KOSMOS
PROBLEMY NAUK BIOLOGICZNYCH

Tom 65 **2016**
Numer 4 **(313)**
Strony **563–571**

Polskie Towarzystwo Przyrodników im. Kopernika

SANDRA WATRAK, MONIKA RAJKOWSKA-MYŚLIWIEC, MIKOŁAJ PROTASOWICKI

Department of Toxicology
Faculty of Food Science and Fisheries
West Pomeranian University of Technology in Szczecin
Papieża Pawła VI 3, 71-459 Szczecin
E-mail: sandra.watrak@zut.edu.pl

THE CONTENT OF TOXIC METALS IN DIFFERENT TYPES OF TEA AND THEIR IMPACT ON CONSUMERS HEALTH

INTRODUCTION

Tea is the second after water most popular beverage consumed by people all over the world. The greatest producer of tea in 2011 was China. Nowadays, 80% of the global consumption constitutes the most popular black tea. However, over the years growing interest in green tea can be observed. Green tea is produced from nonfermented leaves of *Camelia sinensis*, quality of which depends on the conditions of cultivation, the soil on which it grows and numerous meteorological conditions. The Chinese have known about medicinal benefits of green tea since ancient times. Many studies have concluded that green tea has beneficial effects on health, including prevention of many diseases such as skin cancers, Parkinson's disease, cardiovascular diseases, coronary artery and regulation of blood sugar and promotion of digestion (BRZEZICHA-CIROCKA *et al.* 2016). Tea is cultivated all over the world but especially in China, India, Indonesia, Sri Lanka and Japan. Tea is also successfully grown in Africa, namely in Kenya, Malawi, Zimbabwe, and South Africa (GREENOP 1997). Tea grows in the altitude of up to 2100 m, and just as with wine, the aspect, soil, altitude, and climate affect its flavour and characteristics. The chemical composition of tea leaves consists of tanning substances, flavonols, alkaloids, proteins and amino-acids, enzymes, aroma-forming substances, vitamins, minerals, and trace elements (STREET *et al.* 2006).

The annual tea consumption per capita in Poland in 2014 remains at 0,72 kg (STATISTICAL YEARBOOK OF THE REPUBLIC OF POLAND 2015). It is drunk on average 2–3 times a day. About 20% consumers consume tea often, 4–5 times per day. The quality of water, used for brewing tea, significantly affects the absorption of harmful elements. Some batches of tea can also be significantly contaminated with toxic metals, but even trace amounts of cadmium, arsenic and mercury are a threat for human. Their provisional tolerable weekly intake from all sources (PTWI – Provisional Tolerable Weekly Intake) is determined by the Joint FAO/WHO Expert Committee (WOJCIECHOWSKA-MAZUREK *et al.* 2010). Exposure to heavy metals above the permissible level can cause high blood pressure, fatigue, as well as kidney and neurological disorders. Heavy metals are also known to have harmful reproductive effects (MUUBEN *et al.* 2009).

TYPES AND COMPOSITION OF TEA

Tea can generally be divided into categories based on the way it is processed. Some varieties include yellow, green, Oolong (or wulang), black (called red tea in China) and post-fermented tea. Green and black teas are the most popular types of tea (POWELL *et al.* 1998). Green tea is produced by drying and steaming the leaves, whereas black tea is obtained after a fermentation process. Catechins, which are a type of antioxidant,

Key words: aluminium, cadmium, copper, human health, lead, manganese, mercury, tea

and the amino acid L-theanine, which modulate the psychoactive effect of caffeine, are present in tea and contribute to its taste. Tea is rich in polyphenolic compounds. These compounds are also present in red wine, fruit and vegetables. Theaflavins, antioxidant polyphenols that are formed from the condensation of flavan-3-ols in tea, also contribute to the taste of tea (GARBA *et al.* 2015). Preservation of intact green leaves is of highest importance in the preparation of green tea. Freshly harvested leaves are steamed to prevent fermentation, rolled and then dried. This process yields a chemical composition in green tea similar to the fresh tea leaf. Preparation of black tea involves a "fermentation" process in which fresh leaves are withered, rolled and crushed, initiating a chain of oxidative reactions of catechin, polyphenols contained in them. This results in polymerisation of the catechins converting them into higher molecular weight theaflavins and thearubigins, conferring tea its strong dark colour and special flavour. A less extensive, partial fermentation leads to a lighter flavoured tea, known as oolong tea (COOPER *et al.* 2005).

Many elements that are present in food at major, minor and trace levels are reported to be essential to human well-being; however, excessive ingestion of these elements can cause severe health problems. Optimum concentration required for this purpose widely vary depending on the type of element and the age and sex of the consumers. Human body requires both metallic and non-metallic elements for healthy growth, development and proper functioning. Thus, determination of these elements in beverages, water, food, plant and soil is of utmost importance and is currently a subject of studies by various researchers. The study of trace elements in tea is notably vital because these elements play important roles in the complex metabolic pathways in the human system, and their deficiencies or excesses may cause diseases (GARBA *et al.* 2015). Conventional neurochemical studies as well as genomic and proteomic profiling of brain autopsy material from Peritoneal dialysis (PD) patients and more recently from Alzheimer's Disease (AD), have provided evidence for the involvement of supplementary processes, including glutamatergic neurotoxicity, nitric oxide elevation, dysfunction of ubiquitin-proteasome system and mitochondria, which may lead to breakdown in energy metabolizm and consecutive intraneuronal calcium overload, increased expression of apoptotic proteins and loss of tissue reduced glutathione (GSH), an essential factor for removal of hydrogen peroxide (ZHANG *et al.* 2005).

