PREDNOSTI KORIŠTENJA BIOREAKTORA U POSTUPKU KONTROLISANOG KOMPOSTIRANJA BIOOTPADA

ADVANTAGES OF BIOREACTOR IN THE PROCESS OF CONTROLLED COMPOSTING BIOWASTE

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REZIME

Proces kompostiranja biootpada uz obezbjeđenje potrebnih uvjeta i u zavisnosti od sastava kompostiranog materijala, može da se odvija u prirodnim uvjetima. Ukoliko želimo da utičemo na brzinu i stabilnost procesa razgradnje organske materije iz biootpada, potrebno je da jedan ili više uticajnih faktora procesa kontrolišemo na način da obezbjedimo optimalne uvjete koje održavamo čitavo vrijeme trajanja procesa. U svrhu istraživanja korišten je bioreaktor koji obezbjeđuje konstantnu vanjsku temperaturu, mogućnost mješanja i vlaženja kompostne smjese bez vanjskog uticaja. Kontrolisanje pojedinih parametara, odnosno, uticaj na način da se ti parametri održavaju optimalnim dovodi do značajnog ubrzanja procesa a takođe i do poboljšanja kvaliteta gotovog komposta s obzirom da je kontrolisani postupak stabilniji u odnosu na prirodni postupak.

Original scientific papar

SUMMARY

The process of composting of biowaste, while ensuring the necessary conditions and depending on the composition of composted material can be carried out in natural conditions. If we want to influence the speed and stability of the process of degradation of organic matter from biowaste, it is necessary that one or more influencing factors control the process so as to provide optimal conditions to maintain the duration of the process. The purpose of the research was used bioreactor which provides a constant temperature outside, the possibility of mixing and wetting the compost mixture without external influence. Controlling certain parameters, ie, the influence on the way to maintain these parameters the optimum leads to a significant acceleration of the process and also to improve the quality of the finished compost with respect to the controlled process more robust to the natural process

1. UVOD

Jednu od najsveobuhvatnijih definicija procesa kompostiranja dao je Haug (1993): „Kompostiranje je biorazgradnja i stabilizacija organskih tvari, pod uslovima koji osiguravaju razvoj termofilnih temperatura kao rezultat proizvedene biotopline, pri čemu se dobija konačan proizvod koji je stabilan, bez patogena, sjemena korova i koji može biti koristan za odlaganje na tlo“.

Pri procesima aerobnog kompostiranja, proces teče u prisustvu kisika odnosno zraka, a kao glavni proizvodi se javljaju: ugljčni dioksid, voda, toplina i kompost.

1. INTRODUCTION

One of the most comprehensive definition is given of the process of composting, Haug (1993): "The composting biodegradation and stabilization of organic substances, under conditions which ensure the development of thermophilic temperatures produced as a result bio topline, to give the final product that is stable, with no pathogens, weed seeds and which can be useful dumping ground ".

In the process of aerobic composting process flows in the presence of oxygen or air, and the main products appear: charcoal dioxide, water, heat and compost.

Stabilnost procesa kompostiranja u cjelini zavisi od mnogih faktora kao što su temperatura, vlažnost mješavina mulja i dodatne komponente, pH vrijednosti, veličina čestica svake komponente, kisik, C / N odnos i drugih faktora. Uz obezbjeđenje optimalne smjese materijala, granulacije i početne vlažnosti (Gray i sar., 1971a, 1971b), na stabilnost i brzinu procesa kompostiranja možemo uticati održavanjem optimalne temperature okoline i prozračivanja, odnosno dodavanja kisika. Opisani kontrolisani proces moguće je postići u zatvorenom izoliranom bioreaktoru koji ima mogućnost miješanja smjese i ubrizgavanja zraka bez vanjskih uticaja. Kompostiranje je veoma kompleksan proces, posebno ako se ima u vidu da otpad predstavlja trofazni sistem i da se organski dio otpada razgrađuje putem biohemijskih reakcija. Dakle, radi se o velikom broju menusobno povezanih fizičko-hemijskih, mikrobioloških i termodinamskih fenomena koji predstavljaju pravi izazov za empirijsku i teorijsku analizu.

