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Research Article

Dynamics of Microflora in the Process of Composting Organic Waste and Bioplastics

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Abstract

The role and dynamics of microorganisms in the composting process of bioplastic and organic wastes is researched. For the purpose of the study, the influence of bioplastic and Polydegralex material is analyzed. The organic waste used in the first stage of the process was divided into two groups, depending on their characteristics - food waste and green waste. During the composting process, the change in the properties and characteristics of both organic waste as well as the added biodegradable products and Polydegralex is monitored. The experience is set as a vessel by the method of active aerobic composting by periodic aeration (mixing) and maintaining optimal humidity. For all the variants of the experiment, are analyzed (for 5 months), representative microbiological, chemical and physical parameters of the compostable materials. Representative microbiological indicators are analyzed - dynamics and change of the microbial communities during the different phases of the composting process - mesophilic, thermophilic and phase of maturation. A larger microbial number was observed in the samples with food waste as compared to the green waste samples. During the composting process, nonspore-forming bacteria dominate. The composting of biodegradable plastic products does not have a negative impact on the microbial populations typical of this process. Moreover, biodegradable plastic products are an additional food base for microorganisms. By increasing the mass of biodegradable plastic waste to the total mass of waste, the microbial number increases. The results obtained show that the microbiological activity is enhanced in the presence of biodegradable plastic products and is weakened in the presence of oxo-degradable plastics products.

Keywords:*Bioplastics; Oxo Biodegradable Plastic; Composting; Microflora*

Introduction

Composting is microbial decomposition of biodegradable materials and it is governed by physicochemical, physiological and microbiological factors. The importance of microbial communities (bacteria, actinomycetes and fungi) during composting is well established. However, the microbial diversity during composting may vary with the variety of composting materials and nutrient supplements [1].

The activity of the bacteria was observed to vary with the composting materials and degradation pattern [2].

The biodegradation of bioplastics materials strongly depends on both, the environment where they are placed and the chemical nature of the material [3]. In literature, the composting process, according to different authors, can be divided into two, three or four phases. This separation is determined by the change in the type of microorganisms and by the change in temperature regime [4]. The temperature dynamics during the composting process is a determining factor for the metabolic activity of microorganisms [5]. Composting is aerobic process. The need for oxygen is conditioned by the vital processes of aerobic composting microorganisms. It was found that these microorganisms used about 1.6 kg. O_2 to process 1 kg of organic matter [6]. The product obtained is the compost, which contributes to the improvement of physical, chemical and microbiological properties of the soil [7].

Aim of the Study

The aim of the study is to be analyzed the dynamics of microflora in the process of composting organic waste in presence of biodegradable plastic products and polydegralex material. The aim was achieved by performing the following tasks:

1. A model experiment was performed in five variants to give the most complete and accurate source data for analysis;
2. The potential impact of biodegradable plastic products and Polydegralex on microbial community during the composting process was analyzed;
3. The potential toxicity of biodegradable composite materials and the potential negative impacts they may have on microbial communities have been studied.

Methods

Sampling location

The study was conducted at The University of Forestry, Sofia, Bulgaria. The soil used for each of the mixtures is taken from the Dendraium of the University. The soil used is taken from the humusum co-immersing layer of an average depth of 20 cm. Bio-waste and vegetables are used to prepare the compostable mixtures. To simulate closest conditions to those of composite, the samples are stored in the University Greenhouse where they are periodically moistened and aerated to reach maximum conditions for microorganisms

Sampling mixture

We have five experimental samples (containers). The experiment is set as a vessel by the method of active aerobic composting by periodic aeration (mixing) and maintaining optimal humidity. For all the variants of the experiment, are analyzed (for 5 months), representative microbiological, chemical and physical parameters of the compostable materials. In containers №1, №2 and №3, are put food waste, and containers №4 and №5 are with green waste. As starting materials for composting, various organic waste was used to which specific biodegradable plastic products or Polydegralex were added. Bioplastics are products based on potato starch, corn and other substrates [8].

