THE MICROBIOLOGICAL CHARACTERISTICS OF THE MICROWAVE-TREATED SAMPLES AND THE CONVECTION-HEAT-TREATED SAMPLES SHOWS NO DEVIATION IN CASE OF SURFACE WATER TREATMENT

A MIKROHULLÁMMAL ÉS A KONVEKCIÓS MÓDON HŐKEZELT MINTÁK MIKROBIOLÓGIAI JELLEMZŐI NEM MUTATNAK ELTÉRÉST A FELSZÍNI VÍZ KEZELÉSE ESETÉN

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Abstract

Applying the comparative method, we applied microwave and convective heat treatment on water samples from surface water. By determining microbiological parameters, we searched for detectable deviations in any parameter beyond the effect of heat treatments. The effect of heat treatments was detectable in all cases, but the thermal effects were the same regardless of the method of heat treatment, at a frequency of 2450MHz and a power of 900W. We observed microbiological characteristics that may not only change with thermal effects. Highlighting that, our research is based on the exact same treatment time and applied temperature. The microbiological characteristics of the microwave-heat-treated samples showed no deviation as those of the convectively heat-treated samples; this was checked by two-sample t-test at a significance level of $p<0.05$.
Keywords: *microwave heat treatment, microbiological parameters, TBC, heat, water*

Összefoglalás

Az összehasonlító módszerrel mikrohullámú és konvektív hőkezelést alkalmaztunk felszíni vizekből származó vízmintákon. A mikrobiológiai paraméterek meghatározásával kerestük, hogy a hőkezelések hatásán túlmenően bármely paraméterben kimutatható eltérést találunk-e. A hőkezelések hatása minden esetben kimutatható volt, de a hőkezelési módszertől függetlenül a hőhatás 2450MHz frekvencián és 900W teljesítményen azonos volt. Olyan mikrobiológiai jellemzőket figyeltünk meg, amelyek nem csak a hőhatásokkal változhatnak. Kiemelve, a kutatásunk pontosan azonos kezelési időn és alkalmazott hőmérsékleten alapul. A mikrohullámú hővel kezelt minták mikrobiológiai jellemzői nem mutattak eltérést a konvektív hővel kezelt mintáktól; ezt kétmintás t-próbával ellenőriztük $p<0,05$ szignifikanciaszinten.
Kulcsszavak: *mikrohullámú hőkezelés, mikrobiológiai jellemzők, TBC, hő, víz*
JEL kód: *O33*

Introduction

The use of microwaves (MW) in the food industry is still widespread and recently it is represented in environmental engineering. Numerous studies have published the advantages of MW heating over traditional techniques. The most relevant of those advantages are more efficient heating because internal heat generation is highly efficient (80% or more); uses faster treatment time, about 25% of the time used for conventional heat treatment/heating. As a result of the previous examples, quality retention in the processed product is better: due to the high heating rate, the target temperature is reached quickly, thereby reducing the thermal effect on the food and minimizing the avoidable effects on the sensory and nutritional characteristics of the food. It may be mentioned as an advantage to apply the heat-sensitive, high viscosity and multiphase fluids; the possibility of safe treatment after packaging pasteurization; easy operation, low footprint and low power consumption (high efficiency), reducing noise and low maintenance costs; microwave treatment systems can be turned on or off immediately. Furthermore, contamination is minimal due to the elimination of hot heat transfer surfaces, as the tube used remains transparent and cooler than the product. Finally, it is important to mention that it is environmentally friendly processing, as the production of MW does not generate pollutants or toxic waste (MARTINS et al. 2019, BHUSHAND et al. 2017, CHANDRASEKARAN et al. 2013, GUO et al. 2017, MISHRA – RAMCHANDRAN 2015, JIMÉNEZ-SÁNCHEZ et al. 2017, SALAZAR-GONZÁLEZ et al. 2012).

