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BIODEGRADATION OF WOOL WASTE: THEORY AND PRACTICAL ASPECTS

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Abstact

The elimination of waste from every industry is one of the critical problems facing manufacturers. Different technologies for different types of waste can be used in a way that is as convenient as possible for the manufacturer. Textile industry is one of the fields of activity that produces a series of biodegradable waste. Among these, the waste generated by the industrialization of wool is a product whose disposal in the environment requires sustainable treatment processes. Therefore, scientific literature has proposed the transformation of waste wool by composting and its direct use as an amendment for agricultural and gardening soils.

***Key words**: waste wool, biodegradation, recycling, agriculture, composting.*

INTRODUCTION

The textile industry affects the environment by: high consumption of water used for wool washing, energy consumption and pollutants. Also for the solubilization of wool cloth substances that provide protection for animals against precipitation, as well as the large amount of waste generated by the felt processing technology.

Wastes from the wool processing industry, respectively from the felt factory, are a secondary problem, but at the same time important, which is generally solved by the accumulation of large quantities of waste deposited in the special waste disposal site, being transported in the final landfill.

In addition, Directive 75/442/EEC establishes a waste hierarchy. The most desirable is the prevention of waste and the minimization of waste generation, by these measures being understood also the transformation into compost (raw material as an organic fertilizer for agriculture). Waste is thus transformed into raw material for composting that no longer generates waste, being a beneficial product for agricultural production.

European Directive (1999/31/EC) on the landfill of waste for the collection and processing of biodegradable waste as well as the European Directive (2008/98/EC) laying down measures for the protection of the environment and the health of the population. Composting is a means of achieving minimal expense and maximum benefit if used as a concentrated organic fertilizer applied to crops with long-lasting vegetation.

MATERIALS AND METHODS

The compost burst was built on the field of University of Agronomic Sciences and Veterinary Medicine of Bucharest. In the summer of 2017 wool wastes from the felt factory, wheat straw and cattle dung from the Prince Mill. Waste is considered as a residual polluting product by the felt industry but can be used as raw material and not as waste in the form of compost, as an organic fertilizer and as an amendment to soil fertility, generating benefits at minimal cost.

In order to build the composting pile under ideal conditions and to obtain sufficiently high temperatures, for the sterilization of weed seeds and pathogenic microbial agents, other organic waste was used to stimulate the composting process (Wiese et al., 1998; Hustvedt G. et al., 2016).

Due to the high organic nitrogen content of wool fibers (waste), we used the supra unit fraction to obtain the proper proportions of composting materials composting:

$$R = \frac{M_1[C_1(100-U_1)] + M_2[C_2(100-U_2)] + M_3[C_3(100-U_3)]}{M_1[N_1(100-U_1)] + M_2[N_2(100-U_2)] + M_3[N_3(100-U_3)]}$$

where:
R - C/N ratio;
M_1, M_2, M_3 - mass of materials subject to composting (g, kg);
C_1, C_2, C_3 - carbon of materials (%);
N_1, N_2, N_3 - nitrogen of materials (%);
U_1, U_2, U_3 - moisture of materials (%).
Following mathematical calculations, we obtained a C/N ratio of 20-25 (Table 1).

Table 1. The C/N ratio in 2017 to the construction of the compost pile

The material	H_2O %	Mass (g, kg)	C %	N %	Report C/N (20-25)
Straw	10.19	10	48	0.5	22.448
Wool waste	21.47	1	50	17	
Cattle buckwheat	45	3	25	3	

The composting pile contains 10 kg of straw, 1 kg of wool waste and 3 kg of bovine manure in successive layers. The mixture was made in the stamps, so as to obtain uniformity of the materials subjected to composting (Figure 1).

Figure 1. Laying in successive layers of materials subject to composting

The compost burst was built according to P. Pfeiffer's recommendations in 1966 so it is presented in (Figure 2).
The layering of the materials subject to composting has been done manually for a better distribution of materials.
The waste of wool was evenly distributed along with straw and bovine manure.
The height of the compost pile ranged from 1.5 to 2 m depending on the degree of decomposition of the materials.

