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Biodegradation of composites based on maltodextrin and wheat B-starch in compost

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Abstract

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The study is focused on the microbial and chemical parameters of green compost in which composites based on acetylated wheat B-starch and maltodextrin (patented procedure) were biodegraded and also on the parameters of lettuce grown on this compost before and after the biodegradation. With a load of up to 1 g of composites per 1 l of compost, and with a storage period of 0, 7–14, 15–20 and 21–147 days, mixture of compost wiped off the surface both of well-preserved composites and of the immediate surroundings of their residues was evaluated. Microbial biomass, basal respiration (BR), metabolic quotient, dehydrogenase and arylsulfatase activity (ARS) and the parameters of the lettuce growth on this compost did not show any negative changes. On the contrary acetylated wheat B-starch and maltodextrin stimulated both ARS and BR. ARS showed the most rapid onset among all tests. The height of the aboveground parts of the lettuce (*Lactuca sativa* L. var. *capitata*) grown on green compost was significantly better, compared to commercial peat-based substrates.

Keywords: biodegradable plastics; acetylated maltodextrin; lettuce; arylsulfatase

The compost made from the crushed green municipal waste (green compost) has a positive effect on the biological activity of the soil, such as basal respiration and dehydrogenase activity (Saviozzi et al. 2006). It improves stability of soil aggregates (Annabi et al. 2007) and therefore it is often used for the areas threatened by erosion (Paluszek 2010). Compost can be used not only for planting and growing of plants, but also for the biodegradation of wastes coming from biodegradable composite materials that do not exert any negative impact on its quality. Good-quality composts are

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suitable for the biodegradation of biopolymers, and later they are fully usable for plant growth and development even after repeated biodegradations (Šárka et al. 2011, 2012). In these studies biopolymers based on a homogeneous thermoplastic mixture of acetylated wheat B-starch and maltodextrin resistant to water, weak acidic and alkaline solutions, mineral and plant oils, and aliphatic solvents were used (Patent CZ 303840 B6 (Kotek et al. 2013); Utility model CZ 24012 U1; Utility model CZ 24013 U1 (Kotek et al. 2012a,b)). It was determined that this thermoplastic mixture is rapidly and completely degraded in green compost (GC) located in the open air, during the storage periods in the range from 1 to 21 weeks (with an average daily temperature at 2 m higher than +6°C). This model experiment studied if the composite degradation has a negative influence on the compost used for biodegradation, by using biological and chemical characteristics of GC in which the above mentioned composites were biodegraded and using also the parameters of lettuce (*Lactuca sativa* L. var. *capitata*) grown on this compost in 2009–2011 always before and after the storage periods.

MATERIAL AND METHODS

GC was prepared from finely crushed green municipal waste (30%), white high-moor peat (50%), clayey soil from excavation (10%), and pearlite (10%) in 2007 and was loosely deposited inside the composters AL-KO K390 (Kober Ltd., Vrbno pod Pradědem, Czech Republic) located outside. The mixture of coarsely ground dolomitic limestone (1 g/l GC) with fully water-soluble fertiliser Kristalon Start (Agro CS, a.s., Česká Skalice, Czech Republic), in crystalline form, was added annually into GC in 2009–2011. GC evaluation was performed before and after storage periods of composite materials developed for use in agriculture and horticulture. The sheets of composites 165 × 245 × 0.5 mm were inserted into the composters in 1 to 5 layers separated by 100 mm of GC. Storage periods were gradually reduced from the original 21–147 days to 15–20 days (Šárka et al. 2011, 2012) and even to 7–14 days because the degradation rate in some cases was very fast. The maximal load was up to 1 g of composites/l of GC. Before filling, the compost under the composites as well as the surface of the composites were sprayed using an emulsion of 4 ingredients: Supresivit 0.1 g/l (Vochs Bohemia Ltd., Opava, Czech Republic); Lignohumate AM 0.1 g/l (SPA «RET», Saint-Petersburg, Russia); Agrisorb 0.1 g/l (Stockhausen GmbH & Co. KG, Krefeld, Germany), Agro Kristalon Start 1 g/l (Agro CS, Inc., Česká Skalice, Czech Republic). An average sample of GC (14 l) was always sampled from the composters before and after the biodegradation treatment periods. GC mixture wiped off the surface both of well-preserved composites and of the immediate surroundings of their residues was evaluated by biological (microbial biomass, basal and potential respiration, dehydrogenase and arylsulfatase activity) and other tests (4 l) and lettuce (*Lactuca sativa* L. var. *capitata*) was sown on remaining 10 litres. GC for biological analyses were transported in a cooling box (temperature 6–12°C), and stored in a refrigerator (4–6°C) for two weeks. The GC horticultural quality was tested by lettuce growing. Sowing in 160-cell growing trays located in a greenhouse was carried out in 2009–2011, always before (May) and after (August) the biodegradation periods. Lettuce growth was evaluated after 40 days. 80 plants were randomly sampled from the central part of the growing tray of 160 plants, and the following parameters were evaluated: diameter of the root collar, height of the aboveground part, weight of the aboveground part, number of leaves, weight of the roots and length of the roots.

