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Original article

VERMITRANSFORMATION OF BIODEGRADABLE DISPOSABLE TABLEWARE

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Аннотация

Background. The recycling efficiency of disposable tableware can be increased with the help of vermiculture. The optimization of the substrate composition on the basis of the potential toxicity of biodegradable tableware and the use of earthworm prefererence reaction is necessary.

Purpose. The aim of this study was to test the potential toxicity of water extracts from biodegradable tableware sold on the Irkutsk market and find the optimal feed mixtures for tableware vermiculture.

Materials and methods. Disposable sugar cane and corn starch tableware were used in the study (Green Mystery, Eco Friendly, etc.). The level of toxicity of the water extracts of the biodegradable samples was measured using the test-objects: small duckweed (Lemna minor L.), the seeds of Lepidium sativum and terrestrial oligochaetes (Eisenia foetida andrei Bouche). Mature worms were put into the substrate to assess the ability of E. foetida to process biodegradable disposable sugar cane tableware.

Results. Biodegradable disposable sugar cane tableware accounts for 23.5 % of the Irkutsk market. Biotesting conducted on the test plants has revealed the safety of sugar cane tableware. The growth rate of duckweed fronds has increased by 5.7-6.3%, there has been an increase by 1.8% in the aqueous corn starch extract. The experiment on oligochaete survival has proved the safety of sugar cane tableware (100 % survival). Corn starch tableware has shown a little toxicity. The length of the sprouts of L. sativum has decreased and made up 20±1.2%, 33±3.5% of earthworms of E. foetida used in biotesting on earthworms were unviable. After earthworm incubation in the substrate with sugar cane tableware the number of young earthworms has gone up by 69.2±3.0%, the cocoons – 154.5±4.5%.

Conclusion. Biodegradable disposable sugar cane tableware can be used for vermitransformation.

Keywords: biodegradable tableware; environmental safety; vermitransformation; biotesting; Lemna minor; Lepidium sativum; Eisenia foetida andrei Bouche

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Научная статья

ВЕРМИТРАНСФОРМАЦИЯ ОДНОРАЗОВОЙ БИОРАЗЛАГАЕМОЙ ПОСУДЫ

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Abstract

Обоснование. Повысить эффективность утилизации одноразовой биоразлагаемой посуды возможно с помощью вермикультуры. Необходима оптимизация состава субстрата на основе учета возможной токсичности биоразлагаемой посуды и использования реакции преференции дождевых червей.

Цель. Проверка возможной токсичности водных вытяжек из биоразлагаемой посуды, реализуемой на Иркутском рынке, и подбор оптимальных кормовых смесей для вермикультивирования с включением био-посуды.

Материалы и методы. Использовали одноразовую посуду из сахарного тростника и кукурузного крахмала («Green Mystery», «Eco Friendly», др.). Оценивали токсичность водных вытяжек из посуды путем биотестирования на трех объектах: ряска малая (Lemna minor L.), семена кресс-салата (Lepidium sativum), почвенные олигохеты (Eisenia foetida andrei Bouche). Для оценки способности E. foetida перерабатывать посуду из сахарного тростника в субстраты запускали половозрелых червей. По истечении экспозиции (42 дня) подсчитывали количество особей на разных этапах развития.

Результаты. Биоразлагаемая посуда из сахарного тростника занимает 23,5% иркутского рынка. Биотестирование показало практически полную безопасность посуды из сахарного тростника. Скорость прироста листецов ряски превысила контроль в 5,7-6,3 раза (из кукурузного крахмала – примерно в 1,8 раза), выживаемость почвенных олигохет составила 100±0%. Выявлена незначительная токсичность посуды из кукурузного крахмала. Уменьшение длины проростков L. sativum составило 20±1,2%, при этом 33±3,5% особей E. foetida при биотестировании на дождевых червях оказались нежизнеспособными. После инкубации червей в субстрате с посудой из сахарного тростника обнаружено увеличение численности молодых червей на 69,2±3,0%, коконов – на 154,5±4,5%.

