Thesis of Doctoral (PhD) Dissertation

EVALUATION OF THE PRODUCTION AND USE OF POULTRY MANURE-BASED COMPOST PRODUCTS

Edit Gorliczay

Supervisor: Prof. Dr. János Tamás

UNIVERSITY OF DEBRECEN
Doctoral School of Animal Science

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1. THE BACKGROUND AND OBJECTIVES OF THE DOCTORAL THESIS

Among the farming systems, in the 19th century, nutrient supply was based on manure, but with the emergence of industrial systems and the separation of livestock and crop production, nutrient supply became based on fertiliser use. Growing consumption and population growth have increased yields per unit area of crop production, while livestock production has (almost) halved in recent decades. Among the livestock sectors, poultry production is increasing due to its intensive source of protein and the large amount of biodegradable waste and by-products generated by intensification (GARG, 2012), of which the amount of manure generated is significant.

In Europe, an estimated 1.4 billion tonnes of manure were generated in 2011 (FOGED et al, 2012), in which the amount of primary macronutrients was as follows: 7.1 Mt nitrogen, 1.8 Mt phosphate and 8.0 Mt potassium (EHLERT et al, 2015). In Hungary, ~ 4 million tons of manure is produced annually, which is used on 250.000 ha. Due to increasingly strict animal health regulations, manure is an "environmental pollutant" that livestock farmers are trying to get rid of. At the same time, the concept of the circular economy underlines the inescapable role of animal manure in soil management, which has always been a fundamental link between livestock and crop production in agriculture. A biodegradable organic matter management system that focuses on the organic matter cycle to maintain soil fertility in the long term and creates a shared interest between crop and livestock farmers in the use of animal manure should be established (HERMAN OTTÓ INSTITUE, 2020).

The legal classification of manure, according to which the manure is a by-product or a waste, shows a duality, as Decree 72/2013 (VIII. 27.) of the Ministry of Rural Development on the list of waste, which contains the main groups, subgroups and certain types of waste, manure classifies as 02 "wastes from agricultural, horticultural and aquaculture production, forestry, hunting, fishing, food production and processing". The Act of Wastes does only cover the concept of biodegradable waste, which is“ any waste containing organic matter that is aerobically or anaerobically biodegradable or degradable, including bio-waste”.

In contrast, the National Waste Management Plan (2014-2020), in addition to introducing the concept of waste hierarchy, defines in which case a substance can be considered a by-product. The concept of by-product was introduced in order to separate the generation of the main product and the by-product during production. The previous National Waste Management Plan (2009-2014) classified manure as agricultural by-products and waste from the agricultural and food industries. According to the National Waste Management Plan currently in force, the 23% decrease in the amount of agricultural and food waste generated can be explained (among other things) by the fact that “as of 2007, plant and animal by-products that are directly recycled in production processes are no longer included in waste statistics". According to the current National Waste Management Plan, a by-product is any substance for which (1) further use is ensured, (2) it can be used directly after production, (3) it is produced as an integral part of the production process, (4) it does not adversely affect the environment or human health and (5) its further use is lawful, that is, it complies with all legal requirements relating to the protection of the environment and human health. Based on these and those described in the National Waste Management Plan, manure qualifies as a by-product, as it meets the conditions for classification as a by-product.

The further use of manure is ensured, as it can be said about domestic agriculture that there is not enough organic matter in the crop production sectors, but in contrast, the use of manure has decreased significantly. Nutrients are the limiting factors in agricultural production. Nutrients are essential in biomass production, in the crop production sectors. Around 112 Mt of nutrients were used worldwide in 2013, and this increased to 120 Mt in 2018 (based on FAO statistics). Nutrients can be replaced not only with fertilizers, but also with organic fertilizers, because not only the macroelement but also the microelement content is significant. However, in order for manures to be able to replace fertilizers, it is necessary to treat them in such a way that a significant part of their volatile nitrogen content does not leave as air pollutants. However, the processing of organic fertilizers is slowly being incorporated into agricultural practice, as in 2010-2011 only 7.8% of the resulting manure was treated by some process (aerobic or anaerobic fermentation) (FOGED et al, 2012). Maintaining and increasing soil fertility can also be solved by turning plant by-products into the soil, however, the lack of organic fertilizers of animal origin induces such unfavorable effects in the soil as declining crop safety and deteriorating productivity. In addition, the use of animal fertilizers and compost also contributes to the sustainability of the carbon cycle in the soil. Manure are increasingly seen as a problem by farmers, as they cannot be stored on livestock farms due to animal health considerations, but manure can become polluting in the event of improper storage or application. That is why it is important to look for ways to implement circular farming: products made from livestock manure from livestock farms can be used for organic nutrient replenishment in crop production technologies, so that by-products from agricultural activities can be kept on the farm. According to the provisions of the Nitrates Directive, a temporary pile of manure can be established on the agricultural field, so the maturation of the manure to be applied can be solved, and the maturation can also be replaced by composting. Organic fertilisers are increasingly seen as a problem by farmers, as they cannot be stored on farms for animal health reasons, but can become an environmental pollutant if not stored or applied correctly. It is therefore essential to look for ways to achieve circular farming: products from livestock manure produced on farms can be used for organic nutrient replenishment in crop production technologies, thus keeping by-products of agricultural activities on the farm. Under the Nitrates Directive, a temporary manure heap can be set up on the agricultural field to allow the organic manure applied to the field to mature, which can be replaced by composting.

Composting increases the quality of raw manure and reduces the environmental risk of application (BRAKE, 1992; HAGA, 1999), as well as reducing the volume and weight of manure, killing pathogens and weed seeds, and reducing unpleasant odors and stable organic matter, and nutrient-containing compost can be produced as a final product (MICHEL et al, 1996; PARKINSON et al, 2004). Composting is the spontaneous biodegradation of organic matter, dominated by aerobic conditions (BERNAL et al, 2009). Composting plays an important role in waste and by-product management. Only a part of the biomass generated in agriculture appears as waste, as it plays an increasingly important role in both sustainable energy management and circular farming.

According to the database of the Waste Management Information System, the amount of recycled, composted, biomass treated by incineration or biogas production during energy recovery was 744 thousand tons in 2011, which is only 12% of the amount of biomass treated in 2004, but between 2009-2011 the amount of biomass utilized by recycling and composting increased again (I1). According to one of the specific action directions of the current National Waste Management Plan, "composting and direct return of agricultural and food waste and by-products to the biological cycle can also be a good solution". On this basis, it is therefore necessary to promote the introduction of by-products, including manure, into the organic cycle. In line with this, one of the most important measures for the European Union is to introduce the concept of a circular economy instead of a linear (one-way) economic model, focusing on the fact that biodegradable biomass landfilled or incinerated can provide significant potential secondary raw materials. instead of landfilling, they are treated appropriately, ie (primarily) composted, thus creating valuable, high value-added nutrients from it (BÉRES et al, 2017). This approach needs to be centralized in current agricultural practice, as soil fertility can be sustained with compost instead of fertilizers. If manure is treated with the circular economy in mind, the amount of greenhouse gases produced will decrease, the amount of carbon stored in the soil will increase with the use of compost in agriculture, the resulting manure will be used at source and the use of fertilizer will decrease imports about 6 million tonnes of phosphorus manure, a significant part of which (almost 30%) could be triggered by withdrawal from manure.