Prior to biological analyses, the samples were pre-incubated at room temperature (22 ± 2°C) overnight. The following parameters (four replications) were used for compost characterisation:

– Dry mass (d.m.): 5 g of moist green compost (mGC) was dried at 60°C, 24 hours.
– Bulk density: weight of bulk mGC in a calibrated cylinder (1,000 ml).
– Electrical conductivity (EC): 25 ml of deionised water (DW) and 5 ml of mGC were shaken (60 min, 250 swings/min), and EC was measured by the Greisinger GMH 3430 conductivity meter (Greisinger electronic GmbH, Regenstauf, Germany).
– pH (H_2O): 15 ml of DW and 3 g of mGC were shaken (60 min, 250 swings/min), and pH was determined by amplified electrode (Hanna Instruments, Woonsocket, USA).
– Soil organic matter carbon (C_{org}-MW) was measured using a microwave method with an equivalent amount of mGC sample corresponding to 0.03 g d.m. (Růžek et al. 2012).

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- Available organic carbon (C-K_2SO_4) was extracted from mGC samples by 0.5 mol/l K_2SO_4 (Růžek et al. 2009).
- Acceptable nutrients:
  - Ca, Mg and K were determined by atomic absorption spectroscopy using the Varian AA 240FS analyser (Agilent Technologies, Inc., Santa Clara, USA) after extraction of dry green compost (dGC) by reagent Mehlich III (Mehlich 1984).
  - P was analysed photometrically on the Skalar analyser (Skalar Analytical BV, Breda, Netherlands) after extraction of dGC by reagent Mehlich III.
  - N-NO_3^- and N-NH_4^+ were determined photometrically on the Skalar analyser after extraction of dGC by 1% KCl.
  - Microbial biomass carbon (MBC-MW) was analysed after microwave sterilisation (800 J/g d.m. = 600 W, 2 × 67 s, 100 g d.m. = 12 × 1 g of mGC + 1 × 88 g of field-moist soil) and microwave soil extracts digestion (800 J/ml = 250 W, 77 s, 24 ml) with colorimetric determination at 590 nm (Růžek et al. 2009).
- Basal respiration (BR; mg C/kg d.m./h): CO_2-C captured with absorbent (2.5 ml NaOH; 1 mol/l) was determined by titration with 0.1 mol/l HCl after controlled incubation (20 h at 29°C); (Růžek et al. 2012).
- Potential respiration (NR) – CO_2 was released after addition of 1.8 mg N-$(NH_4)_2SO_4$ dissolved in 1 ml DW and applied to 4.5 g of mGC (Růžek et al. 2012).
- Potential respiration (NGR) – CO_2 was released after addition of 1.8 mg N-$(NH_4)_2SO_4$ and 18 mg C-glucose dissolved in 1 ml dry weight (d.w.) and applied to 4.5 g of mGC (Růžek et al. 2012).
- Metabolic quotient qCO_2 (BR/MBC) × 1,000 was calculated as the ratio of CO_2/C captured in BR to C of microbial biomass. Metabolic quotient expresses C-respired per gram of microbial biomass/h (ISO 16072).
- Arylsulfatase activity (ARS) – 1 g mGC was incubated with 4 ml acetate buffer and 1 ml *p*-nitrophenylsulphate for 1 h at 37°C (Růžková et al. 2011).
- Dehydrogenase activity (DHA) – 6 g mGC were incubated in large diameter tubes with 0.1 g $CaCO_3$, 1 ml 3% TTC (2, 3, 5-triphenyltetrazolium chloride) and 2.5 ml d.w. for 24 h at 37°C (Öhlinger 1996).

