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THE EFFECTS OF BEDDING MATERIAL CONTAINING PEAT MOSS ON BROILER PRODUCTION PERFORMANCE AND FERTILIZING QUALITY OF THE LITTER

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Abstract

An experiment was conducted in order to evaluate the effect of alternative bedding materials on broiler production performances and litter quality in plant production. The forty-two-day experiment was carried out on 6885 broilers of ROSS 308 provenience. The broilers were reared on bedding material which consisted of cellulose pellets, wood chips, peat moss, and pH stabilizers. Feeding, zoohygienic and zootechnical measures met technological normative for this provenience. During the experiment, health status and mortality of broilers were observed. Litter pH, moisture, nitrogen, potassium and phosphorus content in litter were determined at the end of experiment. Average live weight of broilers at the end of the trial was 2620 g. Mortality of chickens was 1.52%. The results of the study indicated that use of specified bedding material was beneficial for broiler production. The results of the investigation of litter quality indicate that it can provide similar benefits to inorganic fertilizers in terms of plant growth.

Key words: broilers, wood chips, peat, organic fertilizer

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UTICAJ PROSTIRKE SA DODATKOM TRESETA NA PROIZVODNE PERFORMANSE BROJLERA I KVALITET STAJNJAKA

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Kratak sadržaj

U ovom istraživanju ispitivan je uticaj alternativnih materijala za prostirku na proizvodne performanse brojlera i kvalitet dobijenog stajnjaka u biljnoj proizvodnji. Ogled je izvršen na 6885 brojlera provenijence ROSS 308. Brojleri su uzgajani na prostirci koja se sastojala od celuloznih peleta, drvene piljevine, treseta i stabilizatora pH vrednosti. Ishrana, zoohigijenske i zootehničke mere bile su u skladu sa tehnološkim normativim za provenijencu. Tokom eksperimenta praćeno je zdravstveno stanje i mortalitet brojlera. Na kraju eksperimenta utvrđeni su pH vrednost, sadržaj vlage, azota, kalijuma i fosfora u stajnjaku. Prosečna telesna masa brojlera na kraju ogleda bila je 2620 g. Mortalitet pilića iznosio je 1,52%. Rezultati studije su pokazali da je upotreba odabranih materijala za prostirku povoljno uticala na proizvodne parametre brojlera. Rezultati ispitivanja kvaliteta stajnjaka ukazuju na dobar kvalitet i mogućnost njegove primene kao đubriva u biljnoj proizvodnji.

Ključne reči: brojleri, drvena piljevina, treset, organsko đubrivo

INTRODUCTION

The quality of chickens, feed, and water are of immense importance for poultry industry. However, the selection of adequate bedding material is one of the crucial factors to successful broiler production. This is significant because birds are in continuous contact with litter (Ritz et al., 2017). Litter quality is also important from the aspect of veterinary medicine, animal welfare, protection and preservation of the ecosystem and production effectiveness (Monira et al., 2003). Litter is the mixture of various materials of organic or inorganic origin, most commonly the byproducts of agricultural industry and forestry. Sustainable broiler production requires bedding materials, which are environmentally friendly, effective and inexpensive. The litter material must be safe and comfortable for the birds during growing period, it should be highly absorptive, easy to manipulate and non-toxic for the farm staff (Shao et al., 2015). The selection of adequate bedding material is determined by its ecological safety and biodegradability as well as the price, which is an important factor in production process.

Litter quality substantially affects production performance, health status, carcass quality and broiler welfare parameters (Garcês et al., 2013; Ramadan et al., 2013). Broilers perform to their full genetic potential in an optimal environment. The quality of the in-house environment is highly dependent upon litter quality (Ritz et al., 2017).

A range of materials can be used as litter material depending on their availability. The types of litter materials used in poultry industry include sawdust, rice husk, sugarcane pulp, sugarcane bagasse, chopped straw, paper mill by products, sand, wood shavings, corn cobs, oat hulls, dried leaves, coffee husk (Ramadan et al., 2013; Toghyani et al., 2010). Wheat straw and wood shavings are most commonly used bedding materials in poultry production in Serbia (Avdalovic et al., 2017).

