PHYSICAL METHODS IN AGRO-FOOD CHAIN
ФИЗИЧНИ МЕТОДИ В АГРОХРАНИТЕЛНАТА ВЕРИГА

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ABSTRACT

Chemical additives (fertilizers and plant protection preparations) are largely used for improving the production yield of food produce. Their application often causes the contamination of raw materials for food production, which can be dangerous for the health of consumers. Alternative methods are developed and implemented to improve and ensure the safety of on-farm production. The substitution of chemical fertilizers and soil additives with alternative treatment methods, such as irradiation, ultrasound and the use of electromagnetic energy are discussed. Successful application of physical methods in different stages of food-preparation is recommended.

Key words: irradiation; ultrasound; food, quality, safety.

РЕЗЮМЕ

Химически препарати (торове, растително-защитни препарати) широко се прилагат за повишаване на добивите на селскостопанска продукция. Използването им често причинява замърсяване на суровините за хранителната промишленост, което представлява опасност за здравето на консуматора. Разработени са алтернативни методи за повишаване на добива и осигуряване на безопасна селскостопанска продукция. Обсъдена е замяната на химичните препарати с алтернативни методи за стимулация, като облъчване с електромагнитни вълни, ултразвук и магнитно поле. Препоръчва се прилагането на физични методи в различни стадии от агрохранителната верига.

Ключови думи: облъчване, ултразвук, качество, безопасност, храни.

РАЗШИРЕНО РЕЗЮМЕ

Бурното развитие на химията през миналия век доведе до широко прилагане на химични препарати в различните етапи на развитие на селскостопанските култури - торове, растежни стимулатори, растително-защитни препарати за третиране в полски и складови условия. Остатъчни количества от тези препарати се установяват в суровините за хранителната промишленост. Проблемът е още по-сериозен в животновъдството, където към третираните растения, използвани за хранене на животните, се добавят химични фармацевтични препарати и хранителни добавки. В края на веригата растения-животни-човек вредните вещества се натрупват и представляват сериозна заплаха за човешкото здраве.

Замяната на химичните препарати с третиране с физични фактори като магнитно поле, ултразвук, облъчване с електромагнитни вълни е добра възможност за намаляване рисковете за безопасността на храната, чрез намаляване замърсяването на водата, почвата, понижаване концентрацията на вредни вещества в хранителните суровини.

Изследвано е въздействие с магнитно поле, ултразвук, облъчване с лазер и микровълни върху зеленчукови и зърнени култури. Установено е подобряване на биологичните показатели на растенията.

Предложена е хипотеза за обяснение на стимулиращия ефект от третирането на растенията с физични фактори. Хипотезата се основава на вътреклетъчна трансформация на внесената чрез физичното въздействие енергия.

INTRODUCTION

Impetuous development of chemistry in past century leaded to the large application of chemical products in many stages of plant growth – as soil additives, fertilizers, different plant protection preparations, for on-field as well as storage use. Residual quantities of these substances can be found in the row materials for food industry. The problem is even more ominous in animal breeding, because the plants are used for feeding the animals. Additionally the use of chemical pharmacy products for healing and stimulation of live processes raise the rescue in row materials of animal origin. At the end of the chain plant-animal-man the harmful substances are accumulated and this is a serious menace for human health.

Nowadays the importance of food quality is rising very fast. Different documents on national and European level deal with food quality assurance and control. Urgent measures for decreasing food safety hazards are needed.

The risk of food safety hazards occurring during on-farm production for fresh produce is closely related to the use of herbicides, fertilizers, and other chemicals. Soil and water contamination generates toxic compounds in plants that worsen the food quality. In order to raise food safety it is necessary to control and keep the concentration of harmful substances in foodstuff in reasonable limits.

High levels of toxins, exceeding maximum residue levels (MRLs), may be found in food produce, from the use of soil or foliar fertilizers, soil additives, fumigants, herbicides that are applied for crop nutrition and the management of pests and disease. Soil contamination of growing sites can lead to the contamination of food produce. However, the amount of the chemical present in the food produce is more important than that found in the soil. MRLs permitted for these persistent chemicals in food produce have been set by governmental agencies [6, 7]. Water pollution from nitrates is causing problems in all EU Member States. The source of nitrate pollution is often difficult to be located. The main polluters are farms; even though farmers are strongly sensitive to anything which affects the economic viability of their activity [8]. According to EU statistical data from the 1980s, a progressive worsening of the situation has been detected (i.e., nitrate concentrations in water rose by an average of 1 mg/l per year). As a result, EU directives and regulations have been published urging Member States to consider establishing and implementing action programmes in respect of vulnerable zones [11, 12]. They must include measures prescribed in the codes of good