Objectives of the doctoral dissertation:

In my research, I would like to resolve the contradictions between domestic animal husbandry and crop production by easing the emphasis on the innovative possibilities of using organic by-products of animal origin, mainly from poultry farming, and their application in nutrient replenishment.

The research aims of my work in details:

1. the physical, chemical and biological properties of the windrow composting system how change as a function of the technologies and the possible starting materials and additives.

2. analyzed and modeled the process-modifying effect of temperature, pH, electrical conductivity, and moisture content in the windrow composting system.

3. determined the key parameters of compost tea prepared under non-aerated conditions and their effect on inorganic chemical parameters.

4. determined the optimal cultivation technological parameters of poultry manure-based products in a soil-plant system, based on different horticultural test plants, doses and soil types.

2. MATERIALS AND METHODS

The laboratory experiments and measurements were performed at the University of Debrecen, Research Center of Organic Matter. The broiler and hen manure used during the composting experiments came from Baromfi Coop Ltd. Within the framework of the project entitled "Development and market introduction of a multi-purpose organic bioferment product family", GINOP-2.2.1-1-2017-00043, the Institute of Water and Environmental Management cooperated with Baromfi-Coop Ltd. as a consortium partner. One of the objectives of the project is to evaluate the content parameters of compost raw materials and to optimize the industrial composting system.

2.1 Experimental settings

2.1.1. Preliminary composting experiments

The composting experiment was included as a preliminary experiment in the series of studies. The reason for this was that homogenization by agitation during composting fundamentally affects the heat, water and nutrient management of the compost matrix, i.e. ultimately the efficiency of the entire microbiological process. Under industrial conditions, it is more difficult to create a completely homogeneous space due to the effects of quantity and size, as it depends on the consistency of the material, the design of the reactor space and the mixing solution. It was reasonable to examine what could happen in inhomogeneous "dead spaces" where mixing is less efficient. The aim of the pre-experimental study was to determine the extent to which the suboptimal mixing conditions that occasionally occur in the Hosoya manure fermentation reactors in Nyírjákó influence the fermentation process in the case of composting. Thus, we modeled what processes take place in composters less homogenized by the agitator of the industrial composting system. The size of the prisms was the same and consisted of a mixture of the same 40 kg and 3:1 ratio of broiler and hen manure, for which 0-1-2-5-7% w/w (0.4-2.8 kg) zeolite was added. The ratios were chosen to be the same as those used in the fermentation reactors of Baromfi-Coop Ltd. The time of the composting experiment was 62 days, and the prisms were homogenized by hand every three days.

2.1.2. Preparation of compost tea

Compost solutions were prepared under non-aerated conditions. We examined the key parameters defined and considered by INGHAM (2005). These are compost/water ratio (CWR), extraction time, extraction temperature, mixing and its intensity. These factors affect the parameters of the solution prepared. The settings used in the preparation of the tea are detailed in Table 1.

Table 1: Experimental settings used in the preparation of compost tea

Compost/water ratio (CWR)	1:2,5 1:5 1:10 1:20 1:30 1:40 1:50
Extraction time	1h (absolute control) 24h 48h 72h
Extraction temperature	20°C 25°C 35°C 50°C

The choosing of compost/water ratios we taken into account ISLAM et al. (2016) and ZHANG et al. (1998) previous results. In choosing the extraction time and extraction temperature, according to INGHAM (2005), we worked with extraction time of 24-48-72h. We worked with 1h extraction time too, in order to determine the absolute control, i.e. the initial state in the preparation of the tea. The devices used to set up the experiments were sterilized with wet steam in an AE-75 DRY autoclave. After sterilization, the compost mixture was weighed into a 0.7 l glass jar, and destillated water was added and mixed. After that, I shook the solutions at 130 rpm on an Unimax 1010 shaker and adjusted the extraction temperature as described. After the extraction time, 50 ml of the compost solutions were weighed into a centrifuge tube and centrifuged at 3000 rpm for 3 minutes using a ROTOFIX 32 centrifuge, and the centrifuged solutions were used to determine the nutrient content of the solutions, and the not centrifuged tea were used to determined the pH and the electrical conductivity.

2.1.3. Investigation of the applicability of compost tea in cultivation technology

In this study, our aim was to determine the optimal cultivation technological parameters of broiler and hen manure-based compost solutions in a soil-plant system using different horticultural plants, doses and soil types. The test plants and soils shown in the table below were used to test the compost solution (Table 2).

Table 2: Applied test plants, soil types, water capacity level

Applied test plants	Soil types	Water capacity level
White sweet pepper (*Capsicum annuum* L., fajtája: Ceremony F1)	Slightly humous Arenosol	Water Capacity 70 w/w%
Cabbage (*Brassica oleracea* L. convar. *capitata* provar. *capitata* Dutch, fajtája: Autumn Queen F1)	Arenosol	

To test the suitability of compost tea for cultivation, white sweet pepper (*Capsicum annuum* L.) and cabbage (*Brassica oleracea* L. convar. *capitata* provar. *capitata* Dutch) were chosen as test crops. I chose these test plants because, firstly, they are two plants that are important for horticultural production, secondly, I would like to test the compost suspension mainly on economic crops, thirdly, I wanted to include plants that can be irrigated without any conditions and thus the effects of water stress can be detected quickly, and I wanted to select short-lived varieties and plants for the quick evaluation of the experiment.

I chose Arenosol and slightly humous Arenosol because the forage production areas of Baromfi-Coop Ltd. are located in the Alföld, and one of the typical soil types mainly the Northern Alföld and the Nyírség is sandy soils (Arenosols) with low productivity. The selected soils belong to the category 'Arenosols' according to the World Base Reference of Soil Resources (hereafter WRB). Soils in this category are characterised by low water holding capacity and high water permeability, as well as low nutrient content, all of which causes them to rapidly develop water stress, which was one of the study factors in my research (FAO, 2015). Soils that are sparsely vegetated and susceptible to wind erosion belong to this major group (SPAARGAREN, 2004). Arenosol soils are characterised by a partially developed topsoil layer with low humous content and no subsurface clay accumulation. In addition, the aggregate thickness of the finer textured layers is less than 15 cm, "the proportion of coarse debris within ≤100 cm of the mineral soil surface in each layer is <40 w/v%" (HUNGARIAN SOIL SCIENCE SOCIETY, 2020).

According to the national classification system, Arenosol and slightly humous Arenosol belong to the main type of peat soils, and are found in 8.3% of Hungary. They are characterised by rapid mineralisation of organic matter, lack of organic colloids, poor water management, poor nutrient supply and drought sensitivity. The conditions necessary for biological soil formation processes in the formation of these main soil types are only present for a short period of time, and therefore their impact is limited.