The most relevant disadvantage relates to the uneven temperature distribution, which results in hot and cold spots mainly in solid and semi-solid products. However, MW heating, heat treatment has been proven to be applicable to liquid foods in flow-through continuous appliances. In a heterogeneous system, such as milk, fats and colloidal substances impede ion migration, reducing conductivity, which promotes inequality in heat generation (SALAZAR-GONZÁLEZ et al. 2012, IULIANA et al. 2015, VADIVAMBAL – JAYAS 2010).

Another disadvantage is that we have moderate data for modeling MW heating, analysis of energy and production costs, and the high initial investment also limits the use of microwave energy communication (MARTINS et al. 2019, CHANDRASEKARAN et al. 2013, KHAN et al. 2018).

From 2009 to 2020, the research team of the University of Gödöllő drew attention to the fact that some of the research was focused on the detection of so-called non-thermal effects (GÉCZI et al. 2009, GARNACHO et al. 2012, GÉCZI et al. 2013a, GÉCZI et al. 2013b, GÉCZI et al. 2013c, KORZENSZKY et al. 2013, GÉCZI et al. 2017, KORZENSZKY et al. 2020). Several studies have shown that the bactericidal effect of microwaves is due not only to thermal but also to non-thermal mechanisms; however, little is known about the non-thermal effects of the microwave oven on food hygiene quality. According to CUSICK et al. (2016) the effect of microwave frequency electromagnetic fields on living microorganisms is an active and controversial research area. A significant disadvantage of studying the effects of microwave radiation on mesophilic organisms is the inevitable heating of the body.

In 1998, KOZEMPEL et al. reported that microwave treatment had zero effect on microorganisms in milk at temperatures below 40°C. Recently, the non-thermal effects of microwaves on microorganisms have been debated, as some studies have shown the non-thermal effects of microwaves on certain types of bacteria (BARNABAS et al. 2010, SHAMIS et al. 2011, NASRI et al. 2013, ROUGIER et al. 2014).

Referring to those studies, it can be assumed that high microwave irradiation at low temperatures affects the viable number of certain groups of bacteria, thus consequently providing some level of safety for foods treated with a microwave oven. HAMMAD (2015) examined the non-thermal effect of the household microwave oven with 1100W of irradiation on various groups of bacteria; this study provides the first detailed analysis of the effect of microwave irradiation on raw milk safety.

There are various methods for detecting non-thermal effects. Most research ad (1) aims to detect positive effects that could not have been achieved otherwise. An obvious method for detecting non-thermal effects gives ad (2) low-power or combined irradiation that does not cause a temperature rise. Furthermore, one option ad (3) is to accept thermal effects, but in a comparative way, in addition to thermal effects, we examine what else can result.

Demonstration of the positive effects of MW

The past 20 years, HARANGHY et al. (2020) have intensively investigated the applicability of microwave irradiation to sludge treatment. The studies focused on a detailed analysis of the MW irradiation of waste activated sludge in batch studies. In the study, continuous flow microwave treatment with various irradiated energy and power intensities was used to improve the chemical oxygen demand (COD) solubility and biodegradability of thickened primary milk sludge. The efficacy of MW treatment was also examined by intermittent mesophilic anaerobic digestion (AD) tests. The results present that the solubilization rate (soluble in total COD, SCOD/TCOD) and aerobic biodegradability (expressed as the ratio of biochemical oxygen demand to soluble COD, BOD/SCOD) were biased by energy intake as well as MW power. Increased MW power and/or increased energy consumption lead to higher solubility and biodegradability.

In the absence of knowledge about the microbial effects of microwaves on bacteria, a study by Hammad aimed to investigate the effects of high microwave radiation on the safety of raw milk. Forty samples of raw milk (El Menofia, Egypt) were collected from retail stores. The milk samples were usually heated in a water bath to a temperature of 40°C. Additional samples were used to achieve the same temperature in a household microwave oven (3min, 1100W) using a cooled water jacket. The number of bacterial groups (Enterobacteriaceae, Pseudomonas spp., and Staphylococcus) in the microwave-treated samples was compared with conventional heat-treated and untreated raw milk samples. The bacterial counts were nearly similar in samples treated by conventional heating and microwave. Statistical analysis revealed non-significant effect of microwave treatment at sub-lethal temperature as P values were more than 0.05. This study provides evidence that high household microwave radiation at lethal temperatures does not significantly affect the hygienic quality of milk, so the level of safety for the consumer does not varies (HAMMAD 2015).