Statistical analyses were computed by Statgraphics Centurion XV software by one-way ANOVA (Analysis of variance; Multiple range tests); Scheffe's test; $P \leq 0.01$.

RESULTS AND DISCUSSION

The combination of wheat B-starch, acetylated up to a different substitution degree (0.6–3.0), and maltodextrin, acetylated also up to a different substitution degree (2.0–3.0) was used in the experiment. A number of biopolymers were created in 2009–2011 in accordance with the patented procedure (Patent CZ 303840 B6; Utility model CZ 24012 U1; Utility model CZ 24013 U1), which were subsequently tested for biodegradation in GC from 1 to 21 weeks. Neither GC nor the lettuce grown on the GC showed any remarkable negative changes after the biodegradations. Biopolymer products, prepared according to the aforementioned patented procedure, can be thus liquidated without any limitation.

GC characteristics

Many GC parameters were better than those of commercial peat substrates commonly used in horticulture. Volume mass of GC higher by 20% (382–422 g/l) was the exception caused by a lower proportion of fibrous white peat. During biodegradation, volume mass keeps growing in the nearby surroundings of the composites by an additional 10%, returning back below 400 g/l after biodegradation and compost mixing. Electrical conductivity of the compost found in close proximity of the composites decreased by up to 25% during biodegradation, achieving min. values after 20 days, the time when microbiological parameters of the compost (Table 1) reach their highest level, or at least a higher level than at the baseline. This feature can be explained by immobilisation of ions from the soil solution into the newly formed microbial cells (Šárka et al. 2012). After several consecutive biodegradation cycles and with the perspective of further gardening use of the GC, the decrease in electrical conductivity of GC was limited by applying water-soluble fertiliser Agro Kristalon Start in a four-ingredient emulsion. The beginning of the biodegradation period (days 7–14, Table 1) was characterised by a mild reduction in some activities of microorganisms (BR, qCO_2, DHA), which

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Table 1. Parameters of compost before and after storage periods

Parameter	Green waste compost prepared in 2007				Commercial peat substrate		Usual parameters of quality substrate[1]
Storage periods (days)	Control	7–14	15–20	21–147	for sowing	for growing	
Dry mass (%)[2]	33.41^{b}	33.62^{b}	$31.60^{a,b}$	$32.62^{a,b}$	52.63^{c}	25.99^{a}	21–50
Electric conductivity (dS/m)[3]	1.43^{b}	$1.20^{a,b}$	$1.10^{a,b}$	1.46^{b}	0.47^{a}	0.69^{a}	< 2.80
pH (H_2O)[4]	$5.98^{a,b}$	$5.92^{a,b}$	$6.23^{b,c}$	6.48^{c}	5.44^{a}	5.33^{a}	5.40–6.40
C_{org}-MW (%)	28.79^{b}	28.16^{b}	28.46^{b}	28.05^{b}	21.20^{a}	47.97^{c}	> 28.00
C-K_2SO_4 (mg C/kg d.m.)	378^{a}	410^{a}	468^{a}	415^{a}	477^{a}	800^{b}	< 730
MBC-MW (mg C/kg d.m.)	$2,252^{a,b}$	$2,232^{a,b}$	$2,485^{a,b}$	$2,680^{b}$	$1,298^{a}$	$2,835^{b}$	1,900–4,500
Basal respiration (BR) (mg C/h/kg d.m.)	24.0^{a}	18.0^{a}	27.1^{a}	23.6^{a}	10.3^{a}	21.5^{a}	< 37.0
Metabolic quotient (qCO_2) (BR/h/g MBC- MW)	11.5^{a}	8.1^{a}	11.2^{a}	8.8^{a}	8.0^{a}	7.6^{a}	< 19.00
Respiratory ratio (NR/BR)	1.03^{a}	1.03^{a}	0.77^{a}	1.08^{a}	1.11^{a}	0.89^{a}	1.00
Respiratory ratio (NGR/BR)	11.35^{a}	13.53^{a}	10.11^{a}	15.94^{a}	10.66^{a}	5.78^{a}	> 10.00
Dehydrogenase activity (mg TPF/h/kg d.m.)	$6.69^{b,c}$	$5.95^{a,b,c}$	$8.48^{c,d}$	10.11^{d}	1.74^{a}	$3.02^{a,b}$	> 5.50
Arylsulfatase activity (mg PNP/h/kg d.m.)	292^{a}	477^{a}	520^{a}	463^{a}	129^{a}	77^{a}	> 190

