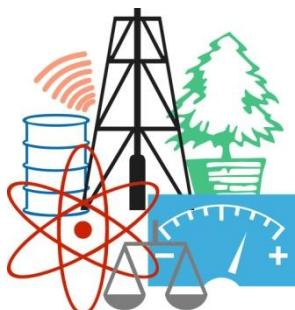


WASTE FORUM



ELECTRONIC PEER-REVIEWED JOURNAL ON ALL TOPICS
OF INDUSTRIAL AND MUNICIPAL ECOLOGY

RECENZOVANÝ ČASOPIS PRO VÝSLEDKY VÝzkumu a VÝvoje
z OBLASTI PRŮmyslové a KOMUNÁLní EKOLOGIE

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Týden výzkumu a inovací pro praxi a životní prostředí 2022
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Czech Environmental Management Center 2022

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Úvodní slovo šéfredaktora

Vážení čtenáři,

tímto číslem tento časopis vstupuje do 15. roku vydávání. Hlavním impulzem k založení tohoto časopisu byla zkušenost z redakce tištěného odborného časopisu **ODPADOVÉ FÓRUM** (a ještě předtím časopisu **ODPADY**), kdy nám byly do redakce zasílány vědecké články, pro které neměli jejich autoři jinde uplatnění. Jenže ony se svým charakterem (a rozsahem) do daného časopisu, který byl určen široké odborné veřejnosti, nehodily. V reakci na to jsem nejprve vymyslel symposium **Výsledky výzkumu a vývoje pro odpadové hospodářství ODPADOVÉ FÓRUM**, jehož první ročník se konal v roce 1996 v Milovech na Vysočině. Od té doby se toto symposium (s výjimkou kovidového roku 2020) koná každoročně. Před pár lety jsme rozšířili záběr symposia (stejně jako tohoto časopisu) rozšířili na celou oblast průmyslové a komunální ekologie a začlenili spolu s konferencí **APROCHEM** do Týdne výzkumu a inovací pro praxi a životní prostředí **TVIP**. Pozvánku na letošní ročník najdete na konci čísla, protože **TVIP** 2022 je patronem čísla.

Koná každoročně. Před pár lety jsme rozšířili záběr symposia (stejně jako tohoto časopisu) rozšířili na celou oblast průmyslové a komunální ekologie a začlenili spolu s konferencí **APROCHEM** do Týdne výzkumu a inovací pro praxi a životní prostředí **TVIP**. Pozvánku na letošní ročník najdete na konci čísla, protože **TVIP** 2022 je patronem čísla.

Ale zpět na začátek. Zpočátku šlo hlavně o to, aby se časopis dostal na oficiální Seznam neimpaktovaných recenzovaných periodik vydávaných v ČR. To se po vyplnění poměrně složitého dotazníku záhy podařilo. Později toto přestalo stačit a na řadě byl **SCOPUS**. To už tak snadné nebylo, nicméně na druhý pokus se to v roce 2017 podařilo.

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Ondřej Procházka

Editorial

Dear readers,

you may be wondering why you should publish the results of your work in WASTE FORUM. There are at least two reasons for this:

First of all: The magazine is freely accessible, so anyone who is interested in this topic can get to your contribution, no matter what country or institution they come from. All he needs is internet access. The survey of interest in the magazine showed the highest numbers of withdrawals of complete issues by visitors from the USA, China, Czech Republic, Ukraine (Long live Ukraine!) and Russia (Russians, home !!!). The order in these top five places has, of course, changed over the years. Plus: There aren't many open access magazines in the world!

Second: It's the speed of publishing. The paper, which corresponds to the quality and passed the review procedure without major problems, is published no later than 10 weeks after the editorial deadline.

Regards

Ondřej Procházka

Pro autory

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Uzávěrka nejbližšího čísla časopisu WASTE FORUM je 8. dubna 2022, další pak 8. července 2022.

For authors

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To cover the costs of publishing the magazine, the authors pay a publication fee of CZK 500 per page. In the event that the article is not published on the basis of a negative result of the peer-review procedure, the author will be invoiced for an editorial fee in the amount of half the publication fee.

The deadline of the next issue is on April 8, 2022, more on July 8, 2022.

Study of the influence of temperature and reducing agents on the chromium content in slag in the air atmosphere

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Summary

The paper presents the results of laboratory experiments of the reduction of chromium and its oxides from slag using carbon and silicon reducing agents. The study of chromium reduction from molten slag to molten steel was carried out for slag originating from the production of stainless steel with an average elemental content of 0.16 wt. % C, 16.25 wt. % Cr, 5.00 wt. % Ni and 1.05 wt. % Mo. Based on the literature studies experiments on chromium reduction from slag with high Cr_2O_3 content (16 wt. %) were designed, implemented, described and subsequently evaluated. The reduction was carried out using a reducing agent of carbon in the form of anthracite and silicon in the form of ferroalloy FeSi. The atmospheric conditions and pressure were used for experiments. The temperature of the slag was raised by an oxy-fuel burner and the carbon and silicon reducing agents were applied on the surface of the molten steel. The experiments confirmed the possibility of reducing up to 62 % of chromium from the molten slag back into the stainless steel melt.

Keywords: Stainless steel, slag, chromium, carbon, silicon, ferrosilicon.

1. Introduction

In stainless steel production, reducing production and energy costs is essential to ensure the competitiveness of metallurgical companies. The production of stainless steel is inherently related to the production of slag, which is nowadays largely disposed of in landfills. In the first quarter of 2021, more than 14.5 million tonnes of stainless steel were produced worldwide¹. Considering that 270 – 335 kg of slag is produced per tonne of stainless steel, 3.9 – 4.8 million tonnes of slag was produced in just a short period 1Q 2021². In doing so, there is a strong drive by manufacturing companies to minimise production costs, reduce environmental impact and ultimately reduce their carbon footprint.³. Research of the thermal reduction of chromium from slag has been published by many authors^{3, 4, 5, 6, 7, 8, 9}. Most of the experimental work was performed only on a laboratory condition and has not been transferred to the practice of large industrial companies¹⁰.

