration device, the refrigeration unit can make the temperature of photocathode of the photo detector far less than the room temperature about 10□. It can keep low noise count, therefore it has a lower detection limitation (the noise is mainly from dark current of the photomultiplier, and increases as the ambient temperature rises). The operating voltage of the instrument is calibrated by the C14 sample. This can ensure the higher efficiency of the detector (higher SNR). Stability relative to the standard deviation is less than 1.5%. The sensitivity is 10-15 W, measuring the weak light source of 10-13 W has a count rate of 1-20000/second, has high detection efficiency.

2.3. Methods

The UWL was measured twice, before and during imbibition of grains. The spontaneous intensity from air-dried grains was detected for 1000 seconds, and then the water-induced emission of the UWL was generated by adding of 5ml of distilled water. Measurements of the UWL from imbibing grains were continued for 1000 seconds. The counts per 10 seconds were the intensity unit. The whole measuring the UWL was recorded at 25±1□. The background noise was measured before every measuring and then deducted from the total counts per second in the measuring process. To avoid recording the light-induced luminescence from prepared samples of grain, they were kept for 30 minutes in the dark room, which is complete darkness, prior to the start of the UWL detection. In addition, the detection instrument is preheated about 30 minutes firstly to stable the background noise and reduce the error in the measurement.

3. Analysis and Results

3.1. The Background Noise Performance

The noise processing is the primary of signal processing. So, it is the key to grab the noise performance. For this study, the background noise is the data obtained while no wheat seeds are in the measurement. After the instrument setting the required temperature (28□) and started 30 minutes, the noise data is recorded. At this, the background noise is no obvious trend item and approximates to be stationary. As all known, the residual term is no contribution to the data information on the statistical significance if the mean of noise is deducted from the raw data. So, it is necessary to verify that the random background noise trends to stationary random signal in the study. To testify the stability of the noise, two steps would be taken. Firstly, the one-way ANOVA is used to examine the significance level among the various data sets. Secondly, the Run Test Method is applied to verify the stationary of background random noise. The sampling rate is 1 CPS (CPS: counts per second). And the quantity of sampling data is 1800. The data is divided into 6 groups. The results of one-way ANOVA are shown in Table 1.

Table 1. The Results of One-way ANOVA

Groups	Data Quantity	F	Fccit
1、2 group	300	1.40 2717	3.85 7056
2、3 group	300	0.01 1049	3.85 7056
3、4 group	300	0.69 654	3.85 7056
4、5 group	300	0.91 6537	3.85 7056
5、6 group	300	0.42 1447	3.85 7056

In Table 1, F is the mean square factor divided by the mean square error as a statistic. Fcrit means the critical value. Through comparing F and Fcrit, the significance can be judged. If F≥Fcrit, the significant difference may be considered. From Table 1, it can see that there is no significant difference among the noise data.

The principle and calculation course of Run Test can refer to the references (22), the test statistic (also called run values) is Z, the results are shown in Table 2.

Table 2. The Run Test Results of Noise Data

Groups	1	2	3	4	5
Z	0.2483	-1.0486	-0.4702	1.0423	1.1155
Groups	6	7	8	9	10
Z	1.1155	1.0565	1.4075	0.2717	-0.3755

As we know, the hypothesis could be received if $|Z| \leq 1.96$ for the significant level $\alpha = 0.05$. Table 2 shows that the background random noise could be as a stationary random signal approximately for one measurement. Because of the above, the measurement and calculation of the mean of noise are taken during each of the data acquisition. The data for subsequent process or analysis is the data deducted by the mean of background noise.

3.2. The UWL Analysis of New and Old Samples

The results of the study are shown in Figure 2-4. In all cases, the spontaneous UWL from both new and old dry grains was quasi stationary in time. The intensity of spontaneous UWL is relatively stable in the whole measurement process. Figure 2 shows that the UWL from the new sample is higher than the old sample.