By chemical composition Polydegralex refers to oxo-degradable plastic products. Polydegralex contains an additional additive that is both photo- and thermally degradable. The rate of degradation depends on both the quality and the presence of antioxidants in the main component of this foil. According to the literature, Polydegralex is a specific material that undergoes physical decay under the influence of temperature and sunlight. It is mainly used in the production of disposable and reusable bags.

- Sample № 1: Food Waste + Soil + Biodegradable Plastic Products.
- Sample № 2: Food Waste + Polydegralex.
- Sample № 3: Food Waste + Soil + Biodegradable Plastic Products - half of the material is placed in a biodegradable bag, and with the other half of the material, the bag is covered.
- Sample № 4: Green Waste + Soil + Biodegradable Plastic Products - half of the material is placed in a biodegradable bag, and with the other half of the material, the bag is covered.
- Sample № 5: Green Waste + Polydegralex.

Culture media and conditions

The number of colony forming units (koe) of the systematic groups of microorganisms studied in samples was determined by the limit dilution method on agar nutrient media [9].

Microbiological analyzes were performed by the dilution method (10^{-1} to 10^{-4}) for each soil sample, by seed culture, in three replicates.

Microbiological analyzes include the determination of:

- Bacillus and non-spore-forming bacteria - they were counted at 28°C after 2 days' incubation on nutrient agar. The following bacillus species are identified: *Bacillus mycoides, Bacillus megaterium, Bacillus cereus, Bacillus subtilis, Bacillus idosus*;
- Fungi - grown at 25°C for 7 days on Czapek Dox agar medium.

Results and Discussions

The results of the study show a different quantitative and qualitative composition of the microflora in the individual variants.

Tracking of temperature variations during the experiment

The temperature of the compostable material is a parameter that best illustrates the progress of the process. When the main temperature is below 25°C, organic matter accumulates even in fully aerated piles [10].

The temperature curve gives information about the appropriate transformation of organic matter by the microorganisms and the proper course of the composting process. The temperature rises very quickly during the thermophilic phase. For all samples, the phase starts between the 9th and 10th weeks, but temperature of sample № 3 rises faster. This is due to the greenhouse effect caused by the placement of part of the waste in a biodegradable bag and the bag was covered with the other half of the waste. This method of composting achieves a faster temperature suitable for the development of thermophilic microorganisms. Thermophilic microorganisms start to multiply exponentially using as nutrient base the organic waste, and biodegradable bag, which leading to breakdown of the biodegradable bag and preventing anaerobic processes. It should be noted that if there is no mechanical disintegration of the biodegradable bag, at the beginning of the thermophilic phase, there is a danger that the process will pass to anaerobic. This risk is associated with the increased viability of aerobic microorganisms that begin to exponentially multiply, deplete nutrients, increase temperature, and use large amounts of available oxygen. With a drastic drop in oxygen, the development of anaerobic organisms will begin and the composting process will be displaced by anaerobic methanogenesis.

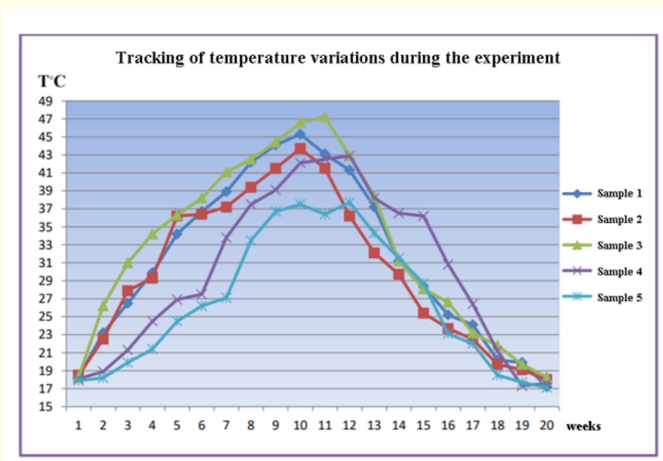

Figure 1

Comparison of temperature and humidity in the samples during the composting process

Temperature and humidity are interrelated factors that influence the composting process and the viability of microorganisms. Liang C finds that moisture content is a dominant factor impacting aerobic microbial activity of the composting blend and also that the Fifty percent moisture content appeared to be the minimal requirement for obtaining activities greater than 1.0 mg g^{-1} h^{-1} [11].

