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Decomposition dynamics of cooking-oil-soaked waste paper in media with low inorganic nitrogen content

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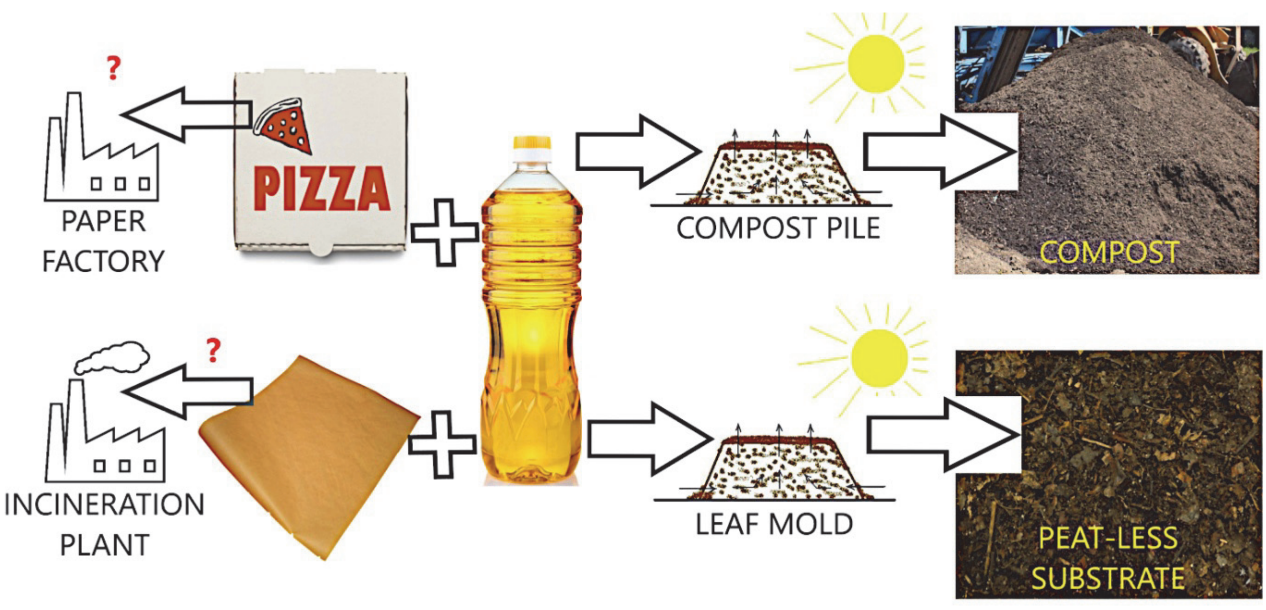
Abstract: Many paper-related products are in daily use all over the world. Although paper is one of the most recycled materials in the European Union, no end-of-waste criteria have been defined. Typical paper and cardboard should be recycled, but paper materials with impurities, such as cooking oil, sand, or plastic, are much more problematic. In particular, paper contaminated with cooking oil or butter (e.g., pizza boxes) is difficult waste. Also baking parchment paper cannot be stored as waste paper after use. Composting could be a solution, but in many municipal solid waste collection systems, this waste types are collected with the mixed waste stream, what finally leads this material to landfilling or incinerating processes. Parchment paper and pizza box cardboard contain a lot of cellulose and in landfills are a source of CO_2 and CH_4. Incineration of these materials also leads to CO_2 emission. The aim of this study was to investigate the degradation of cooking-oil-contaminated paper in media with a low inorganic nitrogen content. Cardboard usually used for packaging purposes was used as pre-test material. Two types of paper usually used in the kitchen were used: pizza box cardboard and parchment paper highly contaminated with cooking oil. Two types of low inorganic nitrogen media were tested: mature municipal waste compost (MSWC) and leaf mold (LM). The decrease of mass of both paper sample types was correlated with process time. Both tested sample types: dry cellulose materials and paper with cooking oil added, were partly or completely decomposed after 6 weeks of bioprocessing in aerobic conditions without an additional dose of inorganic nitrogen. According to waste separation rules, wet paper or paper contaminated with cooking oil have to be stored with other wastes which are „not possible for further use". This work show possibility to change these rules.



