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EFFECT OF MOISTURE TREATMENT ON THE ULTRAWEAK LUMINESCENCE FROM IMBIBING WHEAT GRAIN*

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A b s t r a c t. Ultraweak luminescence (UWL) from mealy and vitreous wheat grain was investigated. Before the investigation the mealy and vitreous wheat grains were moistened in water for a period of 2, 4, 6 and 8 h. The grains were then dried to the mass they had before moistening. UWL measurements were made twice before and during imbibition of the grains. At the imbibition phase UWL was measured for 8 h. It was observed that UWL depended on the grain structure and the time of moistening. As moistened grain was of a more porous structure a higher UWL emission in the initial phase of imbibition was noted. Then UWL from the grains with a more porous structure quickly decayed. Finally after 8 h of imbibition UWL from moistened and not moistened grains was of similar intensity.

K e y w o r d s: mealy, moistened grain, type of endosperm, vitreous, ultraweak luminescence

INTRODUCTION

It is obvious that process of water uptake is indispensable to seed germination and is necessary for seedling development. However, the availability of water at a given period of time determines when seeds grow. If water is available for a period shorter than required, seed germination will be interrupted. However seeds denied water can be viable, provided that the process of water absorption is broken in the early stage of the imbibition phase [3,4].

During maturation, seeds can be moistened by rain or dew and then dried by sunlight repeatedly in varied time periods. Wheat seeds in an ear that are more exposed to interaction with water and light can lose vitrification, obtaining a more porous structure which diffuses light well, so that they look mealy. Qualitatively the mealy seeds are less hard and have lower technological value for milling [3].

Evidently transformation in the structure of seeds moistened and then dried by air may effect a change in the kinetics of the water absorption process when they imbibe for the second time. On the other hand, it can be expected that differentiation in the water absorption kinetics should be more clearly observable as the period of seeds moistening is longer. These assumptions allow us to postulate that these effects can influence variation in ultraweak luminescence (UWL) emitted from imbibing seeds [1]. This was partly proved by the fact that mechanical deformation accelerating the water penetration into wheat grains [5,6] can generate a higher UWL emission. The use of UWL emission as a sensitive and objective method for recording the water absorption rate of imbibing wheat grain has been considered [6].

In the present paper we suppose that UWL can be also modified by the structural change

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and damage to wheat grains as a result of their wetting and subsequent drying [7]. Therefore, the purpose of this study was measurement of UWL from imbibing vitreous and mealy wheat grains moistened previously in water for several given periods of time and then dried in free air.

MATERIAL AND METHODS

Spring wheat grains of Polish Henika variety from 1994 crop were used. The study was conducted after a one-year period of storage of the grains in laboratory conditions. Equilibrium moisture content, determined by drying three 10 g portions of the grain at 403±1 K for 1 h, was 8.2±0.1 % (mean±standard error). One fraction of grain thickness, in range from 2.4 mm to 2.6 mm, was chosen for the study. Vitreous and mealy grains were selected visually as being either completely vitreous or completely mealy. Then they were divided into samples chosen to fill the 180 cm^2 area of the base of a cylindrical measuring vessel. These samples were weighted with accuracy to a mass of one grain, so that they obtained a mean mass of 5.602±0.023 g.

Four samples of both types of grains were then soaked in distilled water for 2, 4, 6 and 8 h. The wet grains were next spread on sheets of paper and dried at a temperature of less than 293±1 K to the mass they had before soaking. One set of two different samples which had not been soaked, was used as control material. All the samples were then placed in small airtight containers and kept in a thermostatic box at a temperature of 293.0±0.5 K until the measurements of UWL were taken.

UWL was measured by apparatus equipped with a photomultiplier as a detector [6]. It was responsive to photons in the wavelength region from 300 nm to 760 nm and had maximal sensitivity at 450 nm. To obtain more accurate results a single-photon-counting technique was applied for UWL recording. Pulses counted upon 1 min periods and corrected for background counts were taken of UWL intensity, so that the counts per minute (cpm) were the intensity unit.

UWL was measured twice, before and during imbibition of grain. Spontaneous UWL from air-dried grain was detected for 60 min and then the induced emission of UWL was generated by adding of 10 ml of distilled water. Measurements of UWL from imbibing grain were continued for 8 h. In both cases UWL was recorded at 293±0.5 K. To avoid recording the light-induced luminescence from prepared samples of grain, they were kept for 3 h in complete darkness prior to the start of UWL detection. All the manipulations necessary before measuring UWL were also done in a dark room.

