Acta Agrophysica, 2005, 5(2), 357-365

EFFECTS OF OSCILLATING MAGNETIC FIELD PULSES ON SELECTED OAT SPROUTS USED FOR FOOD PURPOSES*

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Abstract. In recent years, more and more attention has been paid to the non-thermal food preservation methods. The influence of microwave radiation on food as well as ultrasounds, high pressure, and electric field pulses of UV radiation, laser and electric discharges were tested. Especially promising, though not yet very well known, are the effects of the oscillating magnetic field pulses (OMFP). The OMFP do not increase temperature and therefore they cause no changes in the chemical composition, namely, neither in protein conformation nor in the fall of antioxidant capacity. Moreover, the OMFP might even prevent the growth of new undesired chemical substances. The sprouts of the naked oat (*cv. Akt*), cultivated under control in laboratory conditions, were submitted to the oscillating magnetic field pulses treatment. The treatment significantly reduced the number of microorganism (bacteria, fungi) colonies. At the same time, the level of polyphenols slightly increased, and therefore the antioxidant activity. The obtained results indicate large possibilities of the oscillating magnetic field use in the process of agricultural and food products preservation for storage purposes.

Keywords: oats, sprouts, oscillating magnetic field pulses (OMFP), microorganism survival, polyphenols, antioxidants

INTRODUCTION

So far, food products have been mainly assessed in terms of their nutritive value. At present, more and more attention is also paid to their functional (health – related) properties. Worldwide, the interest in the so called "healthy food" is increasing. New groups of the above mentioned "foods" have developed in recent years. There is, for example, food with slowly decomposing starch, functional oligosaccharides and

*This study was supported by funds of the KBN grant No. 3 P06R 075 22.

bioactive peptides [4,10]. Among others, various sprouts consumption is increasing, which can be observed especially in Europe, where the consumers are not only interested in food of a high nutritive value but also in food with functional (health-related) properties i.e. with a high supply of antioxidant substances.

In the worldwide cereal production, the importance of oats as a part of human diet is becoming more and more significant. The oat nutritive value, its dietetic and health–related properties are very high, which consequently indicates the need to increase its contribution in the diet [14]. In fact, oat contains 15-20% of protein [17], two to three times more fat than other cereals, it has less starch (ca. 10%), and it is richer in non-starch polysaccharides, especially β-glucans, which cause a reduction in the cholesterol level [6]. The nutritive value of oat protein is higher than in other cereal, which is connected with the lower content of prolamins [9].

As a matter of fact, some undesired processes often occur during food storage and cause poor quality food. This is because the conditions required for the sprouting process (the right temperature and humidity) are inductive to micro-flora development (bacteria, mould, saccharamycetes). It is, therefore, extremely important to find a method for sprout treatment that would minimize the danger of microorganism development. That method should, at the same time, preserve high nutritive value of the food and, therefore, its functional (health–related) properties (e.g. antioxidants).

The research conducted was concerned with the effects of microwave radiation, ultrasounds, high pressure, electric field pulses of UV radiation as well as lasers and electric discharges [27]. Among the various non-thermal techniques that extend the shelf-life of food products, the pulses of the oscillating magnetic field (OMFP) are worth noticing from among the physical methods.

The results of research on magnetic fields are variable. Depending on the amplitude and the time of pulse duration, there has been observed inhibition in microorganism development, lack of an effect, and also stimulation of their development.

In the experiments in which the products were subjected to the influence of one or more OMPF pulses of amplitude of 2 T to approx. 50 T, and the time of exposure from 25 μs to few ms, it was observed that single pulses decreased the microbial population by approximately a factor of two [7,18,22,25,29,30]. There are no published research results regarding the OMFP effects on the content of poliphenols and their antioxidant activity.

In order to guarantee shelf-life food safety, it is subjected to traditional, thermal food preservation methods (e.g. postponing or inhibiting microorganism development). However, due to a significant increase in temperature during traditional treatment, a series of undesired effects, like the loss of temperature-sensitive nutrients, protein denaturation, as well as change of structure, colour and taste of a product can be observed [1,13,16,21,24]. They also cause the formation of new and undesirable compounds. In the case of cereal grains, the thermal treatment significantly deteriorates the antioxidant material activity [32,33].