LEAD

Lead is a naturally occurring metal found deep in the ground. It occurs in small amounts in ore, along with other elements such as silver, zinc or copper. Even though it is found in small amounts, there is an abundant supply of lead throughout the earth. Because it is widespread and easy to extract and work with, lead was used for hundreds of years in a wide variety of products found in and around homes, including paint and gasoline (NIEHS 2013). Lead can get into human body in two ways: through breathing (paint dust or chips) or eating. The soil around your home can pick up lead from sources such as exterior paint. Lead can also enter drinking water through plumbing. Both children and adults are vulnerable to the effects of lead. Young children under the age of 5 are particularly vulnerable because their body, brain and metabolism are still developing. Two-year-olds tend to have the highest blood level concentration, because they put many things into their mouth, including toys or other lead-containing products (NIEHS 2013).

In 2006 and 2008 WOJCIECHOWSKA-MAZUREK *et al.* (2010) researched tea from shops in Poland. The medium content of lead came to 0.36 mg/kg in leaf tea and 0.29 mg/kg in express tea. Both of the results did not overstep the limit of lead in Poland. Also in Poland BRZEZICHA-CIROCKA *et al.* (2016) from Gdańsk researched Chinese Green Tea. They proved that PTWI limit for Pb was reached in 0.097% and authors concluded that drinking green tea does not cause any risk to human health. In another research conducted by ZHONG *et al.* (2016), in China the level of Pb in different types of tea averaged 3.04 mg/kg (0.48–10.57 mg/kg). The lowest Pb content was found in jasmine tea, while the highest in green tea. The average lead content in the green tea was approximately nine times that of the white tea and twice that of the oolong tea. OTHMAN *et al.* (2012) determinated lead samples of green tea imported from China. Concentration of lead in green tea products was between 0.231–4.460 mg/kg and in tea infusions in ranged within 0.046–0.265 mg/kg. Average daily intake for all genders amounted to 0.001–0.009 mg/(kg/day). When it comes to herbal teas, WINIARSKA-MIECZAN *et al.* (2011) calculated that the degree of Pb extraction to herbal infusions was 53.16% and the content of lead

in 600 m^3 of infusions was 0.90 μg (PTWI 0,42%).

CADMIUM

Cadmium exerts toxic effects on kidneys, skeletal system and respiratory system and is classified as a human carcinogen (WHO 2010). It is generally present in the environment at low levels; however, human activity has greatly increased those levels. Human exposure occurs mainly from consumption of contaminated food, active and passive inhalation of tobacco smoke and inhalation by workers in the non-ferrous metal industry. Cadmium exposure from drinking-water is relatively unimportant compared with exposure from the diet. However, impurities in the zinc of galvanised pipes and solders in fittings, water heaters, water coolers and taps can sometimes lead to increased cadmium levels in drinking-water (WHO 2010).

WOJCIECHOWSKA-MAZUREK *et al.* (2010) have found the following cadmium content in portion of 2 g of Indian teas sold in Poland: 0.034 mg/kg for leaves tea and 0.026 mg/kg for express teas. The reports on tea pollution by cadmium were similar to reports from other studies in Europe, but lower than studies in Asia. WINIARSKA-MIECZAN *et al.* (2011) showed the content of cadmium in herbal teas: in tea 0.2 μg/g and in infusions 0.07 μg/250 cm^3. The average degree of Cd extraction to infusions was 44.13%. In the studies of cadmium in tea leaves made by SOROJAM (2011) the results were between 0.021–0.064 mg/kg. However, the presented results did not exceed the U.S. FDA limit of 0.3 mg/kg. HOSSENI *et al.* (2013) described significant differences between Cd content in Iranian (16.7–69.85 mg/kg dm) and imported teas (0.05–19.05 mg/kg dm). ZHONG *et al.* (2016) determined cadmium content in different kinds of tea. The average Cd content was 0.08 mg/kg (range 0.01–0.39 mg/kg). The lowest Cd level was found in black tea, while the highest was found in Pu'er tea. The Cd contents of green tea samples ranged between 0.04–0.11 mg/kg.

MERCURY

Mercury is the only metal that is liquid at room temperature. It exists in three oxidation states, (elemental/metallic Hg^0, mercurous Hg_2^{2+} and mercuric Hg^{2+}) and can form inorganic (e.g. mercuric chloride) and organic (e.g. methylmercury) compounds. Clinical presentation of mercury poisoning is influenced by the chemical form, the amount involved, the route of exposure, and whether the exposure was a single acute episode or repeat (BRADBERRY 2007). Concerns about adverse health effects of mercury exposure during foetal development stem in part from well-documented episodes of mass mercury poisoning from consuming food items grossly contaminated with mercury released into Minamata Bay in the 1950s and from consumption of wheat seed treated with mercury-based fungicides in the 1970s (GOLDING *et al* 2013). The main route of exposure for elemental mercury is by inhalation of its vapours. About 80% of inhaled vapours are absorbed by lung tissues. This vapour also easily penetrates the blood-brain barrier and is a well-documented neurotoxicant. Intestinal absorption of elemental mercury is low. Elemental mercury can be oxidised in body tissues to the inorganic divalent form (UNEP 2002).

