Assessment of the degree of secondary luminescence generated by coffee subjected to influence of a constant electric field

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Abstract. The article presents the results of research on the influence of the constant electric field on the size and structure of the ultra-weak photon emission of selected coffee beans. In the research, a combination of the electric field's impact on the material was used, consisting in the use of 1800 cycles in which the time of exposure to the electric field with a voltage of 3kV was interrupted and renewed every 10 seconds. The experimental material was coffee in the form of whole grains and coffee in the form of granules ready to be dissolved in water. The PMT Photomultiplier tube method was used to count individual photons. It has been found that it is possible to use the single photon counting method to identify the type of coffee and stimulation with a constant electric field increases the differentiation of the photon emission values.

1. Introduction

Pilot studies on food parameterization by methods using the registration of fluorescence decay using the Time-Correlated Single Photon Counting (TCSPC) method were carried out on already processed products, observing the differentiation of photon emission [1]. The phenomenon of photon emission has been discovered in many microscopic and macroscopic systems [2,3,4], including in lipid systems, in bacteria [5], in multiplying yeast [6], in leukocytes [7], in nerve cells [8], in mitochondria and chloroplasts [9], in neoplastic cells [10], in liver tissue [10], in the kidney tissue [11], in body fluids [12]. Recent studies indicate that ultra-weak photon emission seems to be a good method to analyze the interaction of nanoparticles with various biological objects [13]. Biological systems emit very dim light without any external stimuli or have external phosphors. This phenomenon is currently commonly referred to as ultra-weak emission of a photon, which is present in practically all metabolically active systems [14]. This phenomenon is also referred to as biophotonic emission, autoluminescence or low level chemiluminescence. Two types of ultra-weak photon emission can be distinguished: spontaneous and induced. Spontaneous emission is defined as emission generated during the course of oxidative metabolism without any influence from external stressors or stimuli. The induced emission of photons can be initiated by various biotic and abiotic stresses and oxidizing factors. The measurement of the radiated light is carried out in the visible range of the spectrum with the highest sensitivity (> 10⁻¹⁷ W).

It seems that the emission of photons from organic matter has been the subject of research by many authors for many years, and its practical use does not raise any doubts, especially at the time that enables to take advantage of new, previously unavailable measuring tools. Trzyniec et al. [3] in USL measurements, which they used to parameterize various food products, e.g. apples, where the DL delayed luminescence method was used, and the sample was illuminated with light with an intensity of...
300 lx and a wavelength of 555 nm for 600 seconds. In this publication, the DL delayed luminescence method was used, exposure time 60 seconds, which resulted from the specificity of the analysed biological material. The method that was used to count the single photons is the PMT Photomultiplier tube. The co-authors of the project validated the USL method by presenting the results of research on the differentiation of photon emission using also traditional and widely recognized methods, where it was observed that eggs with higher photon emission have over 3 times higher content of carotenoids compared to eggs from caged hens. The obtained results confirm the assumption that the greater number of emitted photons is probably associated with a greater content of biologically active substances [15]. It should be noted that the authors of the publication have the accreditation of the Polish Center for Accreditation with the number AB1698 for the procedure of measuring photon emission from biological materials. In addition, they have a registered trademark Z.493517, which allows products to be labeled with a specific number of photons. Kielbasa et al. [16] tested the possibilities of using the ultra-weak luminescence emitted by organic matter for the assessment of its pro-health properties. The number of photons differed both between the studied food groups and in the context of the final products and ingredients constituting their recipe. It can be concluded that the change in the number of photons emitted is associated with a different content of substances added at various stages of production and the changing condition of the food product. The research showed that this method gives a practical possibility of differentiating organic matter in terms of the degree of photon emission.

Among non-alcoholic drinks, there are many options including coffee, tea, juices, sodas, etc. However, coffee ranks second to all water beverages, and people around the world consume about 500 billion cups of coffee annually. The fruit of the coffee tree was used in Ethiopia in the first millennium BCE and it is from the Ethiopian region of Kaffa that it got its name. The first coffee plantation was established in the 6th century AD in the Abyssinian plateau and the Somali peninsula. The Arabic people were the first to eat coffee around the 11th century and it came to Europe quite late, as in the Christian world it was considered a satanic invention. From the 17th century, coffee became a popular drink in Europe, although the issue of its health seems to be unsolved until today. The coffee beans are divided into unroasted (green) and roasted coffee. There are 70 different types of coffee, but the most important are Arabica and canephora. The two varieties differ in taste, appearance and caffeine content. The Arabica type is grown at an altitude of 600-1200 m above sea level in a subtropical or equatorial climate, while Robusta is grown at an altitude of 400-600 m above sea level or in flat areas. The type of bean coffee is drunk after the beans have been ground. Instant coffee is one type of coffee in the form of a dried extract. It is produced from coffee beans after grinding and subjecting to pressure extraction with water at 175 °C. The extract is then concentrated by evaporation or partial lyophilization and the obtained concentrate is dried [2].