When the melt is produced from alloyed chromium waste (hereafter referred to as Cr waste) in an electric arc furnace (hereafter referred to as EAF), chromium is oxidized and lost to the slag in the form of chromium oxide. The loss of chromium from the melt into the slag is up to 97 wt. % if alloyed waste is used. Oxidation of chromium takes place during smelting and to an even greater extent during the process of carbon reduction in the melt by oxygen injection. A minor part of the chromium is oxidised during casting from the EAF into the casting pan^{11, 12, 13, 14, 15}.

Inclusion complexes containing chromium oxides are complicated in that chromium occurs in 3 powers, Cr^{2+} , Cr^{3+} and Cr^{6+} , depending on the partial pressure, temperature and chemical composition of the slag. Bivalent and trivalent chromium is found in stainless steel slags¹⁵. The aim of the production companies is to use the maximum potential of the slags, so today, reduction with silicon, aluminium or calcium is used already during the melting process, which leads to a reduction of the chromium content in the slag. Another option is to reduce the chromium activity and convert the chromium into stable spinel bonds. Commonly used compounds for spinel bond formation are Al_2O_3 and MgO ⁴.

In metallurgical aggregates, reducing additives that have a higher affinity for oxygen than chromium is used to reduce chromium from slag to melt. These are mainly carbon, silicon and aluminium. Slag reducing additives need to have a large reaction surface to produce more intense and faster reduction reactions. For example, the author ¹⁶ ports the use of aluminium with a granule size of 1 – 2 mm with a dosing rate of 50 kg.min⁻¹ for a total dose of 10 kg.t⁻¹ Al per tonne of steel. The flow of production technology, and in particular the dosage of aluminium and carbon, at BGH company in the production of stainless steels is presented in the Figure 1. The Figure 1 shows the period of blowing oxygen, heating gas, electrical input, blowing pulverized carbon, lime and aluminium.

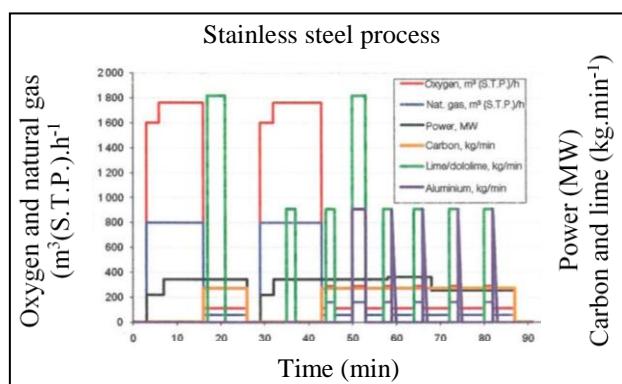


Figure 1: Typical stainless steels production process at BGH with aluminium and carbon dosing¹⁶

The author ¹⁷ states that at the beginning of the oxidation period the silicon content in the melt must be 0.3 wt. % Si. The reason for this is the preferential oxidation of silicon over chromium, thus preventing chromium loss to the slag. The back-reduction of chromium by silicon and carbon follows the chemical reactions (1) and (2) below, according to the authors ¹⁸ and ¹⁹,



From a thermodynamic point of view, the back-reduction of chromium from slag to melt is dependent on temperature, the chemical composition of the slag and the chemical composition of the melt. The author ²⁰ presents below the thermodynamic equilibrium reactions (3),

$$\log(\% \text{Cr})_{\text{slag}} = 4.887 - \frac{8866}{T} + 0.340\log[\% \text{Cr}] - 0.178\log[\% \text{Si}] - 1.721\log B, \quad (3)$$

where B is the slag basicity expressed by the relation (4),

$$B = \frac{\text{CaO}}{\text{SiO}_2}, \quad (4)$$

However, according to the author ²⁰, there is a significant difference between the calculated equilibrium states and the actual data from industrial practice. For this reason, the author presents the thermodynamic equation (5) obtained from a statistical evaluation of data from industrial practice.

$$\log(\% \text{Cr})_{\text{slag}} = 1.118 + \frac{949}{T} - 0.550\log[\% \text{Cr}] - 0.154\log[\% \text{Si}] - 0.508\log B, \quad (5)$$

where B is the slag basicity expressed by the relation (6),

$$B = \frac{\text{CaO} + \text{MgO}}{\text{SiO}_2}. \quad (6)$$

The author ²⁰ presented that from theoretical formulas (3) and (4) and from formulas obtained from practice (5) and (6) it follows that very important aspects for the reduction of chromium from slag to melt are temperature, chemical composition of melt and chemical composition of slag. The temperature dependence of the Gibbs energy for the reduction of chromium by calcium carbide, carbon and silicon is presented by the author ¹⁸ using the graph in Figure 2. Figure 2 shows that the effect of reduction of chromium from slag, by calcium carbide (CaC_2) and carbon, increases with increasing temperature, and that reduction by silicon is not so temperature dependent. Experimental melt reduction of Cr from slag to melt is also described.

