THESES OF DOCTORAL (PhD) DISSERTATION

RENÁTA TIHANYI-KOVÁCS

MOSONMAGYARÓVÁR

2023

THESES OF DOCTORAL (PhD) DISSERTATION
SZÉCHENYI ISTVÁN UNIVERSITY
ALBERT CASIMIR FACULTY AT MOSONMAGYARÓVÁR
DEPARTMENT OF FOOD SCIENCE
Wittmann Antal Multidisciplinary Doctoral School in
Plant, Animal, and Food Sciences
Pulay Gábor Doctoral Program in Food Science

Head of Doctoral School:
Prof. Dr. László Varga, DSc
Head of Doctoral Program:
Prof. Dr. László Varga, DSc
Dissertation Advisers:
Dr. habil Balázs Ásványi, PhD
Dr. habil Péter Böröcz, PhD

THE EFFECT OF PHYSICAL DEMANDS OF SUPPLY CHAINS ON THE MICROBIOLOGICAL QUALITY OF BOTTLED NATURAL MINERAL WATERS

Written by:
Renáta Tihanyi-Kovács

Mosonmagyaróvár
2023

1. INTRODUCTION

Today, global supply chains deliver bottled mineral water to all parts of the world, so they are no longer only sold in the immediate vicinity of the bottling plant. In recent decades, a significant increase in mineral water consumption has been observed not only in Hungary, but throughout the world. The growing market probably reflects the population's scepticism about the quality of tap water, which can be traced back to the frequent contamination of urban water supplies - although this is not relevant in our country -, the unpleasant taste and smell of tap water, as well as the fluoride and chlorine contents of the water. It has already been observed that shaking negatively affects the physicochemical properties of foods in many cases, which manifest themselves in physically invisible changes in the case of low-viscosity matrices. The effect of mechanical stress during transport on the microbiological properties of foods has not yet been investigated.

Without water there is no life and only fresh water is suitable for human consumption. At the same time, in immunosuppressed individuals, such as HIV-positive patients, those infected with coronavirus, those suffering from tuberculosis, but we can also mention the elderly and infants, or the malnourished, bottled water with a high total plate count and free of pathogenic microbes can also cause illness.

1.1 AIMS

The purpose of this research is to investigate the effect of mechanical stresses occurring during transportation on mineral water. Therefore, the microbiological status of a product taken from the production line of a natural mineral water bottling plant in north-western Hungary was investigated depending on transportation stresses. The goal was to find a correlation between the number of microbes detectable in mineral water and mechanical agitation and its intensity.

The aim was a comparative examination of commercially available mineral waters with different bottling locations and times depending on mechanical stress.

Another objective of the research was to explore whether the packaging inspection standard (ASTM D-4169-16) commonly used in logistics can be used to examine changes in the microbiological properties of food. For this, a comparison of real-time and time-accelerated tests was carried out.

2. MATERIALS AND METHODS

Dynamic mechanical vibration simulation was carried out in the Packaging and Environmental Resistance Testing Laboratory, Audi Hungária Faculty of Automotive Engineering, Széchenyi István University The microbiological and other additional tests were carried out in the Microbiological Laboratory of the Department of Food Science at Albert Casimir Faculty of Mosonmagyaróvár. Three model matrices were used during the tests as follows:

- freshly bottled natural mineral water (marked F) from a north-western Hungarian bottling plant,
- previously sterilized mineral water inoculated with a microbe isolated from the tested natural mineral water,
- three commercially available natural mineral waters (marked A, B, and C) with different bottling locations and times.

2.1 VIBRATION TEST

During the tests, the vertical vibration relationship was reproduced, which was simulated on a shaking table operating on the servo-hydraulic principle with time-accelerated and real-time vibrations. For this, the PSD curve of the ASTM D4169-16 packaging test standard was used as a basis, which reproduces the conditions of the shaking movement of truck transport at three power levels. The test parameters are shown in Table 1.

Table 1: Structure of vibration tests

Method of vibration	Time of vibration (h)	Relaxing (h)	Repeat	Temperature (°C)
Time-accelerated	1	12	4	22±1
Real time	5	19	4	22±1

2.2 SAMPLING

A sample was taken before and after each shaking, then every 12 h in the case of time-accelerated testing, and every 24 h in the case of real-time shaking. The control was natural mineral water without shaking, stored at 22±1°C, with the same bottling time as the shaken sample.

2.3 MICROBIOLOGICAL EXAMINATION

The tested microorganisms and the standards for their detection are summarized in Table 2.