Canadian Food Inspection Agency (2011) surveyed mercury in tea. Overall, 53% of the samples tested did not contain any detectable residues of mercury. Of the remaining 47%, dried tea had the highest prevalence of detectable mercury (87% of dried tea samples contained detectable levels of mercury) and also exhibited the highest concentration of mercury observed in any of the samples tested – 0.023 mg/kg. WOJCIECHOWSKA-MAZUREK *et al.* (2010) determined mercury in different types of tea. The mean result in leaf tea was 0.008 mg/kg and 0.007 mg/kg in express tea. Slightly lower result, 0.005 mg/kg in tea leaves, was achieved by FORSBERG and MCQUATTERS (2016).

ALUMINIUM

Aluminium in small quantities acts protectively on mucous membranes and gastrointestinal duodenum. Average daily dose of aluminium consumed by the adult human is about 45 mg and the safety approx. 7 mg per kg of body weight, however, an excess dietary intake has adverse impact. It leads to soft tissue calcification, anaemia and neurological disorders. Elevated content of aluminium in the damaged brain cells in Alzheimer's patients may indicate through indirect effects on the development of diseases by this element (MULLER et. al 1997). WRÓBEL *et al.* (2000) determined aluminium in infusions of different kind of teas. The researchers reported the following content of Al in leafy materials: 759 μg/g in black tea, 919 μg/g in green tea and 272 μg/g in Hibiscus tea. The fraction of aluminium leached to the infusion was between 28.7% (green tea) and 49.6% (Hibiscus). Later, PYTLAKOWSKA *et al.* (2011) studied herbal teas sold in Poland, and the content of alumin-

ium in herb leaves was between 13.0–297 µg/g. After 10 minutes of tea brewing, the content of aluminium in infusion ranged within 0.862–53.4 µg/g and after 30 minutes – within 6.42–52.2 µg/g.

MANGANESE

Manganese is distributed in tissues throughout the body. The highest concentrations are found in liver, thyroid, pituitary, pancreas, kidneys and bones. The total manganese content in a 70-kg man is approximately 12–20 mg (WATTS 1990). The daily requirement for manganese has not been established; however, it appears that a minimum intake of 2.5–7 mg/day meets human needs. The liver regulates manganese via excretion in the bile; however, if the liver excretory route is blocked or if overloading occurs, pancreatic excretion increases. Tissue manganese levels are directly related to the dietary availability. WATTS (1990) showed that alcohol increases the hepatic manganese level and apparently doubles its absorption.

WRÓBEL *et al.* (2000) proved that the content of manganese in leaves from green tea is the highest – 807 mg/kg, then was black tea – 512 mg/kg and the last one was Hibiscus tea – 390 mg/kg. STREET *et al.* (2006) showed the average content of Mn in black teas was 858 mg/kg and in 1 g of green tea – 918 mg/kg. After 5 minutes of brewing black tea leaves infusion contained 1.01 mg Mn/dm^3 and the green tea infusion – 1.22 mg Mn/dm^3. MAYFOU *et al.* (2015) examined four market brands of green tea which were commonly consumed in Libya. The total content of Mn was between 718-2260 mg/kg, and the concentration of Mn in infusion was 6.87 mg/dm^3 after 5 minutes of brewing, 7.57 mg/dm^3 after 10 minutes and 7.48 mg/dm^3 after 15 minutes. The percentage of manganese in infusions was between 13.5% and 18.7%.

COPPER

Copper is an essential micronutrient for human body and its distribution in different organs and tissues, metabolism and physiological impact has not been thoroughly explained yet. Further issues which need clarification are the exact composition and constitution of its combinations with other elements, the physiological impact of copper and copper-enzymes in sickness and health (ANGELOVA *et al.* 2011). Copper is a trace element which can be found in almost every cell of human organism. The highest concentrations of copper are discovered in the brain and liver; the central nervous system and heart have high concentration of copper as well. About 50% of copper content is stored in bones and muscles (about 25% is in skeletal muscle), 15% in skin, 15% in bone marrow, 8–15% in liver and 8% in brain (GIBSON 2005).

WRÓBEL *et al.* (2000) showed that average content of Cu in black tea was 24.8 µg/g, in green tea – 16.0 µg/g and in Hibiscus tea – 5.9 µg/g. The evaluated fractions eluted to the infusions were consecutively 36.6%, 54.0% and 93.4%. STREET *et al.* (2006) proved that in black tea the content of copper was 26.0 mg/kg and 25.8 mg/kg in green tea. After 5 minutes of brewing 2 g of tea in infusions there was 0.072 mg/dm^3 of copper in black tea and 0.173 mg/dm^3 in green tea. ZHONG *et al.* (2016) described results of the studied Chinese tea: the content of Cu was the highest in green tea (17.01–63.07 mg/kg) and the lowest in oolong tea (7.73–20.49 mg/kg).