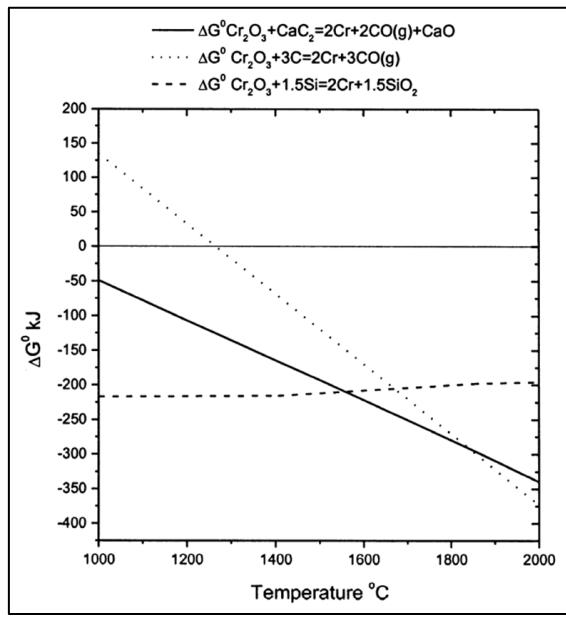


Figure 2: Temperature dependence of Gibbs energy for the reduction of chromium with calcium carbide, carbon and silicon ¹⁸

Based on a literature review describing the relationship of chromium reduction from slag to melt, a design and experimental verification of Cr reduction from slag to melt was performed. Due to the complexity of the experiments, the effect of the content of reducing agents at a constant melt temperature was investigated in the first phase. The aim of the laboratory experiment was to verify the possibility of Cr_2O_3 reduction from slag using carbon and silicon agents.

2. Experimental materials and methods

The experimental melts were carried out on an atmospheric induction melting furnace (INDUCTOTHERM EUROPE LTD, Worcestershire, England) with a nominal melt weight of 1750 kg (hereafter referred to as AIF), frequency 1200 Hz, power input 600 kW. An oxygen-fuelled 1M200 burner (Linde AG, Deutschland), hereafter referred to as KPH, fed by oxygen and propane-butane, was used to heat the slag.

Chromium reduction experiments from slag were performed for a melt with the chemical composition shown in the Table 1. The experiments were carried out in an AIF containing a crucible made of dry Al_2O_3 based asphyxiant. The chemical composition of the externally supplied slag for the experiments is presented in the Table 2. The slag used had a granulometry of about 20 – 50 mm.

Table 1: Chemical composition of melt quality 16Cr5Ni1Mo (wt. %)

	C	Mn	Si	P	S	Ni	Cr	Mo
16Cr5Ni1Mo	0.20	0.36	0.33	0.015	0.005	4.83	16.03	1.04

Table 2: Chemical composition of slag (wt. %)

Component content	C	S	Fe	FeO	Fe ₂ O ₃	MnO	Cr ₂ O ₃	V ₂ O ₅	TiO ₂
Component content	0.12	0.034	12.95	0.01	0.47	2.97	15.87	0.21	3.12

Table 2: Chemical composition of slag (wt. %) (continuing)

CaO	SiO ₂	P ₂ O ₅	Al ₂ O ₃	MgO	CaF ₂	Na ₂ O	Zn	K ₂ O	BaO	Nb ₂ O ₅
24.63	21.27	0.01	8.94	8.72	0.01	0.01	0.01	0.04	0.01	0.47

Slag weighing 45 kg and the slag forming additive MgO, was introduced to the surface of the 1000 kg steel melt. Then KPH was switched on for full and rapid melting of the slag. After melting the slag in about 20 min and heating the melt to 1650 °C, a sample of metal and slag was taken for chemical analysis. Then the reducing additive C weighing 1.7 kg was dosed in the form of anthracite with a granulometry of 1-3 mm. Together with the reducing additive Si in the form of FeSi with a granulometry of 1-3 mm weighing 3.9 kg. The Si and C additives together formed a so-called single reduction batch. In the first experiment, 1x reduction dose was introduced, in the second experiment 2x reduction dose, in the third experiment 3x reduction dose, in the fourth experiment 4x reduction dose and in the fifth experiment 5x reduction dose.

For the sixth experiment, a 3-fold reduction dose was introduced, first only Si was dosed and only after metal and slag sampling (after 10 min) was C dosed. For the seventh experiment, a 3x multiple reduction dose was introduced, containing C and Si at the same time. But during the seventh experiment, the Si content in the melt was twice that of the previous experiments and was 0.6 wt. % Si.

Reducing additives were introduced to the slag surface while the oxy-fuel burner was on. They were then mixed with the slag by external mixing. Slag sampling for chemical analysis and melt temperature measurements were carried out after 5 minutes, for a total of 30 minutes after the first reduction charge was introduced.

After the completion of each set of experiments, the steel melt was poured from the AIF to the pouring ladle and subsequently under protective argon atmosphere a V2A ingot was poured.

3. Results

Change of Cr₂O₃ content in slag is presented in Figure 3. It shows that the highest reducing power was at three times the reducing dose. A total of 53 wt. % Cr was reduced from the slag, i.e. 1.94 kg Cr, see Figure 4 and Table 3. Based on the findings, further experiments were carried out with a triple reduction dose, where the very best result was achieved by successive dosing of Si followed by C in the sixth experimental melt, where 62 wt.% Cr was reduced.