2.4 MOLECULAR BIOLOGICAL TESTS

The taxonomic classification of the microbe used for the model experiment was completed. The order of base pairs (bp) in the DNA molecule was determined by a service provider. The result was “blasted” to the sequences of the NCBI (National Center for Biotechnology Information) database. Primer design was based on the segments that showed a significant difference or similarity in the sequence of the identified and other bacteria relevant to the food industry, at least 20-25 bp long and located at a maximum of 300 bp for efficient and specific amplification.

The Bioline SensiFAST SYBR No-Rox kit was used to detect bacterial DNA in water as recommended by the manufacturer. The annealing temperature was 60°C and the synthesis time was 20 s.

Table 2: Tested microorganisms

Research direction	Standard	Tested quantity (cm^3)	Culture medium	Incubation		
				temperature (°C)	time (h)	conditions
Colony forming units at 22 and 37°C	MSZ EN ISO 6222:2000	1	YEA (Biolab)	22±1 36±1	68±4 44±4	aerobic
Escherichia coli and coliforms	MSZ EN ISO 9308-1:2015	250	CC Agar (Biolab)	36±1	21±3	aerobic
Enterococcus	MSZ EN ISO 7899-2:2000	250	SBA (Biolab)	36±1	44	aerobic
			EAA Agar (Biolab)	44±0,5	2	aerobic
Sulfite-reducing anaerobic (*Clostridium*) spore count	MSZ EN 26461-2:1994	50	TSCA (Merck)	36±1	75±5	anaerobic
Pseudomonas aeruginosa	MSZ EN ISO 16266:2008	250	CN Agar (Biolab)	36±1	44±4	aerobic

YEA: Yeast Extract Agar; CC: ChromoBio Coliform Agar; SBA: Slanetz-Bartley Agar; EAA Agar: Bile-Aesculin-Azide Agar; TSCA: Tryptose Sulfite Cycloserine Agar, CN: Cetrimid Agar

3. RESULTS AND DISCUSSION

3.1 CHANGES IN MICROBIAL COUNTS IN FRESHLY BOTTLED SAMPLES DEPENDING ON SHAKING INTENSITY

The differences in initial plate counts were due to different bottling times and manual bottling.

In the sample exposed to a low-intensity mechanical effect, the autochthonous microbes reached the maximum cell number 12 h earlier, which was an order of magnitude lower than in the control without vibration (i.e., max. $\log_{10}$ $cfu_{control}/cm^3$ = 5.65, max. $\log_{10}$ $cfu_{vibrated}/cm^3$ = 4.56). In the case of allochthonous microbes, the exponential phase of growth was significantly shorter than in the control sample without vibration. The difference in the maximum cell number reached was 2 orders of magnitude (max. $\log_{10}$ $cfu_{control}/cm^3$ = 2.99, max. $\log_{10}$ $cfu_{vibrated}/cm^3$ = 0.94)

In the case of the sample vibrated at low intensity at 22°C, compared to the control, the average generation time (t_g) decreased by over 60% ($t_{g\ control}$ = 27.54 h; $t_{g\ vibrated}$ = 10.72 h). The stimulatory effect of mechanical agitation could also be observed in the case of pathogenic microbes, but the generation time was only halved ($t_{g\ control}$ = 28.82 h; $t_{g\ vibrated}$ = 14.28 h).

Compared to the control samples, the increase in the specific growth rate observed in the shaken samples showed a significant difference for both autochthonous and allochthonous microbes (Table 3).

Table 3: Specific growth rate (μ) for the exponential phase of microbial growth in freshly bottled and control mineral waters as a function of shaking intensity.

Microbe	μ±SD [1/h]			
	Intensity of vibration			Control
	Low	Medium	High	
Autochthonous	0.093±0.002[a]			0.036±0.003[b]
		0.113±0.005[a]		0.149±0.001[b]
			0.045±0.004	0.048±0.004
Allochthonous	0.069±0.418[a]			0.035±0.001[b]
		0.053±0.008		0.070±0.025
			0.199±0.034[a]	0.102±0.011[b]

SD: standard deviation

[ab] Values within a row with different letters differ significantly ($p < 0.05$).

Examining the effect of mechanical agitation on microbial growth at medium intensity according to the ASTM D4169-16 standard, microbial growth was observed only after the shaking stopped at both 22 and 37°C. In the case of autochthonous microbes, an increase in microbial counts started 12 h after the cessation of mechanical agitation, whereas in the case of polluting flora, it started 24 h later. There was no significant difference in specific growth rate between shaken and control samples (Table 3).