2. MATERIJALI I METODE

U analiziranom postupku kompostiranja tretirana je smjesa biootpada od pokošene parkovske trave, lišća i ostataka potkresivanja žive ograde i sitne piljevine sa pojedinačnim udjelima prema tabeli 1. Smjesa je formirana na način da grančice od potkresivanja obezbjeđuju dovoljnu poroznost za nesmetano prozračivanje i spriječe lijepljenje slojeva trave i lišća koje bi dovelo do anaerobnih procesa. Smjesi je dodat i sirovi kompost koji sa sobom nosi mikroorganizme, tj. kao starter procesa kompostiranja.

Tabela 1. *Udio pojedinih komponenti u ukupnoj količini biootpada*

Vrsta biootpada	Maseni udio (%)
parkovska trava	40
lišće	15
ostatak od potkresivanja	23
sitna piljevina	12
sirovi kompost	10

Početne vrijednosti parametara kompostne smjese date su u tabeli 2.

The stability of the composting process as a whole depends on many factors such as temperature, humidity mix of sludge and additional components, pH value, the particle size of each component, oxygen, C / N ratio and other factors. In addition to providing an optimal mixture of materials, granulation and initial water content (and Gray et al., 1971a, 1971b;), the stability and speed of the composting process can affect the maintenance of optimum temperature and ventilation, and adding oxygen. Described controlled process can be achieved in a closed insulated bioreactor capable of stirring the mixture and air injection without external influences. Composting is a very complex process, especially if one takes into account that waste represents three-phase system and that the organic part of the waste decomposes through biochemical reactions. So, It is a large number of interrelated physical, chemical, microbiological and thermodynamic phenomena that represent a real challenge for empirical and theoretically analysis.

2. MATERIALS AND METHODS

The control procedure composting treated bio-waste mixture of the park mowed grass, leaves and debris pruning hedge individual shares according to Table 1. The mixture is formed in a way that branches from pruning provide sufficient porosity for the smooth ventilation and prevent bonding layers of grass and leaves that may lead to anaerobic processes. To the mixture is added and the raw compost which carries microorganisms, ie. as a starter composting process.

Table 1. *The share of each component in the total amount of biowaste*

Type biowaste	Mass fraction (%)
park grass	40
leaves	15
the rest of pruning	23
small chips	12
raw compost	10

The initial parameter values compost mixtures are given in Table 2.

Tabela 2. *Početne vrijednosti parametara kompostne smjese*

Parametar	Vrijednost
masa (kg)	8
vlažnost (%)	63
temperatura (^oC)	13
Ph vrijednost	5,6
granulacija (mm)	8-10

Table 2. *The initial parameter values compost mixtures*

Parameter	Value
weight (kg)	8
moisture (%)	63
temperature (^oC)	13
Ph value	5,6
granulation (mm)	8-10

Jednake količine smjese su postavljene u prirodnim uslovima (Slika 1) i u laboratorijskom bioreaktoru (slika 2). Prirodni uslovi podrazumijevaju postavljanje smjese vani na zemljanoj podlozi u natkrivenom prostoru koji sprječava eventualno prekomjerno vlaženje usljed kiše i sl. Bioreaktor ima mogućnost uduvavanja zraka korištenjem kompresora preko cijevi koje su ujedno i mehanizam za ručno miješanje smjese. Istim putem se smjesi po potrebi može dodati voda i ostvariti prolaz nastalog CO_2. Po dnu su izbušene rupe za odvodnju viška tečnosti. Bioreaktor je obložen izolacionim materijalom čime je spriječen uticaj vanjske temperature i postavljen u zatvorenoj prostoriji.

Equal amounts of the mixture are placed in natural conditions (Figure 1.) And in the laboratory bioreactor (Figure 2.). Natural conditions include setting the mixture out on clay in the covered area to prevent possible over-wetting due to rain and the like. The bioreactor has the ability to use blowing air compressor through pipes which are also the manual mixing the mixture. The same route to the mixture, if necessary, can add water and make the passage generated CO2. After the bottom of the drilled holes for drainage of excess fluid. The bioreactor is coated with insulating material, which prevents the influence of the outside temperature and placed in a closed room.

