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Research Article

Co-Composting As A Method To Decrease Toxicity Of Chicken Manure

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ABSTRACT

Chicken manure is one of the bulk organic wastes generated in the Republic of Tatars tan.Without its specific processing, chicken manure has a serious negative impact on the environment. Compost based on chicken manure can be a valuable fertilizer because it contains a sufficient amount of nitrogen which is insufficient in many organic wastes. However, it is advisable to use a co-substrate for effective composting of chicken manure. In this study, the chicken manure was co-composted with organic fraction of municipal solid waste, sewage sludge (SS), food waste, DE moistenedsewage sludge, grease trap waste and expired canned foods.It has been shown that the maximal total Kjeldahl nitrogen (TKN)increase and decrease in total organic carbon (TOC)was observed for mixtures with SS (at 57 and 100%, respectively) and FW (54 and 118%, respectively). High microbial respiratory activity early in the process (830 $mgCO_2$-$Ckg^{-1}\cdot 24h^{-1}$) and its gradual decline (to 830 $mgCO_2kg^{-1}\cdot 24h^{-1}$) have been also observed for the same mixture with SS. Reduction of microbial biomass was similar to the reduction of TOC contents;on the 90 day of composting it has reached 1988-1301 $mgC_{mic}kg^{-1}$. Composting of the waste mixtures led to a reduction in their toxicity 1.3-17 times with respect to *Parameciumcaudatum* and from 1.4 to 10 times relative to *Daphniamagna*.Germination index of compost mixtures for 90 days of the process has increased from 12-38% to 70-106%.

Keywords: organic waste, co-composting, chicken manure, organic fertilizer.

1.INTRODUCTION

Annually, about 354 thousand tons of chicken manureare generated in the Republic of Tatars tan [1]. Untreated chicken manure is a risk to the health of both humans, and animals and plants. Leaching of nitrates, odors, and other contaminants can cause degradation of environments, namely soil, groundwater upon the unregulated use of chicken manure [2], [3]. At the same time, chicken manure is a potential fertilizer, it contains a large number of micro and macro elements necessary for plant growth. [4]The use of composting technology can reduce the negative effects of chicken manure. It is important to determine the optimal conditions for the composting process to obtain a high-quality compost.The composting process is converting solid organic wastes into nutrient rich soil conditioner and organic fertilizer that has reduced odor, phytotoxic chemicals, weed seeds and pathogens [5]. The intensity of composting depends on the activity of micro-organisms - decomposers (microbes able to decompose compost organic matter). In turn, the activity of the microbial community in composts dependent on physical factors (temperature, humidity, particle size of substrate, intensity of mixing) and chemical factors (substrate composition, content of N, P, K and C, C / N ratio, content ofO_2, pH) [6]. The basic requirement for the use of compost is their safe use for the soil what is determined by the maturity and stability of composts. The stability of compost is determined by the content of organic matter, and maturity byphytotoxicity [7].The literature provides many examples of the fact that the more effective is co-composting of waste [8], [9].Preparation of a mixture of organic wastes with different physico-chemical characteristics of the mixture allows obtaininga compost with optimum pH, humidity, ratio C / N, and size of the particles.

The aim of this study was to choose the additional substrate for co-composting with chicken manure in order to improve the efficiency of treatment of this environmentally problematic waste. The choice was performed on the basis of the groups of parameters: i) physics and chemical characteristics of composting process; ii) microbiological characteristics of composting process incl. respiration activity indicating compost stability; iii) toxicity of the products of composting incl. phytotoxicity indicating compost maturity.

2. MATERIALS AND METHODS

2.1 Composting substrates

Chicken manure (CM) sampled in JSC "PtitsefabrikaKazanskaya", Kazan, was used as the object of the investigation. Chicken manure was treated as a part of mixtures which included wastes generated in large amounts and for which nowadays there is no market or cost-efficienttreatment method (table 1). Compost mixtureswere prepared so as to achieve the recommended values of the ratio C:N (15-30) and humidity (40-60%) [10].It is known that the composting proceeds more effectively if the compost mixture contains a structural agent [11], [12].It was therefore decided to add to the waste mixtures a saw dust polluted by 15% oil as a structural agent.The sawdust was collected at LLC "PEC", Kazan.