Graph 1. Graphical abstract

Introduction

Nowadays, the total amount of paper and paper-derived products produced globally is approximately 400 million tons per year and has increased by 45% over the past 3 years. Approximately 50% of this amount consists of package and labeling paper, whereas 28% is office printing paper. The increase in paper production will probably continue over the next years (Bekiroğlu et al. 2017). Used office paper without impurities can easily be transformed into new paper of good quality, but wet paper, baking paper or packaging cardboard contaminated with cooking oil or other compounds cannot be recycled in this way. In many countries, used office paper that has been stored for at least 5 years will be burnt because of the low profitability of the recycling technology (Karahan 2014). In 2019, the recycling rate in Europe was 72%, so out of the 57.5 million tons of paper produced that year, 22.36 million tons was dumped or burned, contributing to CO_2 emission. Part of this paper had various impurities, such as water, fat, and vegetable oil, or was contained in multi-material products and, therefore, excluded from the typical recycling procedures. Common paper products, such as cardboard or office paper, contain mainly cellulose and hemicellulose, so they are 100% biodegradable (Agarwal et al. 2014).

Various types of organic matter contained in municipal waste or originating from the food industry may, in the absence of other contaminants, be used to create ‘fertilizers’, which could even be reused in the organic production of arable crops or energetic weed areas for intensive biomass production (Ciesielczuk et al. 2016). Especially interesting is the possibility of using wastepaper as organic matter for organic fertilizers, considering the problems with the disposal of cooking-oil-soaked paper. In many countries, this type of waste is placed into the mixed waste stream. This common procedure leads to the storage of tons of wastepaper in landfills under anaerobic conditions, ultimately giving rise to additional methane and carbon dioxide emission what is negative due to atmospheric greenhouse effect (Micales and Skog 1997, Li et al. 2005). On the other hand, composting (including home composters) could be used for recycling organic matter, which is a process of the circular economy. Cellulose contained in cardboard, can easily be decomposed in the presence of an inorganic (or easy available/soluble organic) nitrogen source, such as urea, saltpeter, or free ammonium, for an optimum C:N. The addition of fat, oil, or grease has a significant effect on the biological processes in a compost pile because of low oxygen circulation and an additional carbon source (Al-Mutairi 2009). On the other hand, cooking oil is an easily degradable material, but access to oxygen and nitrogen ions is necessary for microbial processes (Rajae et al. 2008, Saletes et al. 2004). Different materials can be processed while saving energy and organic matter, such as palm oil mill effluents, which were composted in a compost plant with good results for 40 days, but the main problem was maintaining the optimum oxygen level for microbial activity (Wan Razali et al. 2012). Many microbial species are able to degrade cellulose and hemicellulose. These include bacteria from the genera *Clostridium*, *Cellulomonas*, *Bacillus*, *Thermomonospora*, *Ruminococcus*, *Bacteriodes*, *Erwinia*, *Acetovibrio*, *Microbispora*, and *Streptomyces* and the fungi *Trichoderma reesei*, *Trichoderma koningii*, *Penicillium funiculosum*, *Myrothecium verrucaria*, *Sporotrichum pulverulentum*, *Trametes pubescens*, *Mucor racemosus* and *Aspergillus niger* (Andlar et al. 2018, Wołczyński and Janosz-Rajczyk 2014). Oil-soaked paper can easily be recycled in a biogen-rich composting process, but with low availability of nitrogen and lower temperature than during thermophilic composting phase, the process can be very slow even in aerobic conditions (Poluszyńska et al. 2021). Low levels of easy available nitrogen are characteristic for sandy soil, old mature municipal solid waste compost (MSWC), and leaf mold (LM), which can be a problematic media for the biodegradation of oiled or even non-oiled cellulose-containing materials and there are only a few studies which describe this process. The aim of this study was to determine the influence of low easily available nitrogen levels and lower temperatures in comparison to composting process on the degradation dynamics of different paper types heavily contaminated with cooking oil.

General characteristics of vegetable oil and its biodegradation

Natural oils from plants are in daily use for thousands of years. They are commonly used in food and cosmetics all over the world. Chemically, natural oils are a simple combination of fatty acid esters of trihydroxy alcohol or glycerol (Aluyor et al. 2009). The most common oil-rich plants are the rapeseed, the sunflower, the olive tree, the soybean, the peanut, and the palm tree. The oils of other plants (e.g., cottonseed oil) have a lower share in the natural oil market. Plant oils contain many mono- and polyunsaturated fatty acids, e.g., oleic, and linoleic acids, and therefore have a relatively low melting point compared to saturated fatty acids with the same carbon content.

Biodegradation is a multi-stage microbial process that converts organic compounds into simple forms in which basic elements such as carbon, nitrogen, and oxygen are present mostly in inorganic forms. All degradation reactions are catalyzed by enzymes and do not exist in sterile environments. Additionally, some of the substrate’s organic compounds are converted into large humic substances, which form an important part of the humus layer.