[1]Šárka et al. (2011); [2]5 g, 60°C, 24 h; [3]5 ml/25 ml deionised water; [4] 3 g/15 ml deionised water; C_{org}-MW – soil organic matter carbon by microwave irradiation method (1,000 J/ml); MBC-MW – microbial biomass carbon by microwave irradiation method (800J/g DM); NR – potential respiration with 0.4 mg N-$(NH_4)_2SO_4$/g moist compost; BR – basal respiration; NGR – potential respiration with 0.4 mg N-$(NH_4)_2SO_4$ and 4 mg C-glucose/g moist compost; TPF – triphenylformazan; PNP – para-nitrophenol; different letters in the superscript indicate a significant difference (ANOVA; Scheffe's test; $P \leq 0.05$); d.m. – dry mass

Table 2. Acceptable forms of nutrients in green waste compost and in commercial peat substrates for growing and for sowing (2009–2011)

Three-year average of nutrient[1]	Ca-Mehlich III	Mg-Mehlich III	K-Mehlich III	P-Mehlich III	N-NO_3^- 1% KCl	N-NH_4^+ 1% KCl
Green waste compost	7,578	1,302	981	272	208	13
Commercial peat substrate for growing	7,711	849	842	377	805	10
Commercial peat substrate for sowing	2,691	1,740	352	152	179	38

[1]mg/kg in dry compost (substrate)

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Table 3. Statistical evaluation of lettuce parameters (40th day) grown on the green compost and on commercial substrates

Substrate	Green compost[1]	Commercial peat substrate[2]	
		for growing	for sowing
Diameter of the root collar (mm)	3.25 ± 0.49[a]	3.15 ± 0.55[a]	2.93 ± 0.44[a]
Height of the aboveground part (mm)	112.8 ± 23.4[c]	89.6 ± 10.9[b]	77.9 ± 12.5[a]
Weight of the aboveground part (g)	2.75 ± 1.04[b]	2.28 ± 0.81[b]	1.27 ± 0.33[a]
Leaf number	11.58 ± 1.72[b]	11.30 ± 1.47[b]	9.38 ± 0.90[a]
Weight of the roots (g)	0.56 ± 0.10[b]	0.51 ± 0.12[a,b]	0.44 ± 0.10[a]
Length of the roots (mm)	66.86 ± 7.32[a,b]	64.40 ± 6.08[a]	69.88 ± 8.85[b]

different letters in the superscript indicate the high significant difference (ANOVA; Scheffe's test; $P \leq 0.01$); [1]green compost (prepared in 2007) was used 2009–2011 for composites biodegradation; [2]peat substrate (series Profi; Agro CS, Inc., Česká Skalice, Czech Republic)

was probably related to the adaptation of the microorganisms to the changed soil composition by inserted composites. The described phase is followed by rapid growth to the max. values (Table 1), usually achieved between days 15–20. The activity of ARS showed the most rapid onset among all the tests observed, decreasing very slowly when peak values were reached. The ARS peak precedes the peak of dehydrogenase activity by several days and in rare cases also by weeks. Used composites stimulated rapid growth of ARS to max. values, which correspond to 178% of the initial state (Table 1) in the 3-year average. Acceptable nutrients in the GC (Table 2) were comparable to the commercial peat substrate for plant growth. Periodic dosing of a mixture of coarsely ground dolomitic limestone with fully water-soluble fertiliser Agro Kristalon Start (in crystalline form) into GC (annually and also according to the nutrient analyses) ensures good levels of acceptable nutrients and pH values, to be maintained for both biodegradation of the composites and gardening use.

Lettuce – test crop

Aboveground parts of lettuce on GC showed a significantly better status (Table 3) after 40 days of growth, compared with those planted on commercial peat substrates in all cases. It is in agreement with the data of Tavarini et al. (2011) who confirmed very good growth of lettuce on GC (Table 3). Furthermore, our results were probably positively affected by the emulsion sprayed on the surface of the GC and composite surface before every biodegradation cycle. The acrylate ingredient in the emulsion (Agrisorb) optimises plant germination (Rehman 2011), and Supresivit (*Trichoderma harzianum* Rifai aggr.) improves the health of the plants. Similarly Chowdappa et al. (2013) confirmed a significantly better growth of the roots and aboveground parts of the tomatoes, especially of the leaf area, and significantly higher auxin levels (indole-3-acetic acid; gibberellic acid) in the roots by up to 68% after *Trichoderma harzianum* application.