HOW TEA WORKS IN THE BODY

Tea contains hundreds, if not thousands, of bioactive compounds, including amino acids, caffeine, lignins, proteins, xanthines and flavonoids. Tea flavonoids and the related polyphenols account for more than one-third of the weight of tea leaves; the health benefits of tea are most often attributed to tea flavonoids (BALENTINE *et al.* 1997). Human population studies have revealed that people who regularly consume three or more cups of black tea per day have a reduced risk of heart disease and stroke (LARSSON *et al.* 2013). Clinical studies suggest that the risk reduction associated with tea consumption may be due to improvement in some risk factors for cardiovascular disease, including blood vessel function, platelet function and a reduction in oxidative damage (HAKIM *et al.* 2003). An examination of dietary intake data from the National Health and Nutrition Examination Survey (NHANES) reported that differences in total flavonoid intake among subgroups are principally associated with the percentage of tea consumers and their prevalence of tea consumption (SONG and CHUN 2008). Valuable new information has also been reported regarding the bioavailability and metabolism of tea flavanols using novel approaches with *in vitro* digestion models as well as in human studies (HENNING *et al.* 2004). A review on tea and health in the elderly suggested that there is compelling evidence for the efficacy of tea in benefiting cardiovascular disease (BOLLING *et al.* 2009). The antioxidant properties of tea

flavonoids may play a role in reducing the risk of cardiovascular disease by decreasing lipid oxidation (WEISBURGER 1999), reducing the instances of heart attacks and strokes (KELI *et al.* 1996) and may beneficially impact blood vessel function (DUFFY *et al.* 2001). Tea flavonoids may lower the risk of certain cancers by inhibiting the oxidative changes in DNA from free radicals and some carcinogens, and therefore are an important indicator of cardiovascular health (ISEMURA *et al.* 2000) and inhibit the rate of cell division, thereby decreasing the growth of abnormal cells (WEISBURGER 1999). Tea polyphenols are bioavailable to the brain and can act via antioxidant, iron-chelation, signal transduction modulation, and other mechanisms to effect neuroprotective and/or neurorescue action, with potential implications for age-related dementia, Alzheimer's and Parkinson's diseases (MANDEL *et al.* 2006). A unique tea amino acid, L-theanine (γ-glutamylethylamide), plays a role in attentive processing in synergy with caffeine (KELLY *et al.* 2008). Tea-drinking has been associated with oral health (SARKAR *et al.* 2000) and bone health (HEGARTY *et al.* 2000). Compounds in tea other than flavonoids have been shown to support the human immune system (KAMATH *et al.* 2003). Due to the substantial data documenting tea's health benefits, published Healthy Beverage Guidelines suggest that water and tea should provide the majority of daily fluid intake (POPKIN *et al.* 2006).

CARDIAC EVENTS

A Harvard study examined 340 men and women who had suffered heart attacks and compared them to matched control subjects. The study has revealed that those who drank a cup or more of black tea daily had a 44% reduction in the risk of heart attack compared to non-tea drinkers (DUFFY *et al.* 2001). Another Harvard study of 1,900 people found that those who consumed tea during the year prior to a heart attack were up to 44% more likely to survive three to four years following the event compared to non-tea drinkers (MUKAMAL *et al.* 2002). Different researchers have found that those people who drank more than six cups of tea per day (>480 cm^3) had significantly lower prevalence of indications of coronary heart disease (CHD) than non-tea drinkers, even after adjustment for risk factors like age and smoking. The researchers have also found that drinking six or more cups of black tea per day was associated with decreased serum cholesterol and triglyceride concentrations (GELEIJNSE *et al.* 2002). The Zutphen study, which assessed 805 male subjects over a period of five years, found that the incidence of fatal and nonfatal first myocardial infarction and mortality from stroke decreased significantly as the intake of flavonoids, derived mainly from tea, increased in a dose-dependent manner. A follow-up to this study found that high intake of flavonoids significantly lowered the risk of stroke in the study participants (HERTOG *et al.* 1993). Some Dutch researchers determined that people without prior history of heart attack, who drank three or more cups of tea per day, were 43% less likely to develop myocardial infarction and 70% less likely to die from myocardial infarction than non-tea drinkers (ISHIKAWA *et al.* 1997). A study of over 40,000 middle-aged Japanese revealed that people who drank just over two cups of green tea per day reduced their risk of death from cardiovascular disease by 22–33% compared to those who drank less than a half-cup (HIRATA *et al.* 2004).

TEA AND METABOLISM, OBESITY AND BODY COMPOSITION

Researchers suggests that drinking tea may have effects on body weight, fat accumulation and insulin activity. Green tea extract was found to significantly increase 24-hour energy expenditure and fat oxidation in healthy men (DULLOO *et al.* 1999). After a 3-month consumption of green tea extract by moderately obese patients, their body weight decreased by 4.6% and waist circumference decreased by 4,48% (CHANTRE and LAIRON 2002). Average fat oxidation rates were 17% higher after green tea extract intake during moderate-exercise in 12 healthy men, compared to a placebo (VENABLES *et al.* 2008). Japanese researchers found that green tea catechins led to a reduction in body fat, blood pressure and LDL cholesterol compared to the control group, and also the compounds may help prevent obesity and reduce risk of cardiovascular disease (NAGAO *et al.* 2007). Researchers examined mice which were fed different kinds of diets supplemented with 0.1–0.5% tea catechins. The scientists discovered a significant reduction in high-fat diet-induced body weight gain and visceral and liver fat accumulation (MURASE *et al.* 2002). Other researchers compared the body weight and fat mass of mice that were fed a low-fat or high-fat diet, with swimming or not, and with or without tea catechins. They suggest that tea catechins may increase fat metabolism, enabling the body to burn more fat as fuel and store less in the body (MURASE *et al.* 2005). Animals fed a high-fat, high-caloric diet to promote ex-