I chose 70 w/w% of the field water capacity (FWC) (which is a higher water capacity level than in arable technologies) because of the test crops I chose and because plants are sensitive to water supply during planting, especially at rooting, and so I aimed for a "luxury" water supply in my experiment. The field water capacity of 70 w/w% can be ensured in closed greenhouse cultivation, as irrigation rotations in the field result in lower water capacity levels compared to greenhouse technologies.

Based on the inorganic chemical parameters of the compost tea and the nutrient requirements of the test plants, I selected two suspensions and tested their effect in irrigated form. Compost solution I consisted of a mixture of composted broiler manure and hen manure, while compost solution II consisted of a mixture of composted broiler manure, hen manure and meat meal. The chemical characteristics of the suspensions are shown in Table 3.

Table 3. Chemical characteristics of the tested compost solutions

Parameters	**1:10 CWR, 24h extraction time, 20°C extraction temperature compost solution (Compost solution I.)**	**1:10 CWR, 48h extraction time, 35°C extraction temperature compost solution (Compost solution II.)**
pH	7.16	6.59
EC* (mS/cm)	6.27	14.82
NO_3^- (mg/l)	815.55	1002.22
NH_4^+ (mg/l)	317.77	1426.67
PO_4^{3-} (mg/l)	268,88	651.11
K^+ (mg/l)	1444.44	1000.01

*Electrical conductivity (mS/cm)

Due to the concentration of the chosen compost solution and the needs of the test plants, the solution was applied to the test plants in a five-fold dilution. Phosphate is the minimum nutrient in both suspensions, but the nutrient requirements for edible peppers are different depending on the phenological stage: in the generative stage, potassium predominates over nitrogen (N:K ratio 1:1.5), as the correct ratio of these macroelements is essential to maintain the vegetative-generative balance. According to TERBE (2014), if a significant part of the nutrients is present in the soil in a water-soluble form, it contributes to the plant's nutrient supply. In contrast, the chemistry is lower for compost solution II, but the specific conductivity (mS/cm) of suspension II is almost 2.5 times higher than that of compost solution I, but the potassium content is much lower compared to compost solution I.

The experiments were carried out in three replicates, both after 4 weeks and after 8 weeks of eradication, with once-weekly and twice-weekly watering doses.

2.2. Measurements and used equipments

2.2.1. Measurements during composting preliminary experiments

The sampling strategy was developed according to the standard for manure (MSZ-08-0014-78) by sampling the front, middle and rear prism material along the longitudinal axis of the prism in 15, 35 and 55 cm longitudinal sections. Moisture content was monitroing by gravimetric method (MSZ-08-0221-1:1979) on days 0, 1 and 2, and then every three days thereafter. The temperature was measured with a PT100 type thermometer in the three sections mentioned above at a depth of 12 cm. The pH and electrical conductivity (mS/cm) were measured with a HI 2550 laboratory instrument by potentiometric and conductometric methods. Measurement of pH and electrical conductivity was performed by JANCZAK et al. (2017) and IRSHAD et al. (2013) were measured from a 10% destillated water suspension after shaking 24h on an Edmund Bühler KS-15 shaker.

Spectral measurements were performed in the wavelength range of 400–2500 nm using compost samples dried to constant weight. The AvaSpec 2048 spectrometer was used in the wavelength range of 400-1000 nm, in the visible (VIS; 400-700 nm) and near infrared (NIR 700-1300 nm) wavelength range, with a resolution of 0.566 nm, and precision of 1 nm. AvaSpec-NIR256-2.5-HSC spectrometer was used for the 1000-2500 nm wavelength range and also measured in a closed laboratory cabinet. For both spectrometers, 5 spectra were calculated for each compost sample, calculated from the average of 30 measurements each, which was important due to the elimination of measurement uncertainties due to heterogeneity.

2.2.2. Measurement of inorganic chemical parameters of prepared compost tea

The HI 2550 laboratory measuring instrument mentioned in the previous section was used to determine the pH and electrical conductivity (mS/cm) of the compost tea. To measure nutrient content, compost tea were first centrifuged and then diluted as needed and measured for nitrate, ammonium, phosphate, and potassium content using a Macherey-Nagel PF-12 Plus photometer and VISOCOLOR ECO reagents.

2.2.3. Measurements in soil-plant system experiments

The experiments were over after 4 and 8 weeks, respectively, and the following parameters were examined:

- **plant height**
- **number of flowers, number of yield, number of leaves;**
- **wet and dry weight of plants;**
- **yield weight, yield number, yield length** (based on SLEZÁK, 2001);
- **measurement of plant stress** (determination of Fv/Fm, Fv/Fo value) with OS30p+ type chlorophyll fluorimeter. With this portable device, we were able to determine, after calibration, the value of Fv/Fm, which correlates with carbon assimilation for both C_3 and C_4 plants, and the value of Fv/Fo, which is not correlated proved by carbon assimilation,

however, as a stress detection parameter, it is more sensitive than the Fv/Fm parameter. Fv/Fm is a normalized ratio developed by KITAJIMA-BUTLER (1975) and is one of the most commonly used methods for measuring plant stress. According to MAXWELL-JOHNSON (2000), the value of Fv/Fm in the case of healthy vegetation is between 0.79 and 0.89, in the case of a lower value the plant is exposed to stress.

- **determination of chlorophyll and carotenoid content:** fresh leaf samples were homogenized with 80% acetone and quartz sand, and then settled in a HETTICH ROTOFIX 32A centrifuge at 3 minutes at 3000 rpm. 2.5 ml of the clear solution at the top of the centrifuge tubes was pipetted into a quartz cuvette and the absorbance of plant extracts was measured with a SECOMAN Anthelie Light II UV-VIS spectrophotometer at 470, 644 and 663 nm. Prior to the measurements, zero calibration was performed in all cases, using 80% acetone. We used the equation from DROPPA et al. (2003) and I calculated the total chlorophyll content:

Equation 1.

$$CL_{A,B} = (20.2 * A_{644} + 8.02 * A_{663}) * V/w$$

where the factors in the above equation are:

$CL_{A,B}$= chlorophyll A and B (μg/g) (per gram of fresh weight)

A_{644}, A_{663}= the absorbance of 644 and 663 wavelenght

V= volume of liquid plant extract (ml)

w= weight of fresh plant sample (g)

To calculate the carotenoid content we used the equation based on LICHTENTHALER et al. (1983):

Equation 2.

$$CA= (1000*A_{470} - 3.27*(12.21*A_{663} - 2.81*A_{644})-104*(20.13*A_{644} - 5.03*A_{663}))*V/w$$

where the factors in the above equation are:

CA= carotenoid content (μg/g) (per gram of fresh weight)

$A_{470,663,644}$= the absorbance of 470, 663 and 644 wavelenght

V = volume of liquid plant extract (ml)

w = weight of fresh plant sample (g)

The HI 2550 combined laboratory instrument was used to measure the pH and electrical conductivity (μS/cm) of the soil samples from the experiment.

2.3. Statistical data evaluation methods

I used several statistical methods to evaluate the results obtained during the studies. For each measured parameter, I entered the data into Microsoft Office Excel software and created a database. Statistical analyzes were performed using R software in the R Studio user environment (R CORE TEAM, 2017).

