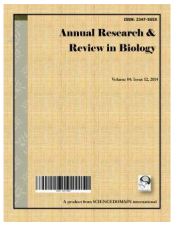

Annual Research & Review in Biology

20(5): 1-6, 2017; Article no.ARRB.37741
ISSN: 2347-565X, NLM ID: 101632869

Ozonation and Microwave Treatments as New Pest Management Methods for Grain Crop Cleaning and Disinfection

Daria Osintseva[1], Evgeny Osintsev[1], Maksim Rebezov[1,2,3], Lubov Prokhasko[1], Saule Seilgazina[4], Saypitin Kurmanbayev[4], Zhanat Nurzhumanova[4], Zhanibek Yessimbekov[4*], Vladimir Voytsekhovskiy[5], Nikolai Maksimiuk[6] and Rustem Zalilov[7]

[1]South Ural State University, Chelyabinsk, Russia.
[2]Russian Academy of Staffing of Agro-Industrial Complex, Moscow, Russia.
[3]Ural State Agrarian University, Yekaterinburg, Russia.
[4]Shakarim State University of Semey, Kazakhstan.
[5]National University of Life and Environmental Sciences of Ukraine, Kiev, Ukraine.
[6]Yaroslav-the-Wise Novgorod State University, Veliky Novgorod, Russia.
[7]Nosov Magnitogorsk State Technical University, Magnitogorsk, Russia.

Authors' contributions

This work was carried out in collaboration between all authors. Authors DO, EO and MR designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors LP, ZY, SS and SK managed the analyses of the study. Authors ZN, VV, NM an RZ managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ARRB/2017/37741
Editor(s):
(1) George Perry, Dean and Professor of Biology, University of Texas at San Antonio, USA.
Reviewers:
(1) Imtiaz Ahmad, University of Peshawar, Pakistan.
(2) Eyyüp Mennan Yildirim, Adnan Menderes University, Turkey.
(3) Helena Viric Gasparic, University of Zagreb, Croatia.
(4) Alexandre Bosco de Oliveira, Federal University of Ceará, Brazil.
Complete Peer review History: http://www.sciencedomain.org/review-history/22203

Original Research Article

Received 26th October 2017
Accepted 4th December 2017
Published 8th December 2017

ABSTRACT

This article shows how high-intensity electric fields are effective in grain disinfection and cleaning. The use of high-intensity electric fields for influencing biological matters opens the prospect for the use of electro-technology in biotechnology, agro-industrial production, medicine and other branches

**Corresponding author: E-mail: zyessimbekov@gmail.com;*

of the national economy. The authors found that the efficiency of disinfection is determined by the duration, intensity and sequence of external physical influences. The parameters were identified, whose effects are destructive for insect cells and safe for grain cells. The longer the exposure time, the effectiveness of disinfection is greater. A 100% lethal effect of all types of insects occurred already at 30 seconds, which indicates a 25% microwave exposure time reduction. In addition, the study shows the function of changes in separation angles of grain from the surface of the crown type electric separator drum, thereby confirming the possibility of implementing electro-technologies in cleaning.

Keywords: Electro-technologies; electro technical installations; grain; grain cleaning; electric fields; process of electrical separation.

1. INTRODUCTION

Prohibitive sanctions enacted to Russia by other countries opens up opportunities for Russian developers in various sectors of the national economy. The Government of the Russian Federation has developed a number of draft laws to support agricultural producers. Particular attention is given to the development of grain production, as well as the introduction of new types of machines and technologies. The technological lines being developed must meet ecological requirements which can be achieved by using high-intensity electric fields.

In any freshly picked grain there are considerable amount of pathogen bacteria, insects and mites [1]. These grain pests under favourable conditions have a negative effect by reducing the amount of dry matter and contaminating and spoiling the grain crop. For preventing the crop failure it is necessary to disinfect and disinsect the freshly picked grain before the storing period. The grain crop that has not been disinfected properly is became the reason of decreasing the quality of grain crop and the level of crop yield [2].

Implementing new electrical technologies and developing new electro technical installations call for a theoretical analysis of electrical grain separation [3,4,5]. The purpose of this work is to determine the parameters of the physical effects on grain during disinfection. Moreover, the aim is to find whether the known calculation methods used in electrical grain separation within the field of crown discharge can be applied in field testing or not.