Slika 1. *Kompostna smjesa u prirodnim uslovima*
Figure 1. *Compost mixture in natural conditions*

Slika 2. *Laboratorijski bioreaktor*
Figure 2. *The laboratory bioreactor*

Obje smjese su praćene tokom 15 dana i mjerene su vrijednosti temperature i pH vrijednosti kao pokazatelji stabilnosti procesa. Takođe je kontinuirano mjerena vlažnost kao indikator potrebe dodavanja tečnosti za optimalan režim procesa.

Za mjerenje temperature i pH vrijednosti korišten je uređaj Multi 350i/SET koji je prikazan na Slici 3. Vrijednost pH, je mjerena svaki treći dan a temperatura kontinuirano svaki dan u 8 sati prije podne. Temperaturni senzori, termoparovi kod mjerenja temperature postavljani su u sredini mase supstrata.

Kalibracija uređaja je izvršena sa tri pufer otopine i to sa pH-vrijednostima 4 i 7. Mjerena je pH-vrijednost svježeg uzorka ekstrahiranog sa destiliranom vodom. Vodeni ekstrakti su pripremljeni mehaničkim miješanjem uzoraka (u trajanju od 30 minuta) sa destiliranom vodom u omjeru 1:10. Suspenzija je zatim filtrirana kroz filter papir Whatman 42 Ashless Circles 125 mm Dia (Whatman, Velika Britanija). U dobijenom filtratu je izmjerena pH-vrijednost, uz konstantno miješanje magnetnom mješalicom. Postupak je ponovljen tri puta.

Both mixtures were monitored for 15 days and measured the temperature and pH value as indicators of the stability of the process. It is also continuously measured humidity as an indicator of the need to add liquid to the optimal setting process.

For measuring the temperature and pH value the machine is used Multi 350i / SET shown in Figure 3. The pH value is measured every day and the temperature is continuously every day at 8 o'clock a.m. Temperature sensors, thermocouples with temperature measurements were placed in the center of mass substrate.

Calibration is performed with three buffer solutions with pH values of 4 and 7. The measured pH-value of the extracted pattern with fresh distilled water. The aqueous extracts were prepared by mechanical mixing of samples (for 30 minutes) with distilled water at a ratio of 1:10. The suspension was then filtered through Whatman 42 Ashless Circles 125 mm Dia (Whatman, UK). In the resulting filtrate was measured pH-value, with constant stirring using a magnetic stirrer. The procedure was repeated three times.

Slika 3. *Uređaj "multi 350i/SET"*
Figure 3. *Device "multi 350i/SET"*

Za mjerenje vlažnosti korišten je uređaj GMH 3830, koji je prikazan na slici 4. Vlažnost smjesa je mjerena kontinuirano svaki dan u 8 sati prije podne.

Humidity measuring device used was GMH 3830 shown in Figure 4. Humidity mixture is measured continuously every day at 8 o'clock a.m.