During the experiment, the dynamics of these two parameters is characteristic of the composting process. As shown in the graphs, although we have an increase in temperature in the thermal phase of the process, the humidity remains within the optimal range for microorganisms- 60 - 70%.

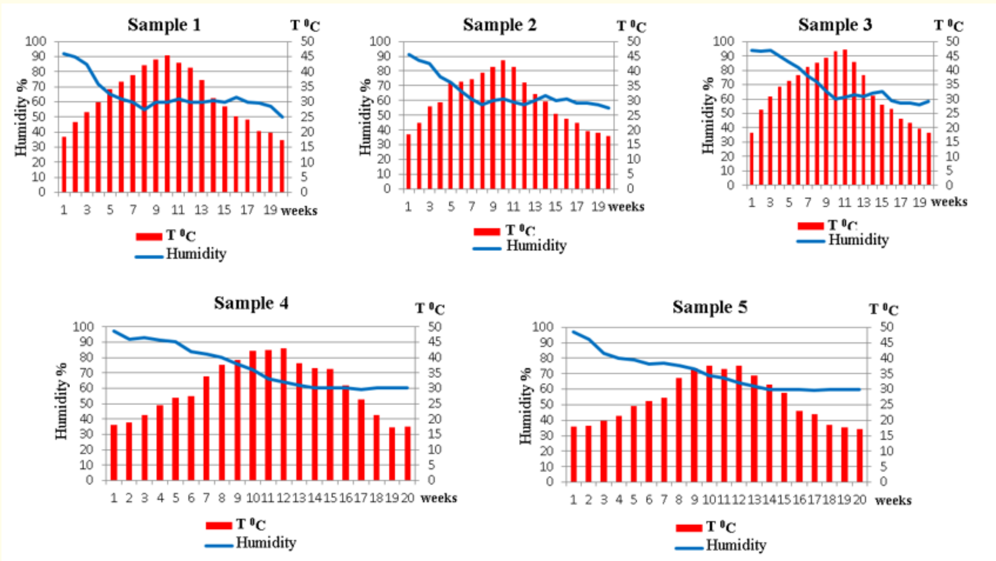

Figure 2

Tracking of pH variations during the experiment

Another important factor is the acidic reaction of compost. Too low, like the too high pH, have a negative impact on the aerobic process of composting because it starts to develop non-typical microorganisms. The low pH (below 6) inhibits microbial activity in a compost pile. The respiration rate is depend from the pH variation during the composting process. The respiration rate can be strongly reduced at 46°C and pH below 6, compared to composts with a higher pH or lower temperature. The combination of high temperature and low pH is a possible adverse factor in large-scale composting of food waste [12].

The consequences are slow organic degradation, phase stagnation and bad smell (anaerobic degradation). The measurements made during the experiment show optimal values for the development of the microorganisms during the composting phases. Biodegradable plastic and Polydegralex do not affect acidity during the composting process.

Microbiological changes in biodegradable waste

Mesophilic phase

The graph shows the amount of different groups of microorganisms during the mesophilic phase. The dominance of non-spore-forming bacteria, compared to bacillus and micromycetes, is much more pronounced in samples of food waste (№1, №2 and №3). The Bacillus are within 14 - 21%, micromycetes are below 1%, and non-spore-forming bacteria dominate by over 65% in all samples. For green waste samples, while maintaining the prevalence of non-spore microorganisms, bacillus participate by over 30%. The small amount of micromycetes is related to the fact that in the preparation of the samples, only in one component of the mixture is possible their presence - the soil. In the initial phase of experiment, the presence of non-spore-forming bacteria and bacilli is normally in the starting components of the test mixture.