Table 1 Initial wastes and waste mixture

Name of additional waste	Sampling place	Name of the composting mixture	Ratio of the wastes in the mixture (CM:SD: Additional waste)
Organic fraction of municipal solid waste (OFMSW)	Waste transfer station, Kazan	CM+OFMSW+SD	23:10:10
Sewage sludge (SS)	Biological wastewater treatment plants Municipal Unitary Enterprise "Vodokanal", Kazan	CM+SS+SD	7:1:1
Food waste (FW)	Dining CFI, Kazan	CM + FW + SD	87:35:1
Dewatered sewage sludge (dSS)	Biological Wastewater Treatment Plant Municipal Unitary Enterprise "Vodokanal", Kazan	CM+dSS+SD	1:1:1
Fat wastes (from restaurants) (F)	"PEC" Ltd., Kazan	CM+F+SD	31:1:1
Food preserves with expired dates (CF)	"PEC" Ltd., Kazan	CM+CF+SD	22:2:1

Besides three-component mixtures described above, raw CM as well as CM: SD mixture (4: 1) were composted.

2.2 Chemical and biological parameters

At 0, 30th, 60th and 90th day of composting there were determined pH according to ISO 10390 [13], dry matter content (DM) according to ISO 11465 [14], total organic carbon content (TOC) according to ISO 14235 [15], total nitrogen content using Kjeldahl method (TKN) in accordance with ISO 11261 [16].To estimate microbial activity, basal respiration in accordance with ISO 16072 [17], and microbial biomass according to ISO 14240-2 [18] were determined. Toxicity of water elutriates (1:10) was estimated using *D. magna* [19] and*P.caudatum* [20], [21] as test-objects.Toxicity was expressed in LID_{10} (lowest dilution factor of elutriate that caused 10% inhibition of test-function).Fertilizing properties of composts were estimated in soil-compost mixtures (10: 1)using oat plant *(Avena sativa)* as a test-object [22].

3. Results and Discussion

3.1 Physical and chemical characteristics of the composting process of waste mixtures

Composting process is the decomposition of organic matter of compost mixture to CO_2, H_2O and humus-like compounds [10]. Upon that,in the course ofcomposting process reduce of the TOC content is observed [23].TOC change data in the process of composting mixtures based on CM are presented in Figure 1.The results showed a maximum decrease in TOC content in the mixture CM + SS + SD by 57% within 90 days of composting.When composting chicken manure without adding a co-substrate and structuring agent,minimal change of TOC content (10%) was revealed.

