The magnetic field stimulation system applied on strawberry fruits

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Summary. This paper presents an influence of three different magnetic fields stimulation systems for growing strawberry fruits: permanent magnetic field generated by neodymium magnets, "high" strengths slow varying amplitudes magnetic fields generated by coreless solenoids supplied by autotransformer and low-frequency and low-amplitude sinusoidal magnetic fields generator created for this research. The system is controlled by computer and allows for an independent control of up to 10 induction coils inducing magnetic fields with amplitudes from 0.1μT to 150μT and frequencies from 0.1Hz to 100Hz. The proposed set-up was used during the growing seasons for strawberry plants stimulation. An increase in the extract level was observed in the case of the alternating magnetic field stimulation with the parameters: frequency – from 50Hz to 100Hz and amplitude – from 50μT to 100μT.

Key words: magnetic fields, strawberry, monosaccharides, firmness.

INTRODUCTION

The development of modern agriculture involves the necessity to use the limited natural resources, which means we have to look for new, ecological methods of the crop increasing and their quality improving [12]. One method of improving the quality of fruits consists in stimulation by means of magnetic, electromagnetic and electric fields. The influence of such fields on biomolecules and whole living organisms is not yet fully understood, heedless of the numerous studies carried out for many years. There are hypotheses concerning the magnetic field influence on the whole organisms [8]. Many publications have reported that the magnetic field, changing the physiological and biochemical processes, also impacts germination and further growth of plants [1].

The alternating magnetic field with frequency in the range from 0.2 Hz to 100 Hz also causes changes in the mechanisms of membrane permeability. Membranes consist of three layers: outer electronegative, intermediate lipid and internal protein layers. Permeability of these structures for different substances constitutes a mechanism which is responsible for precise homeostasis and for the ability to regulate automatically the functions of all parts of the organism, from ribosomes and mitochondria, to the whole organs. The geomagnetic field, impacting changes in cell membrane permeability, can influence vegetable, animal and human organisms [10, 16]. The magnetic component of the slowly varying fields causes arranging action in magnetic dipoles, affects moving charges, cell membranes and neural networks, and most importantly – induces generation of rotary currents, providing the resonance effect which involves the opening and closing of ion channels [13, 15].

So, the influence of the magnetic field on living organisms is beyond doubt: the impact depends on the strength value of a magnetic field as well as on the biological characteristics of a living organism [2-5]. There is a close connection between magnetic field variations and the flow of basic life processes on the Earth; this link is reflected in the rhythm of physiological, biochemical, genetic and biophysical processes. Hence, magnetic fields can have a positive and desirable effect on the vegetation of crops [7, 9]. The organisms of plants can, therefore, be treated as a special kind of antennas receiving electromagnetic waves from the environment [2-4]. In the case of resonance this phenomenon is amplified so that frequently negligible energy of fields causes significantly more powerful effects [4, 15]. It is interesting to confirm these hypotheses experimentally in case of plants.

This paper presents a computer-controlled alternating magnetic field generation system to stimulate biological objects in the low frequency region. The experimental results of stimulation with such magnetic field applied to growing strawberry plants are presented and discussed. These results are related to the influence of permanent fields (5 mT - 100 mT) as well as alternating fields (50μT - 100mT with frequencies not higher than 100 Hz), on the strawberry fruit during their growth in the site of Mazury Experimental Station in west-southern Poland. The prerequisites were found out for the possibility to use the alternating magnetic field with selected parameters of amplitude and frequency for improving the quality characteristics in fruit. Another important aspect is the proposed design based on a stationary system of magnetic stimulation of fruit during the process of their growth and ripening, which enables fully unmanned operation in practice.

MATERIALS AND METHODS

The selected varieties of strawberries (Ventana, Elkat and Honeoye), grown in Mazury Experimental Station in southern Poland, were used as the research material. They were derived from a three-year old plantation grown on the basis of qualified seedlings delivered by Niewczas Group. The fruits of these three varieties were stimulated with magnetic field over the research seasons – the fruits of the above varieties were subjected to stimulation, directly on plants, during the process of growth and ripening.

Establishment of other conditions of stimulation, particularly, duration and intervals was the most important question. It was initially assumed that the 30-minute doses will be divided into 6 cycles of 5-minutes each with 5-day intervals. The idea of dividing the exposure dose into 6 cycles was borrowed directly from medical experiments [12] when the magnetic field treatment is applied: 5-15 minute cycles are usually used, with several-day intervals [6].

The results were analyzed statistically by checking a normal distribution and verified by Tukey's test with the confidence level of $p = 0.05$, $n=16$.