RESULTS AND DISCUSSION

The results of the study are shown in Figs 1-3. In all cases spontaneous UWL from both vitreous and mealy dry grains was quasi-stationary in time and slightly higher than the background of the apparatus. Analysing results in Fig. 1, no significant statistical differences at the level less than 0.05 were found between the average intensities of UWL from the mealy and vitreous dry grains. A slightly lower level of UWL was observed, however, in Figs 2 and 3 for the grains moistened previously for the shorter times.

After the dry grains were placed in water, UWL suddenly increased, giving maximum reading in the first minute of imbibition. The results in Fig. 1 show that UWL from the not moistened mealy grains was higher than UWL from the vitreous grains. Then UWL from mealy and vitreous grains had similar intensity and decreased continuously during the entire time in which the measurements were made.

Kinetics of UWL from the not moistened and moistened mealy wheat grain are compared in Fig. 2. The shapes of the curves at the first few hours of imbibition illustrate a more quick decrease of UWL from moistened grain. However, the UWL had been influenced by previous periods of wetting. Relatively small

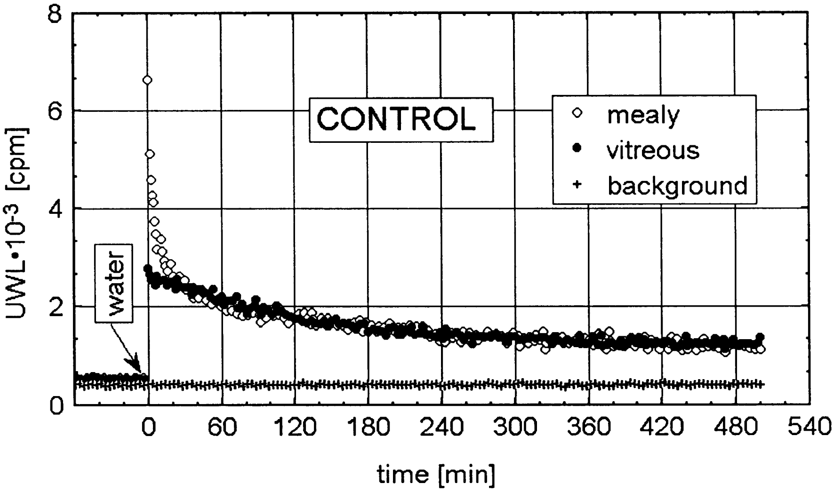

Fig. 1. Comparison of UWL from the control samples (not moistened) of mealy and vitreous wheat grain.

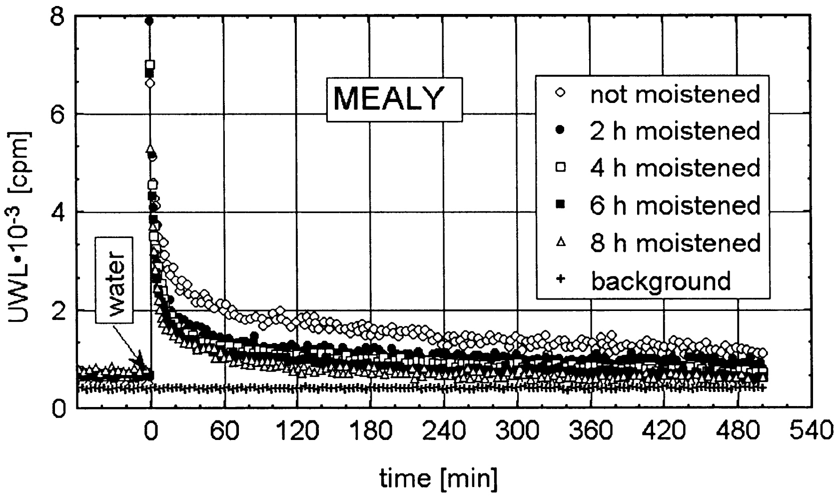

Fig. 2. Comparison of UWL from not moistened (control wheat grain) and moistened mealy wheat grain before initiation and during 8 h period of imbibition.

but observable differences showed that as the times of wetting the grains were longer, lower levels of UWL emission occurred. Comparing these results to those obtained for the not moistened mealy grain we may deduce that moistened grain took the water more quickly at the initial period of imbibition. However, at this period the rate of water absorption seemed to be greater as the time of moisture treatment was shorter.