A soil or compost environment is rich in many microbial groups, such as bacteria, fungi, and yeasts, but microbial colonies need a few days to adapt to a new substrate (Kaakinen et al. 2007). Many microorganisms can secrete extracellular lipases responsible for lipid biodegradation (Salihu et al. 2018). On the other hand, the pH value has an important role in biodegradation processes. Moisture, nitrogen, phosphorus, and other elements are necessary for biodegradation. Vegetable oils can be degraded both under aerobic and under anaerobic conditions, but the aerobic process is more effective. First, microbial enzymes crack the ester bond between glycerol and fatty acids. A wide range of microorganisms produce specific enzymes, such as esterases and lipases, that can cleave ester bonds. Next, β-oxidation is the general process by which the oil components are fully converted. The complete process (with a conversion rate of 70–100%) takes about 28 days under test conditions (Aluyor et al. 2009, Salihu et al. 2018).

Materials and methods

Pre-test

A one-month pre-test was carried out with sandy soil and small (3x3cm) pieces of dry and oiled pizza box (PB) with mass of about 0.33 g and 0.82 g respectively. Cardboard PB samples were soaked in sunflower oil for 24 hours and then the excess of oil was removed prior to use. Samples of pizza box cardboard were placed into plastic containers filled with 240 g of sandy soil (S). Natural rainwater was used for watering the test containers. The water content changed during the experiment because of evaporation and watering. The temperature during the test was 20±2°C. After one month, the mass of the PB and the inorganic nitrogen consumption were measured.

Leaf mold test

A six-week test was carried out with leaf mold and small sheets of cardboard from a pizza box (PB). The details of the preparation of the samples are described in the section "Compost test." About 1.3 g of dry samples and 3.2 g of oiled samples (oiled samples were heavier due to oil content) cut into small pieces (5 × 7 cm) were placed vertically and processed in plastic containers filled with leaf mold (PB:LM = 1:100 w/v). Leaf mold (2–3 years old) was obtained from a local dumping site for tree leaves, where the leaves from a municipal park were deposited. Rainwater collected from a steel roof was used for watering the test containers. The test temperature was 20±2°C. The water content was controlled by weight loss and filled up to the initial mass every week. After 30 days, the mass of the cardboard and the ammonium and nitrate nitrogen consumption were measured.

Compost test

A six-week test with prepared parchment paper (PP; baking sheets) was conducted. Waste PP paper was used as a simulation of baking paper after the baking of a cake. The tested PP (baking sheets) was double-sided covered with silicone which creates non-stick surfaces. Parchment paper which contains a layer of silicone, is unrecyclable (to a new paper product), even clean. These samples were divided into two types: dry (D) samples and oiled (O) samples. Sunflower oil from a local market was used for sample preparation. D samples were dried at 25°C for 24 hours prior to use. O samples were soaked in sunflower oil for 24 hours prior to use. One type of medium was tested: mature municipal solid waste compost (MSWC). This material was made of a mixed waste stream. Compost was obtained from a municipal compost plant and sieved through a 2 mm sieve for the removal of impurities. An additional maturation process of 1 year was carried out for a complete conversion of the waste biomass. The experiments were conducted in plastic pots at the temperature of 20±2°C. To make the decomposition process more difficult and simulate multi-layer PB material, the original PP samples (10 × 10 cm) were folded 4 times (thus obtaining 16 layers) to a size of about 2.5 × 2.5 cm, pressed down, and placed into pots filled with MSWC in a PP:MSWC ratio of 1:125 w/v. The containers were incubated without mixing or fertilizing with nitrogen during experiment. Natural rainwater was used for watering the test containers during the experiment. Rainwater was stored in open plastic containers prior to use.

Basic parameters were measured with standard methods: pH and electrical conductivity (EC) using the potentiometric approach, according to the soil analysis procedures. Organic matter was measured as a "loss of ignition" at 600°C for 3 hours. Organic carbon was measured with a Carl Zeiss Jena C/N analyzer. Easy available nitrogen (a lot of bacteria use ammonium and nitrates) was analyzed with spectrophotometric methods after 1 hour of shaking in 1% K_2SO_4 at room temperature (Gumienna and Czarnecki 2010). Solid medium samples for nitrogen ions analysis were divided into two sample types: (1) material from the paper sample area and (2) material from the external parts of the container as a control. Total phosphorus was measured with the titration method. The content of Ca, K, and Na was measured by the Flame Emission Spectrometry method with a BWB-XP photometer. The sunflower oil mass was determined after petroleum ether extraction in fexIKA® automatic extractor. Sandy soil, leaf mold, and compost samples were collected directly from the paper sample area. The decomposition process was carried out in plastic containers containing the tested media (MSWC and LM) with cardboard or parchment paper added.

