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Determination of the microplastic particle release by tea bags during brewing

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Abstract

The presence of microscopic particles of plastic (MP) in food is currently an urgent problem in the modern food industry and one of the main issues of food safety. However, there are no clear methods for the determination of such particles, nor methods for cleaning food products from them. In the present work, for the first time, the method of Dynamic Laser Light Scattering (DLS) was used to determine the plastic nanoparticles from tea bags when they were boiled in boiling water. It has been established that some of the studied samples of sachets release a huge amount of such nanoparticles into water. Moreover, hundreds of millions of nanoparticles are released per one microscopic particle.

Keywords: Dynamic Laser Light Scattering, microplastic, nanoparticles, tea bags

1. INTRODUCTION

It's no secret that the environment over the past three decades has been polluted by slowly decomposing objects made of polymeric materials (plastics). A huge number of products from polyethylene, polypropylene, polyethylene terephthalate and other plastics are thrown away by people every day. These polymers are widely used not only to create packaging for food products, but they also make disposable tableware, bags, toys and other household products. Being discarded after use, they slowly decompose in the environment, forming microscopic particles that can get into water, soil, living organisms, and therefore into food (Eriksen et al. 2014). Due to the fact that the issue of processing plastic has not yet been resolved, and decaying plastic objects are everywhere around, it is extremely important to study the question of the presence of microscopic particles of plastics in food products, their size and quantity. However, until now, the size of such particles, their density, specific surface area, and zeta potential in food products have not been subjected to serious scientific research. In the present work, we studied the isolation of micro and nanoplastic from tea bags when they were brewed as part of a large-scale study of the content of various foreign nanoparticles in food products.

1.1. Literature review

One of the inevitable results of plastic environmental pollution is the ingress of microplastic particles into the food that a person eats. Investigating this issue, scientists found out how plastic moves along the food chain from plankton to humans (Nelms, Galloway, Godley, Jarvis, & Lindeque 2018). Common table salt is known to contain approximately 0.005 micrograms of plastic per gram (Luo et al. 2020). A new source of microplastic contamination has now been found: tea bags. Brewed with their help, the drink contains thousands of times more plastic than salt and other products (Hernandez et al. 2019).

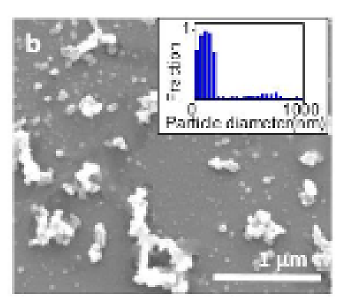


Figure 1. Photograph of microplastics under a microscope from work (Hernandez et al. 2019).

Having bought four types of tea bags in Montreal's stores, they removed all the tea leaves and then placed empty bags in boiling water for five minutes at a temperature 95°C. The resulting liquid was analyzed under a microscope, and it turned out that a five-minute contact of the bag with hot water saturates it with billions of microplastic particles (Figure 2).

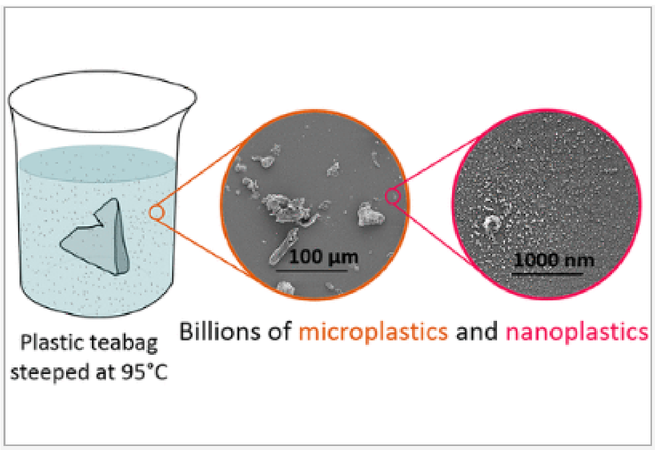


Figure 2. The process of isolation of microplastic, drawing from the work (Hernandez et al. 2019).