The kinetic curves in Fig. 3 illustrate dependencies of UWL on the time of moistening the vitreous grain. Most clear differences between UWL from the not moistened and moistened grain occurred in the first few hours of imbibition. Immediately after addition of water the highest UWL was noted if the grain was moistened for 2 h. Then during subsequent 30 min it obtained the level of UWL from the not moistened grain. It is worth noting that this UWL kinetic curve is similar in shape to that obtained for the not moistened mealy grain presented in Figs 1 and 2. Longer periods of moisture treatments of grain did not influence

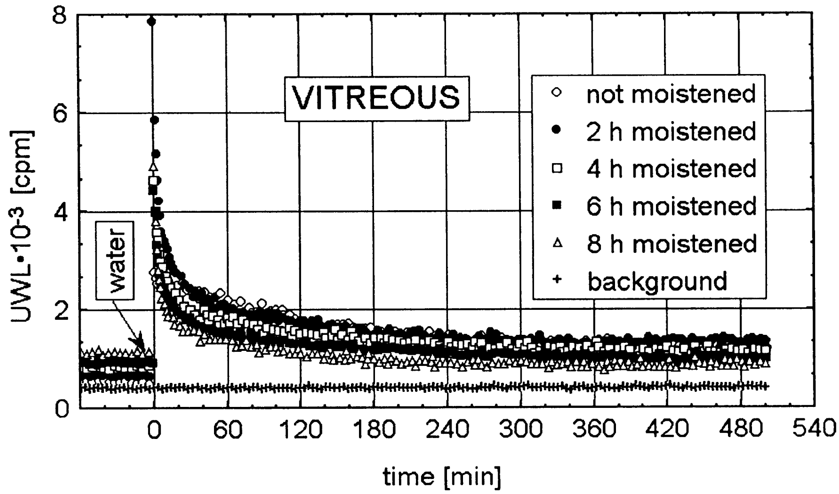

Fig. 3. Comparison of UWL from not moistened (control wheat grain) and moistened vitreous wheat grain before initiation and during 8 h period of imbibition.

significantly the shape of UWL kinetic curves. Generally it is seen that the longer the grains were moistened the lower UWL was noted.

According to the report [5] the intensity, $I(t)$, of UWL as function of time, t reveals two-phase decay with kinetic constant rates k_1 and k_2. This decay was described by two exponential equations of the form

$$I(t) = I_1(t_o)\, e^{-k_1 t} + I_2(t_o)\, e^{-k_2 t}, \quad (1)$$

where I_1 (t_o) and I_2 (to) characterised UWL intensities at $t = 0$ and were related to the first and to the second phase, respectively. As it has been shown values of I_1 (t_o), I_2 (t_o), k_1 and k_2 increased with the rise of the mechanical damage to the grain. A significant increase of the kinetic constant rates k_1 and k_2 as the mechanical damages was increased imlies that UWL depends on the growth of grain porosity accelerating the process of the water absorption.

To fit the data in Figs 2 and 3 by the function $I(t)$ from Eq. (1) the method of last square was used. Values of the estimated parameters are presented in Table 1. The correlation coefficients, r, calculated for the data presented in a linear semi-logarithmic coordinate system, are given in the last column of this table. The high r values (greater than 0.956) confirm our assumption that kinetic of UWL emission from imbibing grain can be well described by Eq. (1).

Analysing the results in Table 1, we can see that $I_1(t_o)$, I_2 (t_o), k_1 and k_2 obtained in the case of the not moistened mealy wheat grain are considerably higher than such representative values for the not moistened vitreous grain. The compared k_1 and k_2 values show that processes leading to UWL emission develop more quickly in the not moistened mealy grain. It seems that k_1 and k_2 values are dependent on the rate of the water absorption process. The higher k_1 and k_2 values may confirm the results of paper [7] in which the water absorption process occured more quickly in the mealy grain.