cessive weight gain and obesity were given green tea extract or placebo and their energy expenditure and fat oxidation were measured. The researchers concluded that green tea extract combined with regular exercise stimulates fat metabolism and may attenuate obesity more effectively than green tea extract or exercise alone (SHIMOTOYODOME *et al.* 2005). Animals fed a diet high in catechin green tea extract were found to increase running times to exhaustion by up to 30% compared to a control animal. In addition, green tea extract appeared to shift metabolism so that the animals burned body fat and spared muscle glycogen, thereby increasing endurance time to exhaustion (MURASE *et al.* 2006). Researchers from Brigham and Women's Hospital and Harvard University published novel data indicating that tea contains a component that can help the body ward off infection and disease and that drinking tea may strengthen the immune system. The researchers identified a substance in tea, L-theanine, which primes the immune system in fighting infection, bacteria, viruses and fungi. A subsequent human clinical trial showed that certain immune cells of participants who drank five cups of black tea a day for two to four weeks secreted up to four times more interferon, an important part of the body's immune defence, than at baseline. Consumption of the same amount of coffee for the same duration had no effect on interferon levels. According to the authors, this study suggests that drinking black tea provides the body's immune system with natural resistance to microbial infection (KAMATH *et al.* 2003).

TEA'S ROLE IN ORAL HEALTH

Drinking tea is minimally erosive to tooth enamel according to study comparing tea (green and black) to soda and orange juice using *in-vitro* tests (BASSIUONY *et al.* 2008). Water was used as the non-erosive control, and vinegar was the erosive control. The 20-week study was conducted under controlled conditions, and results were categorized as highly, moderately, or minimally erosive. Soda and orange juice were shown to be moderately erosive, and vinegar remained highly erosive (BASSIUONY *et al.* 2008). Drinking green tea was inversely related to periodontal (gum) disease, per a modest drop in probing depth, clinical attachment loss, and bleeding on probing. The study analysed 940 Japanese men aged 49 to 59 years who took part in a comprehensive health exam. The relationship seems to be dose-dependent. Each additional cup of tea was associated with a greater decrease in gum disease factors (KUSHIYAMA *et al.* 2009). Tea may also contribute to oral health. The flavonoids in tea may inhibit the plaque-forming ability of oral bacteria and the fluoride in tea may support healthy tooth enamel (SARKAR *et al.* 2000). A study conducted at the New York University Dental Center examined the effects of Black Tea extract on dental caries formation in hamsters. Compared to those who obtained water with their food, hamsters which obtained water with black tea extract developed up to 63.7% fewer dental caries (LINKE AND LEGEROS 2003).

TEA AND REDUCED RISK OF OSTEOPOROSIS

Although high caffeine intake has been suggested to be a risk factor for reduced bone mineral density (BMD), research indicates that drinking tea does not adversly affect BMD, and findings suggest that tea may even play a role in bone health (WU *ET AL.* 2002). HEGARTY *et al.* (2000) found that older women who drank tea had higher BMD measurements than those who did not drink tea. It was also reperted that habitual tea-drinking has a significant beneficial effect on the BMD of adults, especially in those who had been habitual tea-drinkers for six or more years (WU *et al.* 2002). Moreover, drinking tea is associated with preservation of hip structure in elderly women. Studies in adolescent and postmenopausal women found no relationship between caffeine intake and bone health (LLOYD *et al.* 2000).

TEA AND CHOLESTEROL REDUCTION

Researchers from the United States Department of Agriculture (USDA) studied the effect of tea on 15 mildly hypercholesterolemic adult participants following a "Step I" type diet moderately low in fat and cholesterol, as described by the American Heart Association and the National Cholesterol Education Program. After three weeks, researchers found that five servings of black tea per day reduced LDL ("bad") cholesterol by 11.1% and total cholesterol (TC) by 6.5% compared to placebo beverages (DAVIES *et al.* 2003). Clinical trials have not confirmed these results, however additional work is being done in this area. The mechanism behind the blood cholesterol lowering effects of tea may be rooted in the effect of theaflavins, through interfering with the formation of dietary mixed micelles, which could result in reduced intestinal cholesterol absorption. Theaflavin-treated micelles/particles were analysed and theaflavins were shown to

have a dose-dependent inhibitory effect on the incorporation of cholesterol into micelles (VERMEER *et al.* 2008).

CONCLUSIONS

Various reports have discussed the potential health implications of trace metals in tea, since the tea bush is known to accumulate them and studied the contents of various elements in different parts of the tea plant such as shoot, mature leaf, small stem, tick wood. Many elements play a vital role in the metabolic processes and in the general well being of humans. The tea infusion contains very little protein, vitamins and carbohydrates, but may be a source of essential dietary metals and metal binding polyphenols. Tea owes its popularity to both beneficial properties, and clever marketing. Is it worth drinking it? Of course, it is. However, in all matters the best is to keep moderation and common sense. A cup of tea per day for sure will not hurt us, it does have a positive impact on our health, and may replace other, less wholesome drinks. But a litre of tea a day can no longer serve health.

Streszczenie

Herbata jest jednym z najbardziej popularnych napojów na świecie, który obok wielu korzystnych dla zdrowia składników, jak mikroelementy, zawiera również te niepożądane - stanowiące zanieczyszczenie. Wśród nich znajdują się metale ciężkie, których obecność w liściach herbaty może stwarzać poważne problemy dla zdrowia ludzkiego, ponieważ nie ulegają one biodegradacji, a pozostając w środowisku mogą stać się częścią łańcucha pokarmowego. Całkowita zawartość metali w liściach herbat oraz w naparach zależy od rodzaju herbaty (zielona, czarna) oraz od wpływu wielu innych czynników, w tym właściwości gleby. Pomimo ograniczonej migracji metali z suszu do naparów zanieczyszczenie herbat metalami tj. ołów, kadm czy rtęć nie jest obojętne dla zdrowia człowieka.