To confirm statistical differences between treatments, I used one-way ANOVA at a significance level of $p<0.05$. Before performing the analysis of variance, Shapiro-Wilk normality test was used to assess whether the variable under study was normally distributed or not. If the data set was not normally distributed, then I used (non-parametric) Kruskal-Wallis test and if it was normally distributed, then I used Duncan test.

In cases where none of the above tests were applicable (because the singularity of the experimental data made this calculation infinite), I used the Student-Newmann-Keuls (hereafter SNK) test. Since the SNK test does not give the Least Significant Difference (LSD), I used the LSD test to determine it.

Anova with repeated measures factors was used to evaluate the results of the composting pre-test. In the repeated measures model, temperature was the factor of interest, treatment was the fixed effect, week was the random effect, and even prism ID/week was the random fluctuation.

I exported the spectral measurement results from AvaSoft 8.0 to Excel and saved the Excel spreadsheet as a text file. The inflection points were determined in ENVI (The Environment for Visualizing Images) Classic software environment by binary encoding of spectral curves (BÖKFI et al, 2016). I created a database from the spectral data by taking five replicates of the spectral measurements and adding temperature, humidity, pH and electrical conducivity data to the database. From the resulting database, I performed a principal component analysis (PCA) using the varimax method (rotation) with a right-angle rotation, using SPSS 24 software to group the variables under study and determine the correlation between them. To be able to determine the wavelength ranges sensitive to compost maturity and to the material quality of compost mixtures and to form indices, I needed the principal component weights obtained from the principal component analysis and the physico-chemical parameters under study, which belong to which principal component group.

To test the reliability of the prediction models (indices), I also calculated the root-mean-square error (RMSE) and the normalized root-mean-square error (NRMSE).

3. RESULTS

3.1 Results of the preliminary composting experiments

The aim of the composting experiment was to determine the parameters that can be used to model the processes during the composting of poultry manure, and which parameters can be the basic parameters of composting and are sufficient to describe the aerobic degradation process.

Based on my results, the moisture content can be said to be different from the optimal moisture content of around 60 w/w% (KOCSIS, 2005) defined in the literature, in the case of the broiler and hen manure mixture I used, the 50 w/w% moisture content is enough for the composting process. Furthermore, it can be said that the higher the proportion of zeolite incorporated, the lower the moisture content in the prisms. The moisture content of the prism mixed with 7 w/w% zeolite follows the same trend as the lower zeolite mixes, however, the moisture content of this treatment was lower by -5 w/w% and even by -10 w/w% for all measurements. To demonstrate that the moisture content decreases with the mixing of larger amounts of zeolite, I performed a one-way ANOVA to demonstrate significant differences between the 9-week mean moisture contents. Based on the statistical analysis I proved the decrease in moisture content with increasing zeolite content.

At temperature, both the control and zeolite-treated prisms became independent of the ambient temperature. The stages of composting can be separated on the basis of temperature not only from the measurement results, but also statistically (considering the average temperature of the prisms, the homogeneous temperature days formed a group, which were also indicated by the letter indices obtained on the basis of analysis of variance). As the proportion of zeolite increased, the length of the thermophilic phase increased: this stage was 13 days for the control and 27 days for the 7 w/w% zeolite.

In the case of the control prism, the composting stages can be separated on the basis of pH. The 1-3 weeks is a period during which the pH decreased due to the formation of organic matter due to the intensive decomposition of organic matter, then in 3-6 weeks the pH of the compost changed between 7-8, and then the last time of composting. stage (weeks 7-9), the pH was neutral during the maturation phase. In the case of prisms mixed with zeolite, I expected to experience the alkalizing effect of zeolite, but I was able to identify the opposite process, as the increasing zeolite mixing ratio reduced the pH. For prisms mixed with larger amounts of zeolite, the zeolite probably bound not only ammonia but also other exchangeable ions. In the case of zeolite, the binding of hydrogen ions on the particles is weak, which causes competition between the individual ions at the binding sites. Due to the binding of other ions in the manure (calcium, potassium ion) on the surface of the zeolite, the hydrogen ion enters the compost, which causes the acidification of the compost. This is one of the reasons why the pH decreased with increasing amount of zeolite. In addition, the acidification of the prisms was also caused by the shifting of the ammonia-ammonium balance towards ammonia due to the decreasing pH. These effects added up: as the amount of zeolite increased, the medium became acidic, and this decreasing and low pH resulted in a predominance of ammonium ion in the system, which was bound on the surface of the zeolite. For this reason, no odor effect was observed in the windrows mixed with zeolite.

In the case of the electrical conductivity, the composting stages developed in the same way as the pH. The electrical conductivity of the compost remained high until the end of composting, which can be explained by the basically high specific conductivity of the fertilizer mixture. In addition, conductivity can be determined by measuring the total solute content, and substances that increased the specific conductivity were dissolved from the compost into the 10% destillated water extract. Based on the repeated measurement model, it can be said that the interaction of treatment, time (weeks) and treatment:week factors significantly influenced ($p<0.05$) the changes in humidity, temperature, pH and electrical conductivity.

3.2. Results of spectral analysis

Spectral studies were performed in the wavelength range of 400–2500 nm. Before the spectral analysis of the compost samples I examined the spectral characteristics of the raw materials (broiler and hen manure, zeolite). Broiler and hen manure can be described by the reflectance curve characteristic of fertilizers as well as soils. The reflectance curves of the two types of manure have the same course, no significant difference can be detected, however, in both wavelength ranges the reflectance of the hen manure shows a higher value compared to the broiler manure. This can be explained by the difference in organic matter between the two raw materials, which could also be measured by conventional analytical methods, as the organic matter content of broiler manure was 58.81 w/w%, while that of hen manure was 66.18 w/w%. There are also two minimum points in the wavelength range 1000–2500 nm: 1450 nm and 1950 nm, which indicate the absorption sites of water on the surface of manure particles. Due to the greyish-white color of the zeolite, its reflectance is high (above 55%), which can be observed up to 900 nm. The strong decrease in the wavelength ranges 1410-1450 nm as well as 1920-1950 nm can be explained by the crystal water content of calcium chloride and the sensitivity of these wavelength ranges to moisture content. Regarding the spectral characteristics of the compost samples, it can be said that the spectral properties of broiler and hen manure largely determine the development of reflectance. For both control and zeolite-treated compost samples, the reflectance of the sampling days showed a constant increase. In the wavelength range of 400–700 nm, the reflectance curves significantly overlap, in the wavelength range of 700 nm a breaking point is observed. In the near IR range, the reflectance curves can be better distinguished, however, overall it can be said that the maturity of the compost justifies the decrease in the reflectance in the studied range, i.e. with the darkening of the compost the reflectance of the samples decreased.

