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Strawberry Treatment with Low Frequency Electromagnetic Fields

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ABSTRACT

The studies devoted to application of physical methods for improvement of preservation of plant raw material, in particular: studies of the influence of extremely low/ultralow frequency electromagnetic fields (ELF/ULF EMF) at the stage of preparation for storage on resistance against bacteriological damage and market condition of strawberry are always important. It is established that natural microflora of the considered strawberries is presented by mesophilic aerobic and facultative anaerobic microorganisms (MAFAnM) and molds. The average amount of MAFAnM is 7.1×103CFU/g; the amount of molds is 288 CFU/g.
Treatment by ELF EMF at 30 Hz, 10 A for 30 min decreases efficiently microbial contamination of strawberries. In addition to decrease in microbial population, this procedure provides maximum yield of standard products (72.6±2.7) after storage for 14 days at +(2±1)°C. Total losses are by 13.3% lower in comparison with the reference product. Organoleptic evaluation has confirmed the conclusion that preliminary treatment of strawberries by ELF EMF at 30 Hz, 10 A for 30 min provides better retention of organoleptic indicators.
Herewith, the treatment by ULF EMF at 40 Hz, 5 A for 30 min increases total losses in comparison with reference product by 0.8% and impairs organoleptic indicators.

Key words: strawberry, storage, physical methods, extremely low frequency electromagnetic fields, losses, organoleptic indicators.

1. INTRODUCTION

Strawberries are characterized by superior organoleptic properties, they are consumed both in fresh and processed form being valuable source of vitamins, minerals, and bioactive components, such as flavonoids and anthocyanins; they reduce cholesterol level and are characterized by antioxidant activity, anti-inflammatory and anticarcinogenic properties.

Herewith, strawberry is a perishable product. Due to natural physiological features and high propensity to bacteriological damage, the yield losses can be as high as 50%.
In this regard the studies devoted to expansion of strawberry storage period and prevention of bacteriological damage are especially important.
Nowadays the main tools to prevent strawberry bacteriological damage are as follows: low temperature, fungicides and chemical products, however, the issues of safety of food products and environmental considerations restrict their use [1].
Cautious attitude of consumers to possible residual content of chemical substances as well as growing resistance of pathogens against chemical reagents stipulated the necessity to develop new methods of controlling diseases after harvesting. At present the researchers attempt to develop the most promising and efficient methods, including physical methods, of preservation of food products, for suppression or elimination of undesired microorganisms without application of antimicrobial additives: ultrasound, ultraviolet (UV) radiation, pulse electric field (PEF), high pressure processing (HPP), treatment by intensive pulse light (IPL), cold atmospheric plasma (CAP) [2, 3].
UV radiation can be used both for fresh and treated strawberries. Bhat and Stamminger (2015) observed two-fold reduction of total content of aerobic bacteria after the impact of UV radiation (254 nm) during 15–60 min [4].
Photosensitization is a new environmentally safe technology based on the use of photoactive compounds and visible light. This strategy can also be applied to microbial deactivation of strawberry. Luksiene and Paskeviciute studied possibilities of photosensitization using chlorophyllin to control microbial contamination of strawberry. Strawberries were inoculated with Listeria monocytogenes, soaked in 1 mM chlorophyllin solution for 5 min and illuminated with visible light for 30 min. These researchers observed 86% and 97% inhibition of yeasts/molds and mesophylls, respectively, and the storage period of strawberry increased by two days [5].
UV treatment of strawberries is applied not only to extend expiration date and to improve organoleptic properties but also to increase the content of useful substances. The influence of UV light on antioxidant ability and

phytochemical profiles of three various strawberry varieties has been defined; despite the fact that the treatment did not influence antioxidant ability of berries, the biochemical composition of Albion strawberry was significantly improved after the treatment. Oviedo-Solís et al. reported about increased antioxidant activity in vitro, stipulated by increased content of polyphenols (flavonoids, anthocyanins, fisetin, and pelargonidin) in strawberries after radiation by UV light (1.2 W/m^2) for 16.5 min. [6].

Application of UV light is a known technology, namely: radiation in the range from 100 to 400 nm. It is known that UV light exerts biocide action destroying the cell walls and DNA.

The damage degree of cells depends on medium type, microorganisms and applied dose of UV radiation. UV treatment as a nonthermal conservation is based on the advantages that during processing, toxic or significant nontoxic byproducts are not generated, low energy is required in comparison with thermal pasteurization, and maximum odor and color of treated berries are retained. Herewith, more than five-fold decrease in the content of certain pathogenic microorganisms is achieved, such as E. coli [7].