Number of scientists around the world has done research concerning selective heating of agricultural products [6-16], of which some are about the issues of disinsection [3-8]. The main purpose of the research is to determine the optimum time and frequency of microwave exposure. Heating by microwave energy makes possible to accurately dose the heating, thereby fulfilling the selective heating condition for grain and insects.

It was necessary to determine the parameters of grain disinsection with the help of ozone and microwaves during the course of preliminary studies. It is well known that among the various types of electromagnetic field treatments on living tissues, ozonation is the most suitable means for disinsecting grains. Ozone has a harmful effect on the body of insects - it destroys the weak and weakens the strong insects [17]. Ozonation has a stimulating effect on seeds at low ozone concentrations. Thus, ozonation is the most suitable preliminary treatment of grain prior to microwave radiation [18].

The purpose of this paper is to study the effects of electric field on grain crop cleaning and disinfection

2. MATERIALS AND METHODS

The processing of the experimental data was carried out in accordance with the developed methodology.

As can be seen in the Fig. 1 the experimental study consists of next stages: 1 – seed preparation; 2 – insect contamination of seed; 3 - insects rearing; 4 – sampling; 5 – disinfection process.

Wheat seed preparation: Two varieties of wheat seed were selected “Rossiyanka” and “Krasnoufimskaya-100” sampled from “Agro-SelhozProduct” farm in Chelyabinsk city and from “Belorechenskiy” farm in Sverdlovsk region. Wheat seed moisture content was about 14.0%.

Insect contamination of seeds: The wheat seed was stored in the glass jars (10 l each) where the insects (*Sitophilus granaries*, *Sitophilus oryzae*, *Ostrinia nubilalis*, *Plodia interpunctella*) were placed. Each species of insects were placed into jars in the proportions of 30-50 insects per jar. The glass jars were closed with plastic caps with holes for air flow. Totally, 12 glass jars (3 jars for each type of insects) were prepared for experiments.

Insects rearing: The jars were stored at 20-25°C with low light. Such kind of environment allowed quickly reproduction of insects. After 1.5 month the population of insects increased twice. Herewith the insects were in the different stage of growing – from larvae in the crop to adult insects.

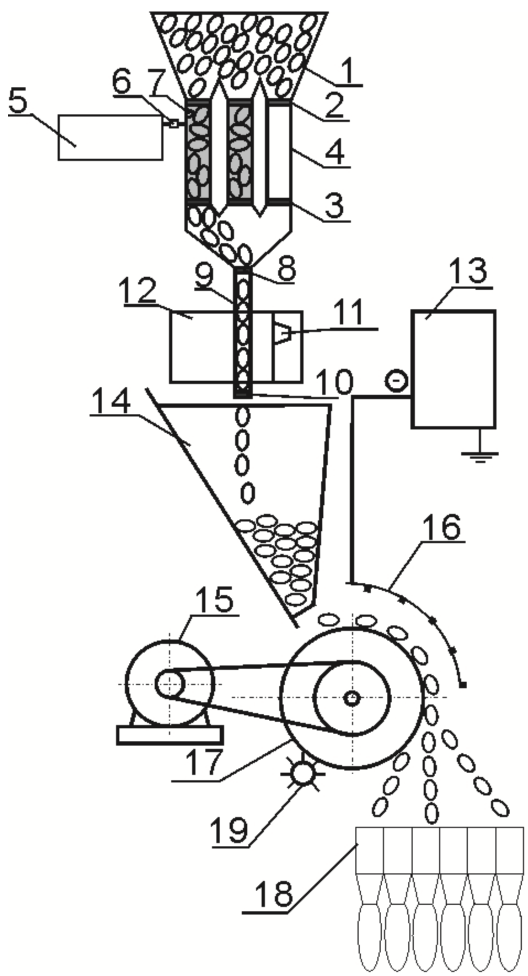

Fig. 1. The seed disinfection and insect removing unit

The disinfection unit (Fig. 1) consists of an electric motor 6, ozonizer and ozonizing chamber, microwave emitter which installed before the hopper 5, high voltage source 7, ionizing electrode 1, receiving electrode 2, separator 4, brush 3 for removing the adhered particles [19].

