Study of the recovery in agriculture of the waste resulted from baker's yeast industry

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Abstract. The baker's yeast industry generates large amounts of waste, rich in mineral and organic substances. The reintegration into the natural cycle of these wastes, as a biological fertilizer, is one of the ways to reuse them and also represents a model for achieving the circular economy in the baker's yeast industry. This paper presents the quality of the sewage sludge and the waste resulted from the separation of the yeast biomass from the spent molasses resulted from a baker's yeast processing plant and the possibility of using them in agriculture. The content of heavy metals as well as the main parameters were assessed in accordance with the requirements of the national Order 344/2004 concerning the protection of the environment and especially of soils, when using sewage sludge in agriculture. These products were used in order to increase the agrochemical soil parameters for the cultivation of some vegetables (eggplant and pepper) in the field. We considered a garden soil poor in humus (1.16% d.m.) and with nitrogen (N), potasium (P) and potassium (K) values below the optimal soil agrochemical parameters, which condition the potential state of its fertility. The products were dosed according to the soil quality, and biometric measurements were made both on plants and harvested fruits. The results were compared with the untreated vegetables cultivated on the soil that was not treated with these products. These preliminary experiments showed that these two products have potential to be used as a source of mineral and organic soil fertilization.
Key Words: biometric measurements, mineral and organic soil fertilization, vegetables, waste from the baker's yeast industry.

Introduction. Molasses is a by-product resulted from the sugar industry that in present represents the main raw material in food industry (Maqueda et al 2011) and has important commercial value due to its use as a carbon source for food fermentation processes such as baker's yeast and ethanol (Pena et al 2003; Gad & El Sayaad 2010), as well as feed and biofertilizers (Jiranuntipon et al 2009; Gad & El Sayaad 2010). The most important food sector that uses mollases as raw material is represented by the baker's yeast industry (Bekatorou et al 2006).

On the other hand baker's yeast industry generates large amounts of waste, such as the spent molasses and the purging sludge (Bekatorou et al 2006). The reintegration of these waste materials into the natural cycle as biological fertilisers is a method of valorising them from the viewpoint of circular economy (Berkesy et al 2009).

The utilisation of the residual products with a high content of mineral and organic substances, for agricultural purposes, is stimulated, seeing that the soil needs increased amounts of fertilisers in order to bring forth superior, stable and efficient products. The maintenance and the increase of the amount of humus for the soil are targeted, too, as humus is an essential factor of fertility, a source of nutritional elements stock, a decisive factor in enhancing the water retention capacity, the thermal mode adjustment capability and in intensifying the biological activity (Berkesy et al 2009).

The requirements of the plants in terms of soil quality. The ecological factors act upon the plant mostly by means of the soil, which enables us to come up during the vegetation period, in order to guide the supply of water and nutrients for the plants and to give rise to the necessary physical conditions – the air and temperature status – for the plants roots to breathe (Trifu 1976).

Some of the multiple properties of the soil have a stable nature, such as the granulometric composition and the total content of nutrients, whereas some others are more dynamic, as they change at random or even during the same period of vegetation. The properties that change more easily under the influence of the various agro-technical and agro-chemical measures include the soil structure, the capacity of absorption, the composition of the absorbed bases, the reaction of the soil, the oxydo-reductive capacity, the content of humus, water and the easily accessible nutrients (Ciofu et al 2003).

The fertilisers, the amendments, the interventions in the soil and the improvement works can greatly change the direction of the chemical and biological processes in the soil in order to enhance fertility (Davidescu & Davidescu 1981).

Seeing their physiological traits, shaped along their entire phylogenetic evolution, plants have got different requirements from the external environment and therefore from the physical, chemical and biochemical conditions in the soil. Certain soils can thus be fertile for some cultures, while others are less or even unfertile (Peterfi & Salageanu 1972).