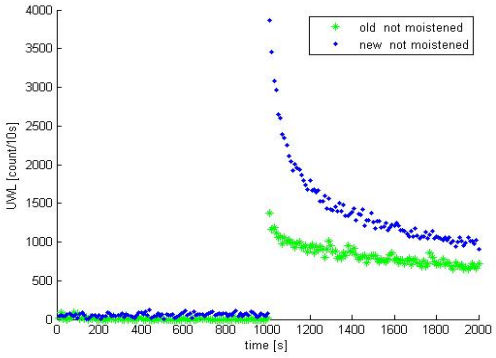

Figure 2a. Comparison of the UWL from group 0 hours of the new and old sample

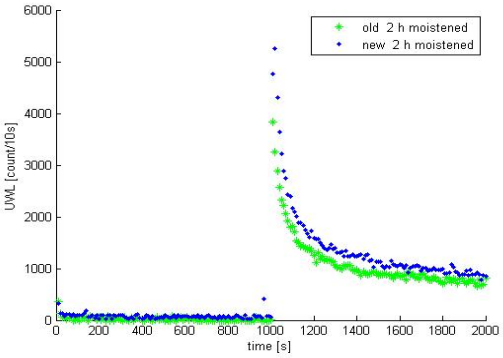

Figure 2b. Comparison of the UWL from group 2 hours of the new and old sample

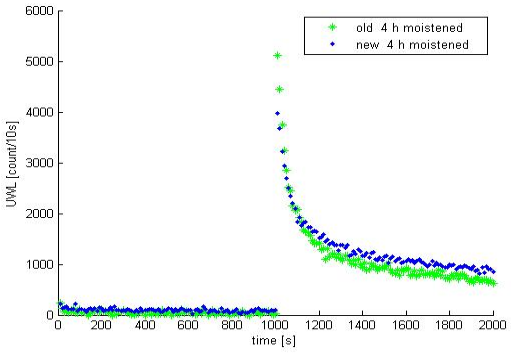

Figure 2c. Comparison of the UWL from group 4 hours of the new and old sample

After the dry grains were placed in water, the UWL suddenly increased, and achieved maximum reading immediately. At the first few minutes, the shapes of the curve of the new samples took a sharper decline than the old. Figure 2a and 2b show that the UWL from the group 2 hours and group 0 hours of the new sample is higher than the old sample. The initial value in the group 0 hours of new sample is 2.9 times that of the old sample. In the group 2

hours of new sample is 1.4 times that of the old sample. From Figure 2c, it can be seen that after the dry grains are placed in water with 30 seconds, the UWL from the group 4 hours of the new sample is higher than that of the old sample. Comparing these results, it may deduce that when the soak time is longer, the differences of the UWL in the new and old sample is smaller. The UWL from new and old grains has similar intensity after 2000 seconds in which the measurement is made. On the whole, the UWL from the old samples are weaker than from the new samples. It should be due to the weaker respiration and lower metabolism, that is, after a longer time of storage, the seed has a certain degree of deterioration and the membrane is repaired slowly, which reflect that there are some internal relationship between amount of biophoton emission and internal metabolic activity of the grains.

3.3. The UWL of New and Old Samples with the Moistened Time Change

Kinetics of the UWL from the not moistened and moistened of old samples are compared in Figure 3a. The shapes of the curves at the first few minutes of imbibition illustrate a quicker decrease of the UWL from old grain. However, the UWL is influenced by the previous period of moistened time. When the moistened time is longer, the UWL intensity is higher. It can be concluded that the UWL emission and the moistened time have positive correlation relations. Comparing these results, it may be deduced that the structure of the old sample moistened in water is more easily changed to produce a porous structure. The more porous structure can take in water more rapid and emit biophoton more highly.

From Figure 3b, it can be seen that the UWL of new sample is less dependent on the length of the soaking time than the old. In addition to water, the highest UWL is noted if the grain is moistened for 2 hours, then it obtains the similar level of the UWL from the not moistened and 4 hours moistened grain. It is worth noting that this curve is similar in shape to that obtained for the not moistened grain presented in Figure 2. Longer periods of moisture treatment of grain do not influence significantly the shape of the UWL kinetic curves. Generally, it is seen that the longer the grains were moistened, the higher UWL is noted.

In conclusion, the UWL initial value after adding water of old sample is higher as the moistened time is longer, the values of new sample are similar. This is because the respiration and metabolism activity of the old sample are strengthen generally in the effect of water stress so that the nutrient are decomposed rapidly and cell division, the effect results in the UWL enhancement. So the change of the UWL values may be reflected the wheat moistened time. These need future research.