The objective of this study was to examine the effect of the OMFP on microorganism survival (bacteria and fungi) on oat sprouts. It was also conducted to observe the OMFP effect on polyphenols and their antioxidant activity. At the same time, the research was to determine whether that physical method is useful in diminishing microbiological contamination and if it can be applied in food preservation.

MATERIALS AND METHODS

The analytical study was conducted on naked oat sprouts (*cv. Akt*) (Polanowice Breeding Station). Fifty (50) grains were sown in Petri dishes which were kept in controlled laboratory conditions (darkness, temperature of 21^{o}C, humidity of 65%). After 5 days, the obtained sprouts were put into phials and subjected to OMFP influence.

A specially constructed generator was used to produce the required field. The concept of the constructed system is presented in "Lipiec *et al*.". The oscillating pulsing magnetic field that has an induction of up to several score Tesla and growing time of orders of magnitude of a millisecond can result from discharging a high voltage condenser through a suitable solenoid. The battery of high-voltage condensers with a total capacity of 1.5 mF is charged up to the required voltage through a high voltage supply, with a maximum working voltage of 5 kV and a working current up to 100 mA. The solenoids producing the magnetic field are single-layer coils which have been wound with a copper wire of 20 to 40 mm^2 surface and a rectangular section. The ca. 17 mm internal diameter of the solenoids has been chosen to enable placing standard test-tubes with the analyzed material inside. The coils were placed inside a special keeper which provides the appropriate mechanical resistance. The parameters of the oscillating magnetic field were accurately measured by an induction probe placed for that very purpose inside the solenoid and connected with the digital oscilloscope Voltcraft DSO 2100.

In order to assess the effects of the OMFP on the microorganism survival the following were used: a/. a single pulse of 8 T amplitude and b/. 5 – times repeated pulse of 5 T amplitude. To analyze the effects of OMFP on the polyphenol content and antioxidant activity, the following were used: a/. a single pulse of 8 T amplitude, b/. 3 pulses of 8 T amplitude and c/. 10 pulses of 3 T amplitude. In all the above cases, the oscillation period was 250 μs, and the total duration time of every single pulse was ca. 3 periods. Both for analyzing microorganism survival and for assessing antioxidant activity, all the exposures were repeated 5 times each.

The oat sprouts were first subjected to the effects of OMFP of 5 x 5 T and 1 x 8 T amplitude, then the microorganisms were removed from the sprouts surface with physiological salt. Next, the appropriate diluents (10^{-1}-10^{-6}) were prepared and that suspension was placed in Petri dishes. Further, the selected mediums i.e. nutritive agar (MPM) for bacteria and malt agar for fungi were poured at the dishes. The dishes were placed in a thermostat for 24 hours in 37°C. After that, the number of bacteria as colony forming unit (c.f.u.) was determined, and next the dishes were put in the thermostat again for 72 hours in 28°C in order to determine the amount of fungi (c.f.u.). The amount of all microorganisms was compared with the control material and the obtained results were subjected to statistical analysis.

In order to preliminarily determine phenol substances, 1g sample was extracted (40 ml 0.16 N HCl 80% methanol) in room temperature for 2h. The extract was grounded to 1500 g for 15 min. Supernatant was obtained and the rest was extracted once again (40 ml 70% acetone) for another 2h. Once being grounded (1500 g, 15 min), the liquid from above the extract residue was mixed with the extract obtained before. The substance obtained in the above described way was stored at –20°C.

The sum of polyphenols was determined with the “Swain and Hillis” method and with the Folin-Ciocalteau reagent (Sigma-Aldrich Chemie GmbH, Germany). To 5 ml of methanol-acetone extract of 0.125% concentration 0.5 ml of 2N Folin-Ciocalteau reagent (attenuation with H_2O 1:1) was added and 0.25 ml 25% of Na_2CO_3 solution. After 15 minutes the samples were grounded (1250 g, 5 min). The supernatant absorbance was read at λ = 725 nm and the polyphenol concentration was given in catechin equivalents (mg g^{-1} d.m.).