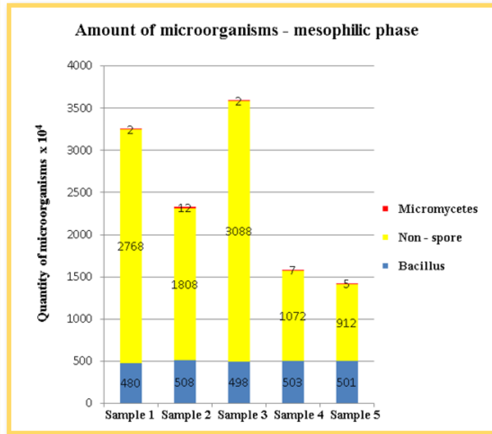

Figure 3

Thermophilic phase (75 days after sample preparation)

During the thermophilic phase, non-spore-forming bacteria still dominate. During this phase, however, there was a sharp rise in micromycetes. This increase in their quantity is the result of catalyzed microbiological processes and the enhanced process of degradation and metabolism. Low pH values activate the growth of micromycetes that participate in the decomposition of lignin and cellulose. Temperature is another fact that leads to an increase in the number of fungi - their optimal environment is about 30 - 37°C. The total amount of microorganisms increased, most notably in sample № 3 and sample № 4. These are the samples where a part of the waste was put in a biodegradable bag that was covered with the remaining half of the same waste. When examining samples № 2 and 5, it was found that for these samples, the amount of microorganisms was the smallest. These are the Polydegralex samples.

The present results from the microbiological studies provide the necessary information to conclude that the Polydegralex in these two samples is not an appropriate nutritional basis for micro-organisms and does not stimulate their development. We also have to suppose that the above-described material (Polydegralex) can lead to inhibition of microbiological activity as it is not a suitable development medium and is a barrier to the microorganisms in their spreading and coverage of the entire compostable mass. The microbiological activity is enhanced in the presence of biodegradable plastic products and is weakened in the presence of oxo-degradable plastics products.

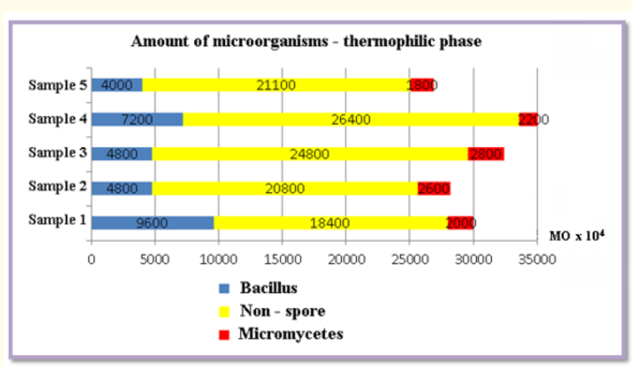

Figure 4

Cooling phase/143 days after sample preparation

The total number of micro-organisms in the third phase compared to the first one has increased 100 times, which allows us to confirm that the composting process continues and the microbiological activity is enhanced. The organic mass has been completely transformed, with the exception of part of the pine needles due to the nature.

Again, the total microbial number is bigger in the samples with added plastic biodegradable waste. In polydegrelex samples, the microbial number also increased but remained less than the microbial number of the samples with biodegradable plastic waste.

This allows us to confirm the thesis that biodegradable plastic waste stimulates the growth of microorganisms, while polydegralex has a negative impact on microbial communities.