The maximum plate count of autochthonous microbes reached a value two orders of magnitude lower than in the control sample (max. $\log_{10}$ $cfu_{control}/cm^3$ = 6.19, max. $\log_{10}$ $cfu_{vibrated}/cm^3$ = 4.00). In the case of allochthonous microbes, there was no significant difference in this regard (max. $\log_{10}$ $cfu_{control}/cm^3$ = 0.90, max. $\log_{10}$ $cfu_{vibrated}/cm^3$ = 1.32).

The generation times in the vibrated samples were as follows: $t_{g\ autochton}$ = 8.85 h or $t_{g\ allochthon}$ = 18.77 h. The corresponding values in the control samples were $t_{g\ autochthon}$ = 6.7 h or $t_{g\ allochthon}$ = 9.1 h. The generation time of allochthonous microbes has doubled.

In the samples shaken at high intensity, there was no difference in specific growth rate of the autochthonous microbes and the number of germs reached compared to the control (max. $\log_{10}$ $cfu_{control}/cm^3$ = 5.87, max. $\log_{10}$ $cfu_{vibrated}/cm^3$ = 5.46). After shaking at this intensity, the growth of the contaminating flora accelerated significantly compared to the control, and the specific growth rate doubled (Table 3). The allochthonous species reached their maximum cell number 12 h earlier than the control; however, no significant difference was observed (max. $\log_{10}$ $cfu_{control}/cm^3$ = 3.46, max. $\log_{10}$ $cfu_{vibrated}/cm^3$ = 3.78).

The generation time of autochthonous microorganisms was 21–22 h, whereas that of allochthonous microbes was 5 or 10 h and they multiplied faster in the samples exposed to agitation.

There was a significant difference in the growth of autochthonous microbes (Table 4) when low-high and medium-high intensities were compared. This difference was also observed when comparing medium-high intensities. A similar result was obtained for the autochthonous microbes (Table 4), with the difference that the autochthonous microbes showed a significantly slower reproduction at high intensity, while the allochthonous microorganisms showed a significantly faster reproduction.

Table 4: Comparison of the specific growth rate (μ) of the exponential phase of microbial growth in freshly bottled mineral water among the investigated microbial groups as a function of shaking intensity.

Microbe	**μ±SD [1/h]**		
	Intensity of vibration		
	Low	**Medium**	**High**
Autochthonous	0.093±0.002[a]	0.113±0.005[a]	0.045±0.004[b]
Allochthonous	0.069±0.418[a]	0.053±0.008[a]	0.200±0.034[b]

SD: standard deviation

[ab] Values within a row with different letters differ significantly ($p < 0.05$).

Comparing the specific growth rates of autochthonous and allochthonous microbes, it was found that autochthonous microbes

reproduced significantly faster at low and medium intensities than did allochthonous microbes, but at the same time, when shaking was performed at the high intensity of the ASTM D-4169 standard, a significant increase was observed in the growth rate of allochthonous microbes (Table 5) Compared to autochthonous microbes, the generation time of allochthonous microbes was reduced to a quarter at high-intensity agitation (Table 6).

Table 5: Specific growth rates (μ) of autochthonous and allochthonous microbes in freshly bottled natural mineral waters as a function of shaking intensity.

Intensity of vibration	**μ±SD [1/h]**	
	Microbe	
	Autochthonous	**Allochthonous**
Low	0.093±0.002[a]	0.069±0.418[b]
Medium	0.113±0.002[a]	0.053±0.008[b]
High	0.045±0.004[a]	0.200±0.034[b]

SD: standard deviation.

[ab] Values within a row with different letters differ significantly ($p < 0.05$).

Table 6: Generation times (t_g) of autochthonous and allochthonous microbes in freshly bottled natural mineral waters as a function of shaking intensity.

Intensity of vibration	**t_g [h]**	
	Microbe	
	Autochthonous	**Allochthonous**
Low	10.75	14.50
Medium	8.85	18.87
High	22.2	5.00

3.2 IDENTIFICATION OF THE ISOLATED MICROBE

A 99–100% match with the sequence of *Acidovorax temperans* was obtained for each isolated colony.