The greatest $I_1(t_o)$, $I_2(t_o)$ and k_1 values were computed for the mealy grain moistened for 2 h. In the group of moistened mealy grain $I_1(t_o)$ and $I_2(t_o)$ decreased and k_2 increased with the rise of the moisture treatment time. The values of k_1 were similar for the grain moistened during 2, 4 and 6 h. The lower k_1 value was computed as grain was moistened for 8 h. Even though this value of k_1 is lower, however, is greater than one obtained for the not moistened grain. The higher k_1 values indicate a more quick decay of the processes generating UWL emission in the initial phase of moistened grain imbibition. Calculating $(k_1)^{-1}$, we get the time t_1, characterising duration of this phase. Averaging k_1 values for the data of the grain moistened upon 2, 4 and 6 h periods, we get t_1= 4.3 min. The

Table 1. Values of I_1 (t_o), I_2 (t_o), k_1 and k_2 parameters from Eq. (1) fitted to the results in Figs 1-3

Structure	Samples	$I_1(t_o)$ (cpm)	$I_2(t_o)$ (cpm)	k_1 (min^{-1})	k_2 (min^{-1})	r
mealy	not moistened	3503	2117	0.09612	0.00136	0.979
	2 h moistened	6335	1487	0.26951	0.00120	0.960
	4 h moistened	5405	1311	0.25441	0.00148	0.963
	6 h moistened	5433	1260	0.26092	000165	0.967
	8 h moistened	3425	1136	0.13822	0.00167	0.963
vitreous	not moistened	1681	969	0.00626	-0.00037	0.989
	2 h moistened	4540	2037	0.11119	0.00114	0.963
	4 h moistened	2197	1727	0.07233	0.00108	0.972
	6 h moistened	2280	1531	0.08422	0.00129	0.967
	8 h moistened	2981	1336	0.13428	0.00107	0.956

times t_1 for the grain moistened during 8 h and for the not moistened grain are sufficiently greater and equal to 7.2 and 10.5 min, respectively. Because UWL is induced by the process of water absorption we may deduce that the shorter time t_1 is the grain more quickly imbibing.The values of k_2 indicate that duration of the second imbibition phase decrease as the grains were moistened longer. Estimating of $(k_2)^{-1}$, we see that time $t_2 = (k_2)^{-1}$ varied in the range from 833 min for the grain moistened during 2 h to 599 min for the grain moistened during 8 h. In comparison to these results the second imbibition phase of the not moistened mealy grain took about 735 min. These results demonstrate that the duration of the second imbibition phase had the tendency to decrease as the moisture treatment time increase.

Considering parameters in Table 1, fitted to the results obtained for the vitreous grain, we see that all $I_1(t_o)$,$I_2(t_o)$, k_1 and k_2 values are greater in the case of the moistened grain. From these parameters only values $I_2(t_o)$ decreased clearly as time of moistening increased. However, it is worth mentioning that higher k_1 and k_2 values suggest that both the first and second imbibition phases take a shorter time in the moistened grain. Computing t_1 and t_2, when k_1 and k_2 values for the moistened grain were averaged, we get 12.4 min and 1091.7 min, respectively. These values are considerably higher as those presented above for the moistened mealy grain. The highest value of t_1 =159.7 min was, however, obtained for the not moistened vitreous grain. These results suggest that the water absorption process develops more quickly in moistened vitreous grain. Negative value of k_2, for not moistened vitreous grain indicates that this grain exhibits a constant increase of UWL in the second imbibition phase.

CONCLUSION

As has been shown, endosperm structure significantly influenced the emission of photons generated during the initial period of imbibition. More porous structure allows more rapid uptake of water and higher emission of UWL. A much faster UWL increase occurs after the addition of water to mealy grains. Then the UWL from mealy grains more quickly decays. The lower UWL from the vitreous grains can be attributed to the existence of a more coherent and consequently harder endosperm structure. Generally it is true that the harder the endosperm, the slower the rate of moisture penetration and the lower the UWL emission, which was noted immediately after the seeds were placed in water.

As a final remark, two basic reasons for lower UWL emission from the vitreous grains in the initial period of imbibition may be considered. The first is that the slower water penetration into these grains cannot generate (or deactivate) such a great number of molecules in an electronically excited states as in the mealy grains. The second may be that mealy grains contain a greater number of substances [1] which interacting with water (or reacting in a wet environment) emit UWL more intensively. Regardless of whether the first or the second assumption plays a more important role, it can be stated here that UWL depends on structural changes in wheat grains moistened and then dried by free air.

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