Figure 2. Compost piles after Pfeiffer P., 1966

This height allowed the heap to generate enough heat to inactivate pathogens (including weed seeds). Removal of the composting pile was done monthly, manually, from top to bottom to ensure that the exposed exposed surfaces were buried inside the pile each time the pile was reshaped. This allowed all weed seeds and pathogens to be exposed to high temperatures inside the heap. Humidity was provided by spraying.

RESULTS AND DISCUSSIONS

In the first month of the pile construction, the temperature was measured in the middle of the pile once every 2-3 days, approximately the same hour, in three rehearsals.
For this, temperature evolution was tested by 18 determinations. Using the Excel application, linear regression (Figure 3) and square regressions (Figure 4) and cubic (Figure 5) were determined for which the correlation ratios (Table 2) were determined to determine the function that best approximates the composting process.

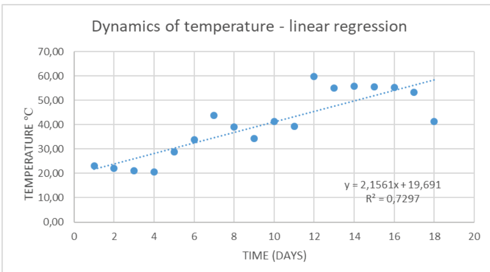

Figure 3. Regression of the temperature relative to the incubation period in the composting piles in the Experimental Field of the Faculty of Agriculture - Bucharest in 2017

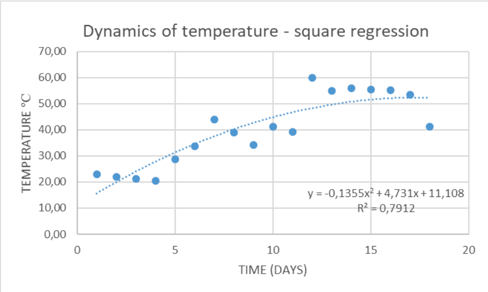

Figure 4. The quaternary regression of the temperature from the incubation period in the composting piles in the Experimental Field of the Faculty of Agriculture - Bucharest in 2017

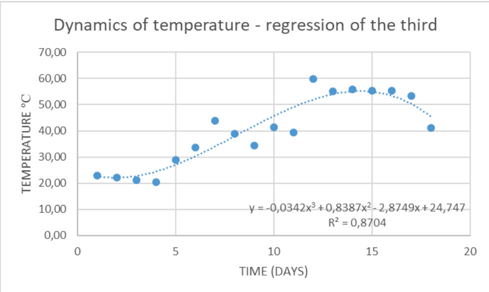

Figure 5. The third degree regression of the temperature from the incubation period in the composting piles in the Experimental Field of the Faculty of Agriculture - Bucharest in 2017

Table 2 shows that the highest correlation correlation coefficients of 0.932 were achieved at cubic regression, although at 18 pairs of values both linear regression with the correlation ratio of 0.854 and the square with 0.888 of the test showed them very significant.

Table 2. Regressions and values of correlation ratios that related to the temperature and incubation period in the incubation process

The type of equation	The value of R under the radical	Semnificației
$y = 2{,}156x + 19{,}691$	0.854	***
$y = -0{,}135x^2 + 4{,}731x + 11{,}108$	0.889	***
$y = 0{,}034x^3 + 0{,}838x^2 - 2{,}874x + 24{,}747$	0.932	***

The mixture was monitored and remixed once a month as the heap temperature began to decrease, averaging 41.23°C.
This low average temperature is due both to the depletion of the sources of nutrition of heterotrophic microorganisms and to the reduction of compostable organic matter, as well as to the decrease of atmospheric temperatures.
One month after the founding of the pile, we found molds on straw but also on wool waste (Figure 6).