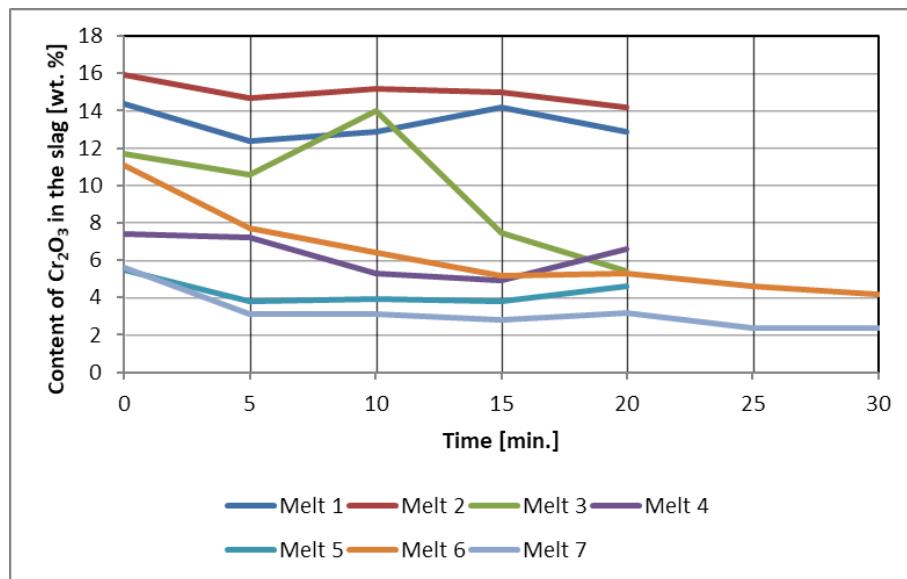


Figure 3: Change of Cr_2O_3 content in slag for all experimental melts

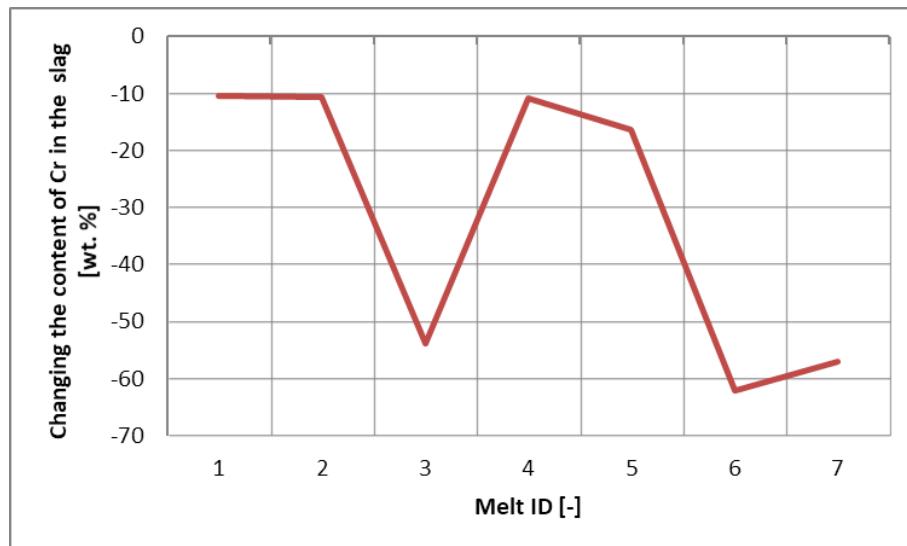


Figure 4: Total change of Cr content in slag in all experimental melts

Table 3: Change of chemical composition and weight of Cr_2O_3 and Cr in slag during individual experiments

	Units	Experimental melts						
		1.	2.	3.	4.	5.	6.	7.
Multiplication of the reduction dose of Si and C	[1]	1x	2x	3x	4x	5x	3x*	3x**
Si content in the melt	[wt. %]	0.33	0.33	0.33	0.33	0.33	0.33	0.60
Slag weight	[kg]	45	45	45	45	45	45	45
Change of Cr_2O_3 content in slag	[wt. %]	-1.50	-1.70	-6.30	-0.80	-0.90	-6.90	-3.20
	[kg]	-0.68	-0.77	-2.84	-0.36	-0.41	-3.11	-1.44
Change of Cr content in slag	[kg]	-0.46	-0.52	-1.94	-0.25	-0.28	-2.12	-0.99
	[wt. %]	-10.42	-10.69	-53.85	-10.81	-16.36	-62.16	-57.14

Note: * initially only Si was dosed and after 10 min C was dosed.

** the melt had a different Si content in the melt compared to the other melts.

An optical assessment of the appearance of the slag was also performed. This evaluation is only indicative or trend. From Table 4 it can be concluded that the slag was, after the introduction of the reducing additives C and Si, fully liquid in experiments 1 and 2 after 20 minutes, in experiment 3 after 10 to 15 minutes, and in experiments 4 and 5 probably due to the large amount of reducing additives it did not fully liquefy.

Table 4: Comparison of the appearance of the collected slag samples for all experiments, after cooling

Time of collection	Cr_2O_3 content [wt. %] in the slag and appearance of the slag sample taken according to the experiment number or multiplication of the reduction dose of C and Si				
[min.]	1.	2.	3.	4.	5.
0	14,4 	15,9 	11,7 	7,4 	5,5
5	12,4 	14,7 	10,6 	7,2 	3,8
10	12,9 	15,2 	14,0 	5,3 	3,9
15	14,2 	15,0 	7,5 	4,9 	3,8
20	12,9 	14,2 	5,4 	6,6 	4,6

Conclusions

The paper presented the results of laboratory experiments of the reduction of chromium and its oxides from slag using carbon and silicon reducing agents. The 16Cr5Ni1Mo stainless steel was used. The atmospheric conditions and pressure were used for experiments. The temperature of the slag was raised by an oxy-fuel burner.

It can be concluded that changes of Cr_2O_3 content in the slag were clearly achieved. The evaluation shows that the highest reduction ability was obtained in the 6th experiment, i.e. a triple reduction dose, when Si (total 11.7 kg) was first applied on the melt surface and C (total 5.1 kg) was applied on the surface after 10 min for 45 kg of slag.

The industrial partner with whom it was cooperating at the time of the experiments seriously considered introducing this technology into production. Further experiments leading to higher Cr reduction from slag to melt are currently being proposed.

The most effective 6th experiment, at three times the reduction dose, showed:

- highest 62 wt. % reduction of Cr₂O₃ from slag,
- optical evaluation of the slag samples collected in Experiments 1 to 5 confirmed that the slag with triple reduction dose showed the highest fluidity. Therefore, the highest contact reaction area between the melt and the slag can be inferred.