REFERENCES

ANGELOVA M., ASENOVA S., NEDKOVA V., KOLEVA-KOLAROVA R., 2011. Cooper *in the human organism*. Trakia J. Sci. 9, 88-98.

BALENTINE D., WISERMAN S. A., BOUWENS L. C. M., 1997. *The chemistry of tea flavonoids*. Crit. Rev. Food Sci. Nutr. 37, 693-704.

BASSIOUNY M. A., KURODA S., YANG J., 2008. *Topographic and radiographic profile assessment dental erosion. III: Effect of green and black tea on human dentition.* Gen. Dent. 56, 451-461.

BOLLING B. W., CHEN C. Y., BLUMBERG J. B., 2009. *Tea and health: Preventive and therapeutic usefulness in the elderly?* Curr. Opin. Clin. Nutr. Metab. Care. 12, 42-48.

BRADBERRY S. M., 1996. *Elemental mercury induced skin granuloma: a case report and review of the literature*. J. Toxicol. Environ. Health. 65, 1273-1288.

BRZEZICHA-CIROCKA J., GREMBECKA M., SZEFER P., 2016. *Monitoring of essential and heavy metals in green tea from different geographical origins*. Environ. Monit. Assess. 188, 1-11.

CANADIAN FOOD INSPECTION AGENCY, 2011. *Mercury in dried tea, soft drinks and corn syrup.*

CHANTRE P., LAIRON D., 2002. *Recent findings of green tea extract AR25 (Exolise) and its activity for the treatment of obesity*. Phytomedicine 9, 3-8.

COOPER R., MOORÈ J., MOORÈ M. D., 2005. *Medicinal benefits of green tea. Part I. Review of noncancer health benefits*. J. Altern. Complement. Med. 11, 521-528.

DAVIES M. J., JUDD J. T., BAER D. J., CLEVIDENCE B. A., PAUL D. R., EDWARDS A. J., WISEMAN S. A., MUESING R. A., CHEN S. C., 2003. *Black tea consumption reduces total and LDL cholesterol in mildly hypercholesterolemic adults*. J. Nutr. 133, 3298S-3302S.

DUFFY S. J., KEANEY J. F. JR., HOLBROOK M., GOKCE N., SWERDLOFF P. L., FREI B., VITA J. A., 2001. *Short- and long-term black tea consumption reverses endothelial dysfunction in patients with coronary artery disease*. Circulation 104, 151-156.

DULLOO A. G., DURET C., ROHRER D., GIRARDIER L., MENSI N., FATHI M., CHANTRE P., VANDERMANDER J., 1999. *Efficacy of a green tea extract rich in catechin polyphenols and caffeine in increasing 24-h energy expenditure and fat oxidation in humans*. Am. J. Clin. Nutr. 70, 1040-1045.

FORSBERG J., MCQUATTERS J., 2016. *Mercury determination in tea leaves, INCT-TL-1, USEPA method 7473, using the Teledyne Leeman Labs Hydra II*$_C$ *Combustion CVAAS*. Teledyne Leeman Labs. Aplication Note – AN1603.

GARBA Z.N., UBAM S., BABANDO A.A., GALADIMA A., 2015. *Quantitative assessment of heavy metals from selected tea brands marketed in Zaria, Nigeria*. J. Phys. Sci. 26(1), 43–51.

GELEIJNSE J. M., LAUNER L. J., VAN DER KUIP D. A., HOFMAN A., WITTEMAN J.C., 2002. *Inverse association of tea and flavonoid intakes with incident myocardial infarction: the Rotterdam study*. Am. J. Clin. Nutr. 75, 880-886.

GIBSON R. S., 2005. *Principles of Nutritional Assessment*. Oxford Univ. New York, 697-711.

GOLDING J., STEER C. D., HIBBELN J. R., EMMETT P. M., LOWERY T., JONES R., 2013. *Dietary predictors of maternal prenatal blood mercury levels in the ALSPAC birth cohort study*. Environ. Health Perspect. 121, 1214-1218.

GREENOP J., 1997. *The lifestyle food index for South African consumers*. Demeter Publications, Gauteng, South Africa.

HAKIM I. A., ALSAIF M. A., ALDUWAIHY M., AL-RUBEAAN K., AL-NUAIM A. R., AL-ATTAS O. S., 2003. *Tea consumption and the prevalence of coronary heart disease in Saudi adults: results from a Saudi national study*. Prev. Med. 36, 64-70.

HEGARTY V. M., MAY H. M., KHAW K. T., 2000. *Tea drinking and bone mineral density in older women.* Am. J. Clin. Nutr. 71, 1003-1007.

HENNING M. S., 2004. *Bioavailability an antioxidant activy of tea flavanols after consumption of green tea, black tea, or a green tea extract supplement*. Amer.J. Clin. Nutr. 80, 1558-1564.

HERTOG M. G. L., FESKENS E. J. M., HOLLMAN P. C. H., *et al.*, 1993. *Dietary antioxidant flavonoids and risk of coronary disease: the Zutphen elderly study*. Lancet 342, 1007-1011.