Figure 6. Appearance of molds on wool waste under composting, 2017

As can be seen in Figure 6, we find that actinomycetes and fungi micelles are colonized on the material subjected to composting (prehumic materials) with heterotrophic bacteria.
Some of these are thermogenic (heat), which contributes to the increase of the temperature from the compost stack to the average of 59.83ºC, as self-biosterilization agent, when the humification and mineralization processes begin to satisfy both the release of mineral molecules and molecules of related pre-human substances.
The color of materials subject to composting becomes more and more dark. The wool (waste) wool due to the keratinous outer cover is hardly biodegradable and therefore we have introduced as a stimulator for the biodegradation of the keratin layer, the bovine waste.
The introduction of the bovine manure into the composting mixture was done to stimulate the growth of the number of heterotrophic microorganisms necessary to stimulate the keratinolytic factors, which would degrade the keratin embodying the wool yarn.
The aspect of biodegradation of wool waste was followed by a microscope, obtaining the photographic image (Figures 3, 4, 5) of the appearance of keratin biodegradation.

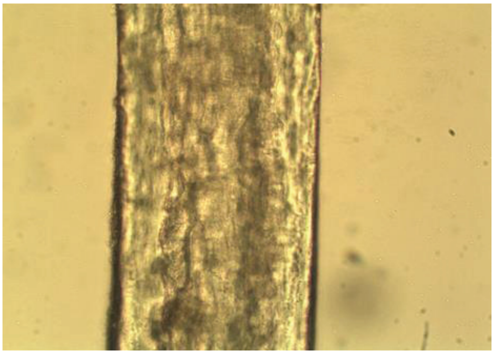

Figure 3. Appearance of uncomposed wool waste

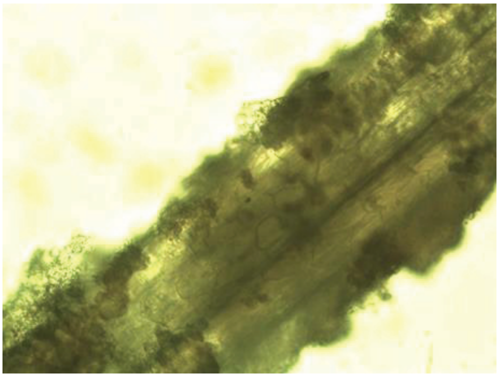

Figure 4. Appearance of compost wool waste in the first month of reshuffle

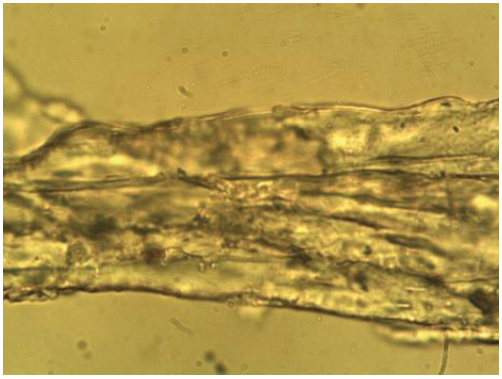

Figure 5. Appearance of wool debris with degraded keratin layer

After maturation, compost produced from wool waste, cattle manure and wheat straw was sifted manually.

The compost samples were then sent for analysis to the Chemistry Laboratory of the Academy of Agricultural and Forestry Sciences "Gheorghe Ionescu-Şişeşti" (Bucharest).

Since the compost pile is diminishing over time in size, the collected samples were inside the pile, for the analyzes to be representative of all materials subject to composting. According to the analysis report, the chemical test method of the mixture of compost materials is shown in (Table 3), as follows:

- Organic carbon (Corganic), wet oxidation;
- Organic matter (MO) through loss at calcination; Methodology I.C.P.A. (1981), Vol. 1, Cap. 23, PT 44;
- Azot Kjeldahl (Nt), SR EN ISO 20483: 2007, PTL 11;
- Nitric nitrogen (N-NO3) determined potentiometrically, ICPA Methodology (1980), ch. 4 PT 98.

Table 3. Analytical results

No	Identification	$C_{organic}$ %	MO %	N_t %	N-NO_3 mg/kg
1	Repetition 1	17.3	34	1.302	178
2	Repetition 2	18.0	37	1.318	177
3	Repetition 3	19.4	36	1.323	178
Average		18.2	35.6	1.314	177.6

The results of these tests indicate that, on average, compost produced from wool waste is suitable for use in agriculture.

CONCLUSIONS

The experiment presented in this chapter was an attempt to understand the use of wool waste for agricultural purposes as an extremely valuable organic fertilizer as raw material for obtaining superior, unpolluted and non-waste agricultural produce.

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