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September 2018

Environmental management, land use, biodiversity

FROM CONTENTS

TESTING OF PALINKAS, DIFFERENT DISTILLATION TECHNOLOGIES ■ THE FERTILITY EFFECT OF DIFFERENT COMPOST MATERIALS ■ AIR POLLUTANT EMISSIONS FROM AGRICULTURE IN HUNGARY ■ STATUS AND DISTRIBUTION OF NON-NATIVE SPINY CHEEK CRAYFISH IN LAKE BALATON

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ANALYTICAL AND SENSORY TESTING OF PALINKAS MADE WITH DIFFERENT DISTILLATION TECHNOLOGIES

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ABSTRACT

Many people think that palinka as a liquid food is going through a renaissance. The product is most often manufactured under small plant or domestic conditions. The spread of palinka distilleries was promoted for a while by the favorable tax system and the appearance of more and more tasty palinkas on the market. With the increase in the number of distilleries it could be observed that the distillation process resulting in the palinka product could be achieved by two fundamentally different systems. Simple fractional distillation repeated twice is considered the traditional method and is called pot-still double distillation. Repeated distillation (rectification), known from crude oil processing, can be realized by a plate, column or tower equipment. Both systems can provide delicious, tasty finished products, however, our research is based on the assessment of palinkas produced by the two different methods. Technological differences can also be found in other areas of the food industry. The heating of liquid foods (milk, fruit juices, etc.) can be achieved using either in a convective way or by microwave energy transfer, but the identity of heat-treated, pasteurized products prepared by the two different methods has been the subject of scientific research for a long time (Géczy et al. 2013, Korzenszky et al. 2013, Sembery & Géczy 2013).
In 2015 and 2016, we attempted to produce palinkas from fermented grape mash using two palinka brewing apparatuses based on different systems, under identical conditions. The products obtained were compared using instrumental analyses and blind taste tests. Taste tests are still ongoing. Partial results have already been reported at the Hungarian-Slovak-Polish organized Risk Factors of Food Chain 2016 and the Gödöllő Synergy 2017 conferences in the course of lectures, and in this article we would like to summarize the experience of three years (Géczi & Korzenszky 2016, Korzenszky & Géczy 2017).

keywords: Palinka, distillation technology, sensory test

INTRODUCTION

Palinka is a traditional food in Hungary. According to Act LXXIII of 2008, the so-called palinka act, palinka is an alcoholic beverage prepared from fruit produced in Hungary or apricots of 4 Austrian provinces by fermentation and distillation, with an alcohol content that is no less than 37,5% and no more than 86%. Its quality is influenced by the condition and ripeness of the fruit chosen as the raw material, as well as the mashing procedure and the brewing technology itself. In a food industrial sense, the latter is a distillation technology.
Distillation is a separation technological process, during which the separation of volatile components entering the vapor phase during the evaporation of the liquid phase is achieved from this liquid phase. This is followed by the cooling of the vapors produced, thus making them liquid again. When distilling the mash, the composition of the condensate obtained after the cooling of the vapors, i.e., the distillate, differs from that of the mash, because the mash contains not only volatile compounds, and because the components will be present in the distillate in higher concentrations than in the mash, depending on their volatilities. During the brewing of palinka, distillation has a dual purpose. On the one hand, to extract the alcohol content of the mash, and on the other hand, to separate undesirable volatile components present in the mash in addition to ethanol from the valuable hearts, by including them in the heads and the tails. (Nagygyörgy 2010)
The traditional Hungarian method is considered to be the double distillation performed in pots, and this is commonly called pot-still double distillation (PSDD) technology. (By definition, pot-still technology is brewing in an apparatus that has a pot with a volume of no more than 1000 liters.) The other technology, which is due to Austrian and German influences and gaining more and more ground, is continuous distillation based on column or tower apparatuses. This is often called single distillation in everyday language, even though the process is

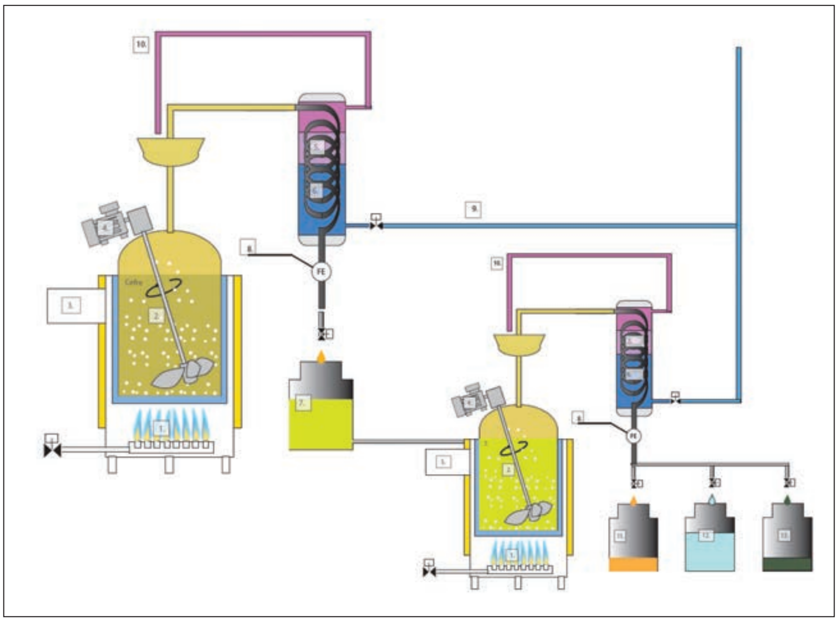

Figure 1: Schematic representation of the pot-still double distillation (PSDD) technology

Note for Figure 1 and Figure 2: 1-heating; 2-mash; 3-flue gas; 4-mixer/agitator; 5-condenser; 6-cooler; 7-first distillate; 8-flow meter/register; 9-cooling inlet; 10-condenser outlet; 11-HEAD spirit; 12-HEART spirit; 13-TAIL spirit; 14-distillation column

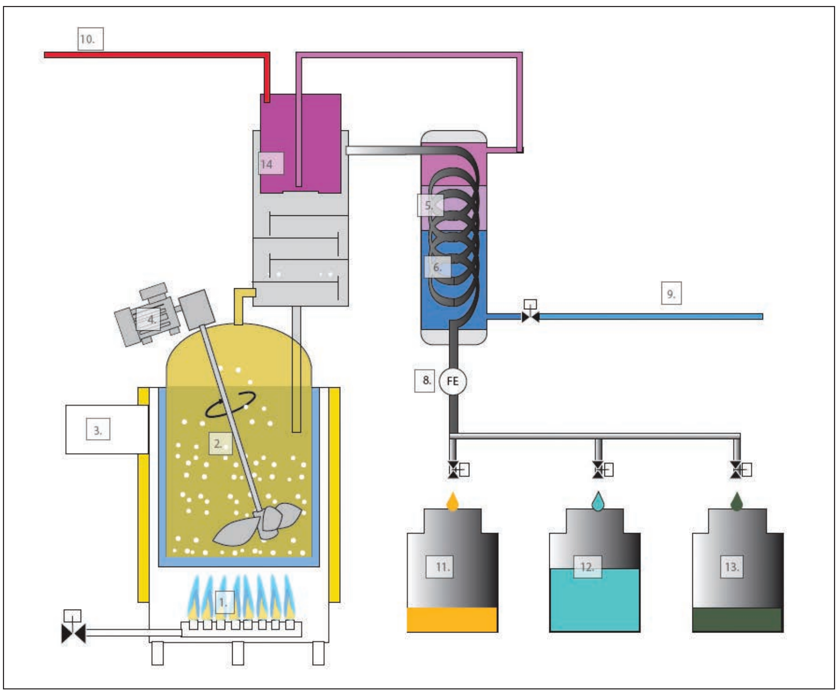

Figure 2: Schematic representation of rectification column distillation systems (RCDS) technology

based on distillation repeated many times. In rectification column distillation systems (RCDS), depending on the design, 4 to 6 rectifications are carried out, but the separation of the heads and the tails is realized in the final distillate (condensate).

In the pot-still technology, first a distillate with an alcohol content of 15 to 30%, called low alcohol, is prepared by fractional distillation from the mash that has a relatively low alcohol content (2 to 10%). The second step is the refining of the low alcohol, that is, the separation of the heads and the tails and the increase of the alcohol concentration to 60-70%. Double fractional distillation in the breweries is usually carried out in two separate pots, mainly due to excise regulation and economical operation reasons. However, technically the second distillation can be carried out in the same pot, but this is most typical of home brewing.

In the case of the rectification column technology, multiple distillation can occur in the distillation column (tower). The operating principle is based on having the upward flowing vapors containing volatile substances meet a downward liquid stream, while providing an adequate exchange of heat and material. The meeting of the vapors and the reflux liquid takes place on the plates in the column. Going up, the alcohol and other volatile component content of the vapor increases and, after condensation of the vapor, a condensate with an ethyl alcohol concentration of 70 to 90% can be obtained.