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Studium termické redukce chromu ze strusky pomocí redukčních činidel v atmosféře vzduchu

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Souhrn

Článek prezentuje výsledky laboratorních experimentů redukce chromu a jeho oxidů ze strusky pomocí redukčních činidel uhlíku a křemíku. Studium redukce chrómu z roztavené strusky do taveniny oceli byla realizována pro strusku vznikající při výrobě korozivzdorné oceli o středním obsahu prvků 0,16 % C, 16,25 % Cr, 5,00 % Ni a 1,05 % Mo. Na základě rozboru problematiky byly navrženy, realizovány, popsány a následně vyhodnoceny experimenty redukce chrómu ze strusky o vysokém obsahu Cr₂O₃ (16 %) pomocí redukčních činidel uhlíku ve formě antracitu a křemíku ve formě ferositiny FeSi. Experimenty byly provedeny v atmosférických podmínkách za intenzifikace teploty strusky pomocí kyslíko-palivového hořáku a současného působení redukčního činidla uhlíku a křemíku. Experimenty potvrdily možnost redukce až 62 % chrómu z roztavené strusky zpět do taveniny korozivzdorné oceli.

Klíčová slova: korozivzdorná ocel, struska, chrom, uhlík, křemík, ferosilicium.

Effect of chemical additives (coagulants) on the nutritional quality of compost prepared from poultry litter

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Abstract

This study was conducted to know about the nutritional quality of poultry litter amended with chemical coagulants after composting. For this purpose, chemical coagulants (i.e. Aluminum Sulphate and Aluminum Chloride, a dosage of 45g /chick) were applied in the selected poultry farms. Three types of poultry litter (i.e. treated with Aluminum Sulfate, Aluminum Chloride and untreated waste/control) were collected for compost and characterized for different macro and micro nutrients. It was observed that pH, EC, organic carbons were decreased while the nitrogen content was increased in chemically treated composts. The percentage difference in pH was -6.5%, -10.5% and -11.3%; -EC 6.1%, -19.3% and -15.6%; organic carbon -12.9%, -20% and -20%, while nitrogen was +24.6%, +28% and +25.2% for control compost, Al_2SO_4 treated litter compost and Al_2Cl_3 treated litter compost. Furthermore, the comparative analysis showed the sequence of high nutrition as control> control compost> Aluminum Chloride treated compost>Aluminum Sulfate treated compost. The recorded metal contents of control and composts were within the permissible limits set by USEPA and considered safe for agriculture. One-way anova among control and compost group showed significant ($p = .000$) effects while the interaction showed a non-significant difference ($p = .744$). However, the extensive and regular application of poultry litter may cause metal contamination. Hence, to ensure its benefits as a soil conditioner, it was recommended to implement management strategies such as chemical amendments of poultry litter, proper composting and regular monitoring of the poultry litter application into the soil.

Keywords: Aluminum Sulfate (Al_2SO_4); Aluminum Chloride (Al_2Cl_3); Amendment; Poultry Farms.

1. Introduction

In Pakistan, the poultry industry is one of the most dynamic, well-organized, growing and profitable agro-based sectors¹. Due to rapid expansion in the poultry sector, poultry litter production is also increasing. Poultry litter is a combination of different materials as feathers, feaces, waste feed, and bedding material etc. Poultry litter is also considered as a soil builder because of its high nitrogen and organic matter that can boost plant growth².

Recently, poultry litter is receiving more popularity as organic fertilizer due to the high cost of inorganic fertilizers coupled with the limited ability of inorganic fertilizers to improve soil quality^{2,3}. In spite of the fact that farmers use poultry litter as organic fertilizer, it contains potentially harmful metals that are also used as feed additives, for the growth of broilers and to

treat diseases. Previous studies have demonstrated an increase in the content of various metals in poultry litter when applied frequently to agriculture fields because soil acts as a sink for metals where they are accumulated for long times. The metal bioaccumulation in the soil and their transfer to cultivated crops affect the food chain⁴. Several other studies found elevated levels of metals in poultry litter amended soil that can be a great source of transfer and uptake in cultivated crops with repeated applications⁵.

Numerous experimental researches have been conducted concerning the poultry litter amendment with chemicals and reported an enhancement in the physical and chemical properties of the soil. The amended poultry litter with chemical coagulants like Aluminum Chloride (Al_2Cl_3) and Aluminum Sulfate (Al_2SO_4) that showed effective results by making the poultry litter suitable for fertilizer^{6,7,8}. The addition of Al_2SO_4 and Al_2Cl_3 in poultry litter could effectively increase the physico-chemical properties of soil^{9,10}.

Mostly farmer's stored poultry litter in the open air before application on the agriculture field¹¹. The storage of poultry litter is a better option but this open storage is a source of unpleasant odor, the release of toxic gases along with the losing of essential nutrients. If poultry litter is covered with a tarp, this practice will not only conserve valuable nutrients but also limit the potential generation of environmental pollution¹². The covered storage method of composting gave the best nutrients for poultry litter as a fertilizer favored by¹³.

Composting is a method for waste recycling, reduction, and control of nitrogen contents. It may reduce the mobility and translocation of metals in the environment compared to raw litter. The application of poultry litter after composting is considered advantageous and beneficial to metal contaminated soil¹⁴. It is documented that unplanned preparation and use of composted litter may result in various related issues i.e. production/growth of crops, release toxic gases and metal contamination of the soil, which may have the potential to enter into the food chain⁵. Hence, it is necessary to identify such techniques that will improve litter quality and reduce nutrient loss. The main objective of this study was to treat the poultry litter with chemical coagulants and know the chemical characteristics for nutrients.

2. Research Methodology

This study was divided into three phases as shown in Figure 1. In the first phase, the chemical amendments of poultry litter to selected poultry farms were carried out. In the second phase, compost was prepared. In the third phase, the characterization of the control and compost group was carried out.