Peat moss has some properties that make it potentially *suitable* for poultry industry. Swamp phosphates, which are considered complex organic mineral fertilizers, are components of the peat moss that is produced by deposition and partial decomposition of mosses and other trees, grasses or shrubs in the soil (Everett et al., 2013). The ability of peat to absorb and rapidly release excess moisture provides good moisture control in broiler houses. Naturally low pH (4.5 to 6.4) could be useful in the control of ammonia by decreasing bacterial population in the litter (Shepherd et al., 2017). Peat moss in bedding material provides conditions for the development and survival of saprophyte microflora, which enables decomposition of organic matter under aerobic conditions.

Poultry litter, which is a mixture of bird excreta and various bedding materials, represents a valuable source of nutrients for plant production (Henuk and Dingle, 2003). Litter is defined as the combination of bedding material, excreta, feathers, wasted feed and wasted water (Ritz et al., 2017; López-Mosquera et al., 2008). Safe disposal of enormous amounts of the litter accumulated in poultry industry involves their use as fertilizers in crop and plant production. It is well established that poultry litter contains essential nutrients required for plant nutrition (C, P, N, K, S, Ca, Mg, B, Cu, Fe, Mn, Mo, Zn) making it an excellent fertilizer. The content and ratio of basic nutrients (N, P, K) in poultry litter is remarkably similar to that in commercial fertilizers and can provide the same effects and benefits in terms of plant growth improvement (Marble et al., 2011). Poultry manure is considered a highly valuable fertilizer in many countries and is preferred over chemical fertilizers due to its capacity to improve physical properties and texture of the soil. It is used in the production of a range of economically important crops such as maize (Moss et al., 2001; Nguyen, 2010), pasture (Kingery et al., 1993), soybean (Adeli et al., 2005; Nguyen, 2010) and horticultural species (Rubeitz et al., 1998; Marble et al., 2011).

The needs for fertilizers in agricultural production are seasonal; however, poultry litter is produced in nearly constant amounts throughout the year. The storage of such material is often challenging because of potential contamination of the air (nitrogen emission), water (chemical and microbiological contamination) as well as spreading of unpleasant odors (López-Mosquera et al., 2008). Poultry and pig farms are considered major sources of phosphorus and nitrogen pollution in the environment, especially of rivers and farmlands (Živkov Baloš, 2010). Composting, active drying and pelletizing are techniques employed to prevent losses of nitrogen and development of undesirable odors from poultry litter (Mondini et al., 1996). Moreover, reliable data on the composition and nutrient contents in the litter are essential for providing the most effective usage of poultry litter and avoiding potential nutrient losses (Nicholson et al., 1996).

The aim of this research was to assess the effects of a novel type of broiler litter on production performance, as well as to investigate its basic physicochemical properties and contents of nutrients essential for crop and plant production.

MATERIAL AND METHODS

Birds and husbandry

A forty-two-day experiment was carried out on 6885 broilers of ROSS 308 provenience. The experimental chickens were housed in two facilities (houses) under the same conditions. The broilers were reared on bedding material which consisted of cellulose pellets, wood chips, peat, and pH stabilizers. Bulk density of bedding material was 320-340 kg/m^3. Feeding, zoo hygienic and zootechnical measures met technological normative for ROSS 308 provenience broilers (Aviagen, 2018). Feed and water were available *ad libitum*. During the experimental period, the birds were fed standard broiler formulations. The following parameters were monitored: mortality rate, body weight, feed consumption and feed conversion. Mortality was recorded daily and expressed as a percentage of the initial number of chicks. The body weights were measured at the end of the experiment on 50 randomly selected broilers. During the experiment, total quantity of the mix given to the broilers was measured.

From the obtained data on feed consumption and total body (live) weight, feed conversion was calculated.

Litter pH, moisture, nitrogen (N), potassium (K) and phosphorus (P) content in litter were determined on days 0, 7, 21, 28, and 35. Litter samples were collected from all four corners and central area of each broiler house including the bedding under the drinkers, and thoroughly mixed to obtain representative material (subsample). Laboratory analyses of litter were performed in 12 replicates (2 objects X 2 subsamples X 3 tests), immediately upon sampling.