From a palinka brewing point of view, one of the most important points of distillation is the sharp separation of the heads. According to the theory, the amount of the heads is appropriate if the highest possible amount of aroma characteristic of the fruit is transferred to the hearts, but unfavorable components, mainly ethyl acetate, are only included in the hearts in such small amounts that they do not cause sensory faults. After the separation of the heads, distillation is continued by the collection of the hearts, but this stage cannot go on forever. The ethyl alcohol content of the vapor decreases continuously and, at the same time, the concentration of the necessary aromas decreases as well, and if distillation is continued, the condensate will have an undesirable, unpleasant sour nature. So the characteristics of the hearts are influenced not only by the distillation apparatus, but also by the selection of the heads and tails cut points. Palinka suitable for consumption is then obtained by rest and dilution with softened water (Nagygyörgy 2010, Panyik 2013).

In order to improve the quality of palinka, research into palinka distillation is ongoing, although the number of scientific publications is still less than those investigating the quality of beer and wine products, but funding by different grants have promoted the publication of scientific articles recently. From the narrow assortment, the research of Zsótér and Molnár (2015), investigating the legal background of palinka production and the effects of its changes, and the article of Kovács et al. (2018) on the importance and feasibility of a palinka vintage identification can be highlighted. Technological issues are discussed in the research of Harcsa (2017), aimed at the comparison of the energy consumptions of the two different systems (pot-still and rectification column), while the research of Nagygyörgy (2016) covered the effects of deflegmation. An Austrian research project is also considered worthwhile to mention. A method for forecasting the cut point was developed by Gössinger et al. (2012) for apple distillates. A large scale questionnaire survey was conducted by Szegedyné Fricz et al. (2017) to evaluate consumer behavior. Their conclusion was, among other things, that a significant proportion of consumers do not have even the slightest knowledge regarding the production of palinka.

In our present research, it was not our goal to determine who, where and when prepares better, tastier palinka. In the research that started in 2015, we intended to compare products prepared using the two different technologies. We sought to answer the question whether palinkas made from the same mash differ from each other, and if so, which one is preferred by palinka consumers.

MATERIAL AND METHODS

The grape variety Muscat lunel, harvested at the Tarcal vineyards, part of the Tokaj-Hegyalja wine region, was selected as the subject of our investigations. Mashing of the raw material harvested on September 10, 2015, and having a degree Brix of 18 (g sugar/100 g of mash), and

Figure 3: The prepared grape mash in 2016

Figure 4: Rectification column distillation apparatus - Tiszta Gyümölcs Kft., Bózsva

of the product harvested on September 12, 2016, with a degree Brix of 20 was performed. The mashing procedure was carried out in both years in Bózsva, at the premises of the Tiszta Gyümölcs Ltd. After short (36 hours) of refrigerated storage, 400 kg and 500 kg of destemmed and crushed grapes were fermented without added sugar at 18°C for 18 days in 2015 and 19 days in 2016, using Lallzyme HC pectin breakdown mixture, Uvaferm 228 yeast and Uvavital yeast nutrient.

On both occasions, the raw material was homogenized by stirring after the fermentation of the mash was concluded, and then it was divided into two. Rectification column distillation using a system with an amplifier head was carried out at the same site, in Bózsva, with a German Christian Carl apparatus of the Tiszta Gyümölcs Kft. As the location of the pot-still technology, the palinka distillery of the Veresegyház was selected, where the brewing process was carried out on consecutive days using a Czech Kovodel Janca s.r.o. double-pot apparatus.

The products resulting from the distillations were bottled after a rest of 2 months, and the one from the rectifica-

Figure 5: Pot-still double-distillation apparatus – Veresi Pálinkaház, Veresegyház

tion column system was marked "I." and the product prepared by the pot-still technology was marked "II.". Starting from December, all occasions and opportunities were taken to perform taste tests in order to determine the product of which technology is considered to be tastier by consumers. For the comparison, a blind test was used, people could choose the tastier one by consuming 10 to 20 ml of each of the products and their opinions cold be given anonymously by completing the questionnaire.

The questionnaire contained a single simple question each time: Which one tastes better, I or II? In addition, it was possible to provide a minimum amount of demographic characteristics (Male/Female; Age:<25/25-50/>50), and there was space for a short comment. Questionnaire data were summarized and evaluated using Microsoft Excel.

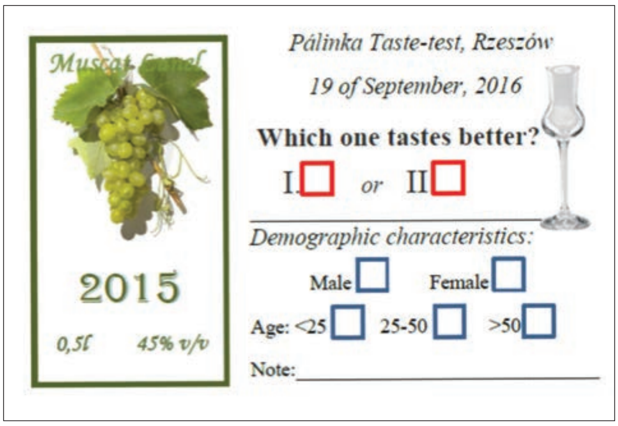

Figure 6: Taste test questionnaire

In addition to organoleptic tests, analytical testing of the products was carried out in the laboratory of WESSLING Hungary Kft. The purpose of nutrition analyses was to find correlations with the sensory results, and to find the possible faults of the products by instrumental analysis.

RESULT AND DISCUSSION

In 2015, after the separation of the heads, based on the experience of the master brewers, 21 liters of 86,6% alcohol was obtained on the rectification column and 29 liters of 63,9% alcohol using the pot-still technology. After dilution to 45%, practically the same yields were obtained (42,1 and 42,3 liters). In 2016, from 250 kg of mash each, 24 liters of 87,6% alcohol was obtained by the column system and 32 liters of 67,2% alcohol using the pot-still technology. After dilution to 45%, yields of 46,6 and 46,8 liters were obtained this year. For the comparison of the 2016 distillations, the graph in Figure 7 shows the ethyl alcohol contents of the distillates as a function of the amount of the distillate.

Table 1 shows the analytical results of the palinka products brewed in 2015. The products of the two distillations were compared with the help of 33 components, highlighting those for which the measured values differed by more than 25%. Based on the measurement results it can be stated that in the case of both distillation the amount of heads separated was more than the desirable volume, since the ethyl acetate concentrations were very low (81,3 mg/l and 180 mg/l). Based on the comparison of organoleptic tests and analytical results, it is known that distillates produced by faulty separation typically contain more than 800 to 900 mg/l ethyl acetate, i.e., ethyl acetate results well below the limit value indicate that supposedly the vast majority of heads-type fruit esters (e.g., ethyl propionate, propyl acetate) were also separated with the heads, even though these components are desirable ingredients of each fruit distillate. The significant concentration difference of one of the components usually enriched around the tails (2-phenylethanol) shows that, in the case of the pot-still technology, separation of the tails should have been started somewhat earlier, since even the lower deflegmation degree characteristic of the pot-still procedure does not justify the observed difference for mashes of the same composition, i.e., the concentration difference of this component measured in the hearts was primarily due to the selection of the cut points during the two distillations. If the concentrations of the same components are examined in the samples resulting from the 2016 distillations, then statements similar to those in the case of the 2015 distillations can be made. Ethyl acetate concentrations were also low. For 50% distillates, concentrations of 92 mg/l and 204 mg/l could be detected for the column method and the pot-still technology, respectively. Perhaps this could be one of the reasons why the concentrations of typical fruit esters were below 1 mg/l this year as well, i.e., the goal of the master brewers was maximum safety at the separation of the heads, resulting in a more

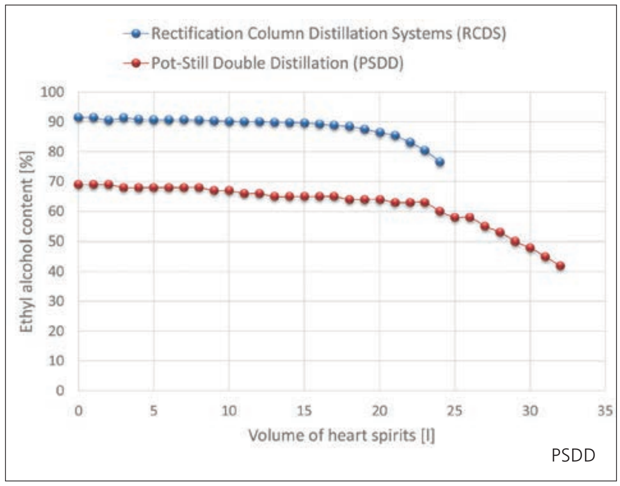

Figure 7: Ethyl alcohol content as a function of the volume of hearts in the case of the two systems

modest aroma of the palinkas. The concentration of the tails-type 2-phenylethanol component is not as high as in the case of the 2015 distillation for the pot-still procedure (8,1 mg/l vs. 12,7 mg/l), therefore, tails characteristics could disturb less the sensory judges.
By the end of August 2018, we had 342 valid questionnaires for the organoleptic comparison of the palinkas produced in 2015. There were also persons who evaluated the two samples more than once over the 3 years. 62% of the respondents were men and 38% were women; 59% were between the ages of 25 and 50, 25% were younger than 25 and 16% were older than 50.
For the palinka samples produced in 2016, 296 questionnaire have been completed so far. The demographic distribution is almost completely identical to the above. Nevertheless, our statistical analysis cannot be considered representative, it was basically carried out with the

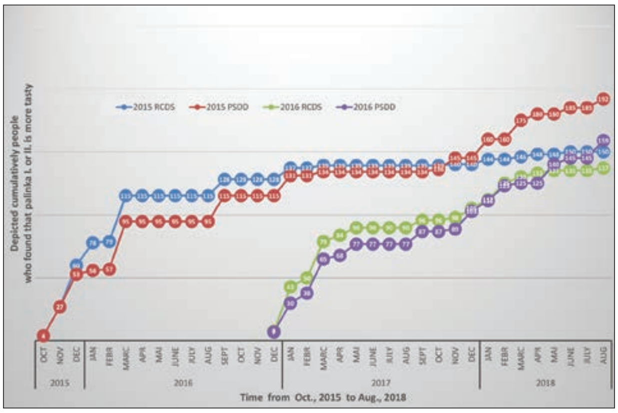

Figure 8: Cumulative sum of the samples chosen as tastier as a function of time

continuous involvement of people attending „palinka" lectures, college students, and friends and acquaintances who like palinka.