The ability of attenuating free radical DPPH$^\bullet$ was determined with the Pekarinen method [20] with the use of stable free radical DPPH$^\bullet$ (α,α-diphenyl-β-picryl-hydrazyl radical) (90%, Sigma-Aldrich Chemie GmbH, Germany). The antiradical features of phenols were estimated through measuring the fall of alcoholic solution DPPH$^\bullet$ absorbance in time. It is due to free radical DPPH$^\bullet$ attenuation because of phenols present in methanol-acetone extracts. Initially, a basic solution was made containing 40 mg DPPH$^\bullet$ in 100 ml of 99% methanol, which was used to prepare a test solution containing 40 mg DPPH$^\bullet$ in 100 ml of 99% methanol. Next, 0.2, 0.5, 1.0, and 1.5 ml of methanol-acetone extract analysis samples were prepared and they were supplemented with methanol up to 1.5 ml. The subsequent extract was mixed with 3 ml of DPPH$^\bullet$ solution, it was carefully mixed and the extinction towards methanol was read at λ = 516 nm during 6 min. The degree of free radicals scavenging (RSA) was given in % as the ratio of absorption change to sample absorption at the beginning.

The statistical analyses were conducted with Kruscal-Wallis test and LSD test in order to show that the microorganism colonies amount varied significantly in number, as well as to show polyphenol concentration and their antioxidant activity after subjecting the oat sprouts to oscillating magnetic field effects.

RESULTS

The number of surviving bacteria colonies on the oat sprouts after being treated with the oscillating magnetic field pulses of 5 x 5 T decreased by half and was significant from the statistical point of view ($p<0.05$) (Tab. 1). The decrease in the number of these microorganism colonies after the sprouts were exposed to a field of 1 x 8 T amplitude was lower and statistically insignificant. In both cases (pulses of 5 x 5 T and 1 x 8 T amplitude), a nearly triple and statistically signify-cant ($p<0.01$) drop in the number of surviving vegetative bacteria forms was observed. The amount of microscopic fungi after exposing the oat sprouts to the field of 5 x 5 T pulse amplitude dropped by a factor of approximately 10 and was statistically significant ($p<0.01$).

Table 1. Number of microorganisms isolated from the oat sprouts after oscillating magnetic field exposure (OMFP)

Field pulse	Number of microorganisms c.f.u.			
	Control		OMFP	
	Bacteria	Fungi	Bacteria	Fungi
5 x 5 T	243^a $(168)^c$	14.6^e	120^b $(64)^d$	1.3^f
1 x 8 T	240^a $(160)^c$	–	210^b $(51)^d$	–

The number of vegetative bacteria forms is given in brackets. Symbols “a” and “b” indicate significant statistical differences in the number of bacteria colonies, “c” and “d” show the differences in the number of surviving vegetative bacteria forms, and “e” and “f” are for fungi.

Table 2. Polyphenol content and antioxidant activity in oat sprouts

Field pulse	Control		OMFP	
	Poliphenol Content mg $(100g)^{-1}$	Antioxidant Activity (%RSA for 1000 µl of the extract)	Polyphenol Content mg $(100g)^{-1}$	Antioxidant Activity (%RSA for 1000 µl of the extract)
10 x 3 T	336^a	35.8^d	505^b	47.5^e
1 x 8 T	727^c	36.4^f	710^c	37.8^f
3 x 8 T	727^c	36.4^f	725^c	28.5^f

Symbols “a”, “b” and “c” show statistically significant polyphenol content differences and symbols “d”, “e” and “f” show the difference in antioxidant activity.

Polyphenol content in oat sprouts treated with the oscillating magnetic field pulses of 10 x 3 T amplitude increased 1.5 times. The difference was statistically significant ($p < 0.05$). As to the other exposures, the polyphenol content in test samples and the sprouts exposed to the magnetic field did not vary (Tab. 2). The antioxidant activity of oat sprouts (stated as RSA % for 1000 µl of extract) for exposure to the field of 10 x 3 T amplitude increased by about 30% (a difference statistically significant ($p < 0.05$). However, the exposure to the field of 1 x 8 T amplitude was not different from the test trial and the exposure to 3 x 8 T caused a drop by about 20%. In both of these cases the differences were not significant from the statistical point of view.

DISCUSSION

The raw material used for the study was naked oat (*cv. Akt*). Typical oat microbiological flora develops during growth on the field before harvest, during storage and during treatment. An important development can be also observed during sprouting, which might be significantly inhibited in high temperatures of about 135°C during 30 minutes [2]. It is, though, accompanied by all the undesirable side effects connected with product heating. Further to the above, a significant growth of interest in new food preservation methods can be observed. These methods preserve high nutritive values and cause a reduction in the microbiological contamination of the stored food.