TREMONTE et al. (2014) found that due to a lack of knowledge about the susceptibility of pathogens and their toxins to varying time, threshold, and temperature combinations of microwave treatments, milk safety requirements need to be based solely on microwave heat with an internal milk temperature of at least 95°C.

In addition to the beneficial effect of MW irradiation on biodegradability, there are only a very small number of studies comparing the efficacy of microwave-assisted alkaline and acid pretreatments. JÁKÓI et al. (2018) investigated the effects of microwave irradiation with alkaline and acid treatment on the biodegradability of food sludge under aerobic and anaerobic conditions. The study revealed that microwave irradiation is suitable to increase the solubility and biodegradability of milk sludge in organic matter, however, the degree of degradation combined with alkaline, or acid addition was increased. Microwave-alkali pretreatment (in the pH range of 10–12) was the most favorable to increase the solubility in organic matter. The SCOD/TCOD with microwave intensive alkaline treatment was achieved 34% higher values than acidified sludge. However, the use of acidic conditions (pH range 2-4) was more suitable to increase aerobic biodegradability in a shorter time. Their results confirmed that continuous-flow MW pretreatment is suitable to increase the aerobic and anaerobic biodegradability of sludge and concluded that MW-assisted acid treatment is more effective in enhancing aerobic biodegradability. In addition, the use of alkaline conditions during MW irradiation increased biogas yield.

PRIJANA et al. (2016) aimed to evaluate the applicability of the microwave oven in the preparation of the laboratory medium. Various media (MacConkey agar in Petri dishes inoculated with Escherichia coli; Sabouraud agar in Petri dishes inoculated with Candida albicans; Kligler iron agar in reaction tubes inoculated with Escherichia coli and Salmonella Typhs; in citrate agar reaction tubes inoculated with Klebsiella pneumoniae, in Mueller-Hinton broth reaction tubes inoculated with Escherichia coli, and Motility Indole Urea in semi-solid agar, reaction tubes inoculated with Proteus sp) were treated in a microwave oven for 1, 2 and 3 minutes. Results: Contamination was detected in only 5 cups out of 54 dishes/tubes out of a variety of microwave sterilized media. The use of a microwave oven as an alternative sterilizer in microbiological growth media is significantly potential, especially for two- and three-fold heating.

Low power or combined irradiation

The aim of the research of JÁKÓI et al. (2019) was to investigate the effects of microwave irradiation on the enzymatic degradation of the lignocellulose content of tobacco-based biomass. For the study, a mixture of different parts of by-product tobacco plants was applied in a 10(m/m)% aqueous suspension and MW pretreatment was applied at two different levels of energy density. The effects of chemical (acidic/alkaline) conditions during MW irradiation were also investigated in this study. To characterize the energy efficiency of the pretreatments, the specific energy requirements of each experimental setup were evaluated. The choice of operating parameters of microwave irradiation (aka power level, exposure time) greatly influences the efficiency of enzymatic hydrolysis, but also economically influences the investment and operating costs of microwave treatments. It was found that the alkaline state (pH=12) allows to reduce the energy requirement of MW pretreatment.

YE et al. (2013) found that lower-dose (20W-40W) continuous-wave microwave irradiation of the 2450MHz microwave did not cause a temperature increase in muscle tissue with the titanium alloy implant. However, at 50W and 60W doses, a significant temperature rise was observed in surface and deep muscle fibers. According to those results, low-dose microwave therapy may be a promising method for patients with internal titanium alloy fixation.

SINGH et al. (2019) developed a microwave ultraviolet sterilization system to study the synergistic effect of milk sterilization. In a microwave chamber, electrodeless lamps emitting ultraviolet radiation showed a synergistic effect without changing food safety standards. This study compared the results of microwave and microwave-ultraviolet sterilization of milk in terms of microbial tests and physicochemical properties. It has been found that a microwave-ultraviolet system is more efficient than a microwave oven.