Заключение. Выявили безопасность и возможность вермитрансформации биоразлагаемой одноразовой посуды из сахарного тростника.

Ключевые слова: биоразлагаемая посуда; экологическая безопасность; вермитрансформация; биотестирование; Lemna minor; Lepidium sativum; Eisenia foetida andrei Bouche

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Introduction

The principles of sustainable production and responsible consumption are a key issue in shaping the *sustainable development* agenda until 2030. Most states now implement various programmes aimed at a closed-loop economy, natural resource management, environmental and biodiversity conservation, sustainable methods of production and consumer goods. 127 countries have implemented the measures restricting the use of disposable plastic goods. 12 countries have imposed a ban on the production, use and import of disposable tableware [14].

Russia held IX Nevsky International Ecological Congress in May 2021, devoted the projects associated with ecology and environmental protection. One of the vital problems discussed was plastic pollution, the reduction of its use, disposable plastic goods in particular.

There has been a rise in a new market segment for the last 5-6 years. It is the production of disposable tableware from biodegradable polymers, including corn starch and sugar cane. For instance, the share of eco-ware exceeds 40 % in Europe [11]. A number of patents for producing completely biodegradable disposable tableware in the food industry has been registered in Russia (D.A. Koloskov, N.M. Efremov, A.I. Tokunova) [3; 4]. Biodegradable disposable tableware consists of tree bark, moss, cellulose in the form of purified cotton, straw or cake of sunflower seeds, starch of oyster plant or potato starch or oat grain. Zoogloea of tea fungus grown by way of incubation under aerobic conditions on a nutrient medium at room temperature can be used as biodegradable mass. Wheat bran and oilseed meals can also be used to produce biodegradable disposable tableware [9].

The use of *biodegradable polymers* for the production of disposable tableware simplifies its disposal along with organic waste [8]. The use of vermiculture contributes to the efficiency of its disposal, it also increases its speed and makes it possible to get vermicompost (valuable organic fertilizer) [5] и biomass of earthworms [17]. The optimization of the substrate composition on the basis of the potential toxicity of biodegradable tableware and the use of earthworm prefererence reaction is necessary in this case.

Purpose

The objective of the research was to test the potential toxicity of water extracts from biodegradable tableware sold on the Irkutsk market and find the optimal feed mixtures for tableware vermiculture including bio tableware.

Materials and methods

Disposable sugar cane (*Green Mystery*; Russia-China, *Eco Friendly*, the Netherlands); corn starch (trademark is not specified, China) tableware were used in the study.

Water extracts were prepared from the test samples of biodegradable tableware (sugar cane, corn starch). 50 grams of the tableware were grinded, put into the conical flask 750 ml. and 250 ml. of distilled water was added (tableware and water in the ratio of 1:5). The contents of the flask was stirred with a shaker (temperature – 30 ^{o}C, the speed of the shaker is 180 rpm.) and filtered through a paper filter. Distilled water was used as the control. The toxicity of the water extracts was evaluated with three methods of biotesting (the optimal temperature – 20-25 °C):

1) increase in the number of *Lemna minor L.* The time exposure was 7 days [6];
2) change in the length of sprouting seeds of *Lepidium sativum;*
3) survival rate of *Eisenia foetida andrei Bouche* [13]. The incubation period of earthworms was 24 hours. Earthworms survival and reactions to external irritation was assessed.

The level of toxicity of tableware water extracts was determined according to the survival index of *Eisenia foetida andrei Bouche*. There was 20 ml. of water extracts being surveyed in Petri dishes (20 replications per a sample). 5 mature worms of the same size were put in the dishes. Water extract was considered safe if the specimen wriggled being exposed to external irritation.