HIRATA K., SHIMADA K., WATANABE H., OTSUKA R., TOKAI K., YOSHIYAMA M., HOMMA S., YOSHIKAWA J., 2004. *Black tea increases coronary flow velocity reserve in healthy male subjects*. Am. J. Cardiol. 93, 1384-1388.

HOSSENI S. M., SHAKERIAN A., MOGHINI A., 2012. *Cadmium and lead content in several brands of black tea (Camelia sinesis) in Iran.* J. Food Bioscien. Technol. 3, 67-72.

ISEMURA M., SAEKI K., KIMURA T., HAYAKAWA S., MINAMI T., SAZUKA M., 2000. *Tea catechins and related polyphenols as anti-cancer agents*. Biofactors 13, 81-85.

ISHIKAWA T., SUZUKAWA M., ITO T., YOSHIDA H., AYAORI M., NISHIWAKI M., YONEMURA A., HARA Y., NAKAMURA H., 1997. *Effect of tea flavonoid supplementation on the susceptibility of low-density lipoprotein to oxidative modification*. Am. J. Clin. Nutr. 66, 261-266.

KAMATH A. B., WANG L., DAS H., LI L., REINHOLD V. N., BUKOWSKI J. F., 2003. *Antigens in tea-beverage prime human gamma delta cells in vitro and in vivo for memory and nonmemory antibacterial cytokine responses*. Proc. Natl. Acad. Sci. 100, 6009-6014.

KELI S. O., HERTOG M. G. L., FESKENS E. J. M., KROMHOUT D., 1996. *Dietary flavonoids, antioxidant vitamins, and incidence of stroke*. Arch. Intern. Med. 156, 637-642.

KELLY S. P., GOMEZ-RAMIREZ M., MONTESI J. L., FOXE J. J., 2008. *L-Theanine and caffeine in combination affect human cognition as evidenced by oscillatory alpha-band activity and attention task performance.* J. Nutr. 138, 1572S-1577S.

KUSHIYAMA M., SHIMAZAKI Y., MURAKAMI M., YAMASHITA Y., 2009. *Relationship between intake of green tea and periodontal disease*. J. Periodontol. 80, 372-377.

LARSSON S. C., VIRTAMO J., WOLK A., 2013. *Black tea conspumption and risk of stroke in women and men.* Ann. Epidemiol. 23, 157-160.

LINKE H. A., LEGEROS R. Z., 2003. *Black tea extract and dental caries formation in hamsters*. Int. J. Food. Sci. Nutr. 54, 89-95.

LLOYD T., JOHNSON-ROLLINGS N., EGGLI D. F., KIESELHORST K., MAUGER E. A., CUSATIS D. C., 2000. *Bone status among postmenopausal women with different habitual caffeine intakes:a longitudinal investigation*. J. Am. Coll. Nutr. 19, 256-261.

MANDEL S., WEINREB O., REZNICHENKO L., KALFON L., AMIT T., 2006. *Green tea catechins as brain-permeable, non-toxic iron chelators to „iron out iron" from the brain.* J. Neural. Transm. 71, 249-257.

MAYFOU J. A., AL BAYATI H. S., EMMIMA E. M., 2015. *Quantitative assesement of (Ca, Mg, K, Na, Fe, Mn) in some brands of green tea marked in Libya.* ARPN J. Sci. Technol. 5, 303-310.

MUBEEN H., NAEEM I., TASKEEN A., ADIQE Z., 2009. *Investigations of heavy metals in commercial spices brands.* NY Sci. J. 2, 20-26.

MUKAMAL K. J., MACLURE M., MULLER J. E., SHERWOOD J. B., MITTLEMAN M. A., 2002. *Tea consumption and mortality after acute myocardial infarction.* Circulation 105, 2476.

MULLER M., ANKE M., ILLING-GUNTHER H., 1997. *Availabity of aluminium from tea and coffee.* 205, 170-173.

MURASE T., NAGASAWA A., SUZUKI J., HASE T., TOKIMITSU I., 2002. *Beneficial effects of tea catechins on diet-induced obesity: stimulation of lipid catabolism in the liver.* Int. J. Obes. Relat. Metab. Disord. 26, 1459-1464.

MURASE T., HARAMIZU S., SHIMOTOYODOME A., TOKIMITSU I., 2005. *Reduction of diet-induced obesity by a combination of tea-catechin intake and regular swimming*. Int. J. Obesity 30, 561-568.

MURASE T., HARAMIZU S., SHIMOTOYODOME A., TOKIMITSU I., HASE T., 2006. *Green tea extract improves running endurance in mice by stimulating lipid utilization during exercise*. Am. J. Physiol. Regul. Integr. Comp. Physiol. 290, R1550-1556.

NAGAO T., HASE T., TOKIMITSU I., 2007. *A green tea extract high in catechins reduces body fat and cardiovascular risk in humans*. Obesity 15, 1473-1483.

NIEHS, 2013. *Lead and your health.* National Institute of Environmental Health Sciences.

OTHMAN A., AL-ANSI S., AL-TUFAIL M., 2012. *Determination of lead in Saudi Arabian imported green tea by ICP-MS*. E-J. Chem. 9, 79-82.

POPKIN B. M., ARMSTRONG L. E., BRAY G. M., CABALLERO B., FREI B., WILLETT W. C., 2006. *A new proposed guidance system for beverage consumption in the United States*. Am. J. Clin. 83, 529-542.