In the wavelength range of 1000–2500 nm, the spectral profile of the control prism can be said that as the days of composting progressed, the reflectance of the compost samples decreased in line with the results obtained in the wavelength range of 400–1000 nm. I expected this during my research, as my hypothesis was that the reflectance of the samples would decrease with the maturation of the compost, which I could prove in the wavelength range of 1000–2500 nm. In the case of control, the reflectance of the sample from day 0 was almost 60%, even the reflectance of the sample from day 58 was only around 40%. Regarding the reflectance of the zeolite-treated compost samples, the results were similar to the control, however, the mixing of a larger amount (above 2 w/w%) of zeolite had no effect on the curve, even the maximum reflectance was around 75%. In the case of samples with zeolite, the reflectance was below 51% for 2/3 of the sampling days, which proves that the compost matures faster due to the increasing amount of zeolite, and that the zeolite did not affect the zeolite in the wavelength range 1000-2500 nm significantly the development of spectral curves and reflectance.

Based on their studies, BÖKFI et al (2016) pointed out the importance of calculating the inflection points of reflectance curves. In my research, I sought to answer the question of whether the amount of zeolite added can be detected in broiler and hen manure mixtures - not only during mixing and in the initial stage of composting, but also during the composting and compost maturation process. The change in the spectral curve is accompanied by a change in the location of the inflection points. The first and second derivatives of the spectral curve are also used to determine the inflection points, but binary encoding can also be used. With binary encoding, the inflection points of the reflectance curves measured for different mixtures can be determined in such a way that the software I use converts the reflectance curve into a convex and concave interpretation curve. In the 400-1000 nm wavelength range, the inflection points are between 710 nm and 760 nm for each experimental setting.

In the control treatment, as the composting progressed, the position of the inflection points changed: it shifted from 732.135 nm to 741.726 nm, which shifted to 9.591 nm. The position of the inflection points changes with the increasing amount of zeolite, as the degree of displacement of the inflection points is 1.7 nm for 1 w/w% zeolite, 20.89 nm for 2 w/w%, 35.516 nm for 5 w/w% zeolite nm, even for 7 w/w% zeolite it was 39.696 nm. Based on these, it can be said that the higher the proportion of zeolite mixed, the more the inflection points shift towards the near-infrared range.

To prove the correlations between the inflection points and the chemical properties measured from the compostes, I performed Pearson correlation, with which I determined the strength and direction of the relationship between the different parameters and whether the given correlation is significant at $p<0.05$ significance level. I considered the determination of correlations important because spectrometric analyzes could only determine the own and characteristic spectral properties of the given substance, in my case the mixture of the two types of manure and zeolite, but often their correlation with other examined factors can be proved. Based on the correlation studies, it can be said that I found a weak, positive correlation between the inflection points and the temperature, which correlation is significant for every treatments and controls ($p<0.05$). In the case of pH, electrical conductivity and moisture content I showed a weak correlation, in some cases uncorrelation. Although the correlation was weak for pH and temperature (R^2 value 0.14–0.55), the strength of the correlation increased with increasing zeolite ratio.

Indices have been designed for the qualitative analysis of different compost mixtures and for the prediction of the physico-chemical parameters studied. Based on the principal component weights obtained from the principal component analysis, I determined the wavelength ranges that could be used for compost maturity and material quality testing of compost. From the principal component analysis, I was able to identify five principal components in the VIS-NIR range, which are presented in the table below (Table 4).

Table 4. Principal components related to physico-chemical parameters in the VIS-NIR range

Principal components	**Number of items**	**Variance (%)**
PC1	992.631	93.030
PC2	64.262	6.023
PC3	4.957	0.465
PC4	1.421	0.133
PC5	1.044	0.098

The principal components show that variables belonging to the first component (PC1) account for more than 93% of the variance, PC2 for 6.023%, and components PC3-PC5 account for a minimum (0.696%) of the total variance. Based on the principal components, I determined the component to which the physico-chemical parameters I investigated (moisture content, temperature, pH, electrical conductivity) belonged, and further worked with the factor weights belonging to PC4. For the factor weights, I only considered the wavelength range between 450-

950 nm, as the factor weights in the 400-450 nm and 950-1000 nm ranges showed a large variance (similar to reflectance). Based on the factor weights, I determined the wavelengths where the factor weight was the largest and the smallest, so the variance between the two wavelengths was the largest. These wavelengths were 812 nm and 941 nm, from which I calculated the ratios $\lambda_{812}/\lambda_{941}$ and $\lambda_{941}/\lambda_{812}$. Based on these, I developed prediction indices for the prediction of the physicochemical parameters studied, which are presented in the table below (Table 5).

Table 5: Results of prediction models generated in the visible and near-IR wavelength range

Examined variable	R^2	Equation	RMSE	NRMSE
Index 1 $\lambda_{812}/\lambda_{941}$ moisture content (MC)	0.3998	MC=-65.79*NT+88.93	6.99	16.33%
Index 2 $\lambda_{812}/\lambda_{941}$ electrical conductivity (EC)	0.134	EC=7.133*EC-2.6195	1.38	18.07%
Index 3 $\lambda_{941}/\lambda_{812}$ temperature (T)	0.4814	T=-108.09*H+190.17	8.34	23.97%
Index 4 $\lambda_{812}/\lambda_{941}$ pH	0.3467	pH=-5.5327*+11.168	0.28	3.93%

As for the prediction indices generated in the VIS-NIR range, I calculated the highest R^2 value for the Index 3 model for temperature, but the RMSE, i.e. the measurement error, was the highest for this model (8.34°C), even the normalized RMSE was 23.97%, i.e. the temperature estimated by the model differed by 23.97% from the measured value. Prediction models with NRMSE >20% cannot be used with sufficient efficiency to predict the parameter. Based on these results, of the indices trained in the 400-1000 nm wavelength range, Index 4 is the most suitable for predicting chemistry, as the R^2 calculated from the ratio of chemistry to $\lambda_{812}/\lambda_{941}$ wavelengths was 0.3467, RMSE was 0.28, and NRMSE was 3.93%. Based on these results, the accuracy of the model is pH 0.28, i.e. the difference between the measured and estimated value is 3.93%. Index 1 also gave good results for the estimation of moisture content (NRMSE<20%), as the coefficient of determination between $\lambda_{812}/\lambda_{941}$ and moisture content was 0.3998, the measurement error (RMSE) was 6.99 m/m%, yet the normalized RMSE was 16.33%. From the indices obtained in the VIS-NIR range, it can be concluded that the models constructed are suitable for the prediction of chemistry, moisture content and specific conductivity, and thus the physico-chemical parameters of compost can be determined by spectral (fast analytical) analyses.

Similar to the analysis in the VIS-NIR range, I also performed principal component analysis in the NIR range, defining the principal components, which I summarize in Table 6.

Table 6. Principal components related to physico-chemical parameters in the near-IR range

Principal components	**Number of items**	**Variance (%)**
PC1	213.726	93.33
PC2	8.164	3.565
PC3	3.436	1.500
PC4	1.168	0.510

Similar to the principal component analysis in the VIS-NIR range, the PC1 component accounts for 93.33% of the total variance in the 1000-2500 nm wavelength range, while the PC2, PC3, PC4 components account for only 5.575% of the variance. In addition to the principal components, the factor weights were also determined. In the analysis of the principal components, I found that the physico-chemical parameters studied did not belong to the same principal component, so I used factor weights belonging to PC2 for moisture content and temperature, and to PC4 for pH and electrical conductivity.