In the diagrams, the number of „selected as tastier" answers indicated in the questionnaires are depicted cumulatively as a function of time. It is obvious that, of the few months old samples, the product manufactured on the aroma tower apparatus was found to be tastier by more people in both cases. At the same time, it can be seen that the number of people choosing the pot-still palinka increases as time goes by, and for the 2015 distillation after ca. 2 years, and for the 2016 distillation after ca. 1,5 years the products of the two distillations were found to be tastier by the same number of people. After this point, the pot-still product was found to be tastier by more people in both cases.
When looking for correlations with demographic data, it can be concluded that the more fragrant product was clearly selected by younger people and women primarily in the early stages. Also significant was the selection of the pot-still product by older men, even in the initial

Table 1: Analytical results of the 2015 samples

Examined parameters	Results [mg/l]	
	RCDS	PSDD
Methanol	641	822
Acetaldehyde	107	53,9
Ethyl acetate	81,3	180
Acetal	7	22,1
2-butanol	<5	<5
1-Propanol	96	97,3
Izobutanol	222	216
1-Butanol	<5	<5
2-Methyl-1-Butanol	189	186
3-Methyl-1-Butanol	941	945
Volatile matter content *	1640	1700
Acetone	<5	<5
Methyl acetate	<1	2,5
Ethyl propanoate	<1	<1
Propyl acetate	<1	<1
Ethyl butanoate	<1	<1
(2-methyl-1-butyl) acetate	<5	<5
(3-methyl-1-butyl) acetate	<5	<5
Limonene	<1	<1
Ethyl hexanoate	1,7	1,3
Hexyl acetate	<1	<1
Ethyl lactate	<15	60,3
Hexanol	3,9	4,7
Ethyl octanoate	12,3	7,5
Furfural	1	3
Benzaldehyde	<1	<1
Linalool	7,3	7,9
Ethyl decanoate	23	14,7
Ethyl benzoate	<1	<1
Ethyl carbamate	<1	<1
Ethyl dodecanoate	<10	<10
2-phenylethanol	2,46	12,7
Allyl alcohol	<4	<4

phase. Since the same person could participate in the test more than once and it happened several times that their opinions had changed over the months, the demographic evaluation would only be relevant at a given degree of maturity.

CONCLUSION

Based on the feedback of the testers, we consider it important to share the fact proudly that all of the grape palinkas produced in 2015 and 2016 were tasty and enjoyable and did well as palinkas. No negative or very low opinions were obtained. Distinctions were made between the two samples by all testers during the blind tests, but truth to be told, it was emphasized every time that they tasted palinkas that had been made from the same fruit using two different methods.

The conclusion can be drawn from the cumulative results of both vintages, depicted as a function of time, that in the one year period following the production, the more fragrant palinka produced by the rectification column distillation system was found to be tastier. After about a year or so, due to the chemical processes that take place in the products, the popularity of the pot-still palinka increases.

When comparing the two system, many factors could be identified. However, there are no clearly quantifiable data available on the distillation process (such as the quality of the heads, the degree of deflegmation or the amount of energy used). During the separation of the heads and the tails, in addition to the master brewers knowing the given system well, experts experienced in evaluation were also used, but, of course, decisions had to be made regarding the heads at an alcohol content of ca. 90% in the case of the rectification column system and an alcohol content of ca. 70% in the case of the pot-still procedure. For the separation of the tails, these values were around 78 to 80 and 40 to 48 percent (in the case of grapes), and obviously this can lead to errors.

The two experiments carried out with grapes was repeated in 2017 with Williams pear and although there are less test data available for the time being, the trend seems to be similar.

ACKNOWLEDGEMENT

We wish to express our appreciation to Bózsvai Bibendum Pálinka Distillery and Veresi Pálinka House for their participation. We'd also like to thank Wessling Ltd. (Budapest, Hungary) for analytical tests of palinka. Finally, we would like to say thanks to Ádám Bóday for flow charts (Figure 1 and Figure 2) and organizing many test ceremony.

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RAPID BIOTEST TO EVALUATE THE FERTILITY EFFECT OF DIFFERENT COMPOST MATERIALS

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ABSTRACT

Interest in the ecological, toxic and fertility effects of composted materials has been growing recently. A rapid plant biotest could be an option to test and evaluate the positive or negative effects of compost. Many methods and standards are available in this topic, but it is often necessary to modify and develop them to reach the research goal like toxicity, heavy metal content, fertility etc.. One of the key questions in agriculture is to know the fertility of soils and the effects of different artificial and natural soil amendments on arable land. The measurement of the fertility of these materials is usually means chemical and physical analyses. Sowing some indicator plants in the soil and measuring their growth and production is one way to measure fertilisation effects of soils and soil amendments in an indirect way (Nguyen et al. 2003).

In our paper we would like to present a variation in this topic. It works perfectly, even in winter time, if the information is needed urgently. Laboratory pot experiment was established in small scale and Rye grass (***Lolium perenne)***was used as a test plant in each case. Test period maximum 20 days.

Keywords: compost quality, biotest, fertility

INTODUCTION

Composting of agricultural, municipal, industrial wastes are increasing in EU (in 1995 – 14 Mt, in 2016 – 40Mt) because of the recycling requirements set on organic wastes (EUROSTAT, 2018). The Hungarian Biowaste Regulation (Act number 23/2003) defines compost. It also covers the suitable materials, hygiene requirements and technical specifications of composting, but there is no regulation about the end-product quality. Another regulation 36/2006 regulates the minimum criteria and use of all kinds of soil fertilisers, amendments, like composts. Sewage sludge compost is also allowed to produce. Limit values for trace element and pollutant are specified in this regulation. Usage of the sewage sludge composts are regulated by 50/2001 regulation. Threshold values of toxic elements in raw materials and end-product are specified. As it seems the harmonisation among the different Hungarian regulations is an actual question. On the other hand, the harmfulness of solid wastes has been estimated mainly on the basis of its chemical composition. In most European countries the limit values only are focus on the pollutants, particularly heavy metal contents, organic pollutants, impurities (Binner et al. 2008),and there are no requirements for the ecotoxicity or levels of chemicals in compost. There are no standards set for the quality as soil improver. Although composting is a widely used process, there are still gaps in knowledge in this topic due to different feedstock materials, processing technologies, and end-product chemistry (Himanen & Hänninen 2011).

The interest in the ecological effects of composting has been growing recently. No standardized methods are available for measuring the toxicity or fertility of composted materials in biotest. Despite this, international and national quality requirements define that compost shall not contain any environmentally harmful substances (Kapanen & Itävaara 2001).

More experience and knowledge are needed in testing the toxicity and fertility of compost before the most suitable methods can be suggested or limit values established.

MATERIALS AND METHODS

Our experiment was carried at Szent István University, Department of Soil Science and Agrochemistry, Agrochemistry Group. The laboratory small scale biotest experiment was conducted in Winter in 2017. Two grams of Rye grass (***Lolium perenne***) was used as test plant in a 500 cm^3 plastic container. 500 grams of mixture was

Table 1: The basic physical and chemical properties of the soil used in the study

Genetic horizon	Depth	OM	$CaCO_3$	pH	pH	EC	Total N	AL-P_2O_5	AL-K_2O
	(cm)	%	%	H_2O	KCl	µS	%	g kg^{-1}	g kg^{-1}
Ap	0-30	0,61	7,76	8,8	8,2	63,5	0,09	0,17	0,47

applied. In our experiment the following compost:soil ratios were used (1:1; 1:2; 1:4; control) in five replicates. The moisture content of the mixtures in the containers during the test was monitored daily by weighting and was adjusted by distilled water. The test period took 14 days after the first germinated plant.

Soil samples were collected from the Ap horizon (0-30 cm) of an Arenosol from a research field plot of the Szent István University Crop Production and Biomass Utilization Center, Gödöllő, Hungary. The soil samples were stored in a cool (+5°C) and dry storage, until it could be used. The air-dried samples were homogenized and were passed through a 2 mm sieve before the analysis. The basic properties of this soil are given in Table 1.