The study demonstrated that in the tested load up to 1 g of composites (patented procedure) per 1 l of GC, not even repeated biodegradations within the scope from 1 to 21 weeks showed any negative impact on GC quality. On the contrary composite from acetylated wheat B-starch and maltodextrin stimulated both ARS and BR. ARS showed the most rapid onset among all tests. Also the good lettuce growth (all 6 tested parameters, from these aboveground part was significantly higher) signalised that the use of GC for composite biodegradation had no negative effects on GC horticulture quality. Our results have documented that the use of the proposed composite in plastics production (especially for agricultural and horticultural use) does not have a negative influence on the environment.

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References

Annabi M., Houot S., Francou F., Poitrenaud M., Le Bissonnais Y. (2007): Soil aggregate stability improvement with urban composts of different maturities. Soil Science Society of America Journal, 71: 413–423.

Chowdappa P., Kumar S.P.M., Lakshmi M.J., Upreti K.K. (2013): Growth stimulation and induction of systemic resistance in tomato against early and late blight by *Bacillus subtilis* OTPB1 or *Trichoderma harzianum* OTPB3. Biological Control, 65: 109–117.

Kotek J., Kruliš Z., Šárka E., Růžek L. (2012a): Utility model CZ 24012 U1: Biodegradable composite matrix based on modified starch. Prague, Industrial Property Office.

Kotek J., Kruliš Z., Šárka E., Růžek L. (2012b): Utility model CZ 24013 U1: Biodegradable thermoplastic based on modified starch. Prague, Industrial Property Office.

Kotek J., Kruliš Z., Šárka E., Růžek L. (2013): Patent CZ 303840 B6: Biodegradable compositions based on modified starch and a process for its preparation. Prague, Industrial Property Office.

Mehlich A. (1984): Mehlich-3 soil extractant – a modification of Mehlich-2 extractant. Communications in Soil Science and Plant Analysis, 15: 1409–1416.

Öhlinger R. (1996): Dehydrogenase activity with the substrate TTC. In: Schinner F, Öhlinger R, Kandeler E, Margesin R (eds): Methods in Soil Biology, 1st Ed. Berlin, Springer-Verlag: 241–243.

Paluszek J. (2010): The influence of urban green waste compost on the physical quality of soil exposed to erosion. Archives of Environmental Protection, 36: 97–109.

Rehman A., Ahmad R., Safdar M. (2011): Effect of hydrogel on the performance of aerobic rice sown under different techniques. Plant, Soil and Environment, 57: 321–325.

Růžek L., Růžková M., Voříšek K., Kubát J., Friedlová M., Mikanová O. (2009): Chemical and microbiological characterization of Cambisols, Luvisols and Stagnosols. Plant, Soil and Environment, 55: 231–237.

Růžek L., Růžková M., Voříšek K., Vráblíková J., Vráblík P. (2012): Slit seeded grass-legume mixture improves coal mine reclamation. Plant, Soil and Environment, 58: 68–75.

Růžková M., Růžek L., Voříšek K., Vráblík P., Musilová D. (2011): Microbiological characterization of land set-aside before and after Roundup desiccation. Plant, Soil and Environment, 57: 88–94.

Saviozzi A., Cardelli R., N'kou P., Levi-Minzi R., Riffaldi R. (2006): Soil biological activity as influenced by green waste compost and cattle manure. Compost Science and Utilization, 14: 54–58.

Šárka E., Kruliš Z., Kotek J., Růžek L., Korbářová A., Bubník Z., Růžková M. (2011): Application of wheat B-starch in biodegradable plastic materials. Czech Journal of Food Sciences, 29: 232–242.

Šárka E., Kruliš Z., Kotek J., Růžek L., Voříšek K., Koláček J., Hrušková K., Růžková M., Ekrt O. (2012): Composites containing acetylated wheat B-starch for agriculture applications. Plant, Soil and Environment, 58: 354–359.

Tavarini S., Cardelli R., Saviozzi A., Degl'Innocenti E., Guidi, L. (2011): Effects of green compost on soil biochemical characteristics and nutritive quality of leafy vegetables. Compost Science and Utilization, 19: 114–122.

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