Practical harm was tested on small crustaceans from the the genus Dapnia, order Cladocera: in environmental studies they are often used as a model object. The crustaceans were able to survive at very high concentrations of microplastics, but they showed deviations in behavior and anatomy. In particular, in some, the exoskeleton developed with abnormalities, while others changed their usual swimming speed. Researchers emphasize that accurate knowledge about the harmful effects of plastic particles on human health does not yet exist, and attention should be paid to this issue: this will allow us to assess the risks of using certain foods.

2. MATERIALS AND METHODS

The most informative and fastest way to study the size of nanoparticles in solutions to date is the method of Dynamic Laser Light Scattering (Dynamic Light Scattering – DLS), allowing to optically measure the size of particles (their hydrodynamic radius) in a state of Brownian motion(Schmitz 1990). In this method, a laser beam passes through a solution and is scattered by moving particles (Pike & Abbiss 1997). After determining the nature of the scattering of the laser beam, one can determine the particle size (Freud 2011).That is why the DLS method was used in this study as the most convenient and informative for achieving our goals.

In addition, it was by this method that plastic nanoparticles were found by us in some soft drinks earlier (Корнилов, Шатровский, & Анисимов 2020). As objects of research in the present work, we selected standard paper tea bags that are easily accessible for general use (Figure 3).

Figure 3. Objects of investigation.

All results were obtained and processed using the "Microtrac Flex" software for "Zetatrac" particle size analyzers.

3. RESULTS AND DISCUSSION

Tea brew was removed from the sachets when they were opened. After that, the bags were placed in mugs and poured with boiling distilled water (Figure 3). Samples of each of the obtained liquids were placed in a cuvette of the device after cooling. In the device settings before detecting the plastic, the refractive index of the dispersion medium (water) was indicated n=1.3330. The refractive index of the plastic was indicated n = 1.5 – in accordance with the instruction manual of the device (Freud 2011). In particular, the refractive index of polyethylene terephthalate is shown to be 1.575, polyethylene: 1.510, and polypropylene: 1.500. As a result, it turned out the following: – in none of the presented samples were any plastic particles with the indicated characteristics found (Figure 4).

In the presented figure, we can see that in all three cases the concentration of nano and microparticles in the samples was found to be zero. The result obtained did not give us a complete picture of what was happening were inconsistent with with the work (Hernandez et al. 2019). In this regard, we conducted a study not only of flat tea bags made of paper, but also bags in the form of pyramids, the material of which is clearly different from paper (Figure 5):

After cooling the fluid samples obtained by brewing pyramidal sachets in distilled water, the device in both