Some studies demonstrated decrease in content of ascorbic acid, anthocyanins, and common phenols, as well as reduction of antioxidant activity after UV treatment. Other quality parameters, such as content of sugar of organic acids, did not vary after the treatment [8].

The influence of UV treatment on the content of biologically active compounds in strawberry depends on several factors, such as berry variety, climate, season, as well as intensity or duration of treatment.

In recent decades certain experience has been gained relating to application of power ultrasound (US) as a possible nonthermal method for preservation of food products. In comparison with diagnostic US, the power US operates in lower frequency range from 20 to 100 kHz and higher sound intensity from 10 to 1,000 W/cm^2 [9].

Aday et al. (2013) evaluated the influence of strawberry treatment by US with various parameters (20 kHz; 30, 60, or 90 W) for 5 or 10 min on its quality. The US power of 90 W exerted negative influence on berry quality (decrease in color saturation, density, and red shades), the power from 30 to 60 W improved retention of color and firmness, and extended expiration date [10].

Gani et al. (2016) demonstrated that US (33 kHz, 60 W) improved antioxidant activity and provided better retention of pH, color, and structure. US treatment demonstrates high potential for application in food industry not only for fermentative and microbial inactivation but also for extraction of valuable phytochemical properties, which can be additionally used in food as functional ingredients [11].

USA researchers determined that US treatment for 20–30 min at 33 kHz and 60 W provided retention of vitamin C content, total amount of soluble solids, stabilized density and color of berries. Longer time of impact (60 min) increased microbial load, decreased antioxidant potential, and varied desired quality of berries [12].

Application of US becomes more and more important, since it increases microbial safety and expiration date, especially in heat sensitive products. US waves are more advantageous, since they are environmentally safe and nontoxic contrary to other methods used in food industry to extend expiration date [13].

PEF processing is comprised of short high voltage pulses use for microbial inactivation, it does not exert or exert minimum influence on quality of food products. Products for PEF processing are placed between two electrodes, usually at ambient temperature. The applied high voltage generates electric field, which leads to microbial inactivation. This high voltage is usually about 20-80 kV in microseconds. The principles of PEF processing were explained by several theories, including the theory of transmembrane potential, the theory of electromechanical compression, and the theory of osmotic imbalance. One of the most accepted theories is related with electroporation of cell membranes based on the fact that electric fields modify structure in membranes of microbial cells due to formation of pores of cell membrane, which leads to destruction and inactivation of microbes. In comparison with thermal treatment, PEF processing is characterized by numerous advantages. It can preserve initial sensor and nutritional properties of the considered products due to extremely short processing time and low processing temperature. Power saving for PEF processing is also important in comparison with typical thermal processing. Moreover, it is environmentally safe and does not generate wastes [14].

Duarte-Molina, Gómez, et al. studied the influence of various doses of pulsed light (PL) (2.4–47.8 J/cm^2) on moisture loss, bacteriological damage, mechanical properties and structure of strawberries stored up to eight days at 6°C. The frequency of occurrence of postharvest mold on strawberries decreased by 16–42% upon application of PL, the qualitative indicators were retained [15].

The performed analysis makes it possible to confirm the importance of studies in the field of physical methods aimed at increased preservation of strawberry. Recently the authors have performed studies confirming efficiency of treatment of plant materials by ELF EMF [16, 17]. In this regard it would be interesting to analyze the influence of ELF EMF at the stage of strawberry preparation for storage on resistance against bacteriological damage and on market condition.

2. METHODS

Marmelada strawberry (harvested in June, 2019, Krasnodar krai) was used in the studies of influence of treatment by ELF/ULF EMF at the stage of preparation for storage on resistance against bacteriological damage and on market condition.

Microbiological studies were carried out according to appropriate procedures. Visual diagnostics and microscopy were used during the studies.

The influence of ELF/ULF EMF on phytopathogens was studied using a laboratory facility for treatment of plant materials.

Scoring system was used for evaluation of the following indicators of strawberries: shape, appearance, color, odor, freshness, integrity.

All experiments were repeated three times (allowable deviation should not exceed 5%). Mathematical processing of experimental data was carried out by descriptive statistics and dispersion analysis using specialized software packages.

3. RESULTS

The influence of ELF/ULF EMF treatment on strawberry microflora. Natural microflora of the considered berries is presented by MAFAnM and molds. The content of MAFAnM on the considered berries varied from 5,000 CFU/g to 12,000 CFU/g. MAFAnM were presented by spore microorganisms (~69%), enteric bacteria (~15%), and yeasts (~16%). The mold content varied from 110 CFU/g to 1,400 CFU/g. Average value for four samples was as follows: MAFAnM – 7.1×10^3CFU/g; molds– 288 CFU/g.