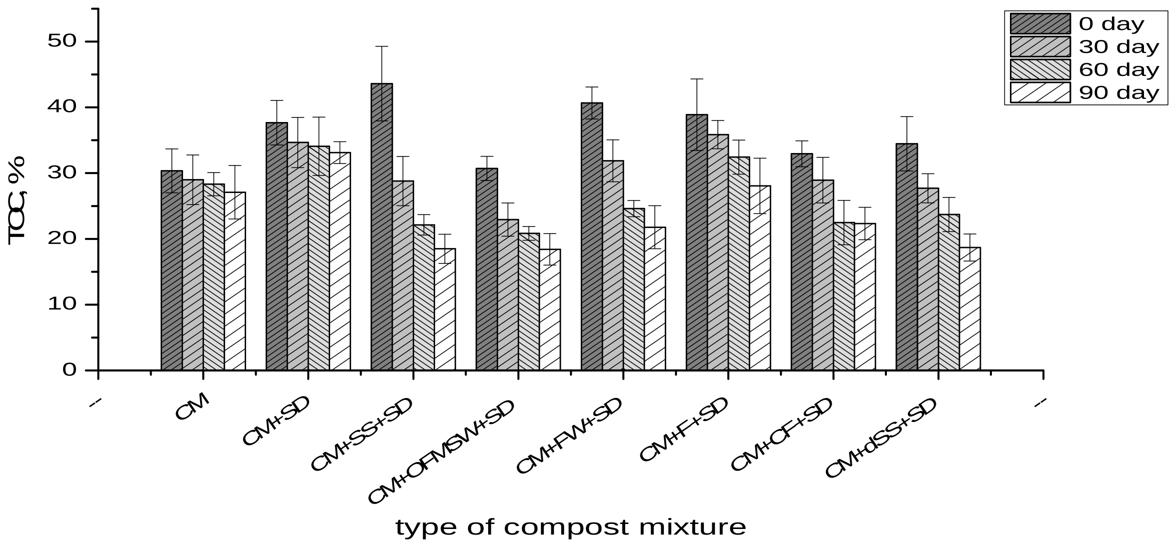

Figure 1. Changesof the TOC in the process of composting of the waste mixtures

In almost all cases the greatest decrease in TOC content occurred within the first 60 days that is associated by the number of authors with presence in the mixture of readily available soluble organic compounds [12]. Goyal et al. [24] noted a decrease in the TOC content by 18% for 90 days when composting chicken manure, with 50% reduction during the first 30 days of composting. Chicken manure which was the basis for the compost mixture characterized by a high content of nitrogen (3%).Wastes with less content of TKN were added in the capacity of substrates that resulted in a decrease of TKN content in mixtures compared to the original CM (Figure 2).In all cases of compost mixtures there was an increase in content of TKN due to destruction of the organic matter.In the variants where there were noted high TOC reduction, maximum (2-fold) increase in the content of TKN (CM+SS+SD, CM+FW+SD) took place.Our findings are consistent with the literature. Thus, when composting chicken manure with rice straw and waste fungi He et al. (2013) have noted an increase in the concentration of nitrogen in 2.5-times to 45 days of composting.In general, the authors note decrease in C/N ratio due to reducing the content of organic substances which is decomposed up to CO_2 and water, and is released as heat energy [5], [24] - [27].