Comparative method

In their research, BESZÉDES, SZABÓ and HODÚR (2013a) aimed to investigate two intensive drying methods - infrared (IR) and microwave drying - in the case of milk sludge. The effects of IR and MW drying at different power intensities on drying characteristics and biodegradability were investigated in the experiments. The results showed that MW drying is more advantageous for milk sludge because the drying time to reach a certain value of the final moisture content is significantly shorter than IR drying. The effects of increased specific power intensity may be more pronounced during the MW process, resulting in faster drying. At lower power intensities, the MW process required a drying period more than 30% shorter to achieve a final moisture content similar to IR drying. At higher power intensities, the drying time was 70% shorter. Considering the change in the degree of biodegradability, the MW drying process has advantages over IR drying. The biodegradability of microwave-dried milk sludge is 13% higher than that of IR-dried milk sludge, which is an advantage in further sludge utilization processes.

BEKE et al. (2014) analyzed non-thermal effects resulting from the properties of microwave irradiation in the drying process of biological materials. In order to demonstrate and optimize the potential impact of non-thermal phenomena, two types of experimental equipment were constructed so that the phenomena of polarity and radial pressure could be measured. It was found that the polarity enhancing effect can be described using the appropriately modified Lambert cosine law, and the non-thermal effect resulting from the microwave absorption mechanism follows Lebedev's theory of radiation pressure, with some modifications. The experiments demonstrated that the parallel phenomenon of polarization and radiation pressure can both improve the intensity of dehydration; however, these effects depend significantly on the characteristics of the material to be dried. Since the non-thermal effect of microwave energy resulting from the phenomenon of radiation pressure is directly proportional to the moisture content during drying, there is a moisture content value below which the radiation pressure ceases.

HAN et al. (2020) in their study discuss the impact of microwave-cooked heated foods on human health. Microwave technology has been widely used in the food industry, but the effect of microwave-heated food on human health is being questioned. Female KM mice were chosen to be treated with microwave-heated milk, and reproductive markers such as litter size, birth rate, survival rate, and ovarian index were evaluated. With longer term feeding, the reproductive status (body weight, birth rate, litter size, neonatal survival rate, interpregnancy interval, and brain superoxide dismutase and catalase activity) of KM mice treated with microwave-heated milk did not significantly change except for the ovarian index of first-generation mice, which was decreased significantly compared with the control group and the group given electrically heated milk. Longer term consumption of microwave-heated milk can affect the ovarian index of reproductive mice.

Material and methods

The purity and usability of natural waters is becoming increasingly important. Natural waters are indicators of optimal habitats in the natural environment. Lake Úrréti, located on the edge of Gödöllő, 30km north-east of the Hungarian capital, is a natural test water with available results by an accredited laboratory. Based on the protocols prepared by Gödöllő City Management and Service Nonprofit Public Benefit Ltd. (VÜSZI), the status of water was monitored three times annually, for 11 test parameters. The average of the test parameters of the last three years well characterizes the condition of the water of Lake Úrréti, so it is a suitable test fluid for our study. In the year of the series of experiments, the examined parameters did not deviate significantly from the three-year average values. Based on the recording logs prepared by the accredited laboratory, the Table 1 contains; the three-year average values (AVG) of the tested parameters, the VÜSZI test parameters, units, test methods and measurement uncertainty.