2. Materials and methods
The aim of the research was to determine the size and structure of secondary luminescence, generated by coffee in two forms: beans (Jacobs Gold Krönung) and instant coffee (Jacobs Krönung Millicano). Additionally, excitation was applied in the form of a constant electric field on the tested material in order to emphasize possible differences in the emission of photons between the two types of coffee. The scope of the research included the preparation of the photon emission characteristics as a function of time, where the unit time interval for counting photons was 300 seconds and the total time interval was 1800 seconds.

Two forms of coffee were used in the research: beans (Jacobs Gold Krönung) and instant coffee (Jacobs Krönung Millicano). 10 g of seeds and instant coffee were weighed, subjected to a constant electric field, and then the photon emission was measured. Stimulation of the material with a constant electric field was conducted on a measuring stand equipped with a high voltage pulse generator with an adjustable voltage range from 0 kV to 30 kV, a control system enabling the maintenance of the preset length of the electric field interaction interval and the brakes between this interaction, and a chamber which was built of two flat electrodes between which pans were placed Petri dishes made of diaelectric material where biological material was placed (Figure 1).
After placing the dishes between the electrodes in the chamber, the material was subjected to an electric field. The following parameters were selected: 1800 pulses, time between pulses - 10 seconds, the value of set voltage 3 kV.

The research was conducted using the proprietary measuring system (Figure 2) consisting of elements that allowed the registration of photons on the basis of electromagnetic radiation emitted from living organisms. The HAMAMATSU R4220 photomultiplier detector was used for the recording. The light-emitting sample is placed in the measuring chamber. The chamber is thermally stabilised depending on the type of tests performed. The light-emitting sample was placed in a light-tight measuring chamber. The light-proof chamber is equipped with a set of targets for periodic shading of photon registration, as a result of which the value of measurement noise and emission are alternately measured. It is especially important when the intensity of the emitted radiation is residual and the recorded signal does not differ much from the measurement noise.

The method of counting single photons was used to determine the ultra-weak photon emission. The time interval of the single photon counting operation was determined experimentally each time depending on
the tested material (shell, albumen, yolk). The minimum length of the sample's residence time in the light-tight chamber is the appropriate time when the difference in the number of photons counted between two immediately adjacent one-minute time intervals is less than 10%. The measurement result of the ultra-weak photon emission is the absolute difference between the number of photons registered by the photomultiplier in the lightproof chamber with the material and the number of photons registered by the photomultiplier in this chamber without material, according to the relationship $L = AB$ [photon], where: $L$ - number of photons emitted by the tested sample, $A$ - number of photons emitted by the sample placed in the lightproof chamber, $B$ - number of indications (photons) generated by the empty lightproof chamber. The sensor calibration was performed each time on the measurement day and consisted in determining the ratio of the system response to the standard radiation dose. After the measurement system was started in the first phase with a time interval of 120 s, the system was stabilised to prevent disturbances resulting from temporary destabilisation of standard conditions. The initial phase was followed by the main (measurement) phase, the time interval of which was 1800 seconds and the frequency of recording the results was 4 Hz, i.e. each recorded result was the sum of photons counted during 0.25 seconds. These parameters were determined as mentioned above through preliminary experiments, but it also took into account the minimum exposure time necessary for observations leading to statistically significant test results. The main phase is followed by the final phase of the measurement in which the measurement sequence is stopped but not turned off. The entire measurement process is monitored in real time by an original application made in LabView.

3. Results
It was observed that the total number of photons emitted by the non-ground Jacobs Gold Krönnung instant coffee was 167 (Figure 3). The lowest number of photons, 21, was recorded in the first time interval 1-300s. After this time, the number of registered photons increased to the value of 34 in the next time interval, which was the highest result of photon emission, which remained at a similar level (33 photons) in the next measurement interval. Then, in the exposure time intervals 901-1200s and 1201-1500s, the number of emitted photons decreased to the value of 24 and 23 photons, respectively. However, in the last period of 1501-1800s there was an increase in the number of emitted photons.

Figure 3. Characteristics of Jacobs Gold Krönnung instant coffee photon emission as a function of their emission time
Taking into account the percentage structure of the number of photons emitted by instant coffee (Figure 4), it demonstrates to the highest emission in the time intervals 301-600s and 601-900s, which together accounted for 40.12% of the total photon emission in the studied period. The difference between the lowest value in the first interval followed by the highest value accounted for 7.79 percentage points. In the 901-1200s and 1201-1500s time periods it remained at a similar level. In the last interval 1501-1800s, the number of emitted photons accounted for 19.16% of the total number of photons and was a value close to the highest recorded during the measurement.