Compost samples are originated from three different composting facilities with different technological background (Table 2). All of them have permission to sell their product. In K treatment sewage sludge compost (maturity – 8 weeks) was used which was made by a fully encapsulated system, the G treatment means city green waste compost (maturity – 4 weeks) which was made by aerated, covered technology; finally the applied T compost was made from green waste (maturity – 8 months) also but the technology was open air windrow.

Table 2: Some macro-, micro-nutrient and metal content in the final composts

mg kg^{-1}	K	G	T
K	4566 ±24	14327 ± 142	18047 ±665
Na	434 ±10	210 ± 24	919 ± 40
Mg	6953 ±18	6734 ± 28	9522 ± 17
Zn	621 ± 2	70,0 ± 0,4	75,4 ± 0,7
Cd	3,68 ± 0,03	2,79 ± 0,17	3,10 ± 0,05
Pb	13,5 ± 0,2	11,7 ± 0,4	15,7 ± 0,9

During the test we measured the average plant height and observed visually the germination rate. After the test period soil and plant analysis was carried out. Experimental data were statistically analysed with analysis of variance (ANOVA) by MS Excel.

RESULTS AND DISCUSSION

During the experiment we surveyed every day the test plants and noticed the germination, the growth of the plants. We observed great differences between the different amounts of compost and among the composts also in the early stage of the biotest (Figure 1). The

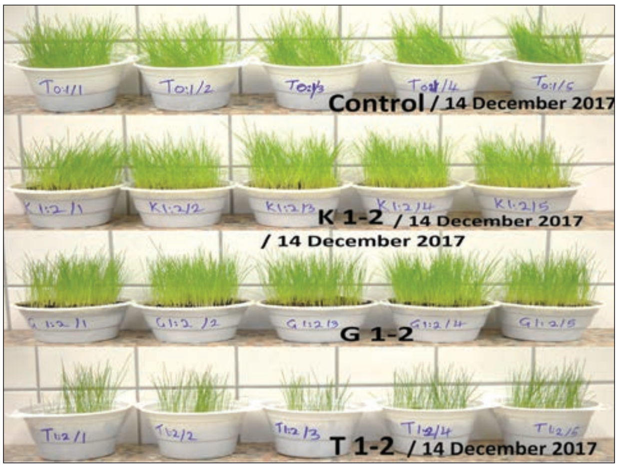

Figure 1: Differences between the test plant emergence and growth

strongest and healthiest plants were observed in K treatment. Visual evaluation is a good and useful method to demonstrate or test the applicable amount of final compost. In the literature often pure compost is used to test this.

Although visual evaluation is a widely used method, it is not enough to determine the toxicity or fertility effect of composts clearly. When we measured the fresh weight of the Rye grass it showed high differences between the treatments. All the fresh weights were higher than the control except the G 1:1; T 1:1 and T 1:2. As the Figure 2 shows that all of the K treatments, which contained the sewage sludge compost, were significantly higher compared to the control. The K 1:1 and K 1:4 were significantly higher compared to all other samples. It was quite interesting that the K 1:2 treatment resulted lower dry mass. If we analyse the trend in case of the three composts it shows that the lower amount of compost resulted significantly higher dry mass in each case. It seems something went wrong with the K 1:2 treatment. All three treatments with the G compost were lower or not significantly different compared to the control, however the fresh weight was significantly higher than the control. This effect is called as dilution effect in agronomy. Treatments marked with T resulted the lowest dry weights, the 1:1 and 1:2 ratios resulted significantly lower dry mass but the 1:4 ratio caused significant increase in dry mass of Rye grass.

The C/N ratios are shown in Figure 2. The C/N ratio in control treatment was the highest due to the chemical composition and the very low nitrogen content. This value is typical in this environment. The originally C/N

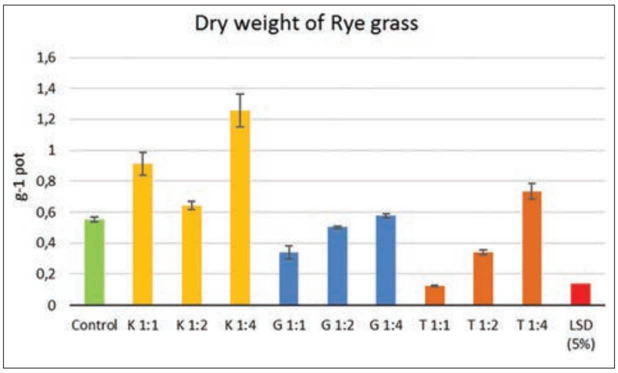

Figure 2: Measured dry weight of Rye grass after the test period

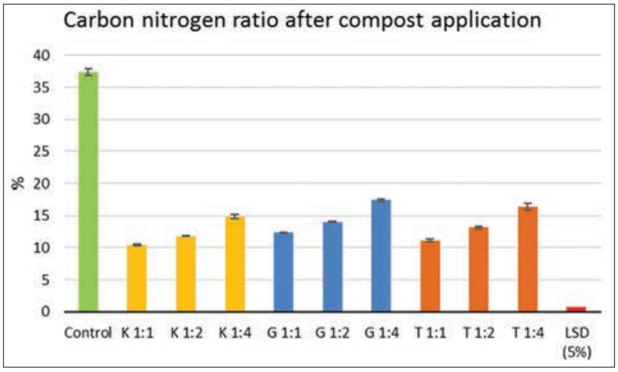

Figure 3: Carbon nitrogen ratios of soil after the test period

ratio of the compost substrate is 25:1; 30:1 but the final product's C/N ratio is typically close to 10:1. In our experiment it was very similar between 8.7- 13.4. It was not unexpected that the C/N ratio in mixtures are decreased significantly. The same trend was obtained for all the three composts If the added amount of compost decreased it means to increase the C/N ratio. It has very deep and close connection with the pentosane effect, humidification and mineralisation process.

CONCLUSIONS

Wide range of biotest methods can be found in the literature. The experimental design, size, test plants, etc. always depend on the research aim, however, there are some common background in this topic. Information is needed as soon as possible, the method has to be suitable for different measurements. Our method demonstrated that the Rye grass is an ideal test plant because it can grow very quickly, it also suitable to test the metal accumulation. It is sensitive to most of the environmental effects.

The size of the containers and the amount of the mixture are enough to determine the chemical, physical composition or it is even suitable for biological tests.

The final conclusion is that all the three composts are available to use in agriculture even the sewage sludge compost which case the application rate was too high. The usage of organic matter like compost as a soil amendment is beneficial but the right amount is more important.

ACKNOWLEDGEMENTS

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AIR POLLUTANT EMISSIONS FROM AGRICULTURE IN HUNGARY

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ABSTRACT

Air pollution is one of the most important topics nowadays. Air pollution has improved considerably in the last decades in the case of some components in Hungary, but there are pollutants that are still at higher concentration in the atmosphere. In order to protect people, plants, animals and the built environment, these values need to be improved. This requires continuous measurements and inspections, where problems arise, stricter standards to establish in those areas and, where possible, technological improvements to achieve cleaner air quality. Thanks to climate change and extreme weather, farmers and growers have more and more hard work to do. In order to ensure proper food supply, we also have to deal with the agricultural sector separately. In addition to many other factors, air pollution also greatly influences the life cycle and development of plants. The emission sources and impacts of air pollutants affecting mainly agricultural plants, and partly the animals, were also discussed in the article. Among air pollutants from agriculture, nitrogen oxides, non-volatile organic pollutants (NMVOC), particulate matter 10 (PM_{10}) and ammonia (NH_3) emissions are significant compared to emissions from other sectors.
Among the effects can be listed: the reproductive ability and development of the plants could remain; spots may

Figure 1: (Photo: Diána Arany)

appear on leaves, petals, stems; less plant or crop could be; they can dry out and die, and raise many other effects can affect their growth. To reduce the amount of air pollutants emitted into the atmosphere, measures should be introduced and technological improvements to the machines used during cultivation. With regard to technological development, it is a very good example, that a twenty-year period has just came to an end, due to continuous improvements and tightening, and the amount of pollutants emitted by agricultural machinery exhaust has decreased. The regulation was first issued in the USA. The productive job has had five stages so far and the next document is expected to be signed in Brussels in 2019.

keywords: agriculture, NO_x, NMVOC, NH_3, PM_{10}, livestock

INTRODUCTION

Nowadays one of the most important theme is the air pollution in the world. In the last few years people can hear every day in the media something about the environment and about the global warming and extreme weather conditions. The effects can be also see in Hungary, not only in the news.

Our country is in a special situation, because it is largely surrounded by high mountains and the entire country lies in a drainage basin. The climate is continental here, summers are very hot with low overall humidity levels, but suddenly large amount of rain showers and cold snowy winters are common. (Kollega Tarsoly et al. 1997, Mez si 2011, OMSZ)

Significant air pollutant components within agriculture

In this article the air pollutants were analysed related to agriculture. The main emission sources were summarized and the components and then, due to the emissions, the impact of different pollutants were analysed on agricultural crops and on animals. Development, growth and life cycle of plants can be influenced to a large extent by some pollutants. Pollution may appear in patches on the leaves, petals, stems of the plant, but yellowing, dryness and total destruction may also occur. It depends on the degree of exposure, the type of pollutant and the external factors, which part of the plant will be damaged, by how and to what extent.