The importance of nitrogen in the life of the plants consists in that it belongs to the composition of the amino-acids of which the complex molecule of the proteins is composed, to the composition of the nucleic acids, of protoplasm, of chlorophyll, of alkaloids, as well as of certain hetero glochids and phosphatids. It is the element of growth, therefore in its absence the plant does not reach the optimum sizes and the fruits are small, because the protein synthesis no longer takes place. During the vegetation, nitrogen migrates from the old organisms into the young ones, under growth. The amount of nitrogen in the leaves, the buds and the fruits diminishes as the plants cover the last phases of vegetation, even though the total amount of nitrogen increases without doubt (Davidescu & Davidescu 1981; Trifu 1976).

Phosphorus belongs to the composition of the various complex protidic substances (phospholipids) that help compose the genetic structures (the nucleoproteids), the protoplasm, certain enzymes etc., as well as to the composition of other organic compounds (phytate, phosphatids, nucleic acids and so on). When there is few phosphorus, plants stop growing, their leaves remain small, get twisted, display usually violet-reddish stains or corrugations and the seeds are not longer created (Ciofu et al 2003; Baker et al 2015).

Potassium improves the plants' health condition and resilience to diseases and to the bad environmental conditions (drought, flood, cold). It stimulates the creation of the fruits and in conjunction with phosphorus it contributes to the roots growth. It is the element that provides quality to the crop, that betters the fruits' and the vegetables' shape, colour and flavour. No or few potassium weakens the intensity of the synthesis processes in the plants and the passage of the substances from the leaves toward the consumption and accumulation places (Davidescu & Davidescu 1961; Trifu 1976). Alongside nitrogen and phosphorus, it enables large quality yields, thanks to the complementarity of their roles in the NPK-based fertilisation technologies. Unlike nitrogen and phosphorus, potassium mainly supports the glucides synthesis and deposit, thus balancing the nitrates reduction and the proteins synthesis (Trifu 1976; http://www.azomures.com/newsletter/potasiul-si-nutritia-plantelor.

The humus of the soil has the ability of absorbing and retaining water, thus enhancing the capacity for water and the permeability for water and air in case of the heavy and medium soils. For the elementary particles, seeing the capacity of coagulation in the presence of the electrolytes, saturated humus or weakly acid humus plays the role of cement, helping shaping the structure. Thanks to its dark colour, it largely influences the adjustment of the thermal status of the soil. By decomposition, humus releases a large amount of CO_2, which partly contributes to the nutrients solubilisation. In conjunction with clay it makes the adsorptive complex of the soil. Humus withholds the bases from the soil under the form of various combinations and especially as (calcium, ammonium etc.) humates. It is the main source of nitrogen (http://www.unibuc.ro/prof/oprea_c_r/docs/2017/apr/14_11_47_4815_16_20_08Curs_4_Mat_Org.pdf).

The aim of this paper is to present the quality of the baker's yeast industry waste and the possibility to use it as a soil fertilizer. We have experienced the use of this waste to improve the agrochemical soil quality of the garden by enriching it with N, P, K. We also watched plant growth, development and fruit quality.

Material and Method. The experiments were carried out on a garden soil, in Bistriţa, in the Dumitra Veche street (Lat = 47.1520555°N, Long = 24.4965935°E and Stereo 70 coordinates: x = 461974.278; y = 628147.716), between June and September 2017. The treatment with waste rich in mineral and organic substances derived from the baker's yeast industry, in order to increase the agro-chemical parameters of the soil, was applied once (stage fertilisation), in various concentrations, in the phase of young plants, by dosing the solutions at the root (local application).

The spent molasses and the purging sludgeresulted from the processing of baker's yeast industry have been obtained from Rompak SRL (Pașcani, Iași county), the only producer of baker's yeast in Romania.

We took under examination a garden soil poor in humus (1.16% dry matter (d.m.)) and with N, P, K values lower than the agro-chemical parameters of an optimum soil, which condition the potential state of fertility (Table 1). Under these circumstances, the addition of fertilisers is called for, in order to get a good crop.