To assess of the ability of oligochaetes to process biodegradable disposable tableware 200 gr. of soil moistened by 100 ml. of distilled water was to put in the polymer container. 50 gr. of shredded tableware sample was mixed with 50 gr. of mashed vegetable waste (beetroot, potato, cabbage, apples) to soften the tableware. Then the mixture of vegetable waste and tableware was put in the container with moistened soil and 20 mature worms. The state of the worms was monitored throughout the experiment (42 days), the optimal conditions were created for them (humidity – 80-85%, temperature 20-25 °C, mashed vegetable fertilizer (50 gr.) – once every two weeks) [1]. The readings were taken after the exposure time by counting the number of mature, immature, newly hatched species and cocoons. The substrates with the addition of cellulose and sewage disposals were used for the comparison. The control was the soil with mashed vegetables.

Each series of experiments was conducted at least 20 times. Microsoft Excel software package was used *for statistical processing of the obtained data*. The arithmetic value was calculated since this setting is the most likely measured value in the case of normally distributed features. Student's criterion was used to evaluate critical *reliability of differences* compared averages. The conclusion has been made with a high probability of accuracy (P≥0,95).

Materials and methods

There is no mass production of biodegradable tableware on the Irkutsk market. There are only three sellers: *Without plastic* (it accounts for 63% of biodegradable tableware), *Eco-city Irkutsk* (21%) and *Alleya hypermarket* (16%). The assortment of biodegradable tableware can be divided into three commodity groups according to the main types of raw materials: paper, cardboard, wood – 38.8%, corn starch – 36.5%, sugar cane – 23.5%, bamboo – 1.2%. The retail price of sugar cane and tableware is 18 times and corn starch tableware – 10 times more the than the price of plastic tableware (table 1).

Table 1.

Price of disposable tableware from different natural ingredients, Irkutsk City

Type of business	Average price of disposable tableware, roubles				
	Plastic	Sugar cane	Corn starch	Wood	Bamboo
Retail business	1.16	21.24	11.65	14.53	-
Wholesale business	0.87	4.58	2.80	5.47	0.30

Biodegradable disposable sugar cane tableware has the following composition: cellulose (bagasse) – 55%, hemicelluloses – 25%, lignin – 19%, waxes – 1%. Bagasse is dry pulpy fibrous material that remains after crushing sugarcane or sorghum stalks to extract their juice. Waxes increase moisture and fat resistance of tableware. Tableware is milky white, it has soft edges and a velvet-soft surface. The production technology of tableware includes 7 stages:

bagasse grinding and pressing, compressed bagasse cleaning, bagasse boiling, adding components, shaking, drying the mass, molding sheets, forming and stamping products, *disinfection* in an *ultraviolet radiation.*

The advantages of disposable biodegradable sugar cane tableware are environmental friendliness; ease disposal; the lack of carcinogenic risks; high density; thermal resistance; air, moisture and fat resistance; strength and high resistance to deformation.

In its appearance and density corn starch tableware can be taken for tableware from food grade plastic (low density, elasticity). However, there are some differences. Corn starch disposable tableware has pleasant tactile sensations and a light-cream colour. Corn starch disposable tableware has the same advantages as sugar cane but its safety and ecological character have not been proved.

The level of toxicity of the water extracts of the biodegradable samples was measured using test-objects.

The speed growth of duckweed small fronds in the aqueous extract of sugarcane increased on average by 7 times (by 5.7-6.3.34%) compared by the controls. There was an increase by 1.8% in the aqueous corn starch extract. Water extract of corn starch tableware decreased the sum of the stem and root length of *Lepidium sativum* sprouts compared to the control. There was no inhibition in the experiment on sugar cane water extract.

The results of biotesting with the use of the seeding of lepidium sativum were the following. The germinating ability was 100% for sugar crane and 95% for corn starch of control. The aqueous extract of corn starch tableware showed the worst results of the length of the sprout that was the sum of the length of the stem and the root; sugar crane – 89.3-101.2%.

The level of toxicity of water tableware extracts of red Californian earthworm survival from sugar cane was 100±0% (all species maintained their viability, reacted to external irritation as well as the ones in the control cups with water); the survival of the worms in water extracts from corn starch was 67±3.5% (the appearance of the survived species got worse, the surface of the body was irregular, rough; the earthworms were inhibited to external irritation).