This unit works in a following way: the ozonizer, microwave emitter and corona-type separator can disinfect the grain crop and kill the insects and separate the crop from the foreign matters. Ozonizing effect weakens the strong insects or kills the weak insects. Without the ozonizer the grains would require longer treatment in microwave emitter (about 35 sec against of 23 sec while using of ozonizer) which can cause grain viability damage. The corona-type separator is required for separating the killed insects from the grain crop.

Theoretical calculation of the values of grain separation angles of different category grains: whole, with insects inside are compared with experimental data obtained during field trials at OAO Beloretskoye.

Certain developed methods are used to calculate the separation angles, which for most laboratory test conditions yield results with sufficient accuracy for engineering calculations.

Investigation includes numerical computation of a grain falling place after separation from a surface of a conveyor belt. The next differential equations are used for calculation of total current density on the surface of an ellipsoid

$$\gamma_2 E_{2n} + \varepsilon_0 \varepsilon_2 \frac{dE_{2n}}{dt} = \gamma_1 E_{1n} + \varepsilon_0 \varepsilon_1 \frac{dE_{1n}}{dt}, \quad (1)$$

On the basis of equation (1), stress relations for the point A

$$E_{1n}^{(A)} = \vec{E}_1 = \vec{E}_0 - \frac{\chi \sigma^{(A)}}{\varepsilon_0}$$
$$E_{2n}^{(A)} = \vec{E}_0 + \frac{1-\chi}{\varepsilon_0} \sigma^{(A)} \quad (2)$$
$$\chi = \frac{1-\beta^2}{2\beta^2} \left(\ln \frac{1+\beta}{1-\beta} - 2\beta \right)$$

where χ is the depolarization coefficient of the ellipsoid

β – ellipsoid eccentricity $\beta = \frac{\sqrt{a^2 - b^2}}{a}$.

This equation takes into account only two axes of the ellipsoid, which makes it possible to calculate objects roughly resembling a biaxial ellipsoid. Some types of grain crops are of forms of flattened ellipsoid and this equation is not applicable, so an adjustment is introduced to the coefficient that takes into account the third axis of the ellipsoid

$$\beta = \frac{\sqrt{a^2 - \frac{c^2}{1 - \frac{\sqrt{b^2 - c^2}}{b}}}}{a}. \quad (3)$$

For the triaxial ellipsoid, the analytic distribution of the field is known on the surface and in the vicinity of the ellipsoid. The electric field strength at the surface of the ellipsoid is written as:

$$\mathrm{E} = -\frac{\mathrm{E_0} \cdot \mathrm{x}}{\mathrm{a^2} \cdot \chi} \cdot \left[\left(\frac{\mathrm{x}}{\mathrm{a^2}}\right)^2 + \left(\frac{\mathrm{y}}{\mathrm{b^2}}\right)^2 + \left(\frac{\mathrm{z}}{\mathrm{c^2}}\right)^2 \right]^{-\frac{1}{2}} \quad (4)$$

where a, b, c are the semiaxeses of the ellipsoid,

As a result, a *Simulink* (Mathlab) program was used for modeling a process of electrical separation of grain of different categories with new refinement coefficients.

3. RESULTS AND DISCUSSION

Fig. 2 shows the relation between the effectiveness of grain disinsection and microwave exposure time after ozonization with specified parameters: the dosage does not exceed 2.5 g / liter; duration of ozonation does not exceed 2.5 minutes. The longer the exposure time, the effectiveness of disinfection is greater. The heating time cannot be increased infinitely; it has a limit based on maintaining the viability of the grain.

Fig. 2 shows that the preliminary ozonation shifts the dependence of the disinsection effectiveness on microwave time to the left meaning that lethal effect occurred with a shorter time. A 100% lethal effect of all types of insects occurred already at 30 seconds, which indicates a 25% microwave exposure time reduction. Thus, it can be assumed that the preliminary ozonation allows reduction of the amount of energy necessary for the complete destruction of insects by a quarter. Types of insects play an important role in setting the parameters of ozonation and microwave irradiation. Sayed (2004) reported that the ozonation treatment killed 100% of all the insects (*Sitophilus oryzae*) in dried wheat seed (moisture 12%) and 78% of all insects in the wheat seed with the moisture content of 15-18% [20].

Experiment results can provide basis to assume that there is a direct relationship between the insect dielectric parameters and the technological parameters of disinsection of grain (ozonation: concentration and exposure; microwave radiation: exposure time).