Table 1: Tested parameters and test methods characterizing the water

Tested parameters	Test methods	Uncertainty	3 years AVG
Conductivity [µS/cm]	MSZ-448-32:1977	5 rel. %	831.9±41.595
pH [-]	MSZ-260/4-71:1987	0.05	7.886±0.05
DO [mg/l]	MSZ EN ISO 25814	5 rel. %	8.008±0.4
BOD /BOD5/ [mg/l]	MSZ EN 1899-2	5 rel. %	3.475±0.174
Ammonium-ion (NH4+) [mg/l]	MSZ ISO 7150-1:1992	7.5 rel. %	0.084±0.006
Nitrite-ion (NO2+) [mg/l]	NANOCOLO Nitrit918.67	7.5 rel. %	0.016±0.001
Nitrate-ion (NO3+) [mg/l]	MSZ 448/12-82	7.5 rel. %	0.759±0.006
Phosphate-ion (PO4+++) [mg/l]	NANOCOLOR o-Phosphate918.77	7.5 rel. %	0.193±0.014
Phosphate -ion (PO4-P) [mg/l]	NANOCOLOR o-Phosphate918.77	7.5 rel. %	0.063±0.005
Total phosphorus [mg/l]	NANOCOLOR SP15985.0.81	7.5 rel. %	0.221±0.001
Oxygen consumption /CODCr/ [mg/l]	NANOCOLOR KOI 160985.026	7.5 rel. %	30.055±2.254
A-chlorophyll [mg/l]	MSZ ISO 10260	7.5 rel. %	73.952±5.546

From April to July (2019) we sampled the water of Lake Úrréti 7 times, the sampling points were the same (Fig.1.), the samples were transported in refrigerated form.

Figure 1. Sampling location - Lake Úrréti, Gödöllő, Hungary.

The heat treatments were repeated three times each time. Samples were given a sampling code for identification after heat treatment. Double-blind testing was performed: the person performing the analysis received mixed and coded samples, and the person performing the heat treatments did not participate in the analysis of the samples.

Methods of measurement configuration and heat treatment

The test equipment was implemented by converting a household microwave oven into a flow-through, continuous operating mode device with 900W output power. Two holes with seven mm diameter located 8 cm apart were made in the oven to introduce and drain the liquid. The microwave equipment complete with special glass spirals was connected to a STENNER 85M5 type adjustable feed rate peristaltic pump (Stenner Pump Company, Jacksonville, FL, USA), and an ALMEMO 2590-9 temperature measuring instrument (Ahlborn, Holzkirchen, Germany) (Fig 2).

Inside the microwave oven, the samples flowing through the glass spirals can be heated to the desired temperature depending on the length of the spiral and the flow rate of the peristaltic pump. The temperature can be easily monitored before entering and after leaving the microwave field, allowing the process to be controlled effectively. One of the advantages of this method is the gradual heating and constant output temperature due to the use of glass spirals. This way the temperature fluctuation characteristics of intermittent operation can be avoided.

For each comparative test, the glass spirals were first installed into the Whirlpool AT 314 microwave oven (MW) and then into the T-PHYWE water bath thermostat (TB), respectivly. The temperature was continuously monitored before (T1) and after (T2) the treatment, using the ALMEMO 2590-9 temperature measuring system. During each measurement, both (T1) and (T2) were kept on constant values. In our research we achieved the target temperature of 62-95°C as a function of the flow rate was set to Q=4.29-10.72liter/hour. Untreated samples were tested as comparing control.

Figure 2. Modular experimental setup for flow-through heat-treatments of liquid foods.

Analysis of food properties

Comparative studies of natural water as a sample liquid were performed in the Research Laboratory of the Hungarian University of Agricultural and Life Sciences. The analysis of the treated and coded samples was tested in an accredited laboratory (Eurofins KVI-Plusz Környezetvédelmi Vizsgáló Iroda Kft., NAH-1-1377 / 2015). The list of standard methods used in the study is shown in Table 2.