3.3 PRIMER DESIGN

For the detection of *Acidovorax temperans*:

- forward primer: 5'-GATGGCAGATTAGGTAGTTGGT-3'
- reverse primer: 5'-G-GTACGGAACGAAAAGACT-3'

General primers for the detection of microbes relevant to the food industry:

- forward primer: 5'-TGYCAGCMGCCGCGGTAA-3'
- reverse primer1: 5'-GGACTACHVGGGTWTCTAATCCT-3'
- reverse primer2: 5'-GACTACHVGGGTWTCTAATCCTGT-3'

3.4 CHANGES IN MICROBIAL COUNTS OF INOCULATED SAMPLES DEPENDING ON THE INTENSITY OF MECHANICAL AGITATION

Compared to the control, specific growth rates of the shaken samples showed a significant difference at all three intensities (Table 7). As the intensity of mechanical mixing increased, the specific growth rate decreased, and this decrease was also significant between individual intensities (Table 7). The same decrease was observed during tests at different intensities in terms of the maximum cell counts reached (max. $\log_{10}$ cfu/cm$^3_{low}$ = 6.48, max. $\log_{10}$ cfu/cm$^3_{medium}$ = 5.4 and max. $\log_{10}$ cfu/cm$^3_{high}$ = 4.83), and the maximum cell counts were reached in the samples during exposure (0–50 h) at all intensities. The increase was 3-4 orders of magnitude.

The generation time of *Acidovorax temperans* varied at different intensities as follows: $t_{g\ low}$ = 7.69 h; $t_{g\ medium}$ = 12.35 h; $t_{g\ high}$ = 16.13 h.

Table 7: Specific growth rates (μ) for the exponential phase of microbial growth in inoculated mineral waters at different levels of mechanical agitation.

Intensity of vibration			**Control**
Low	**Medium**	**High**	
0.130±0.003[a]	0.081±0.003[b]	0.062±0.006[c]	0.186±0.008[d]

[abcd] Values with different letters differ significantly ($p < 0.05$).

Natural mineral waters have mixed microbial populations, and since only one bacterial species was used for inoculation in this study, it was first investigated whether there was a difference between the two matrices in terms of changes in specific growth rate induced by shaking. The optimum growth temperature of *Acidovorax temperans* is 37°C, so comparisons were made with the same data of freshly bottled mineral water.

At all three intensities, a significant difference was observed in specific growth rate between the mixed culture and monoculture water samples (Table 8). As a result of high-intensity agitation, the allochthonous microbes multiplied three times faster in the freshly bottled natural mineral water than did *Acidovorax temperans* in the inoculated water ($t_{g\ fresh}$ = 5.00 h and $t_{g\ Acidovorax}$ = 16.13 h). At low and medium intensities according to the ASTM-D4169 standard, the isolated bacteria multiplied 1.8 and 1.6 times faster ($t_{g\ low}$ = 7.87 h and $t_{g\ medium}$ = 12.35 h) than did microbes in the freshly bottled water ($t_{g\ low}$ = 14.50 h and $t_{g\ medium}$ = 18.87 h).

Table 8: Specific growth rates (μ) in freshly bottled and inoculated mineral waters during the exponential phase of microbial growth.

Sample	Intensity of vibration		
	Low	**Medium**	**High**
Freshly bottled	0.069±0.013[a]	0.053±0.008[a]	0.200±0.034[a]
Inoculated	0.127±0.005[b]	0.081±0.003[b]	0.062±0.006[b]

[ab] Values within a column with different letters differ significantly ($p < 0.05$).

Increases in cell counts were compared in terms of order of magnitude. High-intensity agitation resulted in an increase of 3 $\log_{10}$ cycles in cell counts of both matrices. At low and medium intensities, an increase of 3.5 orders of magnitude was observed in the inoculated samples and only 1 order of magnitude for the allochthonous microbes of the fresh water.

3.5 QUANTITATIVE PCR

3.5.1 Results of freshly bottled mineral water samples obtained by real-time shaking tests

Microbial growth in the control samples without shaking was slower at all three intensities than in the samples exposed to mechanical agitation. A significant difference was observed at both low and high intensities (Table 9).

Table 9: Specific growth rates (μ) in control and freshly bottled natural mineral waters during the exponential phase of microbial growth using real-time shaking.

μ±SD [1/h]			
Control	**Intensity of vibration**		
	Low	**Medium**	**High**
0.005±0.001[a]	0.013±0.001[b]	0.006±0.001[a]	0.008±0.003[c]

[abc] Values with different letters differ significantly ($p < 0.05$).

Comparing the intensities with each other, a significant difference was obtained in all cases regarding specific growth rates (Table 9). As a result of mechanical agitation, the generation time of the microbial population in the vibrated sample at low intensity was so shortened ($t_{g\ low}$ = 76.92 h, $t_{g\ medium}$ = 158.7 h, $t_{g\ high}$ = 120.5 h) that it resulted in the same number of microbes at the same time as in the case of the other two intensities, although the initial cell count was lower.