Based on the factor weights, I worked with the ratios $\lambda_{2115}/\lambda_{1993}$ for moisture content and temperature, and $\lambda_{1922}/\lambda_{2127}$ for pH and electrical conductivity. Prediction models were created in the NIR range and the results are presented in Table 7.

Table 7. Results of prediction models generated in near-IR wavelength range

Examined variable	**R^2**	**Equations**	**RMSE**	**NRMSE**
Index 1 $\lambda_{2115}/\lambda_{1993}$ moisture content (MC)	0.4980	MC=49.282*NT-6.9059	2.42	5.71%
Index 2 $\lambda_{2115}/\lambda_{1993}$ temperature (T)	0.6512	T= -210.02*H+244.42	7.83	22.47%
Index 3 $\lambda_{1922}/\lambda_{2127}$ pH	0.4009	pH=-4.1057*pH+11.156	0.28	3.89%
Index 4 $\lambda_{1922}/\lambda_{2127}$ electrical conductivity (EC)	0.1360	EC=-9.4741*EC+16.481	1.38	18.11%

The smallest R2 value was calculated for the electrical conductivity (0.1360) and for this model the NRMSE between the predicted value and the measured value was 18.11%, which is how much my model deviated from the measured value, even though the RMSE was 1.38 mS/cm. On the other hand, the R^2 value between temperature and the $\lambda_{2115}/\lambda_{1993}$ ratio, although indicating a close correlation between the two parameters, was 22.47%, i.e. the temperature value estimated by the model differed by 22.47% from the measured temperature value. In addition, I calculated the highest measurement error (RMSE) value for temperature, which was 7.83°C. However, the indices calculated for moisture content and pH may be suitable for estimation. The R^2 value between moisture content and the $\lambda_{2115}/\lambda_{1993}$ ratio was 0.4980, indicating a medium-strong correlation between the two parameters. The RMSE (2.42 m/m%) and NRMSE (5.71%) also suggest that the model can be used reliably for moisture content estimation. The best values, however, were calculated between the pH and $\lambda_{1922}/\lambda_{2127}$ ratios, as the root mean square error of measurement (RMSE) was 0.28, yet the normalized RMSE was 3.89%.

Based on these predictive indices in the NIR range, models for moisture content, pH and electrical conductivity can be used for prediction.

3.3. Results of the preparation of compost tea

During the preparation of compost tea, my aim was to determine which is the compost:water ratio (CWR), extraction temperature, extraction time combination, with which I can produce a tea with high nutrient content from compost. In addition, my aim was to select the tea that was tested in a soil-plant system, taking into account the inorganic chemical parameters of the prepared solutions and the nutrient requirements of the selected test plants.

In the first phase of the compost tea preparation, I prepared compost tea between 1:10 and 1:50 CWR, and the inorganic chemical properties of which were examined (pH, electrical conductivity (mS/cm), nitrate, ammonium, phosphate, potassium content (mg/l)). In this phase of the preparation of the compost tea, the effect of CWR and the extraction time was investigated, the extraction temperature was uniformly 25°C. Regarding the development of the pH, it can be said that the pH of the compost solutions with a dissolution time of 24h was in the neutral and slightly alkaline range (pH 7-8.1). As the extraction time increased (48h, 72h), the pH of the compost solutions decreased and shifted in the acidic direction (pH 6.3-6.7). Consistent with these results, a similar process was reported by ISLAM et al. (2016), where the pH of compost solutions decreased with extraction time and storage time (pH 8.8–8.1). The decrease in pH by increasing the extraction time can be explained by the fact that atmospheric CO_2, or CO_2 produced as a metabolic product of microbial activity (mainly anaerobic bacteria, fungi), is converted to carbonic acid in water, which is a weak acid. In addition, the decrease in pH can also be explained by anaerobic conditions, which led to putrefaction, and the acidic character may increase as the ammonium/ammonia balance shifts. Regarding the electrical conductivity, it can be said that with the dilution of the tea, the electrical conductivity decreased, which I also proved statistically, because for each extraction time there are significant differences between the different CWR solutions ($p<0.05$). Based on these, it can be stated that the electrical conductivity of different CWR and compost tea with extraction times differs from each other. The close linear relationship between the nitrogen forms and the electrical conductivity (R^2 value 0.88) supports that nearly 90% of the salts in the compost tea produced are nitrogen salts.

For each compost tea, the nitrogen content is divided between NO_3-N (average value in the solutions 90.0 mg/l) and NH_4-N (average value in the solution 189.1 mg/l), while the reduced form, a smaller amount of NO_2-N (mean value in the solution was 0.96 mg/l) was detected in the tested teas. Different forms of nitrogen are important for plant nutrition, the plant is able to absorb nitrogen in the form of both nitrate and ammonium ions. However, it is important that nitrogen is available as much as possible in the form of NH_4 content, as ammonium is much more stable in the soil and is able to bind more strongly to negatively charged soil particles than nitrate. Nitrate binds to soil aggregates with less absorption energy and may therefore pose a greater risk of groundwater contamination. The strong linear regression (R^2 value 0.81) between potassium and ammonium nitrogen can be explained by the fact that the oxidative conditions in the non-aerated tea started the decomposition processes of the organic matter.

In the second stage of the compost tea preparation, I narrowed the CWR and changed the extraction temperature in addition to the extraction time, because I expected that by increasing the extraction temperature I could produce teas with higher nutrient content. Based on these, I used destillated water as a weak agent to prepare the reduced ratio solutions (similar to the wide ratio compost solutions) and I prepared 1:2.5-1:20 CWR compost solutions. The studied parameters were the same as in the case of wide compost teas. Regarding the development of the pH, it can be said that, similarly to the broad CWR compost solutions, the pH decreased with the extraction time of these compost solutions. The pH values for extraction time of 24h pH 6.47-7.54; at 48h, the pH ranged from 6.18 to 6.85, and at 72h, the pH ranged from 6.17 to 7.18. There are no significant differences between the different CWRs within the different extraction temperatures (20°C, 35°C, 50°C). The pH of the compost used as raw material (in 10% aqueous extract) was pH 7.8. In comparison, the pH of the solutions was significantly reduced. The decrease in pH can be explained by the fact that the decomposition of organic matter (compost) produced substances that reduced the pH as the extraction time progressed. Using the repeated measurement model, I proved that the interaction of the extraction time, the extraction temperature and the extraction time:extraction temperature significantly influences the pH of the compost teas.

Regarding the electrical conductivity of compost teas, it can be said that as the extraction temperature increased, the electrical conductivity of the compost solutions increased for each CWRs. Compost solutions with extraction time of 50°C had a higher electrical conductivity, even for 1:20 CWR solutions. In the development of conductivity, it can be observed that the

EC value of the teas also differs significantly due to the change of all three extraction times and extraction temperatures, as well as the CWRs. I also used a repeated measurement model for the electrical conductivity in order to statistically determine which is the factor that (significantly) influences the evolution of the values. Based on these, the extraction time, the extraction temperature and the extraction time:extraction temperature interaction significantly influence the electrical conductivity of the solutions ($p<0.05$). Regarding the examined nutrient forms, it can be said that the nitrate concentration was the higher of the two examined nitrogen forms. The high nitrate concentration (400-2150 mg/l) confirms that neither anaerobic nor anoxic conditions developed in the compost tea during the preparation of the compost teas, as hydrogen was used in an anaerobic or anoxic medium and various reduced nitrogen forms, even its nitrate concentration indicates oxidative conditions. The low phosphate concentration can be explained by the fact that the phosphate ion is more soluble in acidic media, so there is a tendency for the phosphate concentration to increase with increasing extraction time, as the pH of the teas decreases over time. The high potassium concentration can be explained by the fact that potassium is well soluble in both aqueous and neutral solutions.