There are also generated materials and substances during agricultural activities which are emitted into the atmosphere and contribute to the increasing air pollution. Among the air pollution components measured in Hungary, the following are significant from an agricultural point of view:

- **nitrogen-oxides** (NOx): NO_x emissions from biogenic sources may be significant, especially in agricultural regions where nitrogen fertilizers are applied. Soil NOx is produced primarily by microbial processes. The amount of NOx emissions from soils depending on environmental conditions for example N availability, water filled pore space and temperature. The agricultural practices also influence the microbial activity such as fertilization and irrigation (Hall et al. 1996). NOx gases also contribute to local elevated ozone concentrations (Moiser 2001). The ground-level ozone has harmful effects on plants.

- **non-methane volatile organic compounds** (NMVOC): Livestock, their wastes and animal manures produce several NMVOCs which are emitted into the atmosphere. The ruminants exhale a range of acetone and dimethyl sulphide (DMS), the anaerobic storage and management of livestock manure produce over 150 types of NMVOCs. Most of them are principally comprised of sulphides, volatile fatty acids (VFAs), phenols and indoles. VFAs and other oxygenated hydrocarbons can induce generation of atmospheric oxidant production such as peroxyacetyl nitrate (PAN) and ozone (Hobbs et al. 2001).

- **ammonia** (NH_3): Ammonia is the major gaseous base in the atmosphere and serves to neutralize about 30% of the hydrogen ions in the atmosphere. One third

- of agricultural emitted ammonia originates from synthetic fertilizer application and the other two-third comes from animal manure (Moiser, 2001).

- **particulate matter 10** (PM_{10}): The period with the most emissions within agriculture is land works, such as ploughing and harvesting (Holmén et al., 2001). In the arable period deflation could also be a problem, not only in connection with the PM_{10} emission, but also because of the humus spreading. Agricultural vehicles' exhausts can also emit PM_{10}. During the burning of agricultural waste or burning of stubble-fieldsthe concentration of PM_{10} increases in the air.

Air pollutants which affect agricultural crops and livestock

Air pollution has an effect on people, and also on animals, plants and on the built environment. Firstly the health effect on humans is always talked about, but others have to be emphasized too. Earlier the air pollution only effected the industrial areas and residential areas, but today the agricultural and environmental areas are also affected. According to researches plants may be more affected by pollution, for example lichen is one of the most important indicator species, that has visible signs of changes.. Air contains several kind of pollutants in different physical state. Particulate matters mainly exert effects on the plants to consolidate on their surface, and therefore the leaf surface and the assimilation will decrease. Colloidal particulate matters, for example cement clogs the gas exchange openings of the plant. Toxic particulate matter have an impact in the metabolic processes. The pollutants can get in to intercellular space through the gas exchange openings. For example from SO_2 (sulphur dioxide) mixed with H_2O turns into H_2SO_3 (sulphurous acid) and H_2SO_4 (sulphuric acid), which is harmful to the environment. Besides that it can react with chlorophyll, which can paralyze the photosynthesis. If the damage is bigger, the leaf's tissue may shrink, wrinkle, wither. Due to the destruction of colorants and chlorophyll colour changes may occur: at the surface the leaf may develop yellow, red and brown patches. This phenomenon can also be seen on flower petals. It is the marginal necrosis, where the edge of the petal can die. Sulphur dioxide mainly attacks spongy parenchymas. In the centre of the leaves dry, translucent or light coloured patches may occur. Ozone attacks the columnar cells, the leaves will turn sparsely spotty. Two types of smogs can also damage the plants. The plant's stage in life greatly affects the damaging effect. The young and dividing organizations are more sensitive, but the harmful effect doesn't last long and they can regenerate faster. In the older tissues the damage is usually lasting. Different plant species are not equally sensitive to contamination. For example in the case of sulphur dioxide the order of sensitivity is the following: clover, barley, cotton, wheat and apple, other species may be resistant too. Examples of sulphur dioxide can be seen on potatoes, onions, oats. (Barótfi 2000, TAMOP 4.2.5 Pályázat könyvei 2008)

Various air pollutants can cause serious damages to agriculture. In our country too, the wine of vineyards became unpalatable due to the smell of chemical fumes, the orchards were ruined because of cement and sulphur dioxide pollution. In addition to such dramatic effects, there is a significant, although less noticeable, continuous damage which occurs in crop decline. According to literature data, a 50% drop in yield was also observed. Due to long exposure, the growth of vegetation may fall back, fewer and smaller leaves will grow. The plant will have fewer flowers and crops, and its crop will be smaller. Chemicals in the atmosphere spoil the quality of the crop. The viability and reproductive capacity of damaged plants decreases. Chronic exposure results in a decrease in the number of individuals and species. Resistant species can multiply, the composition of the population can change. (Barótfi 2000)

The direct impact of air pollution on animals is rare. Livestock farms are usually located , futher off from industrial areas, at the edge of towns and villages. Many bird species migrate to another area from polluted places. PM is rather detrimental to wild animals. PM on the surface of the plants is harmful to those animals, which consume these plants. The fluoride adhering to pollen is endangering bees. (http1)

Insecticides, organic phosphate esters, chlorinated hydrocarbons are increasingly present among air pollutants. Excessive improper use has caused pollution of the same size in the air, as in live water during mortality. Instead of harmful insects, it is often the case that useful arthropods of forests and fields are destroyed, which can cause biological imbalance. In addition, in some cases, chemicals can cause mass destruction of birds and mammals. (TAMOP 4.2.5 Pályázat könyvei 2008)

Sulphur dioxide can cause for example milk and milk fat loss in the body in the case of animals. Fluorine damages primarily fodder crops for animal feed and the following effects may occur: Diarrhea, loss of appetite, digestive disorders and in the worse case, the bones will deform, lameness could also occur. The acidic environment, however, causes a threat to populations in the air, water and soil too. (TAMOP 4.2.5 Pályázat könyvei 2008)

MATERIAL AND METHODS

Emission data processed in this article were obtained from the results measured by the Hungarian Meteorological Service (OMSZ) measuring stations. From the year 2005, OMSZ annually prepares an emission cadaster from the measurement data of the measuring stations. The sectoral breakdown of measured results were based on the 2015 INFORMATIVE INVENTORY REPORT (Kis-Kovács et al. 2015).

Based on the data provided by the Hungarian Meteorological Service (OMSZ), the release of activities within the sectors were also investigated, so those areas are visible, where further emission reduction provisions are needed. The Emission Inventory and the Emission Account Scheme are used to describe human (anthropogenic) air pollution. Emissions can be derived from the CRF (the greenhouse gas inventory system for emission inventories) codes and the NFR (the classification system for air pollutants other than glass-containing gases from emission inventories) codes. The data sent by OMSZ is divided into 12 main categories (public power, industry, fugitive solvents, road transport, off-road transport, aviation, shipping, waste, agri_livestock, agri_other, other stationary combustion, etc.) with emission values together with NFR codes. In this article data have been restricted to 5 main groups: residential, waste management, agriculture, traffic, industry and energy.

Changes of significant air pollution components from agriculture of the Hungarian state between 2006 and 2016

The following charts show the quality of pollutants emitted by subgroups of different sectors (units of measure: kilotons).

The total emission of nitrogen-oxides shows a decreasing trend compared to the year 2006 (Figure 2). The major emitter is traffic, it is responsible for around half part of the total emissions. The rate of decline is due to the reduction of emission in the transport sector and energy sector.

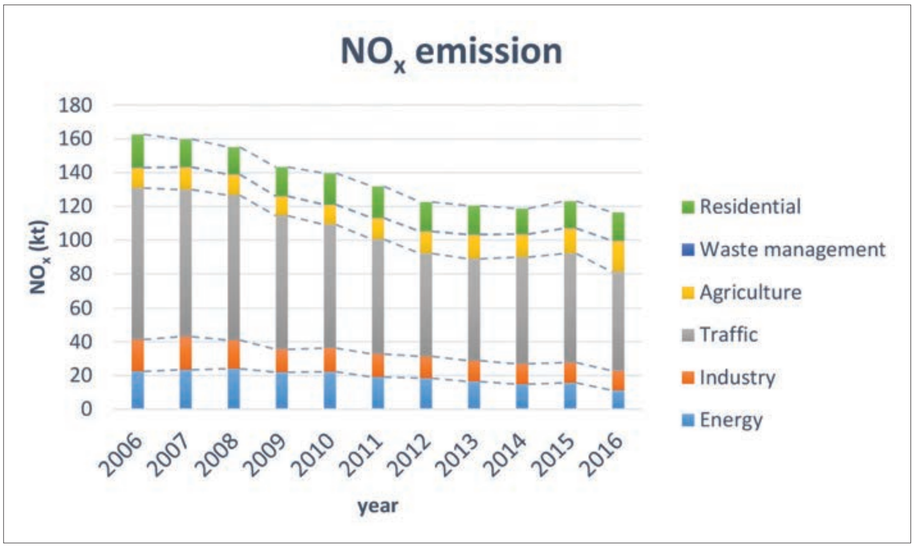

Figure 2: Changes of NO_x emissions in sectoral breakdown between 2006 and 2016 (Source: OMSZ)