3.5.2 Results obtained with time-accelerated shaking of freshly bottled mineral water samples

When testing the mechanical impact at different intensities of the ASTM D-4169 standard, a significant difference was observed at all three intensities compared to the control, as a result of which the generation time compared to the control was reduced to a fifth and a third ($t_{g\ control}$ = 200 h; $t_{g\ low}$ = 58.82 h, $t_{g\ medium}$ = 47.62 h, $t_{g\ high}$ = 41.67 h).

3.5.3 Time-accelerated shaking of freshly bottled and commercially available mineral waters bottled at different places and times

As for samples F, B, and C, there was no significant difference in maximum cell counts reached during the study (max. $\log_{10}$ $cfu_{F,B,C}/cm^3$ = 5.98–6.09). In contrast, the maximum plate count of sample A was an order of magnitude lower (max. $\log_{10}$ cfu_A/cm^3 = 5.19).

The mechanical impact performed according to the ASTM D4169-16 standard had a different effect on specific growth rates depending on intensity and sample (Table 10).

Table 10: Specific growth rates (μ) in freshly bottled (F) and commercially available natural mineral waters of different bottling locations and times (A, B, C).

Sample	**μ±SD [1/h]**		
	Intensity of vibration		
	Low	**Medium**	**High**
F	0.017 ± 0.001^{ad}	0.021 ± 0.006^{ab}	0.024 ± 0.003^{bcd}
A	0.010 ± 0.002^{aef}	0.027 ± 0.004^{a}	0.035 ± 0.002^{be}
B	0.029 ± 0.007^{ad}	0.032 ± 0.009^{a}	0.014 ± 0.005^{bfg}
C	0.039 ± 0.010^{adf}	0.026 ± 0.007^{a}	0.021 ± 0.001^{ag}

[abc] Values within a row with different letters differ significantly ($p < 0.05$).
[defg] Values within a column with different letters differ significantly ($p < 0.05$).

3.5.4 Real-time and time-accelerated shaking of freshly bottled mineral water samples

The time-accelerated test performed at all three intensities of the ASTM D-4169 standard resulted in significantly higher growth rates (Table 11) and, therefore, lower generation times (Table 12) than did the real-time shaking test.

Table 11: Specific growth rates (μ) as a result of real-time and time-accelerated testing in freshly bottled natural mineral water.

Method	**μ±SD [1/h]**		
	Intensity of vibration		
	Low	**Medium**	**High**
Time-accelerated	0.017±0.001[a]	0.022±0.006[a]	0.002±0.005[a]
Real-time	0.013±0.001[b]	0.006±0.001[b]	0.008±0.003[b]

SD: standard deviation.

[ab] Values within a column with different letters differ significantly ($p < 0.05$).

Table 12: Generation times (t_g) in the exponential phase of microbial growth in freshly bottled natural mineral waters under real-time and time-accelerated mechanical agitation.

Intensity of shaking	**t_g [h]**	
	Type of agitation	
	Real-time	**Time-accelerated**
Low	78.12	57.47
Medium	158.73	46.51
High	120.48	42.19

The rate of increase in cell counts observed at medium and high intensities (Table 13) was the same for the real-time and time-accelerated test methods. In contrast, low-intensity real-time shaking induced an increase of 0.5 $\log_{10}$ cycles in cell counts.

Table 13: Changes in cell counts in the case of real-time and time-accelerated modelling.

Intensity of mechanical impact	**Change in cell count (log_{10} dcfu/cm^3)**	
	Method	
	Real-time	**Time-accelerated**
Low	0.90[a]	1.40[b]
Medium	0.94[a]	0.93[a]
High	1.15[a]	1.07[a]

[ab] Values within a row with different letters differ significantly ($p < 0.05$).

As shown in Figure 1, the changes in cell counts caused by real-time mechanical shocks could be characterized with a good approximation with time-accelerated mechanical agitation. As the intensity increased, the regression of the examined variable also increased, which is well illustrated by the R^2 values of the fitted curves ($R^2_{low} = 0.90$; $R^2_{medium} = 0.96$; $R^2_{high} = 0.98$).

In conclusion, the applied ASTM D-4169 standard was suitable for modelling real-time mechanical stress at three performance levels in terms of cell number changes.