Slika 4. *Uređaj GMH 3830*
Figure 4. *Device GMH 383*

3. ANALIZA REZULTATA ISTRAŽIVANJA

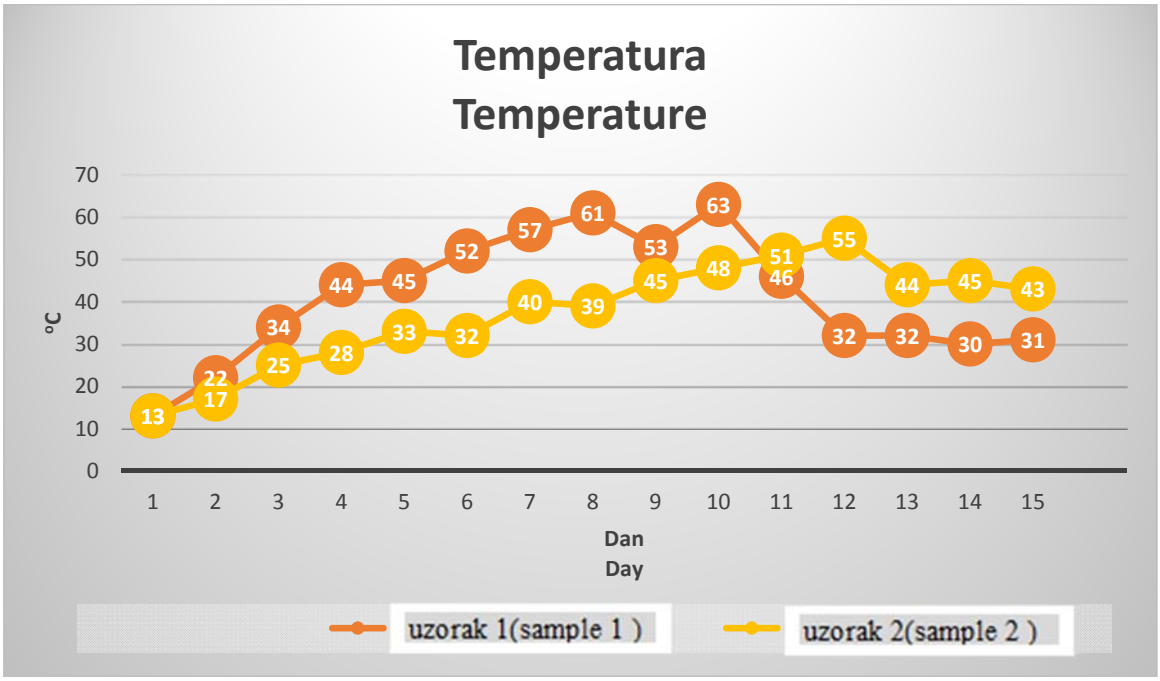
U zasebnim procesima, u bioeraktoru i kompostnoj hrpi u prirodnim uslovima, praćena je temperatura kao osnovni pokazatelj aktivnosti mikroorganizama, odnosno, razvoja procesa razgradnje organske materije. Promjena temperature u toku kompostiranja prikazana je na Slici 5. Kod procesa u bioreaktoru već nakon drugog dana se razvila temperatura iznad 30 ^{o}C što je znak ispravnog startanja procesa. Petog dana je temperatura prešla 50 ^{o}C uz zadržavanje na toj i većoj razini tokom narednih pet dana što obezbjeđuje potpunu higijenizaciju mase, odnosno, uništenje svih štetnih pa i patogenih mikroorganizama. Maksimalno postignuta temperatura je 62 ^{o}C.

S druge strane na kompostnoj gomili u prirodnim uslovima tek deseti dan je temperatura prešla u termofilni dijapazon temperatura i to bez dužeg zadržavanja, što može biti uzrokovano padom vanjske temperature u periodu od petog do devetog dana.

3. ANALYSIS OF RESEARCH RESULTS

On a separate process, in bioreactor and compost heaps in natural conditions, followed by the temperature as the main indicator of microbial activity, ie, the development process of decomposition of organic matter. Changing temperatures during composting is shown in Figure 5. In the process, the bioreactor after the second day of the developed temperatures above 30 ° C which is a sign of correct starting process. On the fifth day the temperature exceeded 50 ° C while maintaining at this and higher levels in the next five days, which provides a complete hygienic disposal of the masses, that is, the destruction of all harmful and even pathogens. The maximum temperature reached was 62 ° C.