Physicochemical analysis

Moisture was determined using gravimetric method. Dried samples (105°± 2° C) were weighed until constant weight was obtained. Total nitrogen was determined by dry combustion (Dumas method) with Elementar Rapid N Cube Analyzer, Germany. For determining pH value, 10.0 g litter samples were taken in 100 ml of distilled water. The samples were stirred for 30 minutes, and filtered liquid was measured using pH meter (Consort, Belgium). Total mineral matter contents were determined by annealing at 550˚C ± 20° C. Organic matter contents (%) in the samples were determined by calculation. Potassium and phosphorus contents were determined by atomic emission spectrophotometry (Varian SpectrAA10, Varian) and spectrophotometry (LLG), respectively.

Statistical analysis

Statistical analysis was performed using the PAST software package, version 2.12, Oslo, Norway. The data were presented as mean, standard deviation, minimum, maximum values, and coefficient of variation.

RESULTS

Broiler production performances included into this study are presented in Table 1. The results for monitored broilers performances were satisfactory, that is, within the range of expected performance objectives and in line with relevant guidelines (Aviagen, 2019).

Table 1. Body weight, consumption and feed conversion values of experimental broilers

Production parameter	Measured value
Average live weight of broilers (g)*	2620 ± 408; 1711 – 2850
Mortality (%)	1.52
Consumption (kg)/broiler	4.44
Feed conversion (kg)*	1.69 ± 0.13; 1.48-2.10

* Data are presented as mean ± standard deviation and range (min-max)

The results shown in Table 3 indicated that moisture content in the litter did not exceed the critical value on day 35, i.e. the range was between 35-40%. The analysis of moisture content in litter samples revealed a decreasing trend (Figure 1) corresponding to broilers age. On day 0, the moisture content reached almost 70% (major portion of moisture originated from peat moss) (Table 2). On day 7, significantly lower moisture content was recorded and it continued the decreasing trend during following few weeks of the experimental period.

Table 2. Physicochemical properties of peat moss

	Nitrogen (%)	Moisture (%)	pH
	Mean ± standard deviation Range (min-max) Coefficient of variation		
Peat moss	0.71 ± 0.10 0.69 -0.79 14.08	60.02 ± 4.38 58.48-64.51 7.30	5.81 ± 0.19 5.62 – 5.93 3.27

The acidity or alkalinity of the litter (pH value) is an important determinant of its quality. In poultry production, additives for reducing litter pH (acidifiers) are used in order to decrease the production of ammonia and carbon dioxide, metabolic byproducts of heterotrophic microorganisms residing in the litter. Lower pH inhibits the growth of bacteria responsible for ammonia production. As shown in Table 2, litter pH has changed insignificantly and quite slowly over the experimental period; however, the average pH of samples collected on day 35 deviated from the initial value (day 0)for some 1.5 units.

Table 3. Physicochemical properties of broiler litter

Time of trial (days)	Moisture (%)	pH	Nitrogen (%)	Potassium (%)	Phosphorus (%)
	Mean ± standard deviation Range (min-max) Coefficient of variation				
0	65.78 ± 4.36 60.90 - 69.51 6.63	6.53 ± 0.31 6.27 – 6.97 4.69	0.62 ± 0.06 0.57 – 0.69 9.03	0.08 ± 0.02 0.06 – 0.10 22.82	0.025 ± 0.008 0.019 – 0.036 31.70
7	43.23 ± 3.63 40.51 – 48.48 51.45	6.87 ± 0.25 6.57 – 7.16 3.62	1.86 ± 0.06 1.79 – 1.92 3.36	0.65 ± 0.08 0.54 – 0.73 12.24	0.22 ± 0.04 0.17 – 0.25 16.97
21	33.78 ± 8.16 25.64 – 42.67 24.15	6.47 ± 0.68 5.88 – 7.23 10.55	2.35 ± 0.16 2.17 – 2.52 6.77	0.94 ± 0.08 0.87 – 1.01 8.28	0.37 ± 0.03 0.34 – 0.41 8.02
28	27.56 ± 2.20 25.01 – 29.64 7.99	7.32 ± 0.23 7.01 – 7.53 3.12	2.82 ± 0.04 2.78 – 2.86 1.24	1.25 ± 0.02 1.23 – 1.26 1.20	0.47 ± 0.02 0.44 – 0.49 4.74
35	30.52 ± 4.20 27.34 – 36.51 13.76	8.13 ± 0.54 7.36 – 8.60 6.59	2.75 ± 0.11 2.65 – 2.89 3.98	1.39 ± 0.18 1.15 – 1.56 12.76	0.45 ± 0.03 0.42 – 0.48 5.74