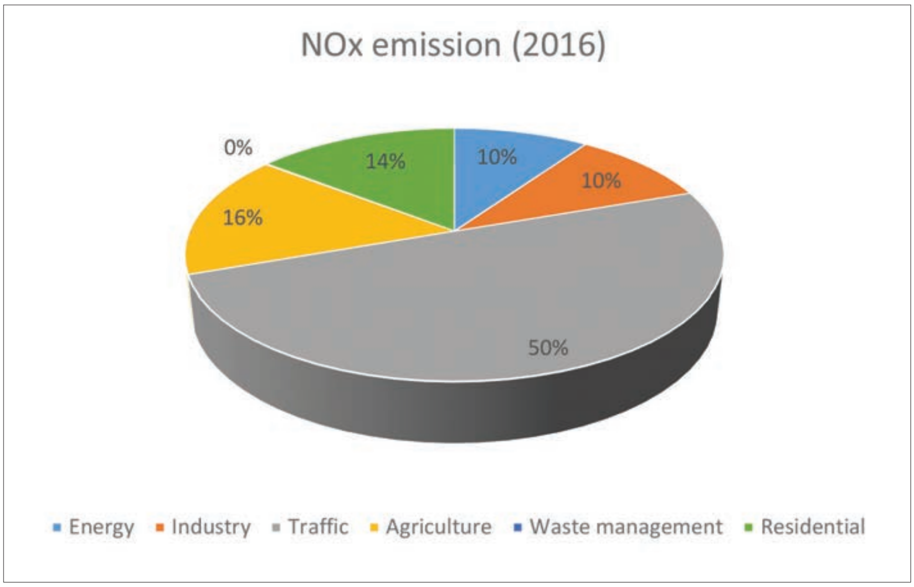

Figure 3: NO_x emissions in sectoral breakdown between in 2016 (Source: OMSZ)

The agricultural sector contributed to the second highest proportion of atmospheric concentration of nitrogen oxides by nearly 16% in 2016 (Figure 3). This percentage is almost twice as high as in 2006, because the emission in this sector increased from 12kt to 18kt in the past 10 years.

Significant part of volatile non-methane organic compounds of emissions is generated in industry (Figure 4). The amount of total emissions has not changed significantly over the past 10 years due to the wavering of residential emission values. There is a slight decrease compared to 2006 due to drastic reduction in transport emission. A little increase of the emissions was noticable within the agricultural and industrial sector.

During organic fertilizer usage on the fields small diameter particles (PM_{10} – particular matter 10 micrometres) could be emitted into atmospheric air. PM_{10} could originate from many other activities. The most important emission comes from residential heating which exposes more than half of the total PM_{10} emission.

The fluctuation of residential PM_{10} emission correlates with the households' NMVOC emission which clearly correlates with the seasons' changing heating (Figure 4, Figure 5). Weather influences fuel consumption, the spreading of dust and increase of PM_{10} concentration. During the colder winter period residents use more fuel and the cold, humid, windless, foggy weather assists the accumulation of pollutants in the air. Polluted air is heavier than the air above it, that's why it can not rise up and the concentration of pollutants will increase in the air close to the surface due to the continuous pollution. The phenomenon is augmented by the topographical features of Hungary because of its pool type.

During the application of organic fertilizers not only PM_{10} production happens but also ammonia is released. The reason for this is the excessive nitrogen supply and the overdosed usage of nitrogen fertilizers. Plants can not adsorb the dispensed nitrogen therefore it turns into gaseous ammonia. The situaton is similar regarding livestock. Animal feeds have a higher protein content compared to what the animal needs, so the excess is discharged with the manure. Up to 80% of the nitrogen from the feeds may be released into the environment. Almost half of the amount of the excess nitrogen leaves the animal's body in the form of ammonia. Fertilizers of animal origin are good nutrients for plants, but it is expensive to safely pretreat and store them. Farmers prefer to use synthetic fertilisers instead of organic fertilizers. Regarding the components of air pollution ammonia emissions from agriculture are the most significant compared to other sectors (Figure 6), they add up to nearly 90% of the total ammonia emissions.

History of exhaust fume purification of agricultural machinery

The diesel engine of agricultural machines pollutes the air with its exhaust fume. Less pollutants reach the atmosphere when the exhaust fume is purified. Over the past two decades, significant changes have taken place in this area.

In Hungary, tractors and mobile agricultural machines are almost exclusively powered by a diesel engine. Only nitrogen, oxygen and water vapor pollutants are environmentally friendly, the other components are harmful and most of them are toxic. (Mészáros 2018, Varga 2012, Varga 2017)

0,3% of untreated gas is harmful and carcinogenic. About half of these are nitrogen oxides, and nearly one-fifth is composed of solid (PM) particles.

The reduction of air pollution of diesel engines began in the 1990s. The first regulatory restriction on the tractor was reported in the USA, which generally was in connection with carbon monoxide (CO), hydrocarbons (HC), non-methane hydrocarbons (NMHC), nitrogen oxides (NOx) and PMs. In the regulations the grades are named Tier (Tier 1-4, Interim Tier 4, Final Tier 4). The European Union has regulated exhaust emission limit values for the diesel engine tractor (non-road mobile equipment) on 16 December 1997 with Directive97/68/EK. In Europe, instead of the Tier, Stage was used. And this regulation was further tightened in 2004 (Directive 2004/26 / EC). The exhaust fume emission test method for tractor diesel engines is broadly the same and in line with American and European specifications.

- **Tier 1 (Stage I):** Started in 1996 and entered into force in 1996 in most engine categories. Fulfilment of specifications was simple during the development.
- **Tier 2 (Stage II):** Started in 2001, and entered into force in 2004 for most engine categories. The emission values of tractor engines were limited for PM, 50% for NOx and 20% for NOx.
- **Tier 3 (Stage III A):** Started in 2006, and entered into force in 2008. Due to its introduction, the NO_x concentration had to be reduced by 40%.
- **Interim Tier 4 (Stage III B**): Started in 2008, and entered into force in 2013. This grade has been drastically increased. The tractor engines with a capacity of 56-560 kW have an average reduction of 90% on PM and 50% on NOx.
- **Final Tier 4 (Stage IV):** Started in 2012, and entered into force in 2015 for all engine performance classes. For tractors with a power output of less than 56 kW a 50% PM reduction was set and for engines with a power rating of more than 56 kW a reduction of 80% NOx was set.

The twenty-year development which started in 1996 has been successfully completed and the air quality has improved considerably thanks to the new tractor engines in agricultural sector. For further improvement, the “Stage V” proposal was submitted to Brussels in 2014 and it will probably be adopted in 2019. The proposal already applies to all engines, imposing stricter restrictions on PM particles.

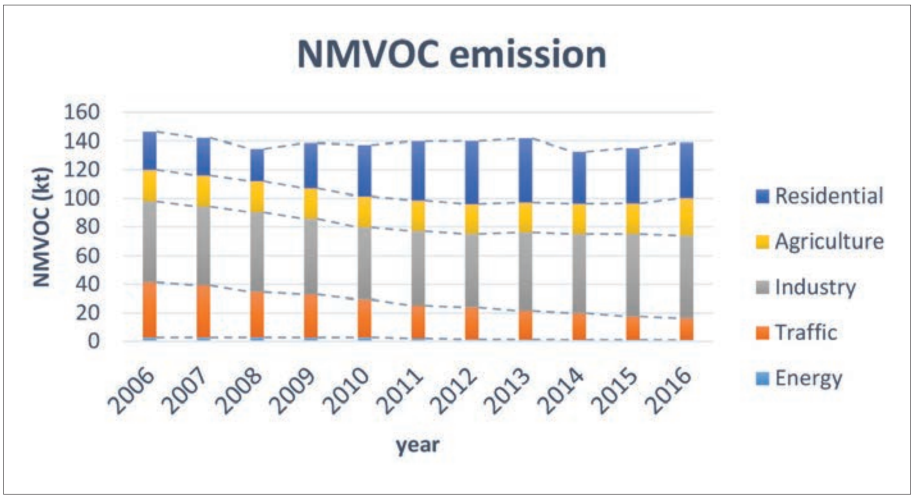

Figure 4: Changes of NMVOC emissions in sectoral breakdown between 2006 and 2016 (Source: OMSZ)

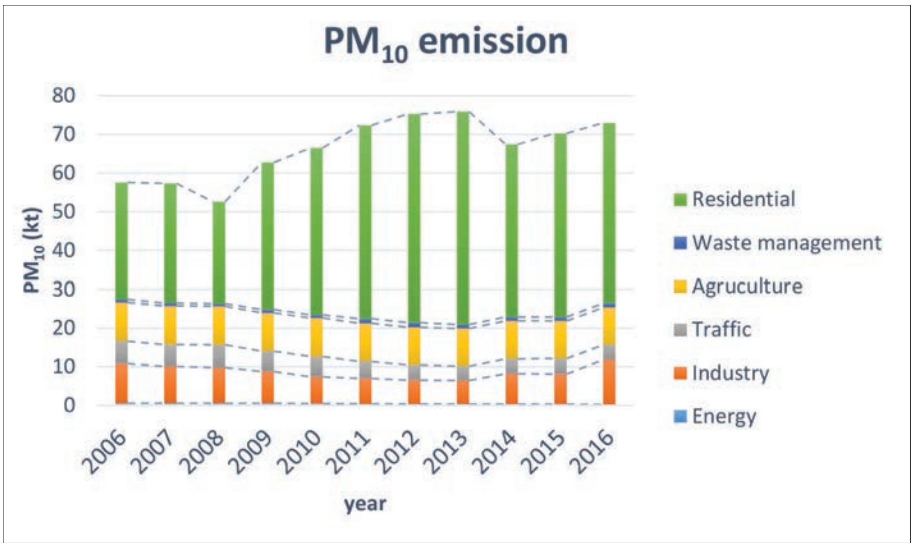

Figure 5: Changes of PM_{10} emissions in sectoral breakdown between 2006 and 2016 (Source: OMSZ)