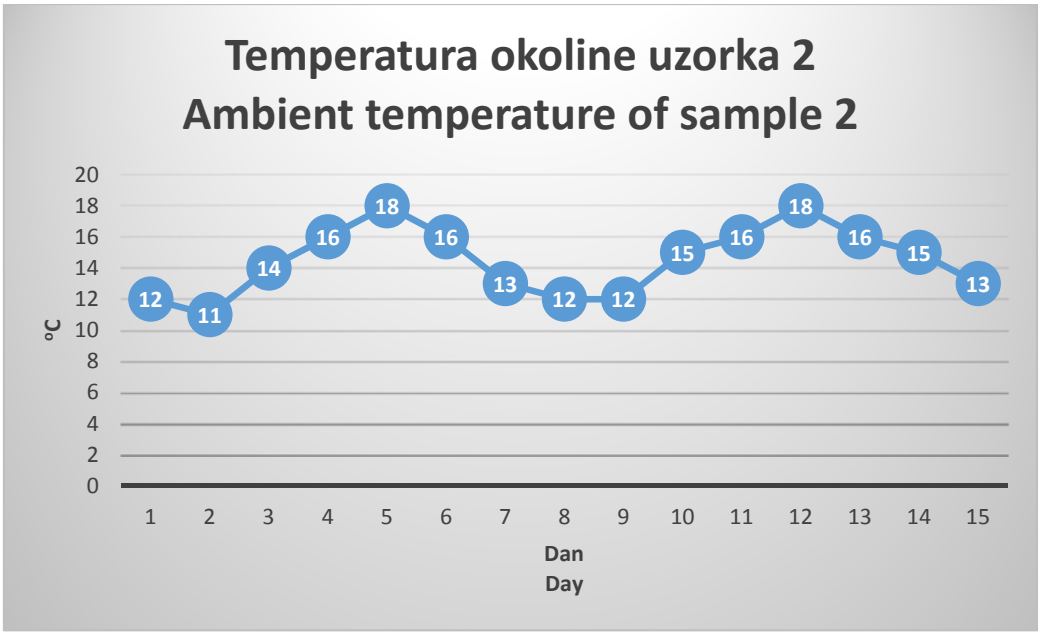
On the other hand the compost pile in natural conditions, only the tenth day the temperature exceeded the thermophilic temperature range and without long retention, which can be caused by a drop in the outdoor temperature over a period of five to nine days.



Slika 5. *Promjena temperature u uzorcima u toku kompostiranja*
Figure 5. *Temperature changes in the samples during the composting*

Na zasebnom dijagramu (Slika 6.) prikazana je promjena temperature okoline uzorka u prirodnim uslovima.

On a separate diagram (Figure 6.) Shows the change in the ambient temperature of the sample in natural conditions.



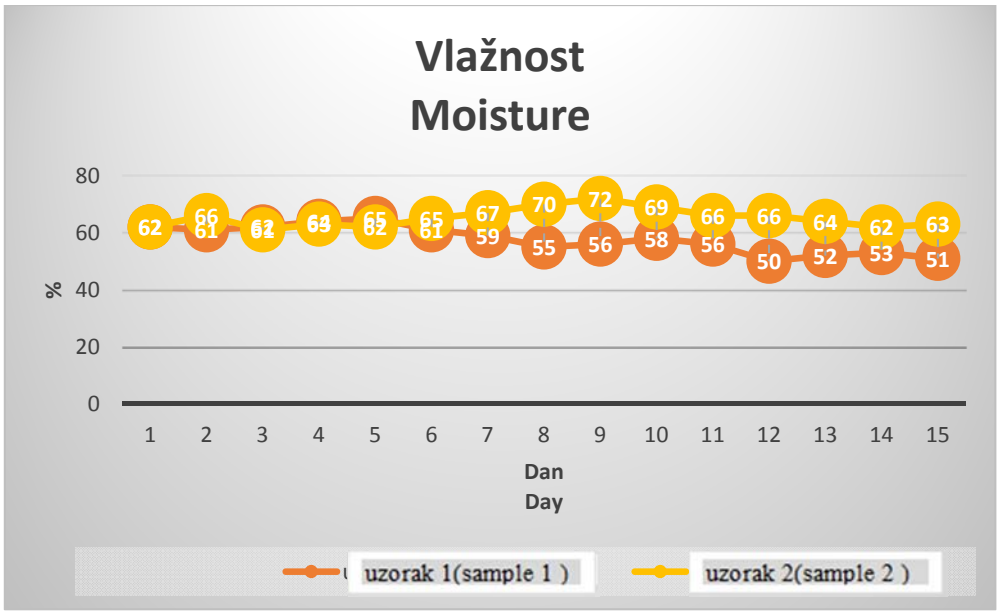
Slika 6. *Promjene temperature okoline uzorka 2 u toku kompostiranja*
Figure 6. *Changes in the ambient temperature of the sample 2 during composting*