Results and discussion

The tested cellulose-containing materials had a differentiated composition (Table 1). Especially high in the case of CaO content (240 times higher for PB), density (about 10 times higher for PB) but also lower differences were observed in all analyzed parameters. Especially important for the susceptibility to microbial decomposition is the C:N ratio. In tested materials this parameter was lower than in typical office paper (C:N=136). The high C:N value in tested samples could have hampered the biodegradation process because of a low source of inorganic nitrogen, especially it was shown in the S medium, where the IN content was very low (Table 2). Density was characteristic for both analysed materials, but slightly lower than that obtained in related works (Nowińska et al. 2019). The highest organic matter content in the PP material is interesting because it was double-sided covered with silicone, which should increase the ash content. The solid media prepared as decomposition environments had a different composition. The pH value was close to neutral for MSWC and LM and was slightly lower for the S samples, which is optimal for the intensity of the microbial processes. The different EC values were typical, especially in MSWC, in which many waste substances were treated. Resources of inorganic nitrogen were important because of the short test time and the problematic decomposition of organic matter with the release of nitrogen. The lowest inorganic N content was found in S, and the highest in MSWC (Table 2). The low amount of all nutrients in S can be problematic for microbial communities, so the decomposition process of cellulose materials will be slow. The tested solid media S, MSWC, and LM had a typical composition (Ghehsareh et al. 2011).

MSWC was a particularly interesting material because of its high content of mesophilic organisms, which remain present a long time after composting processes. However, also for long storage with medium water content, the organic matter was slowly mineralized with the release of mineral biogens forms. Rainwater used for watering of experimental containers contained small amounts of biogens such as phosphates (0.13 mg PO_4/dm[3]), ammonium nitrogen (0.14 NH_4^+ mg/dm[3]) and nitrates (0.37 NO_3^- mg/dm[3]), what was a source of nitrogen for microorganisms.

Results of the pre-test

Only a small amount of the PB samples was decomposed. The visual changes in the PB samples are shown in Fig. 1. Due to the low content of nitrogen and other elements the degradation stage was under 10% in both sample types (Table 3). Despite the large contact area with the solid medium, the decomposition was weak.

Both sample types (dry and oiled) were comparable decomposed, with better results in D samples. After 30 days, the experiment oil content effects are visible in O samples due to smooth surface (Fig. 2) and better elasticity. The PB material is very susceptible to decomposition in soil or other media, but the best C:N ratio is 25-30:1, as in a fresh compost pile. In the presence of compost, complete degradation of cellulose materials was obtained after 21 days, but to ensure a good C:N ratio, a dose of chicken manure with a high nitrogen content was added (Ahmed et al. 2018). The C:N ratio in sandy soil is suitable for microbial communities, but in the case of PB samples, the conditions for decomposition were bad, also because of general low content of nutrients, particularly nitrogen, phosphorus and calcium. In addition to a good C:N ratio, the presence of microorganisms and the availability of nitrogen and other elements are optimal conditions for the

Table 1. Characteristics of the tested paper materials (SD in brackets)

	PB	PP
Density [g/m^2]	387	38.5
Organic matter [%]	83.31(0.01)	97.56(0.08)
TOC [g/kg]	295.7(6.9)	333.9(3.4)
Total N [g/kg]	5.35	3.76
C:N ratio	55	89
P_2O_5 [g/kg]	6.93	7.35
CaO [g/kg]	67.3(0.4)	0.28(0.01)
K_2O [g/kg]	0.24(0.003)	0.16(0.03)
Na_2O [g/kg]	0.84(0.004)	1.13(0.01)
Vegetble oil absorptivity [g/g]	2.44(0.21)	1.74(0.16)

Table 2. Characteristics of mediums with low inorganic nitrogen

	S	MSWC	LM
pH (H_2O)	6.52–6.61	7.89–8.02	7.46–7.47
pH (KCl)	5.85–5.90	7.12–7.19	6.93–6.97
EC [mS/cm]	158–166	2870–2995	853–941
OM [%]	2.58(0.17)	48.16(4.18)	60.71(4.66)
TOC [%]	0.45(0.03)	21.9(2.6)	23.4(1.2)
Total nitrogen [%]	0.021	0.95	1.04
C : N	21.4	26.2	22.5
NH_4^+ [g/kg]	0.023	0.682	0.141
NO_3^- [g/kg]	0.030	0.876	0.459
P_2O_5 [g/kg dm]	0.16	1.36	4.62
CaO [g/kg]	4.09	62.29	15.99
K_2O [g/kg]	0.135	3.798	1.781
Na_2O [g/kg]	0.209	5.270	0.157