When treating with the oscillating magnetic field pulses, and therefore not increasing the temperature, a significant decrease both in the number of bacteria colonies (with an especially high drop in the number of vegetative cells) as well as fungi was achieved.

As it is widely known, free radicals that develop during metabolic organism processes damage proteins, fats, DNA and even carbohydrates. The antioxidant substances that are in cereal grains are one of the two groups of preventive antioxidants that protect cells against free radicals activity. Biologically active compounds can be divided into hydrophilic (C, ubichinon, polyphenol) since they protect the water environment of cells, and hydrophobic (tocoferols, carotenoids) since they protect the inner cell membrane. Phenol compounds are a part of plant defence mechanism. They defend plants fighting with pathogens, vermin and other stresses like drought, UV radiation influence and others. Generally, they have antymicrobiological, antioxidant and anticancerogenic properties [23].

Low-molecular polyphenol compounds, as well as tocoferols and sterols that are in cereal grains, demonstrate a high antioxidant activity. It is connected with the presence of hydrocsyle and metacsyle groups and consists in eliminating reactive oxygen forms and metal ions chelation. Polyphenol is mainly responsible for oat antioxidant qualities [11,31]. Numerous authors [8,26,28] state that the total polyphenol content is enough to determine exclusion capacities of free radicals since oat grain contains a lot of polyphenolic compounds like benzoesic acid, cinnamon, chinones, flavines, flavonols, flavons, chalcones anthocyanids and aminophenols [6 after 3]. Oat grain contains specific phenol compounds that are avenantriamids. They are regarded as the main compounds in the defence mechanisms [3,5,20]. Aventramids are both water-soluble and liposoluble, thermostable, inhibiting non-enzymatic oxidant changes and lipid oxidant processes. Moreover, sprouting of the whole grain leads to a rise in poliphenol content [19 after 12]. Treating with the oscillating magnetic field pulses in some cases has even caused a growth in polyphenol content.

As a matter fact, the differences in the growth of antioxidant substances between sprouts and grains have not been studied. This is why the above research was aimed at finding a physical factor which would significantly inhibit microbial development but at the same time preserve the antioxidant properties.

CONCLUSIONS

1. Treating food with the oscillating magnetic field pulses might be a promising non-thermal method of food preservation. While preserving important functional (health-related) properties (the level of antioxidant substances), it is possible to significantly inhibit microbial development. It seems that the changes in macromolecular structure which result from the use of the oscillating magnetic field pulses lead to greater antioxidant substance extraction.

2. In order to define exactly the differences taking place in antioxidant activities, a detailed valuation of the individual polyphenol content should be taken into account in the next study.

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WPŁYW IMPULSÓW OSCYLACYJNEGO POLA MAGNETYCZNEGO NA WYBRANE CECHY KIEŁKÓW OWSA WYKORZYSTYWANYCH W CELACH SPOŻYWCZYCH

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Streszczenie. W ostatnich latach wzrosło zainteresowanie nietermicznymi metodami obróbki żywności. Bada się wpływ promieniowania mikrofalowego, ultradźwięków, wysokiego ciśnienia, impulsowego pola elektrycznego impulsów promieniowania UV oraz laserów i wyładowań elektrycznych. Szczególnie obiecujący, a słabo zbadany jest wpływ impulsów oscylacyjnego pola magnetycznego (OPM). Impulsy OPM nie powodują wzrostów temperatury, a więc nie wywołują zmian w składzie chemicznym żywności, w szczególności takich jak denaturacja białek i powstawanie nowych, niepożądanych związków chemicznych. Działaniu oscylacyjnego pola magnetycznego zostały poddane wyhodowane w kontrolowanych warunkach laboratoryjnych kiełki nagoziarnistej odmiany owsa (Akt). Stwierdzono statystycznie istotną redukcję liczby przeżywających kolonii mikroorganizmów (bakterii i grzybów), oraz pewien wzrost zawartości polifenoli i aktywności antyoksydacyjnej. Uzyskane wyniki wskazują na duże możliwości stosowania oscylacyjnego pola magnetycznego w procesie utrwalania produktów rolniczych i żywności dla celów przechowalnictwa.

Słowa kluczowe: owies, kiełki, oscylacyjne pole magnetyczne, przeżywalność mikroorganizmów, polifenole, antyoksydanty