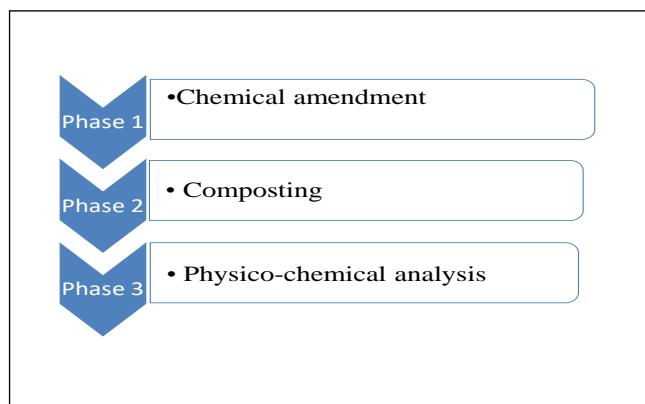


Figure 1: Phases of study

2.1. Field Visit and Chemical Treatment

A total of 6 poultry farms were randomly visited and selected for an experiment in Haripur District. These farms were easily accessible and the owners and workers were willing for the experiment. To maintain the nutrients in the poultry litter, In-situ chemical treatments were given to six selected farms and were kept under observation for a complete cycle. Out of the total, two farms were treated with Al_2SO_4 and two with Al_2Cl_3 . The rest of two were considered as untreated poultry farms (control) for the comparative study. In the treatment process, chemicals such as Aluminum Sulphate and Aluminum Chloride were applied at a rate of 45 grams/bird presented in Table 1 described by¹⁶ i.e. Aluminum Sulfate is typically applied to 45 – 90 grams/bird.

Table 1: Amendment of poultry farms with coagulants

Farm	No. of Chicks	Coagulant	
		Type	45 g/chick
Farm 1	500	Al_2SO_4	22,500
Farm 2	800	Al_2Cl_3	36,000
Farm 3	500	Control	-----
Farm 4	400	Al_2SO_4	18,000
Farm 5	500	Al_2Cl_3	22,500
Farm 6	500	Control	-----

2.2. Poultry Litter Collection

A total of 6 samples, one from each poultry house were randomly collected for the compost preparation. 100 Kg of poultry litter was collected and thoroughly mixed separately from each farm. The larger aggregates from the collected litter were arranged into small pieces, air-dried and stored for compost.

2.3. Preparation of Compost

The prepared (dried and segregated) litter was categorized into control, Al_2SO_4 and Al_2Cl_3 treated litter. Further compost was prepared by a covered heap storage method. In this method, samples were placed as a pile on the ground and covered with a plastic sheet for three months, described by¹⁷.

2.4. Laboratory Analysis of Poultry Litter and Compost

For laboratory experimentation, larger particles from samples were grinded, passed through 2.0mm screen, and stored in plastic bags. Each sample (i.e. control and compost group) was analyzed for different parameters (i.e. pH, EC, organic carbon, nitrogen, arsenic, cadmium, copper and zinc). The EC and pH of the samples were measured using Inolab pH and EC meter in the aqueous extract. The aqueous extract was obtained by mechanically shaking each sample with 10:1 distilled water to litter in a beaker, mixed thoroughly for 5 min as per the standard procedure of ¹⁸. For the estimation of organic carbon, 1g of sample was taken in a silica porcelain crucible and was dried in a muffle furnace at 500 °C for 4 hours. The weight of ash was recorded. Organic carbon content in the samples was calculated by the equation 1. Where 1.8 is for the conversion of total organic matter into organic carbon as given by ¹⁷.

$$C = \frac{100 - (\text{Ash \%})}{1.8} \dots\dots\dots (1)$$

The content of nitrogen was measured by Kjeldahl analysis. In this method, 1 g of dried sample was taken into a Kjeldahl flask with 20 ml of concentrated H_2SO_4 and 3 grams of digestion mixture. The flask was heated until the clear digestate appeared. Nitrogen was determined by distillation followed by titration against 0.01 N H_2SO_4 ¹⁷. As, Cd, Cu, and Zn were analyzed using an atomic absorption spectrophotometer. The samples were digested separately with aqua-regia as¹⁹. In this method, 1gram of each sample was digested in 15 ml of aqua regia at 80 – 180 °C. This solution was filtered and diluted with distilled water to 50 ml to obtain a transparent solution and subjected to an atomic absorption spectrophotometer for metals detection.

2.5. Statistical Analysis

The average, percentage difference and standard deviation were determined by MS Excel 2010. Further, the data was subjected to statistical analysis using SPSS Version 16.0. ANOVA was employed to find the statistically significant differences between groups. The significant difference was considered as $p = 0.05$ with 95% confidence intervals for the independent variable (litter) for each separate group (control, control compost, Aluminum Sulfate treated litter compost and Aluminum Chloride treated litter compost), as well as when all groups are combined (Total).

3. Results and Discussion

3.1. Compost

The compost of control, Al_2SO_4 and Al_2Cl_3 treated litter was prepared. The poultry litter took 90 days (3 months) for complete biodegradation of the material. After composting, poultry litter changed from light brown to dark brown and became fine and soft as compared to raw litter, shown in Figure 2. These results are in line with those of²⁰ that a favorable time for composting was between 60 – 90 days. In this period, the maximum decomposition of organic waste occurred. Composting is an important and effective pre-treatment for effective utilization of poultry litter as fertilizer.²¹ The compost will have a more stable organic content and long-lasting residual effect on soil as compared to the application of inorganic fertilizers²². Thus, the application of compost litter is economically viable and promotes sustainable productivity.