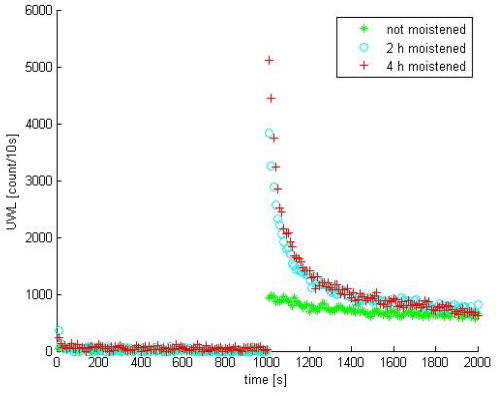

Figure 3a. Comparison of the UWL from 0, 2 and 4 hours moistened of the old sample

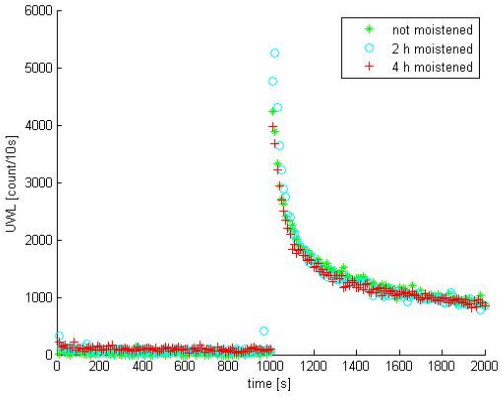

Figure 3b. Comparison of the UWL from 0, 2 and 4 hours moistened of the new sample

This induced UWL is described by an exponential function. With its sum of squares for error (SSE), root mean square error (RMSE) and R-square as fitting standard. Found that the optimal form is two-parameter exponential function.

$$I(t) = I_1(t_0)e^{-k_1 t} + I_2(t_0)e^{-k_2 t}$$

The indexes are shown in Table 3. Where $I(t)$ represents intensity of the initial UWL, $I_1(t_0)$ and $I_2(t_0)$ represent the UWL intensities at $t=0$ of the two exponential functions. k_1 and k_2 increase with the rise of the mechanical damage to the grain. t is the decay time.

Table 3. The Index Value of the Curve Fitting

Class	Sample	SSE	RMSE	R-square
Old	0 hours moistened	1.85E+05	43.89	0.8945
Old	2 hours moistened	3.14E+05	57.17	0.9892
Old	4 hours moistened	4.74E+05	70.25	0.9914
New	0 hours moistened	3.04E+05	56.27	0.9897
New	2 hours moistened	4.61E +05	69.29	0.9919
New	4 hours moistened	3.21E+05	57.83	0.9903

Analyzing the results in Table 4, it can be seen that k_1 increases with the rise of the moistened time and the mechanical damage to the grain, and k_2 increased with the rise of the moistened time in the old sample, there is little difference in the new sample. This implies that the UWL depends on the growth of grain porosity accelerating the process of the water absorption [23]. I_1 and I_2 are strength parameters. They depend on the nature of sample, to a great extent, at the same time they depend on the initial UWL intensity too. Initial intensity is related to excitation stiffness, volume (or dose) and the nature of the sample.

Table 4. The Parameter Value of the Curve Fitting

Class	Sample	k_1	k_2	I_1	I_2
Old	0 hours moistened	0.0146	0.0003278	331	983
Old	2 hours moistened	0.0170	0.0006211	2829	1281
Old	4 hours moistened	0.0199	0.0008337	4349	1452
New	0 hours moistened	0.0159	0.0006566	2309	1789
New	2 hours moistened	0.0166	0.0006598	4404	1593
New	4 hours moistened	0.0171	0.0006438	2810	1599

4. Conclusion

The following conclusions can be drawn from the study of the UWL of the old and new wheat.

1) The longer the grains are stored, the lower UWL is noted after water-induced. The reason is that with the growth of wheat storage time, the life activities are weakening. The UWL intensity is closely related to the vitality strength.

2) As the moistened time is longer, the UWL intensity being higher. This is due to that the endosperm structure will influence the emission of photons during the period of imbibition significantly. More porous structure allows more rapid uptake of water and higher emission of the UWL.

3) The water-induced UWL of the degerminated wheat is increasing obviously. This indicates that the wheat have stress response to mechanical damage so as to result in the rapid growth of the UWL. However, all of these are qualitative analysis. The future research should be more committed to the universal study for the quantitative relationship of samples and the UWL emission of them.

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