Fig. 3 demonstrates a relationship constructed from experimental points with the help of a theoretical model. Fig. 3 shows the results of experiments, constructed from experimental points, which confirms the mathematical model.

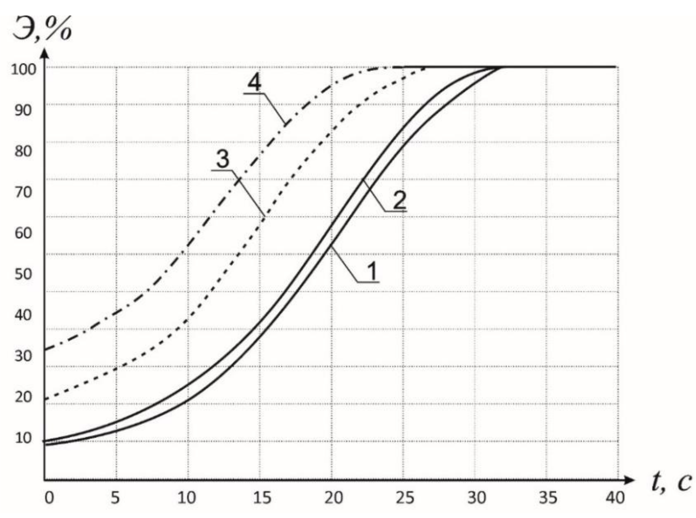

Fig. 2. Relation between the effectiveness of grain disinsection and microwave exposure time after preliminary ozonation: 1 - grains damaged by a *Plodia interpunctella*, 2 - grains damaged by a *Ostrinia nubilalis*, 3 - grains damaged by *Sitophilus oryzae*, 4 - grains damaged by *Sitophilus granarius*

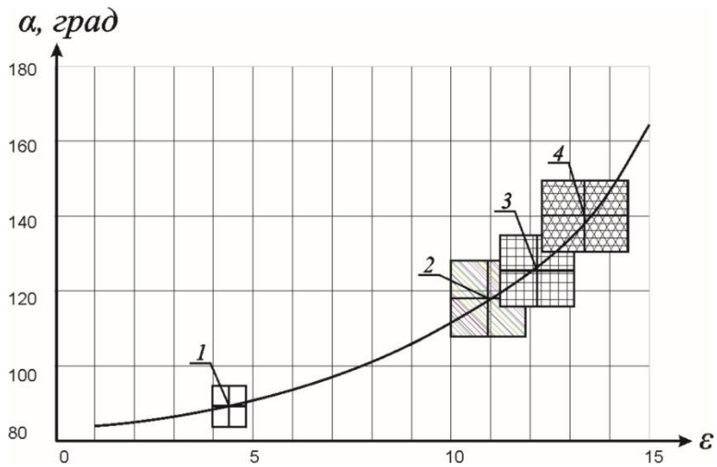

Fig. 3. Relationships of theoretical equation and experimental data on the angle of grain separation: 1 - whole seeds; 2 - seeds with *Sitophilus granaries* inside; 3 - seeds with *Ostrinia nubilalis* inside; 4 – seeds with *Sitophilus oryzae*

The correlation coefficient calculated for the dependence is, r = 0.9.

As can be seen from the figure, whole grains and grains with insects inside have different values of the dielectric permeability, and hence different angles of separation from the drum. For instance, whole grains have a dielectric constant in the range of 2 to 5 and a separation angle of 80°-100°, while grains with insects inside have values of the dielectric constant from 11 to 14 and the angle of separation 110° to 140°. Moreover, the type of insect species significantly influences the value of the dielectric constant and separation angle from the drum, for example, grains with rice and granary weevils differ insignificantly, and the valuesof the permeability are in the range of 13-15 and the separation angles 120°-160°. For grains with *Ostrinia nubilalis*, the permittivity values were obtained in the range of 13-16, and the separation angles from the drum 130°-170°. For grains with grain moths, the range of permeability is 14 -17, and the separation angle is 140°-170°.

4. CONCLUSION

Preliminary ozonation allows reducing the amount of energy necessary for the final destruction of insects by a quarter. Type of insects plays an important role in setting the parameters of ozonation and microwave irradiation. The conducted field tests confirm the mathematical model of cleaning whole grains from grains with insects. Furthermore, the method previously developed by the authors can be recommended for determining grain separation angles from the surface of a crown type electric separator drum. The developed design allows using it as a prototype for creating similar lines with high-intensity electric fields as physical effects, which can be introduced in the production of food, medicine or agriculture.