Table 4. Content of mineral and organic matter in the broiler litter

Litter status	Mineral matter content (%)	Organic matter content (%)
Before placing the birds	5.57 ± 0.39 5.07 – 5.96 7.00	28.65 ± 4.63 24.09 – 33.14 16.16
After the experiment	8.61 ± 0.38 8.40 – 9.18 4.41	60.87 ± 4.57 54.31 – 64.26 7.51

Nitrogen content increased gradually over the experimental period (Figure 1), ranging from initial value of 0.62± 0.06% to 2.75 ± 0.11% at the end of the trial. Litter potassium levels also increased from 0.08 ± 0.02% (Day 0) to 1.25 ± 0.02% at the end of experimental period. As expected, similar trend was observed for phosphorus content as well, which increased from 0.025 ± 0.008% to 0.45 ± 0.03%. Organic matter contents in litter samples (Table 4) increased from 28.65% (before placing the birds into the broiler house) to 60.87% (Day 35).

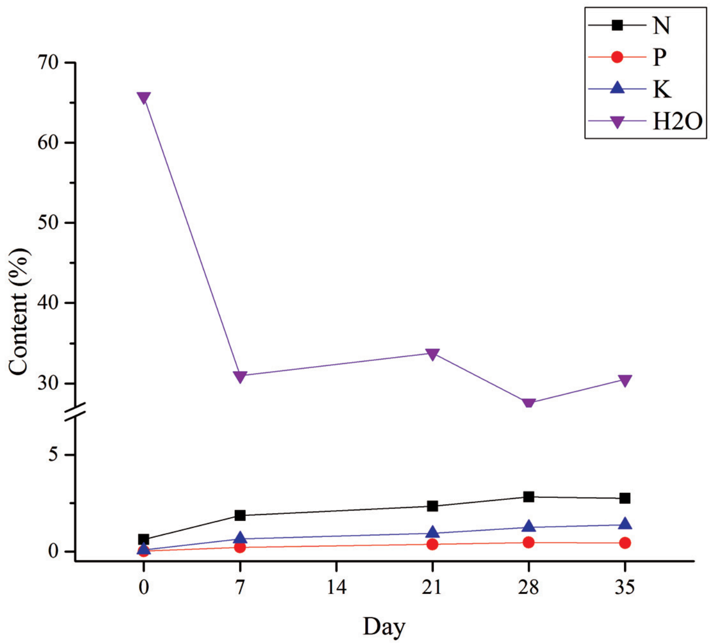

Figure 1. Moisture content, N, P and K in broiler litter during the experimental period

DISCUSSION

Broiler production indicators monitored in this research were satisfactory and comparable with both recommendations of Ross308 and the results of other authors, who used the broilers of the same provenience in their research of effects of diverse alternative bedding materials. As compared to our experiment, body weight of broilers from a 42-day experiment of Toghyani et al. (2010), that used various litter types, were somewhat lower, while feed conversion ratio was very similar to our results. The mortality rate of broilers reported by the aforementioned author was higher than that recorded in our experiment.

The experiment of Ramadan et al. (2013) performed using six different litter types revealed similar results, that is, somewhat better production performance of broilers was observed in our experiment. Avdalovic et al. (2017) reported that body weight of Ross 308 broilers (measured on day 42) in the experiment using bedding materials containing pelleted wheat straw and chopped wheat straw was 2156 g and 2155 g, respectively. It is to be emphasized that there is a range of differences between these studies. Thus, the apparent differences may be attributed to variations in bedding materials, husbandry practice, as well as seasonal and other impacts. Furthermore, numerous authors who used alternative beddings reported that the type of bedding material used does not affect body weight, feed conversion and mortality (Toghyani et al., 2010). Hence, we can conclude that a type of bedding material has no direct impact on production performance and health status of birds. The selection of litter can have an effect on ambient factors (moisture, pH, ammonia) and animal welfare parameters, i.e. the incidence of footpad damage that consequently affects the overall health status and production performance of broilers.