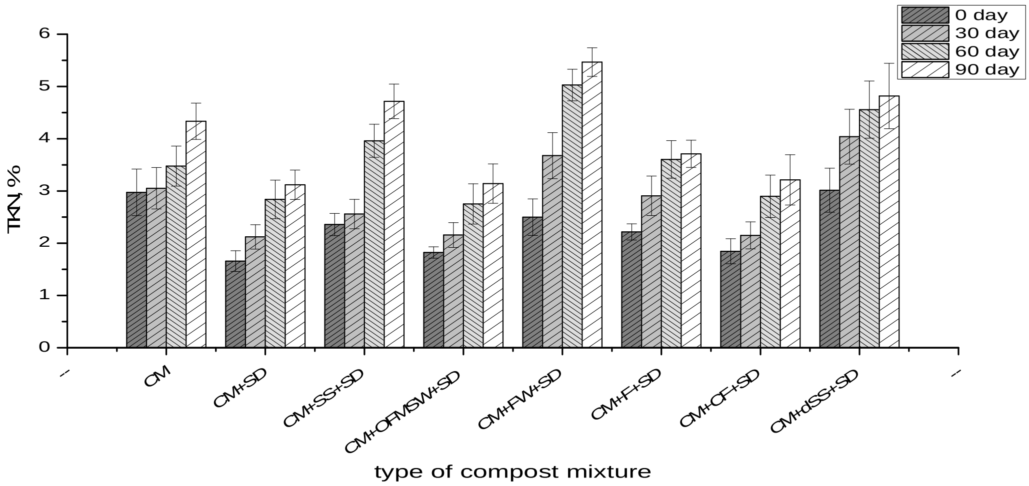

Figure 2. Changes of the TKN in the process of composting of the waste mixtures

3.2. Characteristics of microbial community ofcompost mixtures

Change of microbial community of compost may be used as an indicator of the efficiency of the decomposition process [7], [26]. Indicators of microbial activity make assertions on the compost stability [2], [5], [28].Data on changes in microbial respiratory activity during composting of the wastemixtures are presented in Figure 3. It was found that the high respiratory activity waspeculiartoinitial mixtures of CM+SS+SD – 830 $mgCO_2$-Ckg^{-1}·$24h^{-1}$ and CM+F+SD – 750 $mgCO_2$-Ckg^{-1}·$24h^{-1}$that is probably due to the sufficient number of readily degradable organic matter. In the process of composting, a monotonic decrease in respiratory activity was detected only in one variant (CM+SS+SD).In the mixtures CM+F+SD, CM+dSS+SD, CM+CF+SD the sharp decline in activity followed by reduction was detected in the 60th day, and in the sample CM in 30th day.No reliable dependencies of the microbial respiration activity were observed for the CM+SD, CM+FW+SD, and CM+OFMSW+SD variants.Different of terms maximal respiratory activity have beennoted by other authors.Thus, when composting chicken manure with the waste water from the production of olive oil,Hachicha et al. [28] have revealed peaks of activity from 1 to 60 days of composting.At the same time, Goyal et al. [24] noted the high respiratory activity in 90th day of co-composting CM with strawthat difficultly undergoes biological degradation.

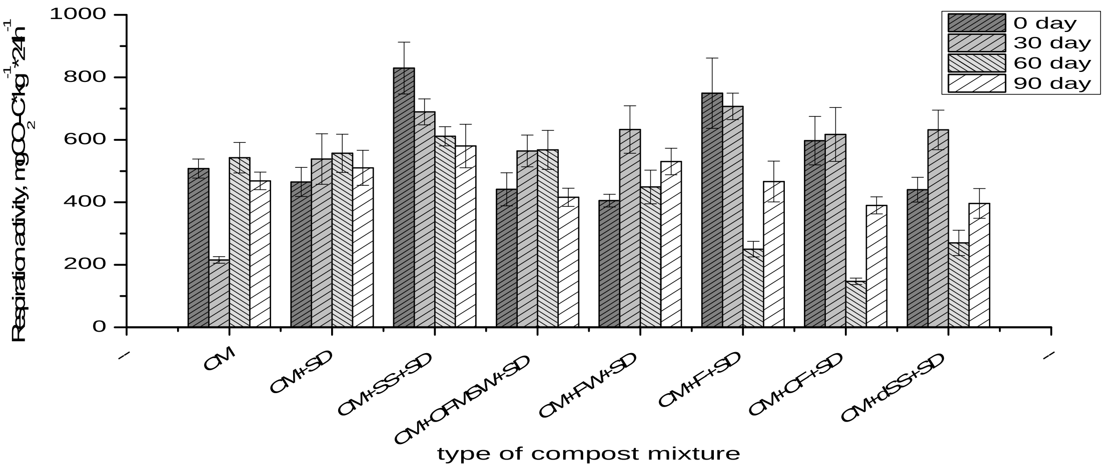

Figure 3. Changes of the microbial respiration activity in the process of composting of the waste mixtures

The maximum values for microbial biomass were observed at 0-30th days of composting (Figure 4). The exception were mixture of CM+F+SD and CM where the maximum values ofmicrobial biomass were accounted for 60th day 9900 mg $C_{mic}\cdot kg^{-1}$ and 8200 mg $C_{mic}\cdot kg^{-1}$, respectively,. In all mixtures, except as specified, there was 2-5 times monotonic decrease in microbial biomass at 90th day which correlated with a decrease in activity of the organic matter degradation on the day 90.