Table 1

The physico-chemical characteristics of the garden soil – Bistriţa

No.	*Parameter*	*MU*	*Determined value*	*Testing method*
1	Nitrogen	% d.m.	0.235	SR ISO 11261:2000 SR EN 13342:2002
2	Phosphorus	% d.m.	0.114	STAS 7184/14-79 pt.4 STAS 12205-84
3	Potassium	mg kg^{-1} d.m.	3802	SR EN ISO 17294-2:2005
4	Cadmium	mg kg^{-1} d.m.	< 0.05	SR EN ISO 17294-2:2005
5	Copper	mg kg^{-1} d.m.	46.9	SR EN ISO 17294-2:2005
6	Nickel	mg kg^{-1} d.m.	30.7	SR EN ISO 17294-2:2005
7	Lead	mg kg^{-1} d.m.	28	SR EN ISO 17294-2:2005
8	Zinc	mg kg^{-1} d.m.	91.9	SR EN ISO 17294-2:2005
9	Mercury	mg kg^{-1} d.m.	0.19	EPA 7471B/2007 SR EN ISO 17294-2:2005
10	Total chrome	mg kg^{-1} d.m.	21.6	SR EN ISO 17294-2:2005
11	Calcium	mg kg^{-1} d.m.	1771	SR EN ISO 17294-2:2005
12	Magnesium	mg kg^{-1} d.m.	2492	SR EN ISO 17294-2:2005
13	pH	pH units	7.6	SR EN 15933:2013
14	Dry matter	%	94.52	SR ISO 11465:1998 SR EN 12880:2002
15	Humus (Organic carbon)	% d.m.	1.16	SR ISO 14235:2000 STAS 7184/21-87

MU = measure unit; d.m. = dry matter.

Waste from the baker's yeast industry. The spent molasses have got a 61-63% concentration of d.m., a liquid consistency, the dark brown colour, low viscosity and the smell like caramel. Their complex and highly valuable chemical composition provides the necessary macro-elements (N, P, K) and micro-elements (Mg, Fe, Cu, Zn) for the plants growth and development. The medium samples analysed show that it is a product rich in potassium, less rich in nitrogen and poor in phosphorus (Table 2).

The purging sludge resulted from the baker's yeast technology is concentrated by mechanical procedures up to the 5% concentration of d.m. (Table 3). Its content of nutrients (N, P, K) is of particular importance, given its valorisation as agricultural fertiliser or as a soil conditioning agent. Moreover, the agricultural utilisation of sludge is conditioned by the presence and the amount of heavy metals (Negulescu 2006). As compared to the sludge from the urban purging stations, the sludge under study has got a lower content of nitrogen and phosphorus and a far greater content of potassium (Kumar et al 2017).

Table 2

The physico-chemical characteristics of the spent molasses resulted from the baker's yeast technology – medium values

No.	*Parameter*	*MU*	*Determined value*	*Testing method*
1	Nitrogen	% d.m.	4.57	SR ISO 11261:2000 SR EN 13342:2002
2	Phosphorus	% d.m.	0.197	STAS 7184/14-79 pct.4 STAS 12205-84
3	Potassium	mg kg^{-1} d.m.	2401	SR EN ISO 17294-2:2005
4	Cadmium	mg kg^{-1} d.m.	< 0.05	SR EN ISO 17294-2:2005
5	Copper	mg kg^{-1} d.m.	2.59	SR EN ISO 17294-2:2005
6	Nickel	mg kg^{-1} d.m.	6.50	SR EN ISO 17294-2:2005
7	Lead	mg kg^{-1} d.m.	4.60	SR EN ISO 17294-2:2005
8	Zinc	mg kg^{-1} d.m.	18.49	SR EN ISO 17294-2:2005
9	Mercury	mg kg^{-1} d.m.	< 0.05	EPA 7471B/2007 SR EN ISO 17294-2:2005
10	Total chrome	mg kg^{-1} d.m.	1.55	SR EN ISO 17294-2:2005
11	Calcium	mg kg^{-1} d.m.	10556.5	SR EN ISO 17294-2:2005
12	Magnesium	mg kg^{-1} d.m.	407.5	SR EN ISO 17294-2:2005
13	pH	pH units	8.0	SR EN 15933:2013
14	Dry matter	%	62.43	SR ISO 11465:1998 SR EN 12880:2002
15	Humus (Organic carbon)	% d.m.	11.68	SR ISO 14235:2000 STAS 7184/21-87