ACKNOWLEDGEMENTS

Our works are carried out as a part of the contract "Development of a technological line for obtaining high-quality seeds from illiquid grain material", signed within the framework of the program "participant of the youth scientific and innovation contest" organized by the foundation for promotion of small forms of enterprises in the scientific and technical spheres. The research project was awarded first place in two contests: Skolkovo competition "Startup tour 2016" and the Umnik contest, both occasions took place in Chelyabinsk on February 16, 2016.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Guedes RNC, Smagghe G, Stark JD, Desneux N. Pesticide-induced stress in arthropod pests for optimized integrated pest management programs. Annual Review of Entomology. 2016;61:43-62.

2. Gorskiy IV. Using of ozone for wheat seed disinfection. Scientific works of All-Russian Institute of Mechanization. 2003;148:192-196.
3. Basteev AV, Bazyma LA, Kutovoy VA. Complex high-frequncy technology for protection of grain arain against pests. Journal of Microwave Power and Electromagnetic Energy. 2000;35(2):179-184.
4. Feng H, Tang J, Cavalieri RP. Dielectric properties of dehydrated apples as affected by moisture and temperature. Transactions of the ASAE. 2002; 45(1):129–135.
5. Nelson, S.O. Radio – frequency and microwave dielectric properties of insects. Journal of Microwave Power and Electromagnetic Energy. 2001;36(1):47–56.
6. Nelson SO. Agricultural applications of dielectric measurements. IEEE. Transactionson Dielectrics and Electrical Insulation. 2006;3:567–574.
7. Nelson SO, Bartley PG, Lawrens KS. RF and microwave dielectric properties of stored – grain Insect and their Implications for potential Insect Control. 1998;672–685.
8. Nelson SO. Radio – frequency electric fields for stored – grain insect control / S.O. Nelson, W.K. Writney // Transactions of the ASAE. 1960;3(2):133–137.
9. Nelson SO. Rewiev and assessment of radio-frequency and microwave energy for stored-grain insect control / S.O. Nelson // Trans. ASAE.–NewYork. 1996;39(4): 1475–1484.
10. Nelson SO. Radio – frequency electric fields for stored – grain insect control / S.O. Nelson, W.K. Writney // Transactions of the ASAE. 1960;3(2):133–137.
11. Ondracek J, Brunnhofer V. Dielectric properties of insect tissues. Gen. Physiol. Biophys. 1984;3:251–257.
12. Ryynanen S. The electromagnetic properties of food materials: A review of the basic principles. J. Food Eng. 1995; 29:409–429.
13. Schroth, P. Biosensoren auf der Basis von Haibleiter FeldeffektstrukturenmitangekoppeltenInsektenantenn. P. Schroth. Dr. rer. nat.; 2009.
14. Tang J, Feng H, Lau M. Microwave heating in food processing. Advances in bioprocessing engineering. 2002;1-43.
15. Tretyak L, Rebezov M, Toshev A, Zalilov R, Prokhasko L, Abuova A, Loretts O, Okuskhanova E, Zaitseva T. The use of ozone-air mixture for reduction of microbial contamination in grain brewing raw material. Annual Research & Review in Biology. 2017;14(6):1-9. DOI: 10.9734/ARRB/2017/33292
16. Wang S, Tang J, Cavalieri RP, Davis DS. Differential heating of insects in dried nuts and fruits associated with radio frequency and microwave treatments. Transactions of the ASAE. 2003;46(4):1175–1182.
17. Lesser VM, Rawlings JO, Spruill SE. Ozone effects on agricultural crops: Statistical methodologies and estimated dose-response relationships. Somerville: Crop Sci. 1990;148–155.
18. Atefe S, Ashraf MT, Hossein A, Gholamreza M. Modified ozonation process performance with the nanoparticles of copper in disinfection of *Leachate*. Journal of Environmental Science and Technology. 2016;9:157-163.
19. Osintseva DV, Osintsev Ye G. Crown type electric separator of dielectric particles: Utility Patent, Order #2013146472/03(072156), 17.10.2013. Date of publishing 10.04.2014, Bulletin # 10, Russia.
20. Sayed YKM. Biological activity of ozone for disinsection of stored grain. PhD-thesis abstract. Moscow; 2004.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/22203