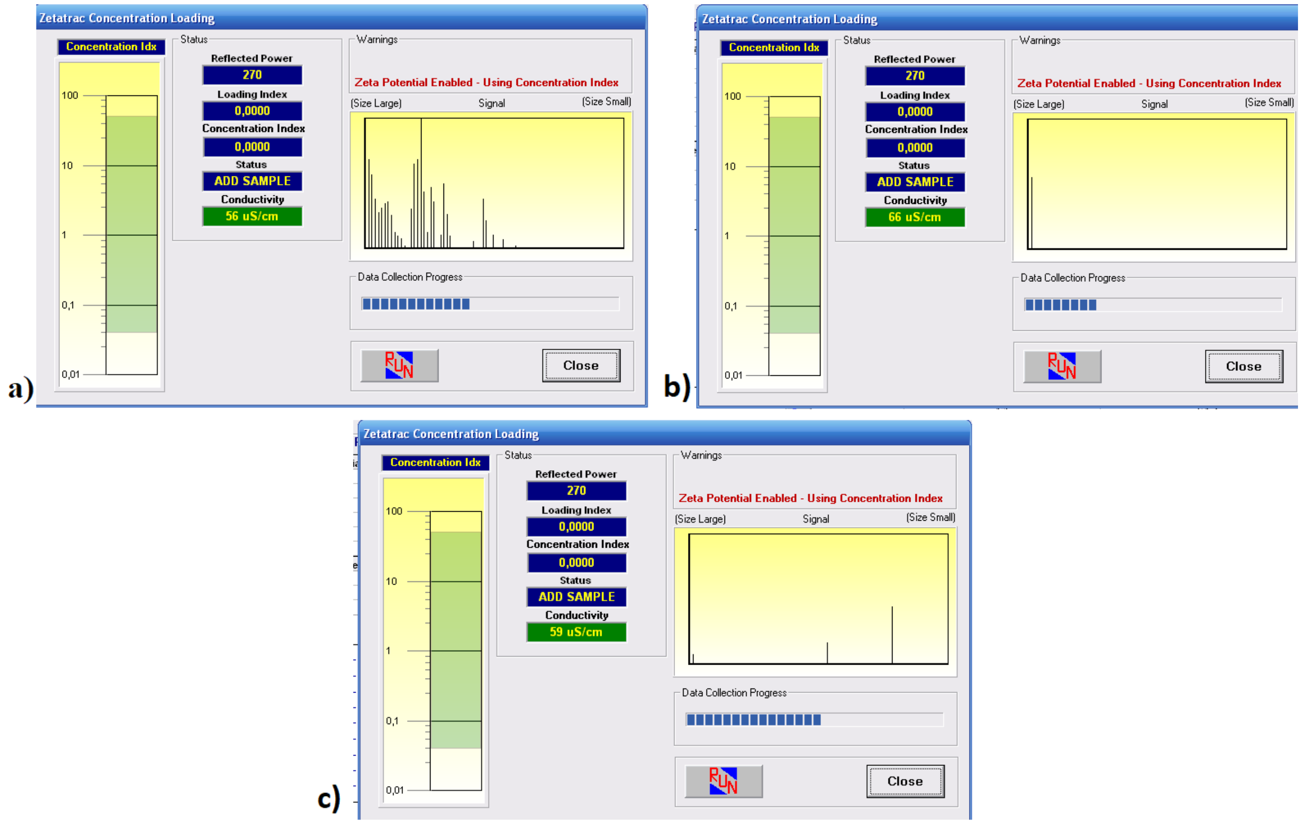
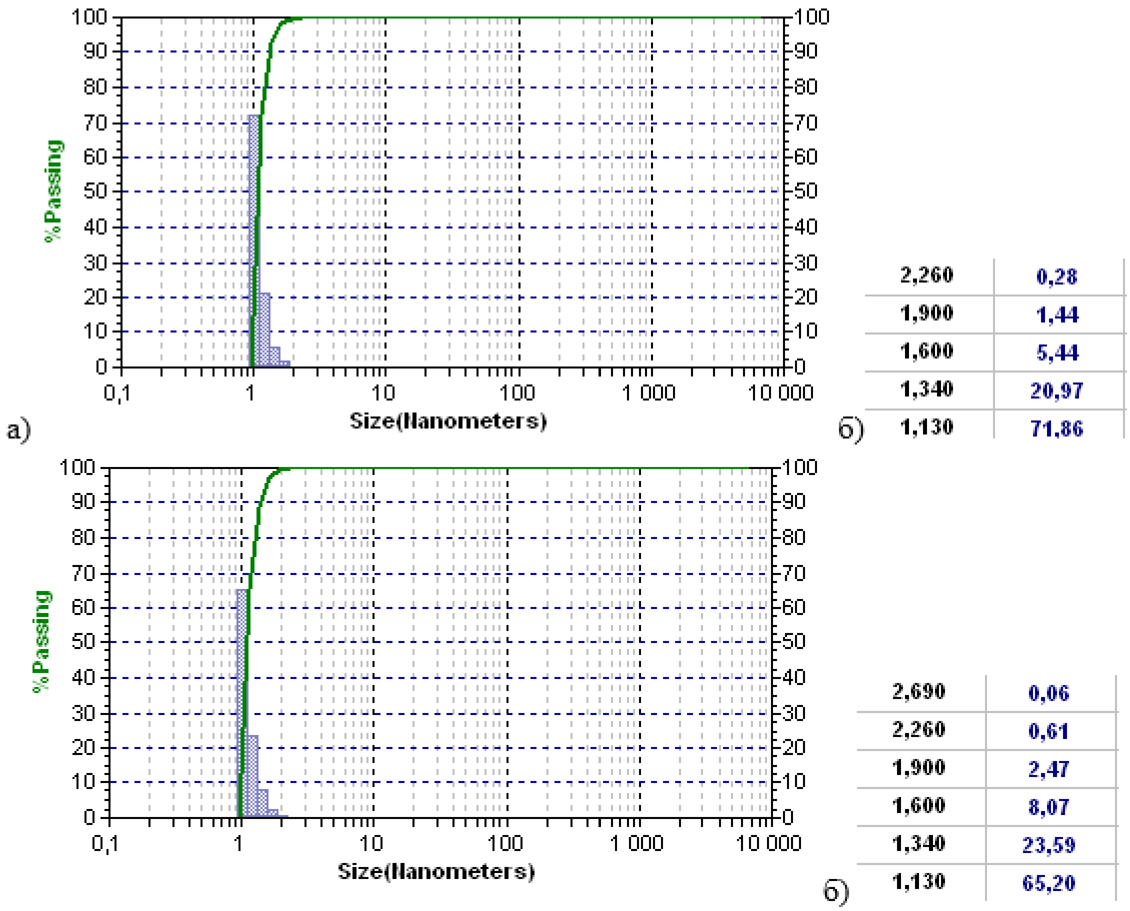