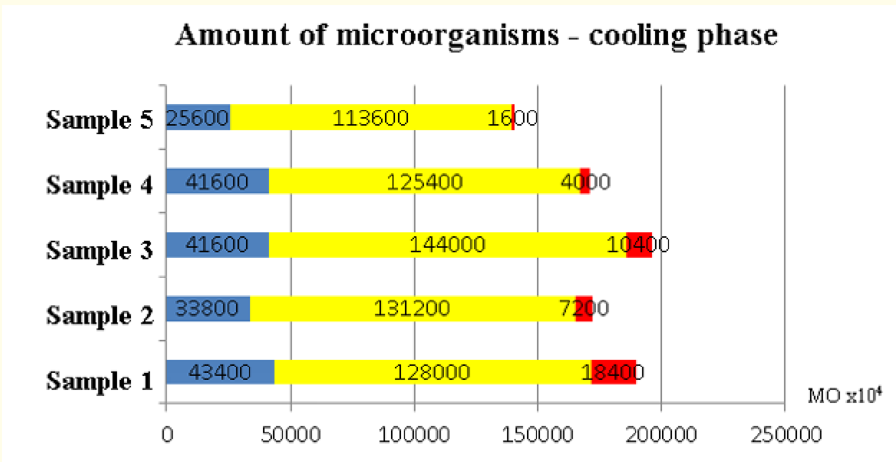

Figure 5

Total microbial number

During the three readings of the results, the ratio of the microbial groups in the samples tested is comparable with compostable materials in which there are no biodegradable plastic products and Polydegralex products. During the three phases of the compostable process (mesophilic, thermophilic and cooling), predominant non-spore-forming bacteria followed by bacilli and micromycetes.

We assume that the composition of microbiocenosis is not affected by biodegradable plastic products. During all phases, non-spore microorganisms dominate, followed by bacilli and micromycetes, which is a normal quantitative ratio, in the course of a standard composting process.

The results of the experiments prove that the composition of the starting materials influences the dynamics of the development of the microbial community. Biodegradable plastics waste has an impact on the amount of microorganisms, as biodegradable plastic products stimulate the growth of microorganisms, while the oxodegradable waste inhibit it.

The total microbial number of the samples tested clearly showed an increase in the amount of microorganisms in the samples with biodegradable plastic products compared to the polydegralex samples (№2 and №5).

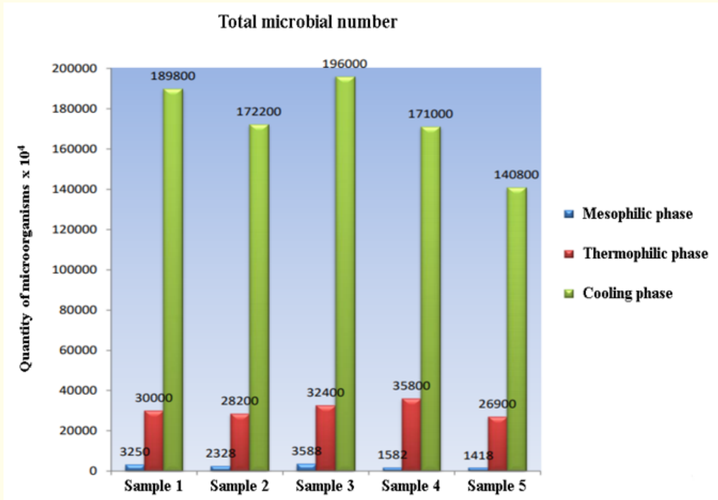

Figure 6

Conclusion

As a result of the research, the following conclusions can be drawn: The treatment of biodegradable plastics by composting in combination with food or green waste is completely environmentally friendly. The composting of biodegradable plastic products has no negative impact on the microbial populations typical of this process. Moreover, biodegradable plastic products are an additional food base for microorganisms. The total microbial number is less in the Polydegralex samples. Biodegradable plastics and Polydegralex do not have a toxic effect on the final product. The results obtained show that the microbiological activity is enhanced in the presence of biodegradable plastic products and is weakened in the presence of oxo-degradable plastics products.

Acknowledgements

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