The magnetic fields kinds used for stimulation were arranged into three groups: the first group included permanent fields with the strengths of 5 mT, 50 mT and 100 mT generated by means of the neodymium magnet poles pairs – 100 cm2 in surface and 2 cm in height, placed at a distance from 12 to 40 cm in order to obtain the required strengths; the second kind of magnetic field included slowly varying amplitudes of the so-called ”high” strengths, i.e. 5 mT, 50 mT and 100 mT, at the frequency of 50 Hz generated by means of coreless solenoids – 11 cm in internal diameter and 15 cm in length, supplied from the source of one-phase alternating current (the solenoid's winding included 13 layers of 115 turns each); the last kind of magnetic fields included amplitudes of 50μT, 100μT and 150μT combined with the frequencies of 10 Hz, 50 Hz and 100 Hz, which enables the generation of 9 different types of magnetic fields. A system generating the above low-frequency and low-amplitude sinusoidal magnetic fields working consistently with smoothly changing frequency and amplitude, should be created to attain this aim.

The set-up constructed for the purpose of generating the above fields was based on a microprocessor-controlled current module. After 30-minute stimulation cycle (in 6 repetitions of five-minute sessions) for each of the fruits being stimulated with particular magnetic field group, the most suitable harvesting time was determined for each variety and then the fruits were subjected to further analytical tests. Those, among others, included following ones:

– Firmness tests by Zwick Roel Z010, using analytical norm: PN-90/A-75101/02;
– Determination of extract level with the use of the refractometric method,
– fructose and glucose contents by HPLC Young Lin liquid chromatography, using analytical norm: PN-EN 12630: 2002.

RESULTS AND DISCUSSION

The firmness parameter measurement results, for control and magnetic field stimulated fruits and for different strawberry varieties are shown in Table 1. It can be seen that in the case of a strong magnetic field impact from 5 to 100 mT with the frequency of 50 Hz in all the varieties there is observed a decrease in the firmness parameter up to 25%. There was no significant difference between control fruits and fruits treated with permanent and low induction field. Protopectins and pectins are responsible for fruit firmness, which in fact depends on the speed conversion at which the former are transformed into the latter. A similar hypothesis in relation to peroxidase and catalase has been proposed by Portaccio et al. [11].

Table 1. Firmness level [N] for three varieties of strawberries after exposure to magnetic stimulations during growth

Magnetic field used		Varieties of strawberries		
Induction [mT]	Frequency [Hz]	Elkat	Honeoye	Ventana
0	0	3.45 [a]	2.50 [a]	4.01 [a]
5	0	3.42 [a]	2.45 [a]	3.99 [a]

50	0	3.41^{a}	2.51^{a}	3.98^{a}
100	0	3.36^{ab}	2.52^{a}	4.00^{a}
0,05	10	3.44^{a}	2.45^{a}	3.98^{a}
0,05	50	3.42^{a}	2.45^{a}	3.98^{a}
0,05	100	3.40^{a}	2.40^{ab}	3.95^{a}
0,10	10	3.41^{a}	2.42^{ab}	3.98^{a}
0,10	50	3.42^{a}	2.41^{ab}	3.97^{a}
0,10	100	3.39^{a}	2.41^{ab}	3.98^{a}
0,15	10	3.42^{a}	2.39^{ab}	3.91^{ab}
0,15	50	3.40^{a}	2.42^{ab}	3.92^{ab}
0,15	100	3.41^{a}	2.45^{a}	3.81^{ab}
5	50	2.87^{c}	2.10^{c}	3.25^{cd}
50	50	2.67^{c}	1.98^{c}	3.21^{cd}
100	50	2.58^{c}	1.97^{c}	2.99^{d}

Means with the same letter in column are not significantly different; α=0.05 (Tukey's test)

A more important parameter of strawberry fruit is the total extract content, including fructose, glucose and some organic acids and trace elements. As it can be seen in Table 2, an exposure to strong magnetic fields, whether permanent or alternating, does not lead to an increase in this parameter.

A completely different situation occurs as a result of exposure to weak alternating fields. There is a significant increase in this important parameter, i.e. total extract in all the varieties of strawberries. The increase is particularly significant (5-8% relative to the control sample) for the fields with the amplitude of 100 μT and the frequency of 50 Hz and 100 Hz. It can be concluded that the impact of alternating magnetic fields with the parameters listed here causes a significant increase in the content of total extract in the fruits of all the strawberry varieties.

Table 2. Extract level [%] for three varieties of strawberries after exposure to magnetic stimulations during growth

Magnetic field used		Varieties of strawberries		
Induction [mT]	Frequency [Hz]	Elkat	Honeoye	Ventana
0	0	8.21^{a}	8.91^{a}	8.98^{a}
5	0	8.13^{a}	9.00^{a}	9.01^{a}
50	0	8.14^{a}	9.02^{a}	9.00^{a}
100	0	8.20^{a}	9.01^{a}	9.12^{a}
0,05	10	8.33^{ab}	9.34^{ab}	9.29^{ab}
0,05	50	8.42^{ab}	9.23^{ab}	9.21^{ab}
0,05	100	8.50^{b}	9.32^{ab}	9.33^{ab}
0,10	10	8.62^{bc}	9.54^{bc}	9.31^{ab}
0,10	50	8.77^{c}	9.69^{c}	9.50^{b}
0,10	100	8.81^{c}	9.74^{c}	9.49^{b}
0,15	10	8.40^{ab}	9.39^{b}	9.20^{ab}
0,15	50	8.40^{ab}	9.43^{b}	9.24^{ab}
0,15	100	8.41^{ab}	9.31^{ab}	9.25^{ab}
5	50	8.32^{ab}	9.00^{a}	8.90^{a}
50	50	8.14^{a}	8.90^{a}	8.95^{a}
100	50	8.13^{a}	8.91^{a}	8.95^{a}

Means with the same letter in column are not significantly different; α=0.05 (Tukey's test)

Table 3 shows how permanent and alternating magnetic fields with specific parameters affect the content of two main monosaccharides, i.e. fructose and glucose.