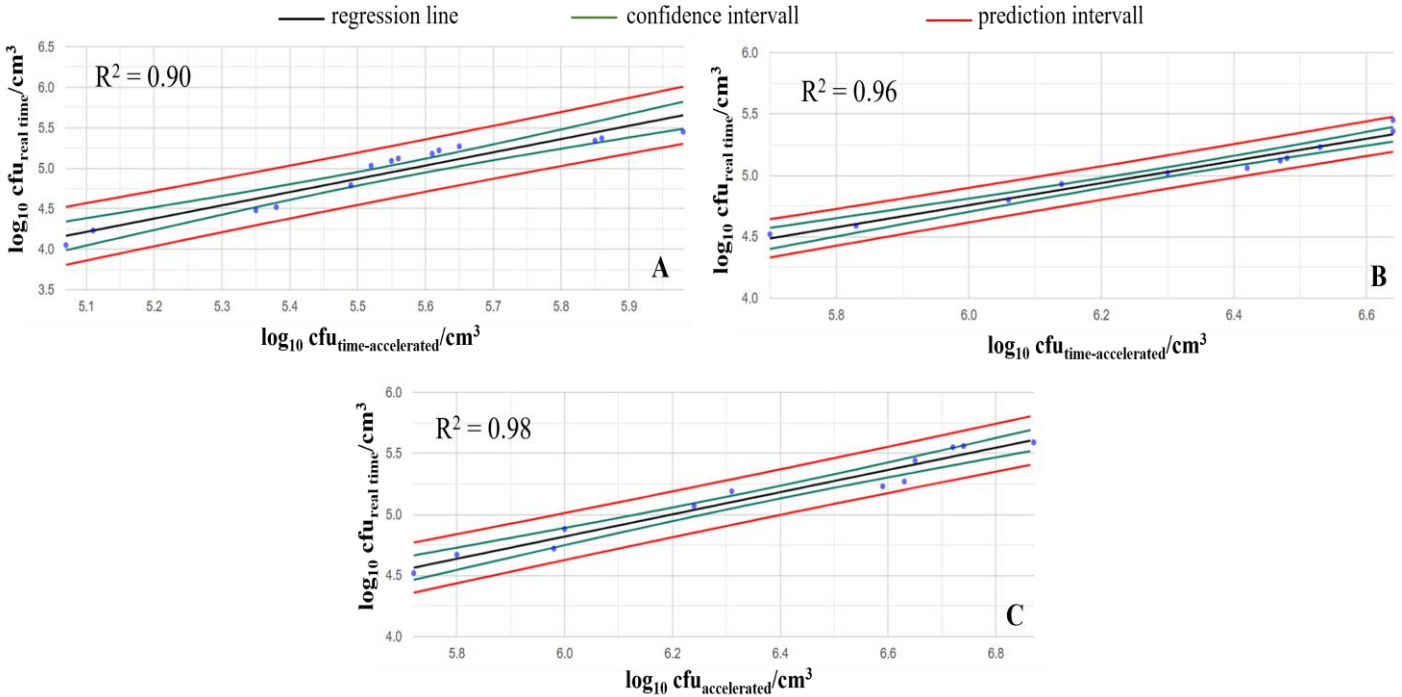

Figure 1: Regression lines and confidence intervals ($p<0.05$) for cell number changes caused by time-accelerated and real-time mechanical agitations at the intensities tested (A: low; B: medium; C: high).

4. NEW SCIENTIFIC RESULTS

1. I have isolated *Acidovorax temperans* from natural mineral water from a bottling plant in north-western Hungary. To date, this bacterial species has only been isolated from sewage sludge, tap water, spring water, and human clinical samples (e.g., urine); however, it has not been previously detected in natural mineral water.

2. The generation time of the microbiome in the natural mineral water from a bottling plant in North-West Hungary, determined by a traditional culturing technique, in the exponential phase of growth without mechanical agitation, varied from 6.71 to 28.57 h, which is significantly different from the typical generation time of microbes occurring in water (i.e., 20–40 min).

3. Depending on its intensity, dynamic mechanical agitation influences the growth of autochthonous and allochthonous microbes in natural mineral water. Autochthonous microbes grow faster (μ_{low} = 0.093 1/h and μ_{medium} = 0.113 1/h) than allochthonous species (μ_{low} = 0.063 1/h and μ_{medium} = 0.053 1/h). Standard high-intensity dynamic mechanical shaking increases the specific growth rate of allochthonous microbes ($\mu_{allochton}$ = 0.200 1/h) compared to the autochthonous ($\mu_{autochton}$ = 0.045 1/h) population by four times, which may represent a potential health risk.