Table 3. PB samples after 30 days of decomposition

	D	O
Mass lost (% of degradation)	7.6	9.5
NH4+ budget [g/kg]	-0.053	-0.072
NO3- budget [g/kg]	-0.015	-0.026

dynamics of the biodegradation process. The obtained results with the decomposition of the PB samples in a relatively short time could probably have been better with a stable water content. The sandy soil humidity varied in a wide range from 26 to 49 g of water per pot. Differences in sandy soil humidity can be an important factor for microbial communities and the final grade of paper deterioration but even in good conditions, PB samples are not quickly degraded (Bogaard and Whitmore 2002, Nowińska et al. 2019).

Results of the leaf mold test

The second test with PB samples incubated in LM for 6 weeks showed a great susceptibility of this material to microbial decomposition (Table 4). Both sample types (D and O) were covered with microbial organisms, and after 6 weeks of incubation, only 58.3% and 56.6% of the original samples were left, respectively. The oiled surfaces were relatively big and the direct contact with LM led to a quick decomposition with almost the same results as for the D samples. Oxygen is 5 times more soluble in sunflower oil than in water, so this phenomenon increases the degradation speed in sunflower oil (Cuvelier et al. 2017). Moreover, used sunflower oil has a high content of linoleic acids (over 60%) and oleic acids (over 20%), which are prone to oxidation (Cichosz and Czeczot 2011). Fungi play a central role in the decomposition of plant litter, so LM is a special material. These organisms produce a suite of extracellular enzymes responsible for the decomposition of lignin, cellulose, and other components in litter. Moreover, they produce a unique nonenzymatic oxidative system which together with ligninolytic enzymes is responsible for polymers degradation. The action of fungi is slow, but they can grow in environments with a low content of inorganic nutrients, where typical composting process will not be present (Andlar et al. 2018). Despite a relatively high density of PB, the degradation process was successful in the presence of a low content of inorganic nitrogen, but not very effective in nutrient-rich environments (Nowińska et al. 2019). Leaf mold is rich in multiple fungi communities, so vegetable oil did not slow down the decomposition of paper because multi-enzyme systems of fungi microorganisms enable them to use different nutrient sources (Borrego et al. 2016, Osono 2019).

The samples showed a relatively quick decrease in oil content (Fig. 7), which indicates high microbial activity and finally a good transformation rate (over 40%) just after 14 days of incubation. Similar results were obtained in composting experiments with cardboard, fresh grass, and sewage sludge, but the nitrogen amount was high, and the decomposition was aided with eight dig-overs, which were performed every 30 days of the process (Balada et al. 2016).

Fig. 1. PB samples before (B) and after (A) the 1-month experiment in sandy soil

Fig. 2. Fibres of a PB samples, after 1-month experiment experiment in sandy soil

Results of the compost test

Although the PP samples were folded and pressed down, the decomposition of both sample types (D and O) in the old MSWC medium was fast. Many eubacteria and fungi and some anaerobic protozoa and slime molds are able to degrade cellulose, but better conditions are present in fresh compost because mature compost is likely to slowly the release of inorganic and organic nitrogen (Perez et al. 2002). Enzymatic reactions will be different in the sample area: more aerobic conditions on the external surfaces (2 by 6 cm), where there is direct contact with the compost medium, in comparison to semi-anaerobic conditions and low amount of water conditions inside the sample, where only a layer of cooking oil is present between the PP layers. As a result of these facts, the speed of PP degradation differs within a sample, especially in the first 7–10 days of incubation. Inside a PP sample, the degradation is slow because of a low nutrient concentration. The internal parts of the folded sample was degraded by the end of the experiment. The conditions of degradation are much better on the external surface of the sample, which has direct contact with the compost particles and so has access to water and oxygen. On the other hand, silicone layer can be a border for microbial consortia colony growth due to no-biodegrability properties of silicone. The worst conditions are inside the sample, also because of the low content of mineral nitrogen. Therefore, the semi-anaerobic microbial communities need more time for growth between the oiled PP surfaces. In many cases, the rule is that the depletion or lack of the hydrophilic carbon substrate and availability of using a lipophilic source opens the metabolic pathway for biosurfactants synthesis what increases the sunflower oil degradation (Gumienna and Czarnecki 2010). In normal waste processing, the PP sheet is partly crumpled and disposed of with the mixed waste stream on a dumping site or in incineration plant. Despite the anaerobic conditions inside a waste pile, the decomposition can be fast because of a high nitrogen content. The PP mass is transformed into CH_4 and CO_2, which are some of the greenhouse gases emitted from a dumping site. Methane itself can be used as a fuel source, but if not captured, it has a global warming potential 21 times stronger than CO_2.