MU = measure unit; d.m. = dry matter.

Table 3

The physico-chemical characteristics of the sludge derived from the wastewater purification as a result of the baker's yeast technology – medium values

No.	*Parameter*	*MU*	*Determined value*	*Testing method*
1	Nitrogen	% d.m.	1.105	SR ISO 11261:2000 SR EN 13342:2002
2	Phosphorus	% d.m.	0.140	STAS 7184/14-79 pct.4 STAS 12205-84
3	Potassium	mg kg^{-1} d.m.	137397	SR EN ISO 17294-2:2005
4	Cadmium	mg kg^{-1} d.m.	0.63	SR EN ISO 17294-2:2005
5	Copper	mg kg^{-1} d.m.	3.64	SR EN ISO 17294-2:2005
6	Nickel	mg kg^{-1} d.m.	35.2	SR EN ISO 17294-2:2005
7	Lead	mg kg^{-1} d.m.	13.97	SR EN ISO 17294-2:2005
8	Zinc	mg kg^{-1} d.m.	43.5	SR EN ISO 17294-2:2005
9	Mercury	mg kg^{-1} d.m.	1.21	EPA 7471B/2007 SR EN ISO 17294-2:2005
10	Total chrome	mg kg^{-1} d.m.	4.24	SR EN ISO 17294-2:2005
11	Calcium	mg kg^{-1} d.m.	43735	SR EN ISO 17294-2:2005
12	Magnesium	mg kg^{-1} d.m.	4244	SR EN ISO 17294-2:2005
13	pH	pH units	7.9	SR EN 15933:2013
14	Dry substance	%	38.27	SR ISO 11465:1998 SR EN 12880:2002
15	Humus (Organic carbon)	% d.m.	4.62	SR ISO 14235:2000 STAS 7184/21-87

MU = measure unit; d.m. = dry matter.

The treatments were performed with spent molasses and purging sludge, which are waste derived from the baker's yeast industry, in various concentrations. The biological material used in our experiments was represented by sets of eggplants (*Solanum* *melongena* L.) and peppers (*Capsicum annuum* L.). The plants were grouped in five experimental variants consisting in five individuals for each of the two groups of waste materials under study. Experimental series are represented by the following: 1. control; 2. treatment with spent molasses 1/5 shares of water; 3. treatment with spent molasses 1/7 shares of water; 4. treatment with purging sludge 1/4 shares of water; 5. treatment with purging sludge 1/3 shares of water.

The garden soil on which the experiments took place and the purging sludge that was used as fertiliser show a low content of heavy metals, as compared to the limit values indicated in the Order 344/2004 (Tables 4 and 5).

Table 4

The maximum values allowed for the concentrations of heavy metals in the soils where sludge is applied (mg kg^{-1} of dry matter) in a representative sample of soil with pH amounting to 6-7

Parameters	*Limit values (Order 344/2004)*
Cadmium	3
Copper	100
Nickel	50
Lead	50
Zinc	300
Mercury	1
Chrome	100

Table 5

The limit values for the concentrations of heavy metals in the sludge meant to be used in agriculture (mg kg^{-1} of dry matter)

Parameters	*Limit values (Order 344/2004)*
Cadmium	20-40
Copper	1000-1750
Nickel	300-400
Lead	750-1200
Zinc	2500-4000
Mercury	16-25
Chrome	-

Results and Discusion. The months in the summer of 2017, when the experiment took place (Figure 1), faced persistent pedological drought and scorching heat periods of time all throughout the country. It was a time when the essential role of potassium for the economy of water in the plants could stand out. The task of potassium is to adjust the hydric condition of the plant by controlling the activity of the stomata and by maintaining the turgescence and the permeability of the vegetated cells. The presence and the application of potassium positively influence the balance of water in the plants and reduce the latter ones' sensitivity to drought (Mansfield & Jones 1971; Trifu 1976).

a. b. c.