4. The designed primers (forward primer: 5'-TGYCAGCMGCCGCGGTAA-3'; reverse primer1: 5'-GGACTACHVGGGTWTCTAATCCT-3'; reverse primer2: 5'-GACTACHVGGGTWTCTAATCCTGT-3') together with the developed qPCR method (Bioline SensiFAST SYBR No. Rox kit, annealing temperature: 60°C, synthesis time: 20 s) are suitable for the quantitative determination of total microbial DNA in water.

5. All three intensities of the time-accelerated method performed according to Standard ASTM D-4169-16 are suitable for modelling the effect of real-time mechanical agitation on microbiome changes. The degree of regression is as follows: $R^2_{low} = 0.90$; $R^2_{medium} = 0.96$; $R^2_{high} = 0.98$.

5. PUBLICATIONS

5.1 SCIENTIFIC PUBLICATIONS AND PRESENTATIONS IN THE TOPIC OF THE DISSERTATION

JOURNAL ARTICLES

Peer-Reviewed Papers

In English:

1. **Tihanyi-Kovács, R.,** Böröcz, P., Ásványi, B. (2023): The effect of transportation vibration on the microbiological status of bottled mineral water. *Journal of the Science of Food and Agriculture.* 103(3):1059-1068. (**IF**$_{2021}$**: 4,49**) DOI:10.1002/jsfa.11787
2. **Tihanyi-Kovács, R.,** Hanczné, Lakatos E., Ásványi, B., Böröcz, P. (2018): The effect of the supply chain exerting physical stress on the microbiological status of bottled natural mineral water. *Acta Agraria Debreceniensis*. 74:189-193. DOI: 10.34101/actaagrar/74/1688

In Hungarian:

1. **Tihanyi-Kovács, R**., Hanczné, Lakatos E., Böröcz, P., Ásványi, B. (2019): Szállítási igénybevétel összcsíra-számra gyakorolt hatásának vizsgálata palackozott természetes ásványvizek esetében. *Konzervújság*. 67(1-4):34-38.
2. **Tihanyi-Kovács, R.,** Hanczné, Lakatos E., Böröcz, P., Ásványi, B. (2018): A szállítás, mint mechanikai igénybevétel hatására bekövetkező változások a palackozott ásványvíz mikrobiotájában. *Konzervújság*. 66(1-4):16-21.

CONFERENCE PROCEEDINGS (published in full)

Domestic conference

In Hungarian:

1. **Tihanyi-Kovács, Renáta**; Böröcz, Péter; Ásványi, Balázs (2018): A mechanikai agitáció hatása a palackozott természetes ásványvíz mikrobiológiai státuszára In: Szalka, Éva (szerk.) XXXVII. Óvári Tudományos Napok, 2018. november 9-10.: Fenntartható agrárium és környezet, az Óvári Akadémia 200 éve - múlt, jelen, jövő Mosonmagyaróvár, Magyarország: VEAB Agrártudományi Szakbizottság, Széchenyi István Egyetem Mezőgazdaság- és Élelmiszertudományi Kar, pp. 28-34. [ISBN 978-615- 5837-15-9]

CONFERENCE ABSTRACTS

International conference

In English:

1. **Tihanyi-Kovács, R.,** Ásványi, B., Böröcz, P. (2021): The effect of transportation vibration to the microbiological status of bottled mineral water. In: First Circul-A-Bility Conference Università degli Studi di Foggia. p. 37. Paper: 111.

SCIENTIFIC PRESENTATIONS

In Hungarian:

1. **Tihanyi-Kovács, R**; Hanczné, Lakatos E; Böröcz, P; Ásványi, B. (2019): Szállítási igénybevétel összcsíra-számra gyakorolt hatásának vizsgálata palackozott természetes ásványvizek esetében. LI. Tartósítóipari Napok, Nagykőrös, 2019.05.06-07.
2. **Tihanyi-Kovács, R**; Hanczné, Lakatos E; Böröcz, P; Ásványi, B (2018): A szállítás, mint mechanikai igénybevétel hatására bekövetkező változások a palackozott ásványvíz mikrobiotájában. L. Tartósítóipari Napok, Nagykőrös, 2018.05.07-08.
3. **Tihanyi-Kovács, Renáta**; Böröcz, Péter; Ásványi, Balázs (2018): A mechanikai agitáció hatása a palackozott természetes ásványvíz mikrobiológiai státuszára. In: Szalka, Éva (szerk.) XXXVII. Óvári Tudományos Napok, 2018. november 9-10.