Raw PP samples and PP samples after 5 weeks of incubation are shown in Fig. 4.

The oiled PP samples were only partly decomposed. The cooking oil was more than 80% degraded, and many free paper fibers could be seen. Despite the lack of a thermophilic stage, which is present during a typical composting process, the decomposition dynamics were fast especially in fact of the low level of nitrogen. In comparison with the high temperature during the first composting stage, the low temperature in the experiment was a negative factor for the growth of mesophilic microbial communities and for the speed of the chemical reactions (Franica et al. 2018). An additional anti--decomposition factor was oil layer which creates a border for extracellular lignocellulose degradation enzymes. After 5 weeks, the D samples were almost totally decomposed, other authos a fresh compost were used. In this study – mature compost was tested. (Andlar et al. 2018, Nowińska et al. 2019). The samples were very delicate and fell apart at the touch of a finger. After 6 weeks, it was complicated to extract a PP sample from the compost medium, but it was still possible to

Table 4. PB cardboard samples decomposition (mass lost as% of degradation)

	2 weeks	4 weeks	6 weeks
D samples degradation [%]	12.29	34.21	41.73
O samples degradation [%]	16.71	35.37	43.35
D samples NH4+ budget [g/kg]	-0.027	-0.053	-0.082
D samples NO3- budget [g/kg]	-0.088	-0.136	-0.149
O samples NH4+ budget [g/kg]	-0.061	-0.086	-0.127
O samples NO3- budget [g/kg]	-0.062	-0.096	-0.132
Veg. oil lost [%] (O samples only)	66.5	70.0	72.5

Fig. 3. Dry (D) and oiled (O) PB samples after 0, 2, 4, and 6 weeks in leaf mold

recognize the sample due to the black carbon-looking material. It was not possible to obtain clean parts of PP, as the rest of the samples fell apart during the removal of compost particles. The general characteristics of the decomposition process (weight loss) are shown in Figs. 5 and 6.

Composting conditions (with a high-temperature period) are suitable for paper decomposition, but also in mature "cold" material, the speed of the process is sufficient. In compost maturation processes, white-rot fungi have been isolated, and they may play an important role in the degradation of paper (Perez et al. 2002). Mature compost is rich in nitrates and non-hydrolyzable N forms. The production of non-hydrolyzable N forms ensures that the end product of composting is less susceptible to biological decomposition and N losses. Under these conditions, mature compost provides much more inorganic nitrogen for microbial communities than fresh compost, in which proteinaceous materials are some of the first materials to be used by microbes. Oiled PP samples are complicated materials for degradation, but the multiple communities of microbes that are present in compost medium caused a mass loss of over 70% after 6 weeks, thus showing highly active decomposition dynamics in comparison with the decomposition of leaves by pure fungi cultures (Osono 2016).

The main difference in degradation between both series of samples is the presence of cooking oil. This presence leads to a two-stage process in the case of the O samples. The first stage is the degradation of the oil layer, and the second stage is the decomposition of cellulose. Both substances are fully biodegradable, but the access of specific microorganisms to paper or cardboard is blocked by the vegetable oil layer, which must be removed first. The internal layers were insulated from water and inorganic nitrogen, and they were less decomposed than the external part of the sample.

The O samples were rich in organic substances, a condition that accelerates microbial activity during the composting process. Although it has a low water solubility, cooking oil is a good carbon source for compost microflora, and it can be easily decomposed in the first month of the composting process if water is available (Ozimek and Kopeć 2012). In used MSWC, the total nitrogen content was high because of the high organic matter share but especially because of the easily available inorganic nitrogen (only 16.4% of the total nitrogen content), which accelerates the conversion of lignin and cellulose. Fresh compost is much more suitable, and paper decomposition takes about 20 days or less (Nowińska et al. 2019). Many fungi species that are able to decompose leaves are mesophilic organisms and grow fast at 20–25°C (Osono 2019). The results obtained under these conditions showed a quick mass loss as a result of cellulose decomposition in the presence of a low content of easily available ammonium or nitrate nitrogen. A special place is the solid medium area that stays in direct contact with the PB or PP sample. This microenvironment is quickly depleted of inorganic nitrogen resources, and renewal is not possible except by organic matter