Table 1. Effect of magnetic field on soybean seeds, cv. *Daniela*
Таблица 1. Въздействие на магнитното поле върху семена от соя, *Daniela*

Exposure time (min)	Germination (%)	Germinative energy (%)	Fresh weight (g)
0	**52**	**23.0**	**5.8**
10	**88**	**32.0**	**15.8**
15	**96**	**30.0**	**11.7**
20	**88**	**22.0**	**8.1**
30	**72**	**25.55**	**9.6**

agricultural practice and measures to limit the spreading on land of any fertilizer containing nitrogen.

Soil nutrients and fertilizers are composed of one or more plant nutrients (or fertilizing elements) and also include different chemical compounds. Nitrates and nitrites are major components of soil nutrients and fertilizers and have been used for many years in field treatments. Without the addition of these compounds, crops would deplete nitrogen from the soil. Unfortunately, the use of nitrogen fertilizers can result in contamination of wells and groundwater, causing health risks especially among young people [10].

Experimental

The substitution of chemical fertilizers and soil additives with the influence of different physical factors as magnetic field, microwave and laser radiation, and ultrasound treatment is a good alternative targeted to decreasing food safety hazards. The treatment with physical factors enables the plants to accelerate the initial development, leading to an increased production with a guarantee of a localized impact. In the same time, the substitution of chemical additives by a physical factor of stimulation can lead to lower levels of nitrates and nitrites in produce. This alternative way to decrease the pollution by using physical factors of stimulation has been investigated in number of works and recently reviewed by Aladjadjiyan, 2007 [4].

A number of physical factors for substitution of chemical additives have been investigated: magnetic field, laser irradiation, microwave irradiation, ultrasound treatment. Experiments have been conducted in vegetable production (on tomatoes, carrots and peppers) as well as in grain production (on maize, soybean and beans). The exposure time had been selected considering the intensity of physical factor and intending to assure introduction of enough energy in the treated object. The following relation was used:

$\Delta t = \Delta E/I\ \Delta\ S,$

where E is the irradiated energy, I – the intensity of irradiation, S – the irradiated surface and t - the time of the treatment with the physical factor.

Detailed description of experiments has been presented in [1].

Results of the investigation have been developed as educational material for international master courses [3].

Results and discussion

Part of results is presented in next Tables 1-3. They have been selected among all in order to demonstrate the effect of different methods of treatment on plant growth indices and to allow comparing them.

Table 1 presents the results of magnetic field treatment on the germination, germinative energy and fresh weight of soybean seeds, cv. Daniela.

Table 2 presents the effect of ultrasound treatment on the same parameters for carrot seeds, cv. Nantes.

Table 3 presents the effect of two irradiation methods on the growth of bean seeds. In the first part of the table the result of treatment with He-Ne laser is presented, and in the second – with microwave irradiation. The fresh weight of the roots is measured as indication of the effect of the treatment.

In all cases the fresh weigh was measured with automatic electron weighter with accuracy 0,01g.

It was found out that the physical treatment led to changing of seed vitality indices (germinating energy, germination, and uniformity of germination).

A hypothesis explaining the effect of stimulation on an energetic basis has been proposed by Aladjadjiyan [1]. It is evident that chemical additives import chemical nutrients necessary for plant growth directly in soil from where they are included in food chain. Instead, all of the investigated physical factors import different kind of energy into the cells. The hypothesis presumes that imported energy is absorbed by the electrons in different molecules. The absorbed energy may be transformed in another kind of energy (most probably chemical one) and then used for accelerating the seed metabolism. In this case no foreign substances appear in the food chain; only those produced in the cells.