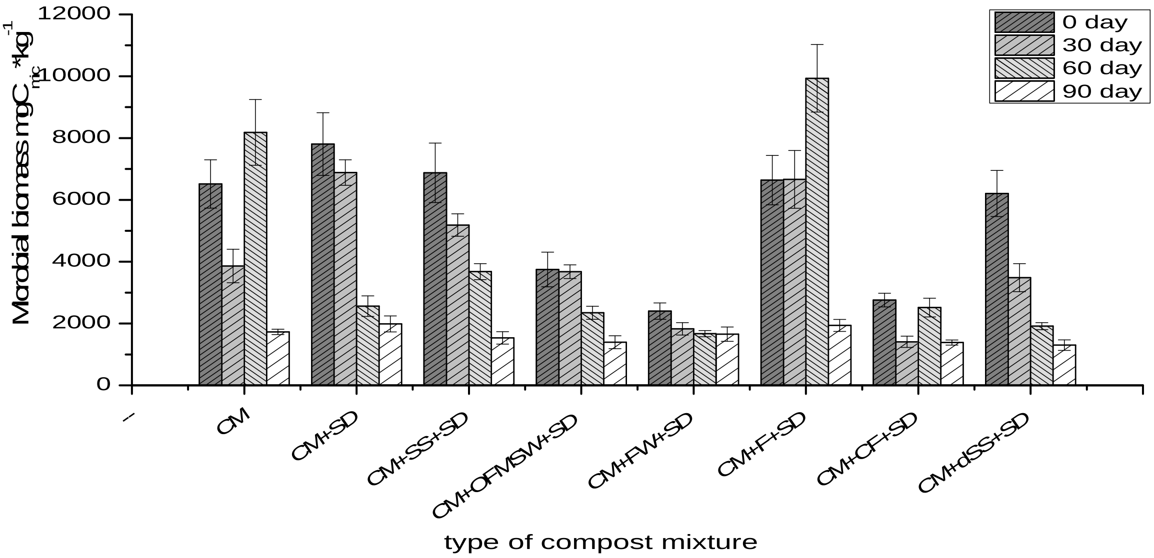

Figure 4. Changes of the microbial biomass in the process of composting of the waste mixtures

3.3Toxicity of compost mixtures

Results of toxicity estimated of waste mixtures' water elutriates presented in Table 2. At 30th day of composting there is no significant change in the toxicity of mixtures in all cases, except for the variants CM (with the test object *P. caudatum* toxicity is increased, andwith*D. magna*is reduced) and CM+CF+SD (with the test object *D. magna*toxicity is reduced). At 60th day there is a decrease in toxicity in all cases, except for the sample CM. A similar toxicity decline continues in 90th day of composting.The maximum reduction in toxicity relative to the initialmixtures was noted for the options CM+CF+SD and CM+FW+SD by 87 and 89%, respectively.

Table 2 Changing of toxicity of the waste mixtures in the process of composting

Sample	Toxicity of compost mixture, LID10							
	0 day		30th day		60th day		90th day	
	*P.c.**	*D.m.***	*P.c.*	*D.m.*	*P.c.*	*D.m.*	*P.c.*	*D.m.*
CM	26	71	42	41	16	56	4	32
CM+SD	50	85	57	94	25	51	7	22
CM+SS+SD	30	71	33	82	37	31	24	7
CM+OFMSW+SD	75	85	89	92	19	25	15	18
CM+FW+SD	50	93	64	71	20	14	5	11
CM+F+SD	92	70	82	83	17	60	10	51
CM+CF+SD	55	74	65	52	17	21	7	9
CM+dSS+SD	84	80	83	65	18	27	5	13

***** Toxicity of waste and wastes' mixture were estimated with the test object *P. caudatum*

** Toxicity of waste and wastes' mixture were estimated with the test object *D. magna*

Results of phytotoxicity assessment of the compost mixture are presented on Figure5. The starting mixtures had a high phytotoxicity with respect to *A. sativa* (GI = 10-38%). By 30th day, GI values did not differ significantly from those on 0th day (15-46%). This was probably due to the fact that during this period the compostsare in theirthermophilic stage; and an active decomposition of organic substances to the compounds having a phytotoxic properties, such as organic acids, particularly, acetic acidoccured [5]. Moreover, CM contains many nitrogen compounds which are decomposed to ammonia having phytotoxic effect at a high concentration [5], [29]. The relationship between the ammonia content in the compost from animal waste and its phytotoxicity was previously demonstrated by other authors [29]. On 60th day, GI in compost mixtures has risen and its value was within the range of 45-76%. On 90th day of composting, mixtures were non-toxic or low-toxic, that allows us to recommend them for use as non-traditional fertilizers. Thus, the minimum GI has been found for the variant CM+CF+SD and amounted to 71%.