4. **Tihanyi-Kovács, R.**, Hanczné, Lakatos E., Ásványi, B., Böröcz, P. (2017): Az ellátási láncok fizikai igénybevételének hatása a palackozott ásványvíz mikrobiológiai státuszára. „A jövő tudósai, a vidék jövője" doktorandusz konferencia, Debrecen, 2017. november 24.

5.2 FURTHER PUBLICATIONS

JOURNAL ARTICLES

Peer-Reviewed Papers

In English:

1. **Tihanyi-Kovács R.**, Gyömörei T., Posgay M.M., Kiss K.A. (2019): Characterization of nutritional status of young adults based on the calculation of body mass index. *EGÉSZSÉG SPORT GAZDASÁG I.* Győr. Mobilis Közhasznú Nonprofit Kft. pp. 94-103.
2. **Tihanyi-Kovács, R.,** Gyömörei, T., Virág, A. (2020): Quantitative and qualitative analysis of fluid intake in university students and its relationship with Body Mass Index (BMI) and sleep. In: Szakály, Zsolt (szerk.). *Egészség SPORT Gazdaság II.* Győr. Mobilis Közhasznú Nonprofit Kft. pp. 174-195.
3. Virág, A., **Tihanyi-Kovács, R.** Gyömörei, T. (2020): Dietary Habits of University Students Suffering from Diet-Related Diseases. In: Gyömörei, Tamás (szerk.) *Egészség SPORT Gazdaság III*. Győr. Mobilis Közhasznú Nonprofit Kft. pp. 242-260.
4. **Tihanyi-Kovács, R.,** Gyömörei, T., Posgay, M.M. (2020): Health survey of the students of Széchenyi István University regarding their nutrition and the various diets. In: Katona, Zsolt Bálint (szerk.). *Egészség Sport Gazdaság IV.* Konferenciakötet. Győr. Mobilis Közhasznú Nonprofit Kft. pp. 50-59.
5. Varga, L., Szigeti, J., **Kovács, R.**, Földes, T. & Buti, S. (2002) Influence of a Spirulina platensis biomass on the microflora of fermented ABT milks during storage. *Journal of Dairy Science*. 85(5):1031-1038. IF_{2001}: 1.691.

In Hungarian:

1. Ásványi B., Tudós Z., **Tihanyi-Kovács R.** Hanczné Lakatos E. (2018): Az ózon antimikróbás hatásának vizsgálata élelmiszer-alapanyagokon. *Konzervújság*. 66(1-4):16-21.

POPULAR PAPER

In Hungarian:

1. Farkas László, **Kovács Renáta**, Sebő Ilona (2002): Az élelmiszerek minőségbiztosításáról. *Moson Megyei Műhely*. 5(1):91-93.

CONFERENCE ABSTRACTS

International conference

In English:

1. Szigeti, J., **Kovács, R**. & Molnár, N. (2004) New trends in the field of food quality control and safety. Sustain Life Secure Survival II – Socially and Environmentally Responsible Agribusiness. Conference proceedings, Prague, p. 174.
2. Ásványi, B., Bugyi, G., Daróczi, L., **Kovács, R**., Szigeti, J. & Varga, L. (2003) Growth of yeast strains during batch production of single-cell protein from cheese whey. 1st FEMS Congress of European Microbiologists. Poster presentation. Abstract Book, Ljubljana, pp. 103-104.
3. **Kovács, R**., Vecseri-Hegyes, B., Ásványi, B., Varga, L., Szigeti, J., Daróczi, L. & Bugyi, G. (2003) Manufacture of honey beer with accharomyces cerevisiae and Saccharomyces pastorianus. 1st FEMS Congress of European Microbiologists. Poster presentation. Abstract Book, Ljubljana, pp. 117- 118.
4. Ásványi, B., **Kovács, R**., Szigeti, J., Varga, L. & Kovács, P. (2003) Selection of Kluyveromyces strains for batch production of single-cell protein from cheese whey. 23rd International Specialised Symposium on Yeasts "Interaction between Yeasts and other Organisms". Poster presentation. Book of Abstracts, Budapest, p. 156.
5. **Kovács, R**., Vecseri-Hegyes, B., Ásványi, B., Varga, L., Szigeti, J., Daróczi, L. & Bugyi, G. (2003) Suitability of Saccharomyces

cerevisiae and Saccharomyces pastorianus for use in honey beer production. 23rd International Specialised Symposium on Yeasts "Interaction between Yeasts and other Organisms". Poster presentation. Book of Abstracts, Budapest, p. 188.