The obtained samples were treated by three preset variants of ELF/ULF EMF (No. 1: 20 Hz, 15 A, 30 min; No. 2: 30 Hz, 10 A, 30 min; No. 3: 40 Hz, 5 A, 30 min) and stored at +(2±1)°C. The content of microorganisms on the surface was determined before the treatment, in 30 min after treatment, and after 14 days of storage.

Table 1 summarizes the data illustrating variations of microbiological properties of strawberries as a function of ELF EMF treatment.

Table 1: Influence of treatment mode on the amount of microorganisms during strawberry storage at +(2±1)°C

Description	Amount of MAFAnM, CFU/g			Amount of molds, CFU/g		
	before storage	30 minutes after treatment	14 days of storage, +(2±1)°C	before storage	30 minutes after treatment	14 days of storage, +(2±1)°C
Reference	6.5×10^3	-	150×10^3	280	-	4,000
Variant 1	6.5×10^3	6.1×10^3	9.5×10^3	280	225	950
Variant 2	6.5×10^3	5.0×10^3	7.2×10^3	280	200	650
Variant 3	6.5×10^3	5.7×10^3	8.3×10^3	280	250	1,200

It can be seen that the treatment variant No. 2 (30 Hz, 10 A, 30 min) is the most efficient to decrease microbial population of strawberries. After 14 days of storage, the berries treated according to this variant were preserved better than other samples.

At the next stage, the influence of ELF/ULF EMF treatment on market condition and strawberry losses was studied.

Table 2 summarizes the data illustrating market condition of strawberries (yield of standard and substandard products, absolute wastes) as a function of preliminary treatment at +(2±1)°C after 14 days of storage.

Table 2: Market condition of strawberries after 14 days of storage

No.	Market condition,%		
	standard	substandard	wastes
Reference	60.0±3.5	21.2±0.5	18.8±0.7
Variant 1	64.4±2.4	18.0±0.7	17.6±1.1
Variant 2	72.6±2.7	13.4±0.5	14.0±0.9
Variant 3	62.0±3.7	18.5±0.6	19.5±0.6

It can be seen that the treatment variant No. 2, in addition to reduced microbial population, provides maximum yield of standard products (72.6±2.7) and minimum amount of substandard product.

Table 3 summarizes strawberry losses due to natural loss and due to bacteriological damage as a function of preliminary treatment after 14 days of storage at +(2±1)°C.

Table 3: Strawberry losses after 14 days of storage

No.	Total losses,%	Natural losses,%	Losses caused by bacteriological damage,%
Reference	47.6±1.5	18.9±0.5	28.7±1.1
Variant 1	43.6±0.8	27.4±0.7	16.2±0.6
Variant 2	34.3±1.0	23.1±1.1	11.0±0.8
Variant 3	48.4±0.9	29.2±0.6	19.2±0.5

It was determined that during strawberry storage at +(2±1)°C, total losses in comparison with reference were lower: for berries treated according to variant 1 – by 4%; according to variant 2 – by 13.3%. Herewith, after treatment according to variant 3 total losses were higher than in reference variant by 0.8%

Figure 1 illustrates qualitative changes of strawberries after 14 days of storage at +(2±1)°C.

Figure 1: Qualitative changes of strawberries, storage during 14 days at +(2±1) C: 1 – reference (w/o treatment); 2 – Variant 1 (ELF EMF parameters: frequency – 20 Hz, current – 15 A, treatment duration – 30 min); 3 – Variant 2 (ELF EMF parameters: frequency – 30 Hz, current – 10 A, treatment duration – 30 min); 4 – Variant 3 (ULF EMF parameters: frequency – 40 Hz, current – 5 A, treatment duration – 30 min).

Analysis of organoleptic indicators of strawberry as a function of treatment parameters after 14 days of storage at +(2±1)°C is illustrated in Fig. 2. The evaluation is based on ten-score scale.