Table 2: The list of standard methods used in the study

ISO	ISO description
MSZ EN ISO 14189:2017	Water quality. Enumeration of Clostridium perfringens. Method using membrane filtration (ISO 14189:2013)
MSZ EN ISO 6222:2000	Water quality. Enumeration of culturable micro-organisms. Colony count by inoculation in a nutrient agar culture medium (ISO 6222:1999)
MSZ EN ISO 7899-2:2000	Water quality. Detection and enumeration of intestinal enterococci. Part 2: Membrane filtration method (ISO 7899-2:2000)
MSZ EN ISO 9308-1:2014/A1:2017	Water quality. Enumeration of Escherichia coli and coliform bacteria. Part 1: Membrane filtration method for waters with low bacterial background flora (ISO 9308-1:2014/Amd 1:2016)
MSZ EN ISO 9308-2:2014	Water quality. Enumeration of Escherichia coli and coliform bacteria. Part 2: Most probable number method (ISO 9308-2:2012)
Pseudalert AFNOR val. (NF 148.11-03-2016)	NF EN ISO 16266 (August 2008): Water quality. Detection and enumeration of Pseudomonas aeruginosa - Method by membrane filtration

Statistical Analyses

Statistical analysis was performed based on the data obtained during the laboratory tests. The difference in the variance of the two-sample series was checked by the F-test. Since there was no significant deviation, a two-tailed independent sample t-test was used to determine a significant difference between any of the examined parameters. We state that there is no significant deviation between the two samples ($p < 0.05$).

Results

50 ml samples were produced from the water of Lake Úrréti by heat treatments for further microbiological studies. In the accredited laboratory, we requested methods suitable for the classification of drinking water, even though our goal was not the qualification of drinking water. Higher level testing requirements were chosen to further demonstrate the efficacy of the treatments. Table 3 shows the tested parameters, their units of measurement and the legal (local) limits.

Table 3: Tested parameters and their limits

Tested parameter	Unit of measurement	Legal (local) limit
Total Coliform count	/100ml	0
Total E.coli count	/100ml	0
TBC on 22°C	/ml	400
TBC on 37°C	/ml	80
Total Enterococcus count	/100ml	0
Total Pseudomonas aeruginosa count	/100ml	0
Total Clostridium perfingens count	/100ml	0

Limit values and qualification in Hungary 201/2001. (X.25.), and related professional guidelines.

Without exception, even in the case of heat treatment at 60°C, no detectable number of microbes was present in the tested sample despite the fact that in several cases the initial values were above the limit value (eg April Coliform number 548TBC/100ml, June E. coli number 31TBC/100ml, June Enterococcus number 120TBC/100ml, June Pseudomonas aeruginosa number 200TBC/100ml, July Clostridium perfingens number 200TBC/100ml). Both heat treatments modified the parameters, eliminated all measured specified species in the samples.

Our results for colony numbers developing at 22°C and 37°C are presented in a diagram. The 22°C colony count is made up of environmental bacteria that are harmless to humans and pose no significant health risk. They are indicator bacteria, indicating if the conditions in the water system allow bacteria to grow. The number of colonies collected from the initial, i.e. untreated, samples ranged from 300 to 600 TBC (Total Bacteria Count)/ml in each case. The comparative diagram (Fig. 3) shows that in all cases the heat treatment at 60°C reduced the number of colonies below the limit value (400TBC/ml) regardless of the treatment method. The Fig 3 diagram obviously shows that there is no significant deviation between the microwave (MW) and conventional convective heat treatment (TB) process in terms of colony count on 22°C.