Figure 4. The results of determining the size of nanoparticles released from tea bags during brewing: a) tea "Ahmad", b) tea "Greenfield", c) tea "Tess".

Figure 5. Study of the isolation of microplastic from pyramidal tea bags.

cases showed the presence of a huge number of freely moving particles of extremely small size - about 1 nm in diameter (Figure 6):

Consider the characteristics of the detected nanoparticles. The **median particle diameter** d_M, according to the analysis, is 1.07 and 1.08 nm. This means that exactly half of the particles in the suspension is less than this value and exactly half is more than that. The error in measuring the diameter of the device is 20%, so both figures can be considered equal to 1.1 nm. **The number average diameter** d_N in both cases is 1,1 nm too. The most common particles with $d_C = 1.1$ nm (72% and 65% of all particles) are also in suspension. The **weigh average diameter** d_w equals to 1.55 in in the first case, and 1,1 nm in the second. According to the formula $M = \rho \cdot (\pi/6) \cdot d^3$ we can find the density of nanoparticles. The diameter which is most expedient to use is the weight average diameter d_w, because the contribution of the largest particles to the molar mass is maximum. Then the density would be equal $\rho = 0.54$ and 0.99 g/cm^3. You can compare these numbers with the density of ordinary polypropylene (PP) in 0.95 g/cm^3, polyethylene (PE) in 0.91 −−0.96 g/cm^3 or polyethylene terephthalate (PET) in 1.38 g/cm^3 (Speight 2005). It can be seen that the density of nanoparticles in the second sample is close to the density of polymers. In the first sample, the density value turned out to be extremely small due to the fact that the average weight diameter of 2 nm is 1.5 times higher than the number average. This is because, in this case, large particles are detected in the suspension, which are very different in size from all the others: in the area of 1.1–2.2 nm there are 99.99% of all particles. But 0.01% of the total number