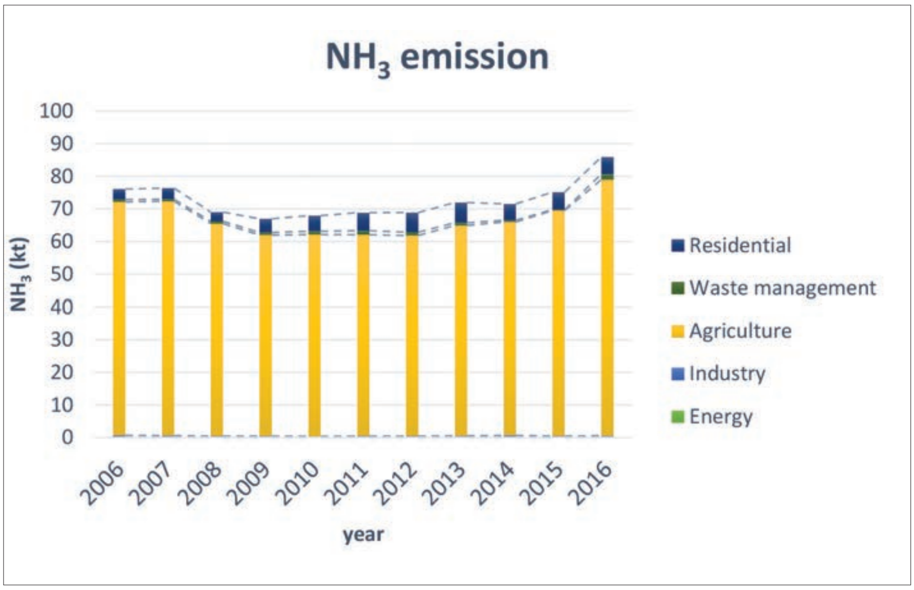

Figure 6: Changes of NH_3 emissions in sectoral breakdown between 2006 and 2016 (Source: OMSZ)

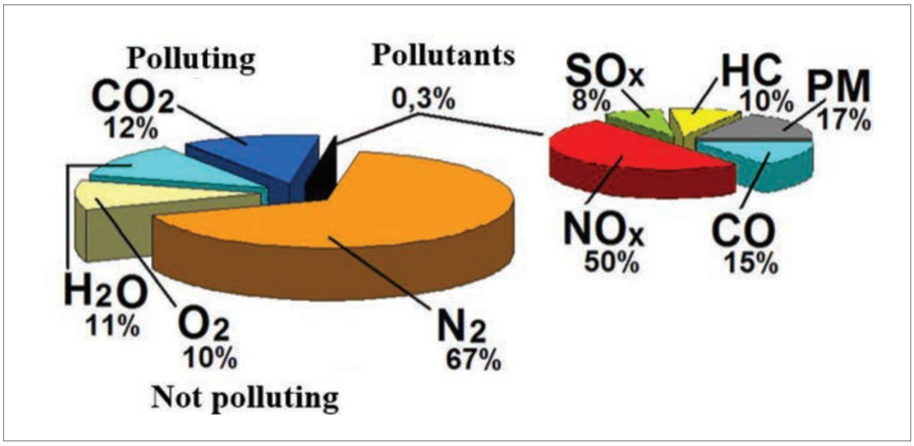

Figure 7: The diesel engine emits untreated exhaust fumes (Source: Varga 2017)

The goal is certainly to develop a cleaner agricultural diesel engine that does not pollute the environment in the following years. (Mészáros 2018, Varga 2012, Varga 2017)

CONCLUSION

During the agricultural activities the most significant air pollutants are ammonia and particular matter 10. In order to reduce the amount of PM_{10} emission it is advisable to consider the tillage frequency or using no tillage, conservation tillage methods if the soil conditions allow these technics. To reduce the amount of ammonia emissions a solution could be to use nitrogen fertilizer combined with crop rotation. Lucerne and clover plants could be good for crop rotation because their roots have a nitrogen-binding ability**.** It is important to choose the proper nitrogen fertilizer and to optimize the protein content of animal feed.

Agricultural production have to be managed properly, because most of our food is grown in agricultural areas. Climate change and extreme weather makes farmers and their situation even more difficult, as we have heard several times and experienced it over the years that a lot of crops have been damaged. There was less produce in those years, and of course the price of the remaining crop was much higher. In order to protect our health and our environment, we must also care for the agricultural sector besides the other sectors, from the point of view of the air pollution.

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CURRENT STATUS AND DISTRIBUTION OF NON-NATIVE SPINY CHEEK CRAYFISH (*FAXONIUS LIMOSUS* RAFINESQUE, 1817) IN LAKE BALATON

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ABSTRACT

Several non-native crayfish species represent a particularly successful group of invasive species in freshwaters, hence their introductions represent one of the main threats to freshwater biodiversity and ecosystem function. In Hungary the noble crayfish (*Astacus astacus*), the narrow-clawed crayfish (*Pontastacus leptodactylus*) and stone crayfish (*Austropotamobius torrentium*) are the native crayfish species. Besides seven non-native Decapoda species, spiny cheek crayfish (*Faxonius limosus*), signal crayfish (*Pacifastacus leniusculus*), marbled crayfish (*Procambarus virginalis*), red swamp crayfish (*Procambarus clarkii*), Australian redclaw crayfish (*Cherax quadricarinatus*), Chinese mitten crab (*Eriocheir sinensis*) and Mexican dwarf crayfish (*Cambarellus patzcuarensis*) are known to be present in different habitats of Hungarian water bodies. The spiny cheek crayfish is currently one of the most prominent aquatic macroinvertebrates in many European countries. The first record of this decapod in Hungary was in 1985 in a side arm of River Danube. Its occurrence in the Sió Canal was first reported in 2004. This study provides a summary of the presence of the spiny cheek crayfish and the dynamics of its distribution in Lake Balaton.

Keywords: Decapoda, Cambaridae, stocking, active expansion, marbled crayfish, Australian redclaw crayfish

INTRODUCTION

The spiny cheek crayfish (*Faxonius limosus* Rafinesque, 1817 – Fig. 1) is one of the most abundant non-indigenous crayfish species not only in Hungary, but in most of the European countries too. This decapod crustacean (other names: American crayfish, striped crayfish) originates from the east coast of the United States (Souty-Grosset et al. 2006). In Europe, this crayfish was first detected in north-eastern Germany and north-western Poland in 1980 (Schulz and Smietana 2001). At that time it was thought to originate from natural habitation as well as the aquarium trade. Nowadays, spiny cheek crayfish has spread across several European countries (Kouba et al. 2014). It was introduced to Hungary from Germany in the late 1950s for economic purposes (Thuránszky 1960). In the wild, the first records in Hungary were from a large secondary branch of River Danube in 1985 (Thuránszky and Forró 1987). Since then, abundant and spreading populations have colonized the complete Hungarian stretch of the River Danube, with a colonization rate estimated at 13 km/year (Puky and Schád 2006). The species also appeared in the River Drava through the River Danube from Hungary (Maguire and Klobučar 2008). The species was found in Slovakia, in the Ipel and Váh rivers (Janský and Kautman 2007, Puky 2009), which are both tributaries of the River Danube. In the second half of the 2000s, the spiny cheek crayfish also reached the drain-

Figure 1: Adult male spiny cheek crayfish from Lake Balaton at Szántód, captured from the deep-water zone of ferry harbour (Photo: András Weiperth)

age area of River Tisza (Sallai and Puky 2008) and a dead specimen was also found in Lake Balaton, while several new populations were found in the different side arms and tributaries in the Hungarian section of the River Danube (Bódis et al. 2012). In summer 2013, the first living individuals of spiny check crayfish were found in the Lake Balaton watershed (Ferincz et al. 2014). Since the first reported occurrence, several reviews have summarised the current location and status of the spiny cheek crayfish in Hungary (Bódis et al. 2012, Gál et. al. 2018, Györe et al. 2013, Ludányi et al. 2016) (Figure 2).