Figure 1. a. Eggplant and pepper plants under garden conditions (15.06.2017); b. Local dosing of the fertilising substances (spent molasses and purging sludge - 30.06.2017); c. The differentiated development of the eggplant and pepper plants as a result of the treatments undergone (20.07.2017).

The eggplants have got high requirements in terms of soil fertility and drainage. They also have high standards for the nutritive elements and they react very well upon the application of the organic fertilisers and of the mineral ones with nitrogen, phosphorus and potassium. They consume lots of nutrients, notably in the first part of the vegetation period. The eggplants prefer neutral soils, with pH amounting to 6.5-7 (https://www.scribd.com/document/252502239/Tehnologia-de-cultivare-a-vinetelor).

The requirements of the pepper for the soil and the nutritive elements are high. The pepper grows and makes good fruits in sandy-clayish soils with a pH around 6.8. It needs a good supply of potassium for the soils, as this positively influences the quality of the crop (Trifu 1976). The fertilisers added to the soil strongly influence the production of greens and of fruits. Nitrogen increases the yield, however it brakes fruits ripening. The double doses of phosphorus and potassium, associated to the largest dose of nitrogen, provide the greatest yields (Adamczewska-Sowiñska & Krygier 2013).

The biometrical measurements carried out showed an increase in the plants' height, namely 51.22-61.95% for the eggplants and 86.27-145% in case of the peppers, depending on the variant of treatment.

As for the control variant at the eggplants, the average of the plants' height was 41 cm. With regard to the variant of treatment with spent molasses – 1/5 shares of water – the plants' height was even (it varied between 66 and 67 cm) and the growth was 61.95% as compared to the control plants, namely a medium growth as compared to the other variants (Figure 2). It is at this variant of treatment that we achieved the largest number of fruits per plant, i.e. 3-5 pieces of big sizes, which was a 110% increase as compared to the control variant (Figure 3).

As far as the variant of treatment with spent molasses 1/7 shares of water is concerned, the height of the plants was even; it varied between 65 and 72 cm and they grew 68.29% more than the control plants. It was actually the highest growth as compared to the other variants (Figure 2). This variant of treatment brought forth a large number of fruits per plant, namely 3 to 5 big-sized pieces, which represents a 100% increase as compared to the control variant (Figure 3).

In case of the treatment variant with purging sludge 1/4 shares of water, the height of the plants was less even, as it varied between 56 and 69 cm, with a medium growth of 60.97% as compared to the control plants (Figure 2). This variant of treatment brought forth a large number of fruits per plant, namely 3 to 6 medium-sized pieces, which represents a 100% increase as compared to the control variant (Figure 3).

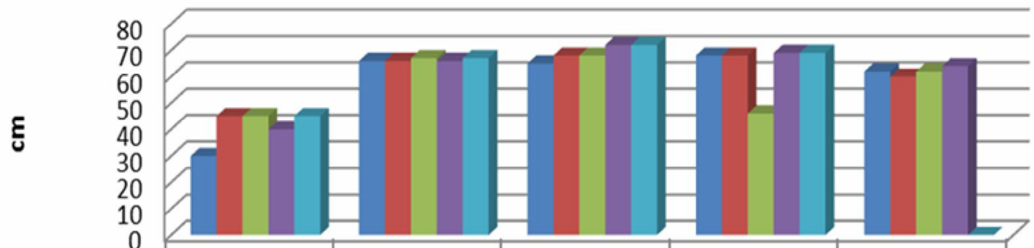
As for the treatment variant with purging sludge 1/3 shares of water, the height of the plants was even; it varied between 62 and 64 cm, with a medium growth of 51.22% as compared to the control plants (Figure 2). This variant of treatment brought forth as many as 2 to 4 medium-sized pieces of fruits per plant, which represents a 62.5% increase as compared to the control variant (Figure 3).