2,260	0,28
1,900	1,44
1,600	5,44
1,340	20,97
1,130	71,86

2,690	0,06
2,260	0,61
1,900	2,47
1,600	8,07
1,340	23,59
1,130	65,20

Figure 6. Results of determining the size of nanoparticles in water after brewing pyramidal tea bags:
a) a histogram – "Greenfield" tea,
b) a table of the distribution of nanoparticles by size – "Greenfield" tea.
c) a histogram – "Lipton" tea,
d) a table of the distribution of nanoparticles by size – "Lipton" tea.

are particles of 6.5 microns, i.e., not nanoparticles, but microplastics. In the second sample, all detected particles have a diameter of 1.1 to 2.7 nm and no large objects are detected. The zeta potential of nanoparticles in the first sample is 36 mV, and 37 mV in the second. Volume concentration of nanoparticles: $2.44 \cdot 10^{-3}$ and $2.25 \cdot 10^{-3}$%. The contradiction of the data obtained by us with those obtained by Hernandez et al. (2019) can be explained by the fact that the study of microplastic was carried out by different methods. Hernandez et al. (2019) used an electron microscope, whose detection limit is 100 nm, i.e., it is not able to see true nanoparticles from 1 to 100 nm. In our DLS method, the most mobile particles are detected, and these make the greatest contribution to the Brownian motion, and hence to light scattering. A huge number of nanoparticles was released from plastic bags when brewing them. It is much higher than the number of particles of microplastic, whose diameter is from 1 to 10 microns. The number of microplastic particles indicated by the (Hernandez et al. 2019) is equal to 11.6 billion from one bag. The concentration of nanoparticles, found by us, also allows us to determine their content in the resulting suspension. The concentrations, calculated by us for the second sample are 22.2 mg^{3}_{dm}, which corresponds to 3.2·1019 particles in one liter. Because the volume of water that we used to brew the bags was equal to the volume of a regular cup for tea (245 cm^3), it turns out that one tea bag was selected during brewing of 7.9·1018 nanoparticles. This number exceeds the number of microparticles by 680 million times! That is why the nanoparticle analyzer "did not notice" MP particles, the number of which is $1.5 \cdot 10^{-7}$ %. At the same time, we note that in the first sample, microplastic was still detected by the device at the very boundary of the detection limit – in 0.01%. And microplastic in the first case even made its contribution to the average mass and diameter of all detected micropartіcles. However, we can consider, that nanoparticles, which a size is 1.1–2 nm, are released hundreds of millions times more than microplastic particles. What may seem unexpected is that of nanoparticles. that stand out when brewing pyramidal tea bags are completely identical in size to the objects that we discovered earlier in “Coca” and “Pepsi Cola” (Корнилов et al. 2020). Their diameter also lay in the region of 1.1–-2 nm, which corresponds to 200–300 carbon atoms in volume. Their density is 0.8–0.9 g/cm^3. But in their concentration, they were significantly inferior to the nanoparticles from tea bags: they were found no more 0.9 mg/dm^3 and $14 \cdot 10174$ particles/dm^3 – i.e., 23 times less both in mass and in quantity. It can be assumed that the nanoparticles previously discovered by us in drinks are completely identical to those that stand out from pyramidal tea bags. However, the plastic in the second case is subjected to heat treatment with hot water, in connection with which the number of particles released is not less than 23 times greater.

4. CONCLUSIONS

For the first time using the Zetatrac laser nanoparticle analyzer, the presence of suspended micro and nano particles in water obtained by brewing tea bags in boiling water was determined. No (released) micro or nanoparticles were detected in any of the three examined samples of paper tea bags. The pyramidal-shaped tea bags released a huge number of nanoparticles with a diameter of 1 to 2 nm. The number of plastic nanoparticles released from tea bags was hundreds of millions of times greater than the number of microplastic particles. The size of the nanoparticles from the pyramidal tea bags completely coincided with the objects found earlier in the study of some non-alcoholic highly carbonated drinks. The number of nanoparticles released during thermal exposure to pyramidal tea bags was not less than 23 times greater than the number of the same nanoparticles found in drinks.

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