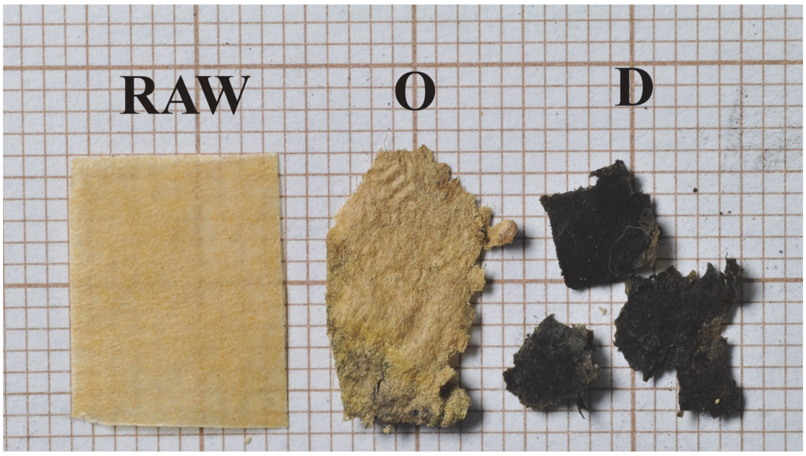


Fig. 4. Samples of PP: raw (before the experiment) and after 5 weeks of incubation, both oiled (O) and non-oiled (D)

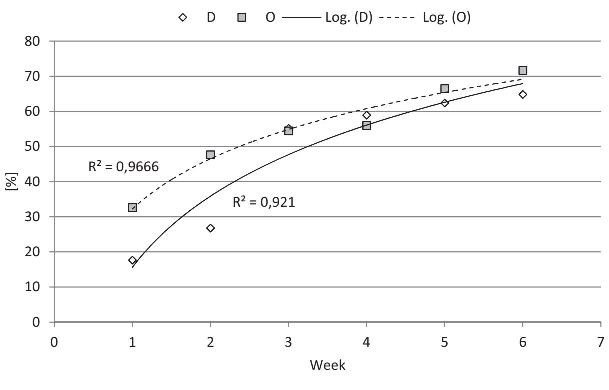


Fig. 5. Weight loss dynamics in the PP samples (dry and oiled)

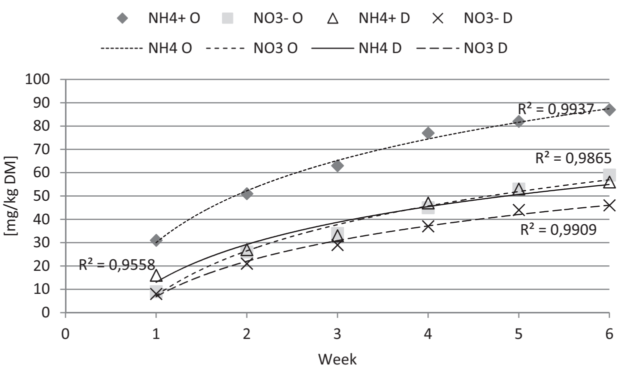


Fig. 6. Nitrogen budget of PP samples (dry and oiled)

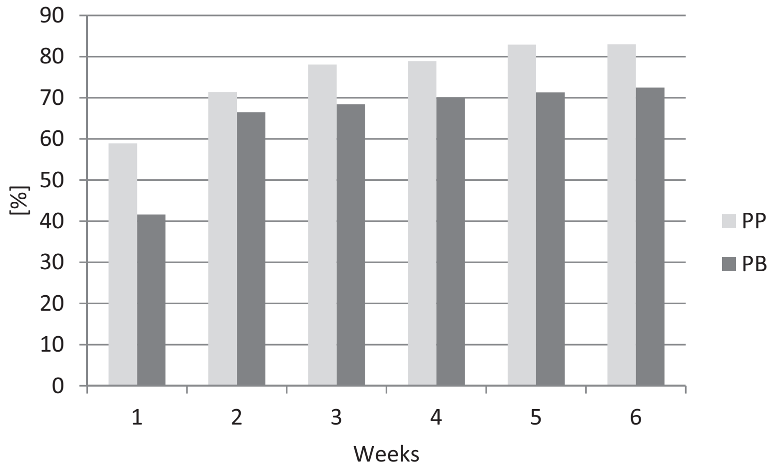


Fig. 7. Decomposition rate (weight loss) of cooking oil during the experiment with PP and PB

decomposition, which is slow because of a lack of nitrogen. The second source of nitrogen could be rainwater, but in this case, the concentrations of nitrogen ions are also low. The third source of nitrogen is the air present in the pores of a solid medium. Nitrogen is bound by facultative anaerobic nitrogen--fixing cellulose-degrading bacteria (Smirnova and Saubenova 2001). Both sources provide microbes with nitrogen because of the low amounts released during the degradation of compounds in the solid media and samples.