In the case of narrow CWR solutions, I used Pearson's correlation matrix ($p<0.05$) to explore the relationship between the chemical components measured in the compost teas. I evaluated the evolution of the relationship between pH, elecrical conductivity, nitrate, ammonium, phosphate and potassium concentrations (mg/l) in compost teas per CWRs. Based on the correlation matrix, it can be said that in most cases I was able to prove significant correlations between the inorganic chemical parameters measured in compost teas. I found a negative but close correlation between pH and electrical conductivity ($r= -0.95$), suggesting an inverse proportionality between the two parameters. The significant negative correlation between pH and electrical conductivity suggests an inverse relationship between the two parameters, since the electrical conductivity of solutions still depends on the concentration of all ions in the solution, while the pH depends on the concentration of oxonium ion in solution. A compost solution whose acidic, electrical conductivity will be high, because as the pH decreases, the concentration of oxonium ions increases, and as the acidification of the medium increases, the concentration of oxonium ions has a positive effect on the conductivity. The correlation coefficient between pH and ammonium concentration ($r= -0.96$) and for electrical conductivity and ammonium concentration ($r= 0.96$) is also negative. All three correlations indicate a significant relationship between the studied parameters. In the more concentrated (1:5 CWR) teas a moderate negative correlation can be observed between the ammonium and nitrate concentrations, which in the case of 1:10, 1:20 CWR solutions already appears as a weak positive relationship. In the case of more concentrated teas, the nitrate concentration decreased with increasing ammonium concentration. Based on the high correlation coefficient between the electrical conductivity and the ammonium concentration (mg/l), I conclude that, similar to broad CWR compost teas, ammonium salts provide a significant proportion of water-soluble salts in narrow CWR compost teas. Based on the correlation matrix, it can be said that the development of the electrical conductivity is largely determined by the concentration of ammonium and potassium in the compost tea.

3.4. Results of the soil-plant system experiments

When testing the compost solutions, my aim was to determine the optimal cultivation technological parameters of poultry manure-based products in a soil-plant system for white sweet peppers (*Capsicum annuum* L., Autumn Queen F1) and cabbage (*Brassica oleracea* L. convar. *Capitata* provar. *Capitata* Dutch, Ceremony F1) test plants using two doses (irrigation in once a week (D1) and twice a week (D2)), one water capacity level (WC 70%) and two soil types (Arenosol, slightly humous Arenosol). Based on the results of the pot experiments, it can be stated that there are significant differences ($p<0.05$) between the examined parameters of the control and compost tea-treated plants and the treatment times. Among the selected test plants, white sweet peppers responded more sensitively to treatments, and in the case of peppers, due to phosphorus deficiency, fruit binding was poor and fruit deformation occurred, as excess potassium inhibited phosphorus uptake. The treatments also resulted in higher leaf counts for cabbage and peppers, and this strong foliage growth is likely due to nitrogen overdose. To determine the stress on plants, I determined the Fv/Fm and Fv/Fo values, based on which it can be said that the high potassium concentration had an effect on the operation of the photosynthetic apparatus (increased stress on plants, ie decreased Fv/Fm and Fv/Fo value). The pH of the soils changed slightly as a result of the treatments, in the case of slightly humous Arenosol the pH of the soils decreased significantly as a result of the treatments. The electrical conductivity of the soils increased significantly ($p<0.05$) upon treatment with the tea.

Based on the studies with the white pepper plants and the statistical analysis, it can be said that on sandy soils, the differences between the irrigation with compost solution I and II are spectacular compared to the control and also when comparing the two compost solutions. On Arenosol, the effect of compost solution II was significantly different from compost solution I for all parameters tested, which can be explained by the higher phosphorus content in compost solution II, which is of particular importance for the plant in the post-planting period and which was provided by compost solution II. The effect of compost solution I is less noticeable and quantifiable. On slightly humous Arenosol, a similar trend to Arenosol can be observed with no significant difference between the two soil types. On slightly humous Arenosol, I recommend the application of D1 of compost solution II and on Arenosol D2 of compost solution II.

For cabbage on Arenosol, there was no significant difference between the 4th and 8th week eradications. On Arenosol, I recommend using D1 for compost solution I and D2 for compost solution II. On slightly humous Arenosol, I obtained almost similar results for both compost solutions (leaf number, shoot length, wet weight), but I recommend the use of D2 of compost solution II.

4. NEW SCIENTIFIC RESULTS

1. During the composting preliminary experiment I developed a fast, non-destructive spectral method and sample preparation method to determine the maturity of compost, for which I analyzed in the 400-2500 nm wavelength range the correlation with reflectance, inflection points, relative standard deviations, compost physical and chemical parameters and the evolution of the prediction indexes
2. Based on the results I proved that the wavelength range of 710-730±20 nm is suitable for the evaluation of different compost zeolite mixtures based on the calculated inflection points, where the displacement of higher value inflection points in the infrared range indicates the maturity of the compost.
3. I developed estimating equations for a rapid, non-invasive analysis of compost quality parameters. The models under the 20% margin of error (NRMSE) are: the quotient formed from the wavelength $\lambda_{812}/\lambda_{941}$ is used to estimate moisture content, electrical conductivity and pH. In the NIR range, the $\lambda_{2115}/\lambda_{1993}$ quotient is suitable for estimating moisture content, while the $\lambda_{1922}/\lambda_{2127}$ quotient is suitable for estimating pH, electrical conductivity.
4. Based on the results of windrow composting, I have shown that the retention time of an intensive composting reactor can be reduced by 30-40% when zeolite is added at 2% by weight.
5. I determined the optimal solubility conditions and parameters of compost teas made from composted broiler and hen manure, which are the following: compost:water ratio (CWR) >> extraction time >> extraction temperature.
6. I found that the yield, fruit set, plant height and total green weight of plants treated with compost solutions significantly increased in both soil types (Arenosol, slightly humous Arenosol) of white sweet pepper (*Capsicum annuum* L., cultivar: Ceremony F1). When looking at the relative ranking of the different solutions: for compost solution I, D1 was more effective on both soils, even for compost solution II, D2 was more effective. In the case of cabbage (*Brassica oleracea* L. convar. *capitata* provar. *capitata* Dutch variety: Autumn Queen F1), if we look at the relative ranking of treatments, I recommend the use of D1 on both soils (Arenosol, sliglthy humous Arenosol) for compost solution I, and D2 on both soils for compost solution II.