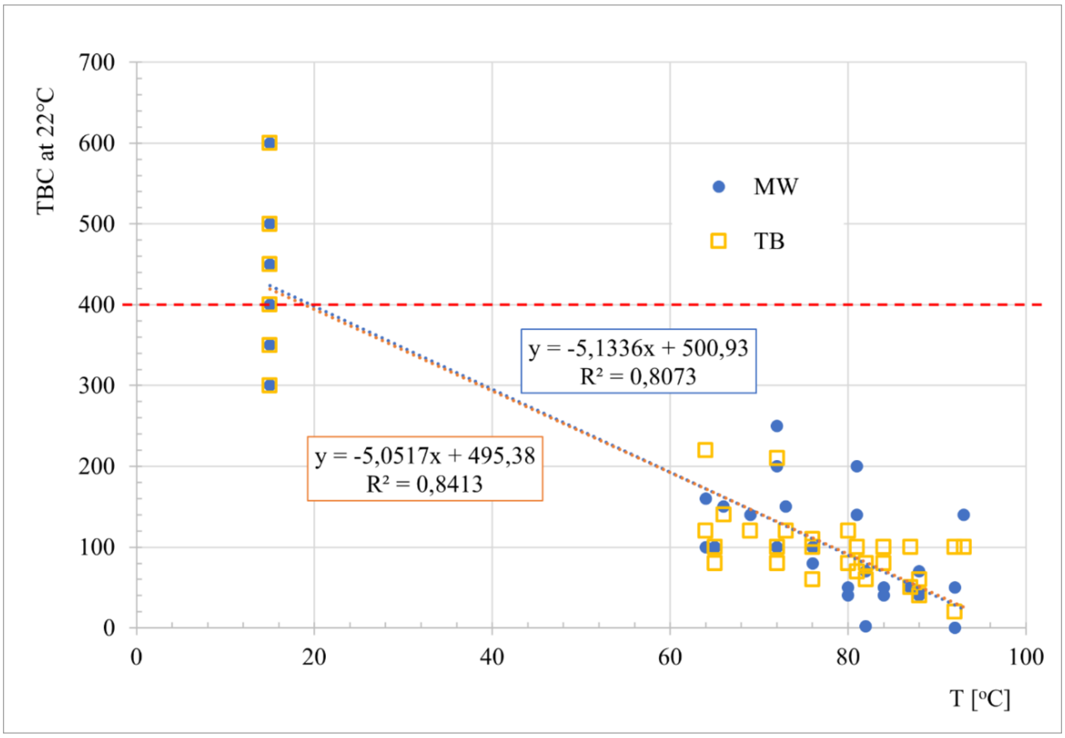

Figure 3. The colony count change on MW and TB treatment, regarding in the aspect of temperature; TBC on 22°C

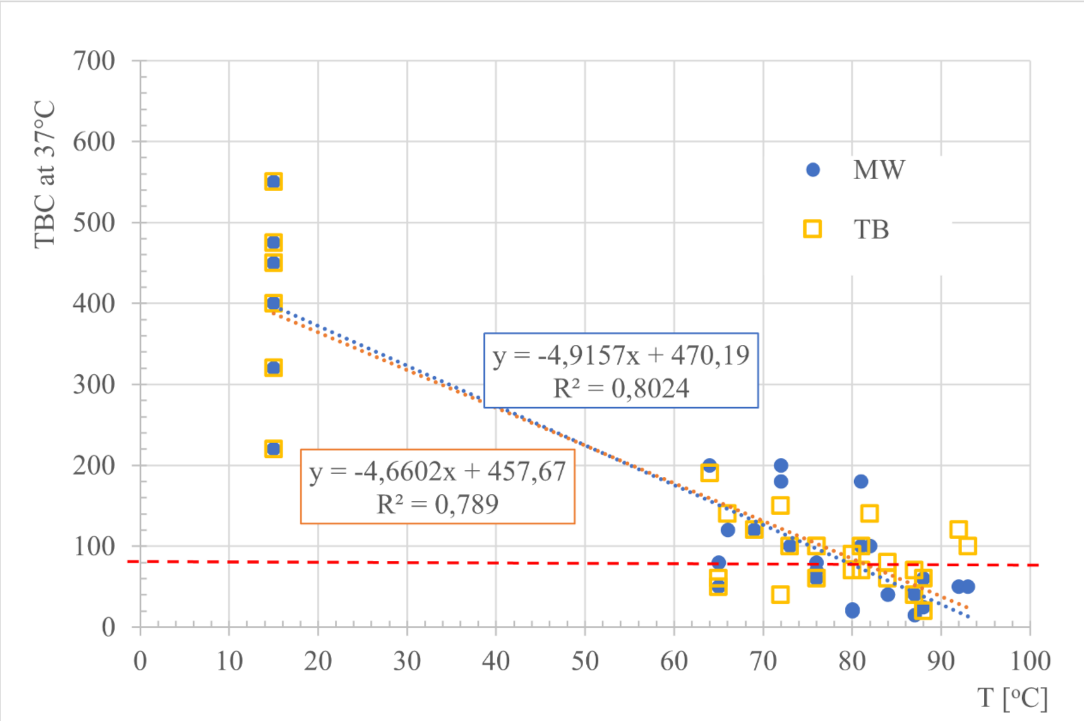

Figure 4. The colony count change on MW and TB treatment, regarding in the aspect of temperature; TBC on 37°C