Figure 2: Comparison of litter and composts group

3.2. Physico-chemical Characterization of Control and Compost Group

3.2.1 pH

The pH value was decreased in the compost group as compared to the control. Although a slight difference in the value of pH was found among composts (Table 2). The pH of poultry litter is a driver of gaseous emissions, directly increased with an increase in pH of poultry litter¹⁰. Poultry litter with pH lower than 7 released 10 times less ammonia than litter with a pH above 8. The addition of $\text{Al}_2(\text{SO}_4)_3 \cdot 14\text{H}_2\text{O}$ and $\text{AlCl}_3 \cdot 6\text{H}_2\text{O}$ as chemical coagulants to the litter can control the release of nutrients^{23,24}. It is quite clear from the recent data that after the chemical amendment at poultry litter, a progressive decline in the pH was observed. The reason may be the acidic nature of coagulants that are used for the poultry litter amendment and the hydrolysis of aluminum that also dropped the litter pH. A similar finding was proved by⁷ that Al_2SO_4 and Al_2Cl_3 dropped the litter pH. The pH of poultry litter has special concerns and effects on the quality of composts. The pH value of poultry litter 6.7 – 9 is considered favorable for composting²⁵. This stated that poultry litter is suitable for composting. Therefore, composting along with the amendment of poultry litter with both coagulants was found to be helpful in reducing pH of litter and made it safe for fertilizer.

Table 2: Physico-Chemical Analysis of control and Composts

Element		Control	Compost		
			Control	Al_2SO_4 treated litter	Al_2Cl_3 treated litter
pH	Min	8	7.4	7.1	7.1
	Max	8.1	7.8	7.3	7.25
	Avg	8	7.5	7.2	7.15
	Std. Dev	0.06	0.21	0.10	0.08
	Percentage Difference (%)		6.45	10.5	11.2
EC (dS/m)	Min	3.1	2.9	2.5	3.0
	Max	3.8	3.3	2.9	2.8
	Avg	3.4	3.2	2.8	2.9
	Std. Dev	0.35	0.67	0.23	0.65
	Percentage Difference (%)		6.1	19.3	15.6
Organic C%	Min	32	28	25	25
	Max	34	30	29	28
	Avg	33	29	27	27
	Std. Dev	1.58	1.82	1.13	1.94
	Percentage Difference (%)		12.9	20.0	20.0
Nitrogen %	Min	1.17	1.72	1.74	1.73
	Max	1.54	1.74	1.85	1.77
	Avg	1.35	1.73	1.79	1.74
	Std. Dev	0.19	1.01	0.06	0.08
	Percentage Difference (%)		24.6	28	25.2

Analytical results revealed a variance of electrical conductivity values among poultry litter and compost group as presented in Table 2. The highest value was observed for control without composting. In composts, the percentage difference of electrical conductivity of both Al_2SO_4 treated litter compost (-19.3%) and Al_2Cl_3 treated litter compost (-15.6%) was on the lower side as compared to control compost (-6.1%) (Table 2). Overall results indicated that EC remained in a normal range with no salinity and was found suitable for crop production. Electrical conductivity is expressing the salinity or potentially toxic salts in the soil. High electrical conductivities indicated high salt contents that can disrupt the

physical properties of soil²⁶. Only a few crops could tolerate an EC having values above 6.0dS/m in poultry litter². In view of these, the control litter and different composts are considered suitable and safe for crops. Another study conducted by ²⁷ reported similar findings as showing decreasing values in EC after composting. A decrease in poultry litter EC is due to humic fractions that might have complexed the soluble salts which tend to reduce the amount of mobile free ions²⁸.

3.2.3 Organic Carbon

The percentage difference data indicated that a numerically lower content of organic carbon i.e. -12.9%, -20% and -20% for control compost, Al_2SO_4 treated litter compost and Al_2Cl_3 treated litter compost, respectively (Table 2). A reduction in organic carbon in compost is also found by ²⁹ which are in accordance with the recent findings. These results are in support of literature that the reduction in carbon value was due to the addition of Al_2SO_4 , causes higher nitrogen content in the poultry litter^{10,30}.

3.2.4 Nitrogen

The overall results demonstrated variations in nitrogen contents at the control and composts. An increasing trend of nitrogen was recorded for Al_2SO_4 treated litter compost (+28%), followed by Al_2Cl_3 treated litter compost (+25.2%) and control compost (+24.6%). The lowest concentration was observed for control given in Table 2.

Nitrogen has profound effects on the fertility of the soil and the productivity of crops as other macronutrients³¹. The type of manure, handling-and management procedure can influence the nitrogen contents in poultry litter that is available for plant growth. Nitrogen content could improve through the amendment of the poultry litter. A high dose of Al_2SO_4 resulted in a doubling of the nitrogen contents in the poultry litter. It increases the value of litter and enhances the crop yield¹⁰. The results of another study justified the higher nitrogen contents from treated litter with Al_2SO_4 regardless of the litter source. Nitrogen content of agricultural compost resulted from the large quantities of nitrates in organic waste, which give stability and maturity to compost³². This study goes in favor of ³³ statements. A similar trend that the addition of Al_2SO_4 to poultry litter results in less nitrogen being lost than normal litter was also reported by³⁴. An elevated nitrogen content in covered composted litter was found by ¹⁷. This was related to plastic sheet cover that reduces nitrogen losses through ammonia volatilization. Another reason could be that the mineralization of the nutrients from poultry litter causes an increase of different nutrients¹³. The results of this study indicated that litter can be a good source of nitrogen.

3.3. Metal concentration in control, control compost, and amended compost

3.3.1. Arsenic (As)

Arsenic was recorded as 0.6 mg/kg for control, and 0.8 mg/kg for control compost, respectively. In treated litter compost, the mean value of arsenic was found as 0.4 mg/kg for Aluminum Sulfate and 0.3 mg/kg for Aluminum Chloride. The percentage difference is given in Table 3. Table 3 indicates that As content was found below the standard value.³⁵ has set the As standard limit as 41mg/kg in composts (Table 3).