![Figure 4. The structure of photon emission of Jacobs Gold Krönung instant coffee during the measurement.](image)

During the examination of instant coffee stimulated with a constant electric field, the total number of recorded photons was 186. During the first three measurement intervals, the number of recorded photons slightly decreased from the value of 31 in the first interval to the value of 28 in the measurement interval of 601-900s. After a slight decrease, there was a significant increase to the highest recorded value of 37 photons in the measurement interval of 901-1200s. In the following period, there was a decrease to the lowest value of 26 photons, and then an increase in photon emission to the value of 34 was again observed. Thus, the oscillating nature of photon emission is clearly visible in the case of stimulation of the material with a constant electric field, although similar oscillation characteristics were observed in the case of unstimulated coffee, then the absolute values of the photon emissions are lower.
Figure 5. Characteristics of the photon emission of Jacobs Gold Krönung instant coffee as a function of the time of their emission, which was subjected to stimulation with a constant electric field.

Analysing the percentage structure of the observed photon emission from a Jacobs Gold Krönung instant coffee sample, which was subjected to stimulation with a constant electric field, it was found that in the first part of the exposure time (from 0 s to 900 s) the level was on average 15.95% (Figure 6). It should be noted that during the fourth emission interval lasting from 901 s to 1200 s, as much as 19.88% of the total number of emitted photons in the entire measurement cycle was registered.

Figure 6. The structure of photon emission of Jacobs Gold Krönung instant coffee subjected to stimulation with a constant electric field in relation to the time of their counting.

Figure 7 presents the photon emission characteristics of Jacobs Krönung Millicano coffee, where the highest photon emission value of 35 was recorded in the second time interval of single photon counting, ranging from 301s to 600s. The lowest number of identified photons was observed in the third counting time interval (601s-900s), where this value was 21 photons. In the remaining specified time intervals,
the number of emitted photons remained at a similar level. The total number of photons emitted by Jacobs Krönung Millicano coffee beans was 164.

Figure 7. Photon emission characteristics of the time function of Jacobs Krönung Millicano coffee beans

Analysing the structure of photon emission in relation to the counting time of single photons (Figure 8) emitted by a sample of Jacobs Krönung Millicano coffee beans, it was found that in the measurement time interval 301-600s, the photon emission was as high as 21.34% of all registered photons during the entire measurement cycle. On the other hand, the time interval of 601-900s accounted for only 12.8% of the total number of recorded photons. In the remaining specified time intervals for counting individual photons, the percentage of registered photons was at a similar level and oscillated around the arithmetic mean of the emission for the entire measurement cycle.

Figure 8. The structure of photon emission in relation to the time of measuring photon emission of Jacobs Krönung Millicano coffee beans

A slightly higher value of the total number of photons, amounting to 170 photons, was recorded for the Jacobs Krönung Millicano coffee beans, which was stimulated with a constant electric field, compared to the number of photons recorded for the Jacobs Krönung Millicano coffee, which was unstimulated
(164 photons). The highest value of 33 photons was recorded in the penultimate time interval 1201-1500s (Figure 9). A slightly lower emission result was registered in the last time interval 1501-1800s specified in the experiment, where the emission amounted to 32 photons. The lowest emission results of 24 photons and 23 photons were found in the measurement intervals of 301-600s and 901-1200s, respectively.

Figure 9. Photon emission characteristics of time function of Jacobs Krönung Millicano coffee beans, which were stimulated with a constant electric field

When analysing the percentage of photon emission in particular intervals of the measurement time, it can be noticed that the oscillatory nature of the emission changes, where the lowest value was 13.53% and the highest 19.41%.

4. Conclusion

It was found that the influence of a constant electric field on Jacobs Gold Krönung instant coffee samples causes an increase in photon emission and a change in the nature of the photon emission structure. In the case of Jacobs Krönung Millicano coffee, an increase in the total number of photons was also noted, however it was much smaller than in the case of Jacobs Gold Krönung coffee and amounted to only 6 photons. Nevertheless, in both cases, significant changes in the emission structure between samples of coffee stimulated with a constant electric field and samples of unstimulated coffee have been observed. There were also differences in the number of photons and the structure of their emission between the tested coffee samples. The results of the research demonstrate that it is possible to identify the coffee based on photon emission, and the use of a constant electric field is a differentiating factor that highlights the observed differences in the total number of photons and in the structure of their emission.

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