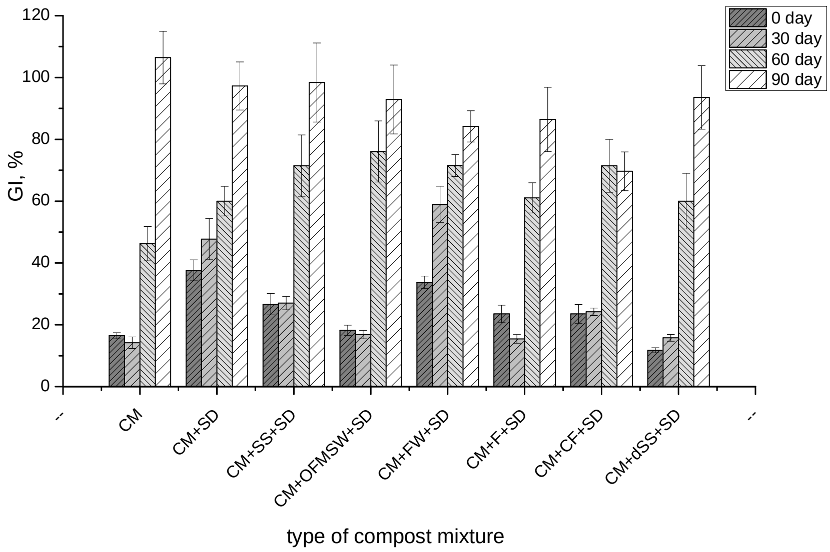

Figure 5. Change in phytotoxicityupon composting waste mixtures based on chicken manure (contact method)

Similar data are presented in the literature. When composting CM with straw, Khan et al. [5] noted an increase in phytotoxicity to 28th-56thdays, followed by a decrease to 126th days, before to GI values of approximately 80%.Gao et al. (2010) observed the sharp increase in phytotoxicity during composting CM with sawdust to 3-15 day (GI was 6-10%), and to 120th day GI changed at between 55 and 94% depending on C / N ratio in mixture. When compostingCM with tomato tops Wei et al. [27] observed a decrease of phytotoxicity from 18% in the initial mixture to 80% to 37th day of composting.According to Shen et al [29], composting CMwith waste of grass and stalks of plants for 25 days made it possible to reduce the phytotoxicity (GI) from 20% to 42-106%.When composting CM with rice straw and waste fungiHe et al. [30] showed a decrease in compost phytotoxicityat 45thday (GI = 96%) compared to the initial mixture (GI = 3%).

CONCLUSION

Thus, when composting CM with the addition of organic waste it was found a decrease in TOC content and increase of TKN for all variants of mixtures. This is probably due to the fact that during the composting process the organic matter is decomposed to volatile compounds, such as CO_2 and H_2O which evaporate;the mass of the compost mixture decreases, whereby a concentration of nitrogen compounds raises. Respiratory activity decreased mainly to the end of composting indicating completion of the active phase of organic matter decomposition; the exception was a mixture of CM+SD, CM+FW+SD. Microbial biomass in general reduced to the end of composting similarly to the change ofTOC content in compost mixtures.CM composting for 90 days resulted in a decrease in toxicity of compost mixtures bothin relation to*P. caudatum*, and to *D. magna*.It is worth noting that the test objects show different toxicityfor the original mixtures and varying degree of reduction of toxicity for 90 days. The initial mixtures had a high phytotoxicity; to 90th day of the process all variants, except for CM+CF+SD reached more than 80% GI what allows using thesecomposts as fertilizers for nonfood cultures.Based on the complex of the data obtained, co-composting of CM withSS proceeds more efficiently in terms of both physical and chemical, microbiological and toxicological properties of the compost.

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