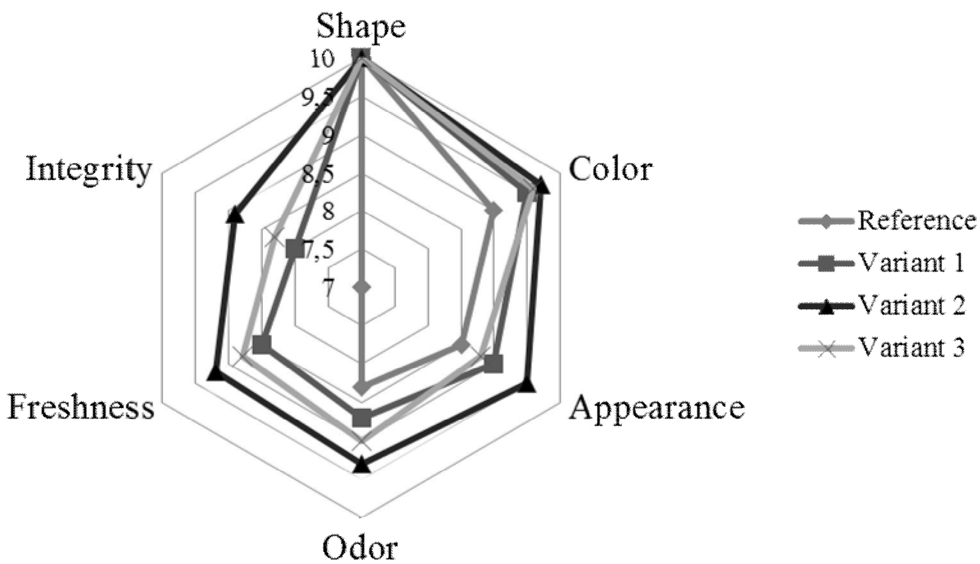

Figure 2: Organoleptic indicators of strawberry as a function of treatment parameters after 14 days of storage at +(2±1)°C.

It can be seen that during strawberry storage at +(2±1)°C, the cumulative organoleptic evaluation is higher in comparison with the reference: for berries treated by ELF EMF according to variant 2 (30 Hz, 10 A, 30 min) – by 4.1 scores.
The obtained organoleptic evaluation makes it possible to conclude that preliminary treatment of strawberries by ELF EMF provides retention of organoleptic indicators during storage at +(2±1) C.

4. DISCUSSION

The performed experiments provided data on the influence of treatment by ELF/ULF EMF at the stage of preparation of Marmelada strawberry for storage on resistance against bacteriological damage and on market condition during storage. Analysis of the experimental data makes it possible to conclude that the natural microflora of the considered berries is presented by MAFAnM and molds. The content of MAFAnM on the considered berries varied from 5,000 CFU/g to 12,000 CFU/g. MAFAnM were presented by spore microorganisms (~69%), enteric bacteria (~15%), and yeasts (~16%). The mold content varied from 110 CFU/g to 1,400 CFU/g. Average value for four samples was as follows: MAFAnM – 7.1×10^3CFU/g; molds– 288 CFU/g.
Treatment of berries by ELF EMF at 30 Hz, 10 A for 30 min was the most efficient to reduce microbial contamination of strawberries. In addition to decrease in microbial population, this procedure provided maximum yield of standard products (72.6±2.7).
It was determined that during strawberry storage at +(2±1)°C, total losses in comparison with reference were lower: for berries treated by ELF EMF at 20 Hz, 15 A, 30 min – by 4%; for berries treated by ELF EMF at 30 Hz, 10 A, 30 min – by 13.3%. After treatment by ULF EMF at 40 Hz, 5 A for 30 min, total losses were higher than in reference by 0.8%. The organoleptic evaluation confirmed that the preliminary treatment of strawberries by ELF EMF at 30 Hz, 10 A for 30 min was the most efficient to retain organoleptic indicators

during storage for 14 days at +(2±1)°C.

5. CONCLUSION

The content of MAFAnM on the considered berries varied from 5,000 CFU/g to 12,000 CFU/g. MAFAnM were presented by spore microorganisms (~69%), enteric bacteria (~15%), and yeasts (~16%). The mold content varied from 110 CFU/g to 1,400 CFU/g. Average value for four samples was as follows: MAFAnM – 7.1×10^3CFU/g; molds– 288 CFU/g.

Strawberry treatment by ELF EMF at 30 Hz, 10 A for 30 min decreased efficiently microbial contamination of strawberries. In addition to decrease in microbial population, this procedure provided maximum yield of standard products (72.6±2.7) after storage for 14 days at +(2±1)°C. Total losses were by 13.3% lower in comparison with the reference product. Organoleptic evaluation confirmed the conclusion that preliminary treatment of strawberries by ELF EMF at 30 Hz, 10 A for 30 min provided better retention of organoleptic indicators.

Herewith, the treatment by ULF EMF at 40 Hz, 5 A for 30 min increased total losses in comparison with the reference product by 0.8% and impaired organoleptic indicators.

The performed analysis makes it possible to conclude that application of electromagnetic fields at the stage of strawberry preparation for storage is very promising to improve strawberry resistance against bacteriological damage and its market condition.

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