U procesu kompostiranja kao prateći produkt pored CO_2 nastaje voda koju je potrebno izdvojiti kako ne bi došlo do lijepljenja u slojevima kompostne smjese i anaerobnih procesa. Bioreaktor po dnu ima rupe kroz koje može da ističe nastala voda. Povremenim mješanjem se održava homogenost smjese i u pogledu vlažnosti. Kod smjese u prirodnim uslovima zbog dovoljne poroznosti nastala voda otiče kroz slojeve i napušta smjesu u zemljanoj podlozi. Značajne razlike u vlažnosti pojedinih uzoraka uočene su nakon šestog dana procesa. Promjena vlažnosti kompostne smjese oba uzorka prikazana je na Slici 7.

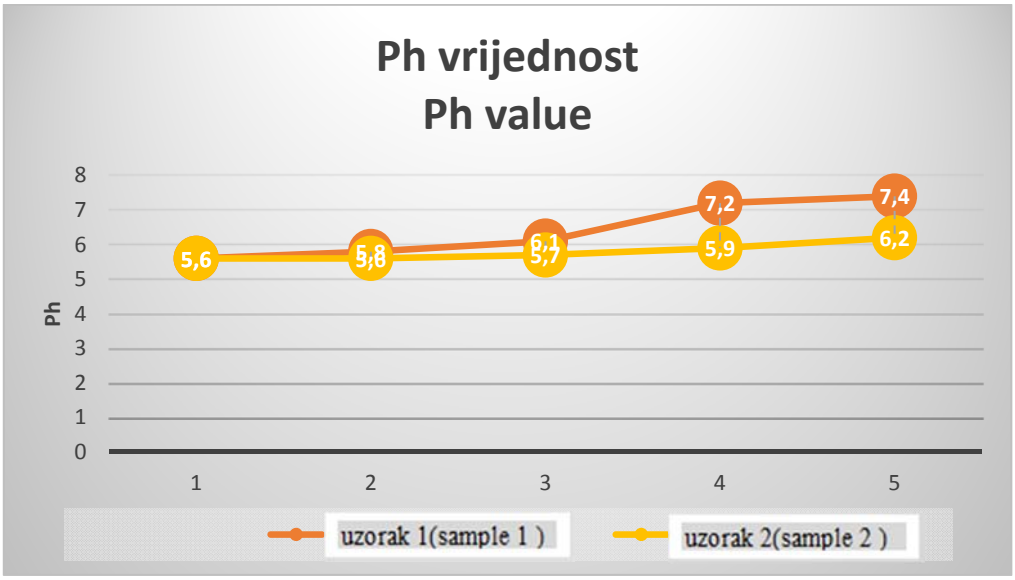
Promjena pH vrijednosti u toku proces kompostiranja je pokazatelj reakcija hemijskog karaktera u postupku razgradnje organske materije. Na oba uzorka je uočen blagi porast pH vrijednosti što ukazuje na prelazak u blago bazično stanje. Promjena pH vrijednosti u posmatranom periodu prikazana je na Slici 8.

In the process of composting, as accompanying the product CO2 is generated near the water that is necessary to separate in order to prevent sticking to the compost layer and anaerobic processes. The bioreactor at the bottom has a hole through which you can escape water formed. Occasional mixing to maintain homogeneity of the mixture and in terms of humidity. The mixture in natural conditions due to sufficient porosity caused water flows through layers and leave the mixture in a clay court. Significant differences in moisture content of individual samples were observed after the sixth day of the process. Changing humidity compost both samples is shown in Figure 7.

Changing the pH value during the composting process is an indication of chemical reaction in the process of guidance of organic materials. In both samples has increased slightly pH value indicating a shift in mildly basic condition. Changing the pH value in the reporting period is shown in Figure 8.