Individuals of this non-native crayfish species are typically dark brown or olive-green with a transverse brown-red band across the abdominal segments and on the pleura. Adults reach about 12 cm in total length. The head is planned in top view, before and behind the cervical cavity, and there are small spikes at the outer edge of the back shield. The claws are smaller than those of native species compared to its body size (Figure 1). The spiny cheek crayfish adapts very well to different environmental conditions e.g. contaminated canals, eutrophic ponds, and brackish habitats, clean flowing and standing waters. Most of its diet is composed of insect larvae, aquatic plants and other organic matter (plant debris, carcasses of fallen animals), but it also preys on fish and amphibian eggs and juveniles (Weiperth 2016). The highly successful colonization and rapid spread of this species is due to its parthenogenetic growth (Puky 2014). The main threat posed by this species, however, is the fungal disease of North American origin, called crayfish plague (*Aphanomyces astaci* Schikora, 1903). The species can also serve as an intermediator (vector) as it is resistant to the disease. Unoccupied habitats can easily be conquered by the species, and large populations can develop. Hungarian researchers have observed that this species can live with native species, which is also possible since not all spiny cheek crayfish in Europe carry crayfish plague (Kozubiková et al 2010). As a result, it can be assumed that it cannot only replace native crayfishes, but can also suppress them. Changes in the ecological status of waterbodies poses a serious risk to native endangered species (Yee 2014). Consequently, the occurrence of *F. limosus* in Hungary was surveyed within a program focused on the status of this non-native crayfish species in Lake Balaton.

MATERIAL AND METHODS

Nineteen sampling points were surveyed for the crayfish fauna in the watershed of Lake Balaton. Fifteen sampling points were in the four basins of Lake Balaton, one in the thermal outflow of Lake Héviz, two in north-part tributaries (Eger-víz, Lesence-stream) and one in the Sió Canal. The crayfish fauna of Lake Balaton was monitored and sampled using baited crayfish traps, different types of handling nets and electrofishing (DEKA 3000 Lord). The samplings were done within three seasons (spring-

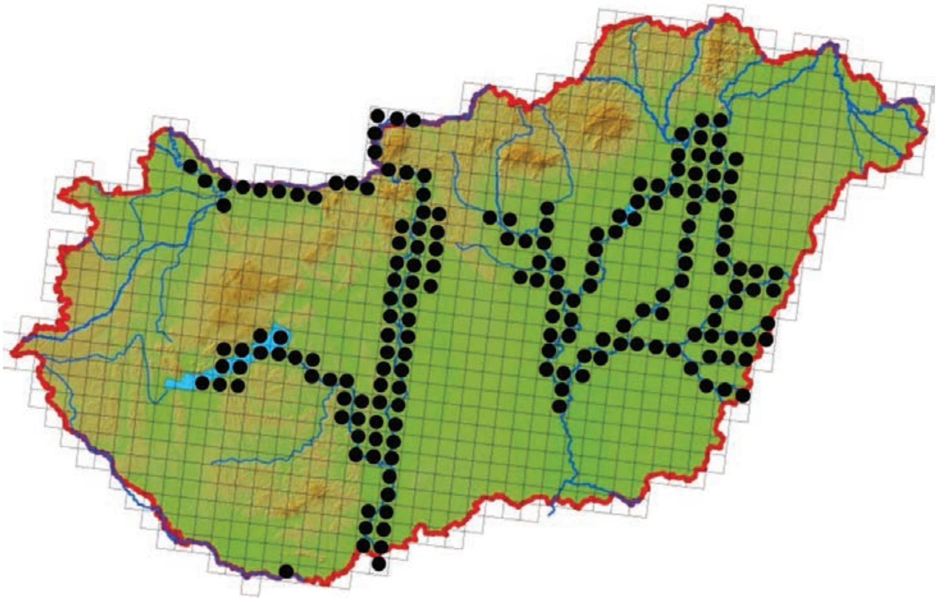

Figure 2: The present distribution of the spiny cheek crayfish (*Faxonius limosus*) in Hungary. Map summarises the data from Bódis et al. (2012), Györe et al. (2013), Ludányi et al. (2016) and Gál et. al (2018)

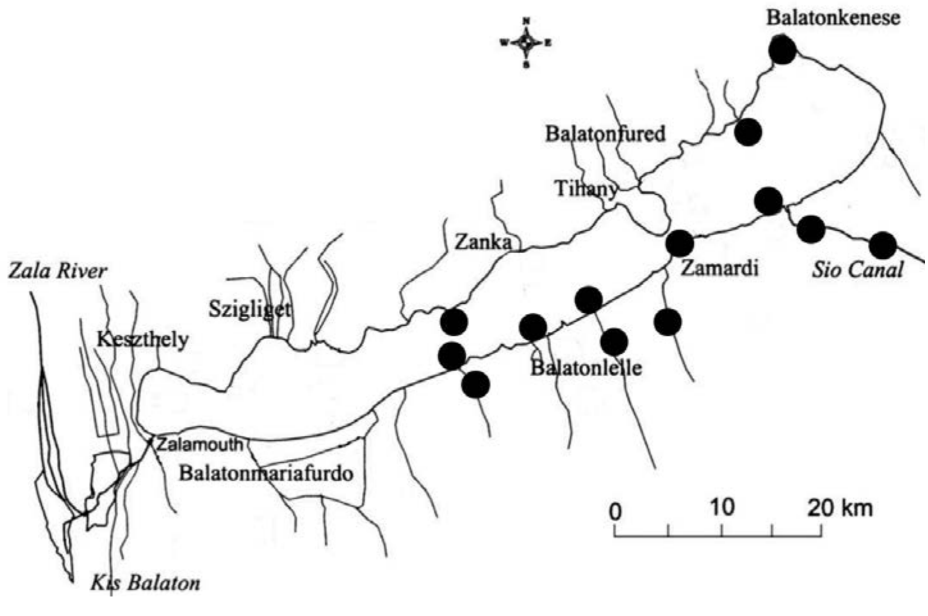

Figure 3: Map of the study area and sampling stations (Map: Nguyen et al. 2005)
The WGS84 coordinates of locations with the spiny cheek crayfish presence are depicted in black circles

summer-autumn) in all sampling areas between 2015 and 2017. Besides our dataset, records made within Balaton-felvidék National Park were summarised. Field staff from the Balaton-felvidék National Park measured the crayfish fauna with crayfish traps in 16 west- and south-part tributaries (Bédai-víz, Tetves-stream, Kiskomáromi Canal, Pogány-völgyi-víz, Jaba-stream, Páhoki Canal, River Zala, Egyesített-övcsatorna, Gyöngyös-stream) between winter 2016 and summer 2018. Our field datasets were used to show the current status and help to understand the dynamics of spiny cheek crayfish spread in Lake Balaton.

RESULTS

In the two research programs, a total of 76 spiny cheek crayfish individuals were sampled in Lake Balaton and in the Sió Canal (Figure 3). During the field sampling the native noble crayfish (*Astacus astacus*) was sampled in the Berdai-víz, Kiskomáromi Canal, Jaba-stream, Pogány-völgyi-víz, Tetves-víz, Zala River and the native narrow-clawed crayfish (*Pontastacus leptodactylus*) only from Lake Balaton. The marbled crayfish (*Procambarus virginalis*) occurred in west-part tributaries and in the Keszthely basin of Lake Balaton. Two adult female individuals of Australian redclaw crayfish (*Cherax quadricarinatus* von Martens, 1868) were sampled in the thermal outflow of Lake Héviz in summer and autumn 2017. Besides the crayfish species, 1361 individuals of 27 fish species were sampled. We recorded the presence of non-native round goby (*Neogobius melanostomus*) in Lake Balaton at Siófok, and in the upper section of Sió Canal (Weiperth 2018).

DISCUSSION

Currently two native and three non-native decapods have been reported in the watershed of Lake Balaton. Based on our results, the spiny cheek crayfish is the most abundant and widespread non-native crayfish species in the whole catchment of Lake Balaton. Ferincz et al. (2014) found the first living individuals of this species in a private pond in the Jamai-stream. Thereafter, the species has been detected in the stream and in the estuarine habitats of Lake Balaton (Figure 3). In the middle of 2000 and at the same time that the first data was published, the spread

Figure 4: Harbor at Révfülöp at Lake Balaton, which is a preferred habitat of Faxonius limosus (Photo: Weiperth András)

of the spiny cheek crayfish was observed from lower and middle section of the Sió Canal (Puky 2004, Puky et al. 2005, Miklós Puky unpublished data). Moreover, it is important to note that several non-native Ponto-Caspian goby species originated from the direction of the River Danube, and in the near future, several goby species could potentially spread into Lake Balaton (Czeglédi et al. 2018). Overall, we can ascertain that the spiny cheek crayfish appeared and spread from several directions of Lake Balaton. The accidental or intentional stocking of this species near the Sió Canal has been proceeded by a relatively fast colonisation and spread of this species throughout the watershed of Lake Balaton.

CONCLUSIONS

In the last five years, several new non-native decapod species appeared not only in the Carpathian Basin but in the entire watershed of Lake Balaton. Among these non-native species, the spiny cheek crayfish colonised the greatest number of aquatic habitats in Hungarian water bodies (Ludányi et al. 2016, Gál et al. 2018). This highly-adaptable, non-native crayfish is known to be an ecosystem engineer and could potentially modify various environmental and biological processes in the locality. Based on the findings we have presented, we can conclude that this North-American crayfish species has been a member of the local fauna of the Lake Balaton watershed in the last five years since the first individual was recorded in this locality. This observation is important for conservationists, wildlife managers, hobby keepers and other stakeholders.

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Figure 5: Faxonius limosus specimens collected at Békésszentandrás along River Hármas-Körös
(Photo: Weiperth András)

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