The following stage was aimed at researching the ability of vermiculture to process disposable tableware from sugar cane. Different substrates according to the number of alive species and cocoons were compared to analyze the level of survival of *Eisenia foetida* in soil containing tableware from sugar cane.

We collected the data of 6 different substrates including:

1. Vegetable waste (50 gr.);
2. Vegetable waste (50 gr.) and cellulose (2 gr.);

3. Vegetable waste (25 gr.) and cellulose (2.5 gr.);
4. Vegetable waste (50 gr.) and tableware from sugar crane (10 gr.);
5. Vegetable waste (25 gr.) and the sources of waste water overrotten more than 5 years ago (MUP Vodokanal, Irkutsk City) (50 gr.);
6. Sources of waste water overrotten more than 5 years ago (MUP Vodokanal, Irkutsk City) (50 gr.).

There were 20 mature earthworms in each substrate at the beginning of the experiments. The exposure time was 42 days.

On the *basis of the data received* we have come to the conclusion that substrate 2 consisting of 50 grams of vegetable waste and 2 grams of cellulose has shown the best results. Immature earthworms have been found only in this substrate and the number of the cocoons has increased the control 3.6 times. The worst result has substrate 6 including waste water. Earthworms did not breed in this substrate.

Sugar cane tableware in the combination with vegetable waste has high rates of vermiculture breeding and viability that significantly exceeds the control rates. The number of cocoons amounted to 254.5±4.5% of the control, the number of the hatched ones was 169.2±3.0%.

The best substrates for vermiculture are those containing cellulose including bagasse [10]. Cellulose contains nitrogen that is necessary for producing cocoons. Therefore, disposable sugar cane tableware is biodegradable and can be used for vermicomposting since earthworm reproduction rate is really high in such substrate. *The increased mass of coprolites was visually recorded.*

There is currently a growing potential of innovative biotechnology, vermicomposting in particular. [15] Vermicompost are organic materials, produced by the activity of earthworms (*Eisenia fetida,* as a rule) is considered as effective organic fertilizers improving soil fertility and increasing crop yield. Such vermicomposts have high and various microbiological and enzymatic activity, a good physical structure and *high water-holding* capacity. They contain macro and micronutrients, phytohormones and humic substances acting as plant growth regulators. Furthermore, such composts contain antimicrobial compounds and repellents that allow to control the number of phytopathogens and insect-pest.

There is a degree of earthworm intensity in relation to the quantity of material processed in the vermitransformation process, i.e. the capacity of processing organic material per a unit of earthworm biomass [5; 7]. The general empirical rule that is fully consistent with available scientific data: one kilo of earthworms can process about 1 kilo of organic material per day with the moisture of 75-85%. The optimal population of earthworms has been identified as the following: 9-18 kilos of adult specimen biomass of earthworms per 1 m2 of the working area of a vermicultivator. These data can be used for vermitransformation of substrates including the wastes of bio tableware from sugar cane.

Conclusion

Biotesting conducted on the test plants has revealed the safety of sugar cane tableware: the growth rate of duckweed fronds has increased by 5.7-6.3%, there is an increase by 1.8% in the aqueous corn starch extract. There has been a slight toxicity of corn starch tableware. The decrease in *L. sativum* sprout length by 20±1.2% compared to the control has proved it. 33±3.5% of *E. foetida* turned out to be inviable under the influence of the water extract from corn starch tableware. The experiment has shown the ability of *E. foetida* to process biodegradable disposable sugar cane tableware. There have been 69.2±3.0% of young earthworms and the cocoons (154.5±4.5%) more compared with the control in the substrate containing vegetable waste and the sample of the test tableware (the weight ratio 5:1). Therefore, the safety and possibility of biodegradable disposable tableware of the trademarks of *Green Mystery* and *Eco Friendly* for vermitransformation has been revealed.

Conflict of interest information. The authors declare that there is no conflict of interest.

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