Usually, during waste disposal, PP is not many times folded but only slightly crushed, which ensures good access of the PP surface to oxygen and microflora. Thus, slightly crushing PP instead of folding it could be a good procedure in waste disposal. Oil-soaked papers, such as PB or PP, should be added to the biodegradable waste stream. The compost from big municipal compost plants is not of top quality, but in many cases, it may be used in agriculture for the prevention of soil erosion and desertification (Balada et al. 2016, Franica et al. 2018). On the basis of the results of this study, it is recommended to divide PB into two parts: (1) dry material for paper recycling and (2) material polluted by cooking oil for composting. Furthermore, PP (baking sheets) should be stored with biodegradable waste. The way to obtain low CO_2 emission and organic matter recycling is to dump the polluted paper in biodegradable waste or even in biomass with a low inorganic nitrogen content.

Conclusion

The results of low temperature and low nitrogen ions experiments showed that vegetable-oil-soaked waste paper can be quickly decomposed. Except pre-test with sandy soil, the low amount of easy-available nitrogen did not inhibit PB and PP decomposition. Both tested oil-soaked materials: pizza box cardboard and parchment paper, are easily biodegradable products, even with a high content of vegetable oil. The decomposition process was fast, and there were no problems with low nitrogen content. The test period (6 weeks) was sufficient for dry PP decomposition and a high degradation rate in the other types of samples. The rules for selective waste collection must be changed. Oiled waste paper, such as pizza box cardboard, should be divided into two parts: (1) dry (upper) part, which should be collected with the paper waste stream, and (2) bottom part (with oil), which should be placed in a biodegradable bin but not in a mixed waste bin. A decomposition time of 6 weeks for paper means that it does not pose a threat to the environment and that it can be a valuable source of organic matter for compost plants.

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Dynamika rozkładu papieru nasączonego olejem spożywczym w mediach o niskiej zawartości azotu nieorganicznego

Streszczenie: Papier i tekturę należy poddać recyklingowi, ale odpady papierowe zanieczyszczone np. olejem spożywczym czy plastikiem, są znacznie bardziej problematyczne. W szczególności papier zanieczyszczony olejem spożywczym lub masłem (np. pudełka po pizzy) jest trudnym odpadem. Również papier do pieczenia nie może być kierowany jako odpad celulozowy. Rozwiązaniem może być kompostowanie, ale w wielu miejskich systemach zbiórki odpadów stałych, odpady te są zbierane ze strumieniem odpadów zmieszanych, co ostatecznie prowadzi do składowania lub spalania tego materiału. Papier pergaminowy i karton do pizzy zawierają dużo celulozy, a na składowiskach są źródłem CO_2 i CH_4.

Celem pracy było badanie niskiego poziomu łatwo dostępnego azotu i temperatury niższej niż w czasie typowego procesu kompostowania na proces degradacji dwóch typów papieru silnie zanieczyszczonego olejem spożywczym. Jako materiał testowy wykorzystano tekturę zwykle używaną do celów opakowaniowych. W eksperymentach zasadniczych wykorzystywano dwa rodzaje papieru zwykle używanego w kuchni: karton (zużyte pudełko po pizzy) i papier pergaminowy silnie zabrudzony olejem spożywczym. Przetestowano dwa rodzaje mediów stałych o niskiej zawartości azotu nieorganicznego: dojrzały kompost z odpadów komunalnych (MSWC) oraz ziemię liściową. Spadek masy obu rodzajów próbek papieru był skorelowany z czasem procesu i ubytkiem azotu amonowego i azotanowego. Obie badane próbki suche oraz z dodatkiem oleju spożywczego uległy częściowemu lub całkowitemu rozkładowi po 6 tygodniach przetwarzania w warunkach tlenowych bez dodatkowej dawki azotu nieorganicznego. Możliwe jest deponowanie papieru zanieczyszczonego olejem roślinnym wraz z odpadami biodegradowalnymi, aby uniknąć zwiększenia masy strumienia odpadów zmieszanych.