The quality of bedding material is reflected in its high absorbency and quick drying time (Garcês et al., 2013) while enabling natural behavior of birds such as dust bathing. The moisture content in the litter in broiler houses commonly ranges between 25 and 35%. The increase of litter moisture to more than 35-40% results in progressive growth of microbial population as well as increased emission of harmful gases in poultry house. Consequently, increased production of unpleasant odors, retarded growth, breast blisters and dirty feathers, footpad dermatitis, insect problems and health impairments including increased incidence of respiratory infections can occur (Lonkar et al., 2018). The results of our research revealed that litter moisture content did not exceed 35% with an average value being 30.52 ± 4.20% on day 35. Initial high litter humidity corresponds with the findings of Kaukonen et al. (2017), who reported that there were no significant differences between moisture content in diverse bedding materials at the end of their trial. The results of our experiment are consistent with the results reported by Garcês et al. (2013) who conducted a trial using a variety of bedding materials. The results of our research are similar to those obtained by Kaukonen et al. (2017) revealing that moisture contents determined at the end of the trial were 33.1% and 32.3% in broiler litters based on peat moss and wood shavings, respectively. The ability of peat moss to rapidly absorb and release excess moisture has most likely been contributed to a decrease of moisture content in the litter during the experimental period. Peat moss can absorb 20 times its weight in water (Everett et al., 2013).

Moisture reaches the litter through feces and urine excretion (water content in the feces is about 75%), spilling from the drinkers, condensation, leaking or absorption from the air (Garcês et al., 2013). The bedding around the drinkers with moisture content of 38-48% proved more favorable for microbial growth as compared with the bedding samples taken from the areas that are more distant from the drinkers with a moisture content of 24-27% (Wadud et al., 2012). Wet litter is most commonly attributed to wet droppings, microclimate disturbance, equipment malfunctions as well as to the type and depth of the litter. Moisture content highly affects physical properties and manageability of the litter (compression, compactness and cohesiveness). Increased moisture contents and the resulting compactness of bedding material diminish the thermal insulation properties of the litter, which results in creation of anaerobic conditions and decreased pH.

Fresh litter is not considered an appropriate fertilizer due to its high moisture content. Thus, it requires composting before application in crop and plant production.

The acidity or alkalinity of the litter (pH value) is an important determinant of its quality. In poultry production, additives for reducing litter pH (acidifiers) are used in order to decrease the production of ammonia and carbon dioxide, metabolic byproducts of heterotrophic microorganisms present in the litter (Lonkar et al., 2018). Lower pH inhibits the growth of bacteria responsible for ammonia production. Elliott and Collins (1982) found that litter ammonia concentration is related to litter pH and moisture. Everett et al. (2013) reported that peat has naturally low pH, which is a highly desirable property when it comes to reducing the number of bacteria in the litter. During the experimental period, the litter pH moderately increased from 6.53 ± 0.31 on day 0 to 8.13 ± 0.54% on day 35 (total 24.5%), which is somewhat lower than the results obtained by Garcês et al. (2013) and higher than those reported by Lonkar et al. (2018). Potassium level in broiler litter increased with the age of the birds reaching 1.39 ± 0.18% (2.00% dry matter) at the end of the trial period, which corresponds with the results reported by López-Mosquera et al. (2008). The initial value (on day 0) was somewhat lower than that reported by aforementioned authors; yet, different compositions of bedding materials were used in the experiments.

Broiler litter, which is a mixture of bird excreta and various bedding materials, represents a valuable source of nutrients for plant production (Henuk and Dingle, 2003). Poultry litter contains substantial amounts of nitrogen. The moisture in the litter associated with high ambient temperature is supportive of growth of bacteria transforming nitrogen from the litter into ammonia (Garcês et al., 2013). Production of large amounts of ammonia is responsible not only for environmental pollution but also for decreased biological value of the manure, which is due to the evaporation of considerable amounts of nitrogen. In our research, the concentration of nitrogen in the litter (3.95% in dry matter) was somewhat higher compared to some researches (Garcês et al., 2013); yet lower than in the research of Shao et al. (2015) who used the bedding containing wood shavings. Differences in total nitrogen contents in the litter might be attributed to diverse factors such as duration of experimental period, type of bedding material, litter depth, etc. Moreover, it should be emphasized that nitrogen content in peat moss was 1.77% in dry matter, which also affected the total nitrogen content in the litter. Although the nutritional value of feed was not tested, it is possible that the protein content in the diets was excessive, which was reflected in the elevated nitrogen content in the litter.