Table 3. Fructose and glucose level [%] for three varieties of strawberries after exposure to magnetic stimulations during growth

Magnetic field used		Varieties of strawberries					
		Elkat		Honeoye		Ventana	
Induction [mT]	Frequency [Hz]	fructose	glucose	fructose	glucose	fructose	glucose
0	0	2.90^{a}	2.01^{a}	3.05^{a}	1.74^{ab}	3.11^{a}	1.75^{a}
5	0	2.90^{a}	2.03	3.12^{ab}	1.75^{ab}	3.12^{a}	1.77^{ab}
50	0	2.93^{a}	2.02^{a}	3.09^{a}	1.75^{ab}	3.10^{a}	1.74^{a}
100	0	2.94^{a}	2.02^{a}	3.11^{ab}	1.74^{ab}	3.10^{a}	1.70^{a}
0,05	10	3.00^{a}	2.05^{ab}	3.19^{ab}	1.69^{a}	3.15^{ab}	1.81^{ab}
0,05	50	3.01^{ab}	2.04^{ab}	3.19^{ab}	1.70^{a}	3.17^{ab}	1.80^{ab}
0,05	100	3.15^{b}	2.04^{ab}	3.21^{b}	1.71^{a}	3.12^{a}	1.82^{ab}
0,10	10	3.20^{b}	1.99^{a}	3.20^{b}	1.75^{ab}	3.15^{ab}	1.83^{ab}
0,10	50	3.45^{c}	2.09^{b}	3.55^{c}	1.85^{b}	3.27^{b}	1.90^{b}
0,10	100	3.45^{c}	2.11^{b}	3.49^{c}	1.85^{b}	3.35^{bc}	1.90^{b}
0,15	10	3.13^{b}	1.99^{a}	3.35^{bc}	1.74^{ab}	3.21^{ab}	1.80^{ab}
0,15	50	3.14^{b}	2.01^{a}	3.32^{bc}	1.72^{a}	3.12^{a}	1.75^{a}
0,15	100	3.11^{b}	2.02^{a}	3.20^{b}	1.75^{ab}	3.11^{a}	1.74^{a}
5	50	2.89^{a}	1.98^{a}	3.05^{a}	1.69^{a}	3.09^{a}	1.70^{a}
50	50	2.85^{a}	2.01^{a}	3.02^{a}	1.70^{a}	3.08^{a}	1.74^{a}
100	50	2.90^{a}	2.00^{a}	3.04^{a}	1.71^{a}	3.10^{a}	1.73^{a}

Means with the same letter in column are not significantly different; $\alpha=0.05$ (Tukey's test)

As it follows from Table 3 there is a significant increase in the fructose content in all the varieties after exposure to the alternating magnetic field with the amplitude of 100 μT and with the frequency in the range from 50 Hz to 100 Hz. The results representing the glucose behaviour show slightly lower differences compared to control then those for the fructose, but the maximum values for the same magnetic field amplitudes and frequencies can be observed, as well. Therefore, the increase in the total extract parameter as well as in the fructose and glucose content is confirmed by the obtained results only for these values of the magnetic field amplitude and frequency: 100 μT and 50 Hz – 100 Hz, respectively.

CONCLUSIONS

The effect of alternating magnetic field stimulation on the increase of the content of main monosaccharides, especially on fructose (as well as the total extract) in strawberries reveals a clear selectivity. This increase occurs only in the case of the magnetic fields with amplitude 50μT and 100μT and frequencies 50Hz and 100Hz. Magnetic fields with certain sublimated frequencies (50Hz and 100Hz) and of 100μT induction may cause increased enzymatic activity in plant tissue and consequently increase the transfer of monosaccharides through cell membranes. This mechanism leads to consistently increased flow movement within cell membranes connected with the membrane transport of the products of photosynthesis, generated in the leaves of the plant whose fruits are exposed to the operation of an external magnetic field [13, 14, 16]. This response may lead to an increase of several per cent in the quantity of the valuable components, namely the monosaccharides, and as a consequence improve the quality of fruit for commercial and processing purposes. To achieve this aim it is necessary to use stabile magnetic stimulation generator e.g. Magnetic Field Generator projected for the above study which is patented as "The device generating the variable magnetic signals for stimulation of biological material" (P.399624).

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