Slika 7. *Promjena vlažnosti uzoraka u toku kompostiranja*
Figure 7. *Change of soil moisture content during composting*



Slika 8. *Promjena Ph vrijednosti u uzorcima u toku kompostiranja*
Figure 8. *Ph value changes in the samples during the composting*

4. ZAKLJUČAK

Prema rezultatima istraživanja neupitne su prednosti korištenja bioreaktora za kontrolisani postupak kompostiranja. Temperatura kao pokazatelj aktivnosti mikroorganizama i postupka razgradnje organske materije u slučaju korištenja biorektora je povećana do razine iznad 50 °C i na toj temperaturi održavana tokom 5 dana. Na taj način dolazi do ubrzanog postupka razgradnje i uništenja štetnih i eventualno patogenih mikroorganizama.

4. CONCLUSION

According to research results are unquestionable advantages of using a bioreactor for controlled composting process. Temperature as show activities of microorganisms and organic matter degradation process in the case of use bioreactor is increased to a level above 50 ° C and maintained at that temperature for 5 days. This leads to an accelerated process of degradation and destruction of harmful and potentially pathogenic microorganisms.

Vlažnost smjese je održavna na nivou koji je optimalan za razvoj termofilnih mikroorganizama a Ph vrijednost je rasla do vrijednosti iznad 7 što govori o stabilnosti postupka kompostiranja i razvijanja procesa u pravcu formiranja sirovog komposta.
S druge strane praćeni parametri postupka u prirodnim uslovima pokazuju usporeniji razvoj procesa i uticaj vanjskih uslova u smislu pothlađivanja kompostne smjese. Niže temperature razvijene u procesu u odnosu na proces u biorektaru, ukazuju na usporeniji proces razgradnje. Kraće zadržavanje temperature na nivou iznad 50 ^{o}C nije dovoljno za potpunu higijenizaciju smjese.
To takođe ukazuje i na nedovoljnu aktivnost mikroorganizama za potpunu razgradnju organske materije što svakako utiče na kvalitet gotovog komposta.
Ekonomski pokazatelji procesa u kontrolisanim i prirodnim uslovima mogu biti predmet sljedećeg istraživanja u ovoj oblasti.

Humidity is on State mixture at a level that is optimal for the development of thermophilic microorganisms and the pH value is increased to a value above 7 which shows the stability of the process of composting and the development process towards the formation of raw compost.
On the other hand monitored parameters of the natural conditions showed slower development process and the impact of external conditions in terms of hypothermia compost. Lower temperatures developed in the process compared to the process in bioreactor, indicating slower degradation process. Short stop temperature at a level above 50 ° C is not enough to complete the hygienic mixture.
It also points to the lack of activity of microorganisms for complete decomposition of organic matter, which certainly affects the quality of the finished compost.
Economic indicators process in controlled and natural conditions may be subject to the following research in this area.

5. LITERATURA - REFERENCES

[1] Haug, R.T. (1993): *The practical handbook of compost engineering*. Lewis . Boca Raton, 385-436.
[2] Gray, K.R., Sherman, K., Biddlestone, A.J. (1971): Review of Composting - Part 2: The Practical Process. *Process Biochemistry* 6(10), 22-28.
[3] Gray, K.R., Sherman, K., Biddlestone, A.J. (1971a): Review of Composting - Part 1. *Process Biochemistry* 6(6), 32-36.
[4] Sanchez-Monedero, M.A., Roig, A., Paredes, C., Bernal, M.P. (2001): Nitrogen transformation during organic waste composting by the Rudgers system and its effects on pH, EC and maturity of the composting mixtures. Bioresource Technology 78: 301-308.
[5] Tiquia, S.M. (2003): Evaluation of organic matter and nutrient composition of partially decomposted and composted spent pig litter. Environmental Technology, 24: 97-107.
[6] Morisaki, N., Phae, C.G., Nakasaki, K., Shoda, M., Kubota, H. (1989): Nitrogen Transformation during Thermophilic Composting. *Journal of Fermentation and Bioengineering*, Vol. 67, No. 1, 57-61. Nakasaki, K., Shoda, M., Kubota, H. (1985d): Effect of temperature on composting of sewage sludge. *Applied and Environmental Microbiology*, Vol. 50, No. 6, 1526-1530.

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