Genetic progress and improvement and an intensive increase of broiler weight resulted in problems concerning the bone quality of chickens. Implementing novel dietary practices, application of new feed formulations and additives as well as new technological approaches may be a way to addressing these problems. Ecological aspect of the problem must also be taken into consideration. In many regions worldwide, rapid growth and intensive nature of crop and poultry farming created regional and local phosphorus imbalance in agricultural industry "P input and output" (Toor and Haggard, 2009). Excess phosphorus in feed results in increased amounts of phosphorus soluble in water in the manure. It can be easily transported (through the water) over the soil surface and eventually to surface waters (Sistani et al., 2001; Živkov Baloš, 2010). Phosphorus is an essential element required for animal and plant growth and thus inevitable for the maintenance of profitable agricultural production. However, phosphorus in surface waters can speed up eutrophication. Nitrogen and carbon are vital for the development of aquatic life forms due to difficult *exchange of carbon between* the *atmosphere* and hydrosphere and fixing of atmospheric nitrogen in some blue-green algae. However, the focus is still on phosphorus. Adequate control and prevention of excess phosphorus outputs into surface waters are of crucial importance for reduction of freshwater eutrophication (Sharpley, 1999; White and Brown, 2010). Phosphorus content in broiler litter in our research was similar to minimal values reported by other authors (Garcês et al., 2013; López-Mosquera et al., 2008; Nicholson et al., 1996). Phosphorus concentration in dry matter of broiler litter in our study was 0.65% on day 35. López-Mosquera et al. (2008) presented data from numerous studies about physical, chemical and biological properties of the fresh broiler litter, and they reported that phosphorus content was ranging from 0.6 to 3.9 % dry matter. In our research, litter samples were collected on 35-day-old chickens, whereas in the majority of other studies, the sampling was performed on 42-day-old ones, which probably somewhat affected lower concentration of this element in the litter. Lower phosphorus content determined in our research can be attributed to phytase supplementation into the broiler feed mixes. Adding phytase to the diet formulations significantly increases phytate phosphorus utilization from feedstuffs of plant origin, and reducing use of inorganic phosphorus source (Živkov Baloš, 2010). The availability of phosphorus in feedstuffs of plant origin is increased so its contents in the feces and consequently in the litter are significantly lower.

Mineral and organic matter contents in broiler litter (Table 4) increased significantly over 35 days of experimental period. Broiler litter provides high nutrient doses for crops, and it also adds organic matters to the soil. Organic matters improve soil structure, aeration, soil moisture-holding capacity, water infiltration, and soil acidity (Nguyen, 2010).

The management and disposal of poultry litter has become an important issue for poultry producers, due to growing environmental concerns. Land application is the most common use of litter. The role of the land application is twofold: first, it solves the problem of growing accumulation of the litter and second, it fertilizes arable and vegetable crops, and other plants. A wide range of factors such as management, environmental and physiological factors can affect litter production and its composition. N, P and K content in the litter may vary between flocks reared at the same litter. Type of bedding material used can affect the composition of the litter (Edwards and Daniel, 1992).

CONCLUSION

The bedding material and litter affects production performances, health, carcass quality, welfare of broilers and fertilizing value of broiler litter to a great extent. The results of the study indicated that use of specific bedding material, which consisted of cellulose pellets, wood chips, and peat moss, was beneficial for broiler production parameters. Broiler litter can provide benefits in terms of plant growth and it can supplement inorganic fertilizers to some extent, while potentially minimizing negative environmental impacts. The variability in composition of the litter strongly suggests that its chemical analysis should be performed prior to being used as a fertilizer. Sampling and analysis of the soil with an aim of preventing soil nutrient deficit or surplus is necessary as well.

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Authors' contribution

M.Ž.B., and S.K. made contributions to conception and design of the article and drafted the manuscript; D.B. made substantial contributions to the basic idea; S.J., N.P., and Ž.M. carried out the chemical analyses; S.V.K. was involved in drafting of the manuscript; S.K. and M.P. collected the samples and experimental data. All the authors have read and approved the final manuscript.

Competing interest

Authors declared no conflict of interests regarding the present paper.

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