POWELL J. J., BURDEN T. J., THOMPSON R. P. H., 1998. *In vitro mineral availability from digested tea: A rich dietary source of manganese*. Analyst 123, 1721-1724.

PYTLAKOWSKA K., KITA A., JANOSKA P., POŁOWNIAK M., KOZIK V., 2011. *Multi-element analysis of mineral and trace elements in medical herbs and their infusions.* Food Chem. 135, 494-501.

SARKAR S., SETT P., CHOWDHURY T., GANGULY D. K., 2000. *Effect of black tea on teeth*. J. Indian. Soc. Pedod. Prev. Dent. 18, 139-140.

SHIMOTOYODOME A., HARAMIZU S., INABA M., MURASE T., TOKIMITSU I., 2005. *Exercise and green tea extract stimulate fat oxidation and prevent obesity in mice.* Med. Sci. Sports. Exerc. 37, 1884-1892.

SONG W. O., CHUN O. K., 2008. *Tea is the major source of flavan-3-ol and flavonol in the U.S. diet.* J. Nutr. 138, 1543S-1547S.

STATISTICAL YEARBOOK OF THE REPUBLIC OF POLAND, 2015. Year LXXV, Warsaw.

STREET R., SZÁKOVÁ J., DRÁBEK O., MLÁDKOVÁ L., 2006. *The Status of Micronutrients (Cu, Fe, Mn, Zn) in Tea and Tea Infusions in Selected Samples Imported to the Czech Republic*. Czech J. Food Sci. 24, 62-71.

UNEP, 2002. *Chemicals. Global Mercury Assessment*. United Nations Environment Programme.

VENABLES M. C., HULSTON C. J., COX H. R., JEUKENDRUP A. E., 2008. *Green tea extract ingestion, fat oxidation, and glucose tolerance in healthy humans*. Am. J. Clin. Nutr. 87, 778-784.

VERMEER M. A., MULDER T. P., MOLHUIZEN H. O., 2008. *Theaflavins from black tea, especially theaflavin-3-gallate, reduce the incorporation of cholesterol into mixed micelles*. J. Agric. Food. Chem. 56, 12031-12036.

WATTS D. L., 1990. *The nutritional relationships of manganese*. J. Orthomol. Med. 5, 219-222.

WEISBURGER J. H., 1999. *Tea and health: the underlying mechanisms*. Proc. Soc. Exp. Biol. Med. 20, 271-275.

WHO, 2010. *Preventing disease through healthy environments. Exposure to cadmium: a major public health concern.* http://www.who.int/ipcs/features/10chemicals_en.pdf

WINIARSKA MIECZAN A., KWIECIEŃ M., KWIATKOWSKA K., 2011. *Lead and cadmium content in herbal teas.* Probl. Hig. Epidemiol. 92, 667-670.
WOJCIECHOWSKA-MAZUREK M., STARSKA K., MANIA M., REBENIAK M., KARŁOWSKI K, 2010. *Pierwiastki szkodliwe dla zdrowia w herbacie - ocena zagrożenia dla zdrowia.* Bromat. Chem. Toksykol. 43, 233-239.
WRÓBEL K., WRÓBEL K., COLUNGA-URBINA E. M., 2000. *Determination of total aluminum, chromium, cooper, iron, manganese and nickel and their fractions leached to the infusions of black tea, green tea, Hibiscus sabdarifa and Ilex paraguariensis (Mate).* Biol. Trace Elem. Res. 78, 271-280.
WU C. H., YANG Y. C., YAO W. J., LU F. H., WU J. S., CHANG C. J., 2002. *Epidemiological evidence of increased bone mineral density in habitual tea drinkers.* Arch. Intern. Med. 162, 1001-1006.
ZHANG Y., JAMES M., MIDDLETON F. A., DAVIS R. L., 2005. *Transcriptional analysis of multiple brain regions in Parkinson's disease supports the involvement of specific protein processing, energy metabolism, and signaling pathways, and suggests novel disease mechanisms.* Am. J. Med. Genet. B. Neuropsychiatr. Genet. 137, 5-16.
ZHONG W. S., REN T., ZHAO L. J., 2016. *Determination of Pb (lead), Cd (cadmium), Cr (chromium), Cu (cooper), and Ni (nickel) in Chinese tea with high-resolution continuum Skurce graphite furnace atomic absorption spektrometry.* J. Food Drug Anal. 24, 46-55.

KOSMOS Vol. 65, 4, 563–571, 2016

SANDRA WATRAK, MONIKA RAJKOWSKA-MYŚLIWIEC, MIKOŁAJ PROTASOWICKI

Department of Toxicology, Faculty of Food Science and Fisheries, West Pomeranian University of Technology in Szczecin
Papieża Pawła VI 3, 71-459 Szczecin, e-mail: sandra.watrak@zut.edu.pl

THE CONTENT OF TOXIC METALS IN DIFFERENT TYPES OF TEA AND THEIR IMPACT ON CONSUMERS HEALTH

Summary

Tea is one of the most popular beverages in the world, which, along with a number of beneficial health ingredients, such as trace elements, also contains undesired substances – as impurities. Among the impurities occur heavy metals, and their presence in tea leaves can pose serious problems to human health because they are not biodegradable, remain in the environment and can become part of the food chain. The total metal content of the tea leaves and infusions depends on the type of tea (green, black) and on the influence of other factors, including the properties of the soil. Despite the limited extent of metal migration from the dried tea to infusions, tea pollution with metals such as lead, cadmium or mercury is not indifferent to human health.