Increasing the number of colonies at 37°C is only specified if on special cases; for example, if the water temperature exceeds 20°C. In our case, this value is also an indicator parameter. The number of colonies (on 37°C) collected from the initial, i.e. untreated, samples ranged from 220 to 550 TBC/ml in each case. The comparison chart (Fig. 4) shows that as the treatment temperature increases, TBC decreases at both heat treatment methods. 56% of the heat treatments yielded results below the limitation (<80TBC/ml). No significant difference was found between the nature of the colony count reduction.

Conclusion

The heat treatment of surface water by microwave energy transfer and convective presents that the fact of heat treatment can be detected, but there is no detectable difference between the methods. Heat treatment above 60°C eliminated Coliform, E. coli, Enterococcus, Pseudomonas aeruginosa, and Clostridium perfingens species in both methods.

Starting from the same number of colonies at the time of sampling, the reduction effect of microwave heat transfer and convective heat transfer after heat transfer above 60°C shows result below 400 TBC/ml on 22°C. The results of the count of colonies in the heat treatments between 62°C and 95°C are correlated, it is not possible to determine if the TBC decreased better of one or the other treatment.

In Fig 4, in the case of the colony count test on 37°C, the number of colonies below the limit value of 80 TBC/ml of drinking water was only visible in the case of treatment between 80°C and 95°C. However, even in this case, it was not possible to separate the results of MW and TB treatment. There is also no significant difference between microwave and convective heat treatment processes in terms of the microbiological parameters studied.

In our previous research, we obtained similar results by examining physical and chemical parameters. We proved by measurements and then published that the effect of heat treatments was clear in the examination of the total germ count of milk. On 17 different occasions, heat treatments of a minimum of 64°C and a maximum of 82°C were applied (without heat retention) and it was found that the reduction of the total number of germs by microwave energy transfer and heat transfer in an external water bath was similar. Summarizing our results, we concluded that microwave heating is considered equivalent to convective heat treatment, however, the existence of non-thermal effects cannot be excluded (GÉCZI et al. 2013a).

In 2014, the fermentation of Nero and Bianca grape stum was decelerated by heat treatment (microwave and convective). The results are similar again. Based on the comparative studies, it was found that based on the increase in CO_2 concentration that represents the fermentation process, the heat treatments delayed the fermentation process in all cases. But there was no detectable difference between the effect of microwave and convective heat treatment methods in this study either (KORZENSZKY – MOLNÁR 2014).

In contrast using a flow-through microwave treatment, BESZÉDES et al. (2013b) found that microwave pretreatments are suitable for improving the biodegradability of sweet whey. Flow rate and specific power intensity have also been shown to affect the biodegradability of whey and biogas production. To quantify the structural change in sweet whey organic matter, biochemical oxygen demand (BOD), chemical oxygen demand (COD), and biogas yield were checked as control parameters.

BIFFINGER et al. (2016) reported a surprising result when applying MW treatment. The MW treatment significantly increased TBC growth rate, so that the total biomass in the culture was >80% compared to convective heat treatment at the same temperature (65°C). This contradicts today's knowledge, as MW radiation is commonly used to kill microbes, such as in the sterilization of meat and fruits and in the treatment of dairy products, rather than in their cultivation. Furthermore, most of the published work on microorganisms and MWs is related to biomass processing and elimination of microorganisms with MW radiation and not to the deliberate cultivation of thermophilic microorganisms with sustained MW radiation.

Microwave technology has been discovered for 75 years and is used in our everyday lives, but its mechanism of effect has not yet been clarified.

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