In regard to the control variant for the pepper plants, the average of the plants height was 20.4 cm. In the variant of treatment with spent molasses 1/5 shares of water the plants' height was even (it varied between 49 and 52 cm) and the growth was 145% as compared to the control plants, namely a maximum growth as compared to the other variants (Figure 4). It is at this variant of treatment that we achieved the largest number of fruits per plant, i.e. 3 to 5 big-sized pieces, which was a 110% increase as compared to the control variant (Figure 5).

As far as the variant of treatment with spent molasses 1/7 shares of water is concerned, the height of the plants was even; it varied between 47 and 49 cm and they grew 133% more than the control plants. It was actually a high growth as compared to the other variants (Figure 4). This variant of treatment brought forth a large number of fruits per plant, namely 3 to 5 big-sized pieces, which represents a 90% increase as compared to the control variant (Figure 5).

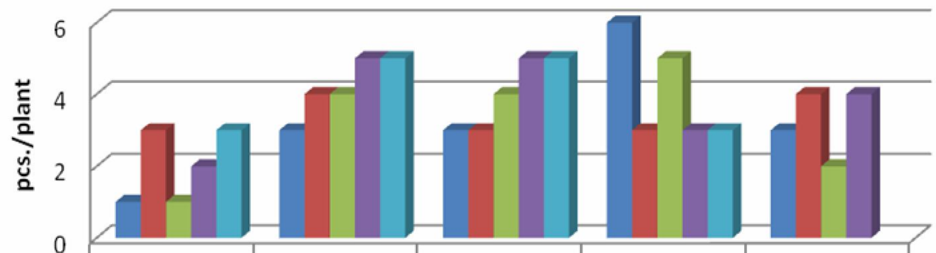
In case of the treatment variant with purging sludge 1/4 shares of water, the height of the plants was less even, as it varied between 39 and 42 cm, with a medium growth of 99% as compared to the control plants (Figure 4). This variant of treatment brought forth a medium number of fruits per plant, namely 3 to 4 medium-sized pieces, which represents a 60% increase as compared to the control variant (Figure 5).

As for the treatment variant with purging sludge 1/3 shares of water, the height of the plants was even; it varied between 37 and 40 cm, with a medium growth of 86.27% as compared to the control plants (Figure 4). This variant of treatment brought forth as many as 2 to 4 medium-sized pieces of fruits per plant, which represents a 50% increase as compared to the control variant (Figure 5).



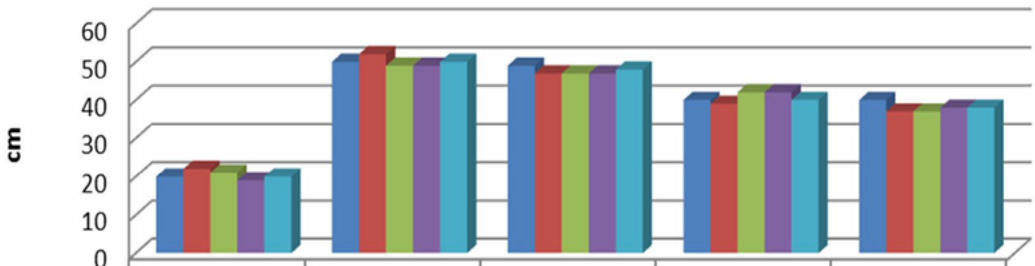
	Control	Spent molasses 1/5	Spent molasses 1/7	Purging sludge 1/4	Purging sludge 1/3
Series1	30	66	65	68	62
Series2	45	66	68	68	60
Series3	45	67	68	46	62
Series4	40	66	72	69	64
Series5	45	67	72	69	0

Figure 2. The variations in the height of the eggplants treated by spent molasses and purging sludge in different concentrations, as compared to the control variant.