The influence of physical treatment on vitality indices of microorganisms and the possibility to use it as disinfector has been a subject of number of investigations. A thorough study of alternative processing technologies was performed in the Center for Food Safety and Applied

Table 2. Effect of ultrasound treatment on carrot seeds, cv. *Nantes*
Таблица 2. Въздействие на ултразвук върху семена от моркови, *Nantes*

Exposure time (min)	Germination (%)	Germinative energy (%)	Fresh weight (g)
0	**76.3**	**65.3**	**67.6**
1	**75.3**	**65.6**	**68.0**
5	**89.3**	**79.6**	**82.6**
10	**83.0**	**68.6**	**73.6**

Table 3. Effect of two irradiation methods on the growth[a] of bean seeds

He-Ne-laser irradiation[b]

Таблица 3. Въздействие на два вида лъчение върху растежа[a] на семена от боб

Облъчване с He-Ne-лазер[b]

	Without Water		With Water	
Exposure time (min)	**Day 14**	**Day 21**	**Day 14**	**Day 21**
0	**3.8**	**4.4**	—	—
5	**3.8**	**5.8**	**3.90**	**4.6**
10	**4.6**	**6.2**	**2.60**	**4.5**
15	**5.1**	**5.9**	**5.05**	**5.1**
	Microwave irradiation[c] ***Микровълново лъчение***[c]			
0	**0.097**	**0.106**	—	—
10	**0.129**	**0.136**	**0.147**	**0.159**
20	**0.157**	**0.161**	**0.172**	**0.192**
35	**0.176**	**0.197**	**0.194**	**0.213**

[a] Fresh weight (g) of roots

[b] Bean seed cv. *Plovdiv 564* [13]

[c] Bean seed cv. *Dobrudjanski* [5]

Nutrition of U. S. Food and Drug Administration in 2000 [9]. The result was the identification and "understanding of many exciting, emerging, alternative technologies that have potential for enhancing the safety and quality of food". A rich review of the bibliography on the use of physical factors in food safety is presented in the study.

The study includes some explanations of the results of physical treatment. There are two mechanisms proposed for inactivation of microorganisms by microwaves. The first states that microwaves inactivate microorganisms entirely by heat through mechanisms comparable to other biophysical processes induced by heat, such as denaturation of enzymes, proteins, nucleic acids, or other vital components, as well as disruption of membranes. A second proposed mechanism for inactivation by microwaves involves non-thermal effects. Four predominant theories have been used to explain non-thermal inactivation by microwaves or "cold pasteurization": selective heating, electroporation, cell membrane rupture, and magnetic field coupling. The selective heating theory states that solid microorganisms are heated more effectively by microwaves than the surrounding medium and are thus killed more readily. Electroporation is caused when pores form in the membrane of the microorganisms due to electrical potential across the membrane, resulting in leakage. Cell membrane rupture is related in that the voltage drop across the membrane causes it to rupture. In the fourth theory, cell lysis occurs due to coupling of electromagnetic energy with critical molecules within the cells, disrupting internal components of the cell.

The study offers also two explanations for the influence of magnetic field treatment. The first one stated that a "weak" oscillating magnetic field (OMF) could loosen the bonds between ions and proteins. Many proteins vital to the cell metabolism contain ions. In the presence of a steady background magnetic field such as that of the earth, the biological effects of OMF are more pronounced around particular frequencies, the cyclotron resonance frequency of ions. A second theory considers the effect of static magnetic field and OMF on calcium ions bound in calcium-binding proteins.

The mechanism of inactivation of vegetative bacteria by ultrasound treatment appears to be intracellular cavitation. Maximum effectiveness results in cellular lysis. For spores, the mechanism is not clear. Cavitation must play a role, but it is an auxiliary one since ultrasound alone has no effect on spores.

The lethality of the light pulses is different at different

wavelengths. Therefore, the full spectrum or selected wavelength may be used to treat the foods. Wavelengths known to produce undesirable products in foods are eliminated by filtering through glass or liquid filters. Light pulses induce photochemical or photo thermal reactions in foods. The UV-rich radiation causes photochemical changes, while visual and infrared radiation cause photo thermal changes.

The substitution of chemical amelioration with convenient physical methods of treatment has two advantages - one is decreasing pollution of on-farm produced raw materials for food production and the other – disinfection through inactivation of microorganisms.

CONCLUSIONS

The substitution of chemical soil additives and fertilizers by physical methods of stimulation is a good opportunity to reduce the risk of food safety hazards in fresh produce. It could guaranty enough high plant productivity with lower risks of soil and water contamination to the farmers and hence – higher quality of fresh and processed food for the consumer.

The good news is that physical treatment can be used not only as stimulator for plant development but also as inhibitor for harmful microorganisms. Keeping in mind that the old meaning of physical methods is natural ones this is good.

The bad news is that usually the stimulation is possible at lower levels of treatment intensity (that means lower energy) and disinfection – at higher. A combination of lower intensity with additional treatment could be helpful.

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