5. IMPORTANT RESULTS OF THE THESIS FOR PRACTICE

1. To optimize intensive composting, I performed preliminary experiments, which I modeled with windrow composting. Based on my results, I provided quantified technological data on temperature, pH, electrical conductivity, moisture content, and these parameters can be considered as the basic parameters of composting. With the repeated measurement model developed during windrow composting, I was able to determine that the treatment, time, and treatment-time interaction significantly influenced the development of the examined parameters ($p < 0.05$).
2. I found that in the case of composting a 2/3:1/3 mixture of broiler manure and hen manure, a moisture content of 50 w/w% is sufficient for the composting process, which allows to reduce the composting time of raw materials even in an industrial composting environment.
3. Based on the four phases of composting, I found that the residence time of the materials in an industrial composting reactor can be effectively reduced by mixing an additive. By mixing a larger amount of zeolite, the length of the temophilic phase can be increased (+14 days compared to the control), so that the mixture of substances enters the maturation phase earlier through the mesophilic phase, during which the treatment of animal by-products and waste can be made more efficient.
4. Based on the calculated RMSE and NRMSE values, indices in the VIS-NIR spectral range can be used to estimate pH, moisture content and electrical conductivity. This method can also be used to determine the physico-chemical parameters of compost by spectral (rapid analytical) analysis.

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A vizek mezőgazdasági eredetű nitrátszennyezéssel szembeni védelméhez szükséges cselekvési program részletes szabályairól, valamint az adatszolgáltatás és nyilvántartás rendjéről szóló 59/2008. (IV.29.) FVM rendelet (https://net.jogtar.hu/jogszabaly?docid=a0800059.fvm)

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List of publications related to the dissertation

Foreign language scientific articles in Hungarian journals (3)

1. **Gorliczay, E.**, Szőllősi, N., Kiss, N. É., Tóth, F., Tamás, J., Nagy, P. T.: Examination of the effect of pelleted poultry manure products on a sunflower test plant in a laboratory model experiment.
   Agrártud. Közl. 1 (1), 83-88, 2021. ISSN: 1587-1282.
   DOI: http://dx.doi.org/10.34101/actaagrar/1/8477

2. **Gorliczay, E.**, Tamás, J., Kun, S., Huzsvai, L., Bárány, L.: Examination and statistical evaluation of physico-chemical parameters of windrow composting.
   Agrártud. Közl. 1, 33-38, 2020. ISSN: 1587-1282.
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3. **Gorliczay, E.**, Pecsmán, D., Tamás, J.: Testing laboratory parameters of compost tea.
   Agrártud. Közl. 75, 31-36, 2018. ISSN: 1587-1282.
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4. **Gorliczay, E.**, Boczonádi, I., Kiss, N. É., Tóth, F., Pabar, S., Biró, B., Kovács, R. L., Tamás, J.: Microbiological Effectivity Evaluation of New Poultry Farming Organic Waste Recycling.
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5. **Gorliczay, E.**, Tamás, J., Bárány, L.: Maturity and stability evaluation of composted poultry manure.
   Nat. Res. Sustain. Develop. 10 (1), 10-19, 2020. ISSN: 2066-6276.
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6. **Gorliczay, E.**, Tamás, J., Mézes, L.: Effect of biochar and zeolite on the ammonia production of poultry litter.
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Hungarian conference proceedings (1)

7. **Gorliczay, E.**, Tamás, J., Mézes, L.: A pH és a hőmérséklet hatása a zeolittal és biocharral előkezelt baromfi almos trágya ammónia kibocsátására.
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8. **Gorliczay, E.**, Bárány, L., Pecsmán, D., Tamás, J.: Anoxikus körülmények között előállított komposzt oldatok vizsgálatának előzetes értékelése.
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9. **Gorliczay, E.**, Kiss, N. É., Nagy, P. T., Tamás, J.: Examination of inorganic chemical parameters of non-aerated compost tea.
   In: A klímaváltozás kihívásai a következő évtizedekben : előadások kivonatai, Szent István Egyetem, Keszthely, 38-38, 2020.

List of other publications

Foreign language scientific articles in Hungarian journals (1)

10. Kiss, N. É., **Gorliczay, E.**, Nagy, P. T., Tamás, J.: Effect of compost/water ratio on some main parameter of compost solutions.
    Agrártud. közl. 1 (1), 117-121, 2021. ISSN: 1587-1282.
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11. Kiss, N. É., Tamás, J., **Gorliczay, E.**, Gálya, B., Nagy, A., Jóvér, J., Riczu, P.: Analysis of nutritional parameters of biogas slurry.
    Nat. Res. Sustain. Develop. 10 (1), 57-66, 2020. ISSN: 2066-6276.
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13. Tamás, J., **Gorliczay, E.**, Borbély, J.: Atmospheric spreading model for ammonia released from the poultry house.
An. Uni. Oradea Fasc. Ecotoxi. Zooteh. Tehno. Industr. Alimentara. 15, 331-338, 2016. ISSN: 1583-4301.

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14. **Gorliczay, E.**, Juhász, E. K., Mézes, L., Tamás, J.: Különböző szemcsefrakciójú előkezelt baromfitrágya minták elemtartalmának vizsgálata.
In: Tavaszi Szél 2017 : tanulmánykötet. Szerk.: Keresztes Gábor, Doktoranduszok Országos Szövetsége, Budapest, 30-43, 2017. ISBN: 9786155586187

15. **Gorliczay, E.**: Baromfitrágya előkezelése biochar és zeolit felhasználásával.
In: Tudományos diákköri közlemények 3. : A DE MÉK Kari tudományos diákköri konferencia díjazott előadásainak kivonatai. Szerk.: Gyüre Péter, Juhász lajos, MÉK, Debrecen, 8-15, 2016.

Hungarian abstracts (2)

16. Kiss, N. É., Tamás, J., **Gorliczay, E.**, Gálya, B., Jóvér, J., Riczu, P.: Biogáz üzemi fermentlé beltartalmi paramétereinek vizsgálata és kijuttatása nitrátérzékeny területre.
In: XXIII. Tavaszi Szél Konferencia 2020: Nemzetközi Multidiszciplináris Konferencia. Absztrakt kötet I.. Szerk.: Barna Boglárka Johanna, Kovács Petra, Molnár Dóra, Pató Viktória Lilla, Doktoranduszok Országos Szövetsége, Budapest, 45, 2020. ISBN: 9786155586705

17. **Gorliczay, E.**, Juhász, E. K., Mézes, L., Tamás, J.: Különböző szemcsefrakciójú előkezelt baromfitrágya minták elemtartalmának vizsgálata.
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Foreign language abstracts (1)

18. Kiss, N. É., Nagy, P. T., Tóth, F., **Gorliczay, E.**, Madar, L. A., Kun, S., Tamás, J.: Improving the water management properties of different soil type.
    In: A klímaváltozás kihívásai a következő évtizedekben : előadások kivonatai, Szent István Egyetem, Keszthely, 54-54, 2020.

Total IF of journals (all publications): 2,925
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The Candidate's publication data submitted to the iDEa Tudóstér have been validated by DEENK on the basis of the Journal Citation Report (Impact Factor) database.

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