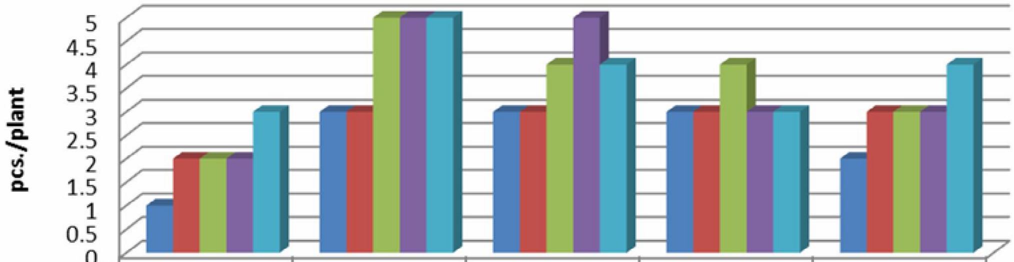
	Control	Spent molasses 1/5	Spent molasses 1/7	Purging sludge 1/4	Purging sludge 1/3
Series1	1	3	3	6	3
Series2	3	4	3	3	4
Series3	1	4	4	5	2
Series4	2	5	5	3	4
Series5	3	5	5	3	

Figure 3. The variations in the number of fruits of the eggplants treated by spent molasses and purging sludge in different concentrations, as compared to the control variant.



	Control	Spent molasses 1/5	Spent molasses 1/7	Purging sludge1/4	Purging sludge 1/3
Series1	20	50	49	40	40
Series2	22	52	47	39	37
Series3	21	49	47	42	37
Series4	19	49	47	42	38
Series5	20	50	48	40	38

Figure 4. The variations in the height of the pepper plants treated by spent molasses and purging sludge in different concentrations, as compared to the control variant.



	Control	Spent molasses 1/5	Spent molasses 1/7	Purging sludge 1/4	Purging sludge 1/3
Series1	1	3	3	3	2
Series2	2	3	3	3	3
Series3	2	5	4	4	3
Series4	2	5	5	3	3
Series5	3	5	4	3	4

Figure 5. The variations in the number of fruits of the pepper plants treated by spent molasses and purging sludge in different concentrations, as compared to the control variant.

The increased height of the plants, the development of their leaves and the large number of big-sized fruits that bring forth good yields showed that the addition of fertilisers under the given conditions had replaced the defficiencies of the garden soil used. These fertilisers were dosed up in order to reach an optimum ratio for the basic N/P/K nutrients.

Conclusions. In the present work we experimented patterns of valorising such waste from the baker's yeast industry as the spent molasses and the fermentation sludge.

The biological material used in our experiments was represented by sets of eggplants (*Solanum melongena* L.) and peppers (*Capsicum annuum* L.). The analysis of the biometrical measurements carried out shows that the treatments undergone positively influenced both the plants growth and the number of fruits per plant, as compared to the control variant, which is due to the rich content of fertilising elements within the composition of the waste materials from the baker's yeast industry that were used.

Acknowledgement. This work was financially supported by the Bridge grant 22BG/2016 - PN-III-P2-2.1-BG-2016-0238 that is supported by the Romanian Executive Agency for Higher Education, Research, Development and Innovation Funding (UEFISCDI).

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Received: 12 October 2017. Accepted: 21 November 2017. Published online: 08 December 2017.
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How to cite this article:
Begea M., Berkesy C., Berkesy L., Cîrîc A., Bărbulescu I. D., Gavriloaie C., 2017 Study of the recovery in agriculture of the waste resulted from baker’s yeast industry. AAB Bioflux 9(3):136-145.