Arsenic exists in the earth's crust with less concentration (i.e. average 2 mg/kg) but man-made activities cause arsenic contamination. Arsenic is a toxic compound and considered carcinogenic by the USEPA, National Research Council and International Agency for Research on Cancer, National Toxicology Program. The high content of As also inhibits Zn uptake by plants³⁶. Arsenic was found below the permissible limits in the soil of Khyber Pakhtunkhwa by ³⁷. The concentration of arsenic as 5.84 – 17.24 mg/kg in the soil of Haripur district was reported by ³⁸. Arsenic observed as 18.8 mg/Kg in the litter that was higher as compared to this study³⁹. Past studies showed that excessive and repeated application of litter may elevate As in agricultural fields. Arsenic in litter applied soils comes from the use of arsenical poultry feed for the growth of broilers and treating diseases^{4,40}. Arsenic in poultry litter is taken up and transported by the plant causing toxicity and food chain contamination⁴¹. Therefore, the safe concentration of arsenic is a need for the safe utilization of poultry litter as fertilizer.

3.3.2. Cadmium (Cd)

Cadmium was found as 0.5 mg/kg in a control and 0.4 mg/kg in control compost. In treated compost, cadmium was found as 0.4 mg/kg in Al_2SO_4 treated litter compost and 0.5mg/kg in Al_2Cl_3 treated compost, respectively. Among the litter and the compost group, the higher value of cadmium was recorded for the control. The lower value was attained in Al_2Cl_3 treated litter compost (50%) followed by Al_2SO_4 treated litter (22.2%) and control compost (22.2%) (Table 3). Poultry litter was considered safe for agriculture in comparison to the legal limit (i.e. 2,800 mg/kg) by³⁵.

Table 3: Metal Concentration (mg/kg) in control and Compost group and Permissible limit of metals for Composts/Organic Fertilizer

Metal	Control	Compost			Limit ³⁵
		Control	Al_2SO_4 treated litter	Al_2Cl_3 treated litter	
As	Min	0.6	0.4	0.5	0.3
	Max	0.7	0.5	0.4	0.4
	Avg	0.6	0.4	0.4	0.3
	Std. Dev	0.006	0.002	0.004	0.006
	Percentage Difference (%)		40	40	66.6
Cd	Min	0.5	0.3	0.4	0.3
	Max	0.6	0.5	0.5	0.7
	Avg	0.5	0.4	0.4	0.3
	Std. Dev	0.06	0.010	0.006	0.020
	Percentage Difference (%)		22.2	22.2	50
Cu	Min	0.7	0.1	0.5	0.1
	Max	1.11	0.9	0.7	0.4
	Avg	0.9	0.7	0.6	0.5
	Std. Dev	0.020	0.042	0.010	0.015
	Percentage Difference (%)		25	40	57
Zn	Min	1.16	1.07	1.16	1.05
	Max	1.25	1.15	1.21	1.12
	Avg	1.2	1.11	1.18	1.09
	Std. Dev	0.046	0.040	0.026	0.038
	Percentage Difference (%)		7.8	7.7	9.6

Food is considered one of the major sources of cadmium exposure. 0.5 mg/kg of cadmium exists in the earth's crust. A higher content of cadmium is carcinogenic. Several literature reported organic fertilizers as the common source of cadmium in agriculture fields. Cadmium is used in the feed of poultry birds. A study conducted by³⁸ reported 0.06 – 1.32 mg/kg of Cd in agriculture soil in Haripur. It was found lower as compared to a report by⁴² in the soil of Pakistan. In comparison to this study,³⁹ reported a high content of Cd as 1.7 mg/Kg in poultry litter.

3.3.3 Copper (Cu)

The higher value of Copper was found for control as 0.9mg/kg followed by control compost as 0.7mg/kg and Al_2SO_4 treated litter compost as 0.6 mg/kg while the low level of copper was attained in aluminum chloride treated litter compost as 0.2mg/kg. The percentage difference was observed as 25%, 40%, and 57% for control compost, Aluminum Sulfate treated litter compost and Aluminum Chloride treated litter

compost compared to control as presented in Table 3. The recent results showed that values of copper were detected below the permissible limit set by³⁵ for copper (1500mg/kg) in compost (Table 3).

Copper is a naturally occurring micronutrient of soil. Past literature on poultry litter and their compost showed a higher concentration of Cu. Poultry litter has been observed to contain a potentially harmful content of Cu that may be related to the chemicals used to treat poultry diseases. Copper was reported as 8.10–39.33 mg/kg in the soil by⁴⁰. In comparison,⁴³ found Cu content as 59 mg/kg and⁴⁴ measured between 90–139 mg/kg in poultry litter. Cu concentration ranged between 92 – 128 mg/kg during composting of poultry litter was found by⁴⁵. Among the control and compost group, copper content was detected below among compost. Similar results were also reported by⁴⁶. They found a decrease in copper contents of the composted organic waste. The reason for the decline of copper content might be associated with the progressive humification of organic manure applied and the formation of stabilized Cu complexes with humic substances⁴⁷. Copper is a great source of transfer and uptake in the cultivated crops. The compost and amended poultry manure for the optimization of copper in contaminated soil was recommended by²¹.

3.3.4 Zinc (Zn)

Zinc concentrations in control and composts are given in Table 3. The percentage difference for zinc was observed as 7.8%, for control compost, 7.7% for Al₂SO₄ treated litter compost and 9.6% for Al₂Cl₃ treated litter compost as compared to control (Table 3). These values of Zn were detected below the permissible limit (2,800mg/kg) by³⁵ (Table 3).

The past studies reported that Zn in the soil of Pakistan was below the toxic level. A study conducted by³⁸ reported the Zn between 12.99 – 162.00 mg/kg. In these points of view, the soil is zinc deficient but the application of control and treated litter compost reduces this deficiency to some extent. Past studies showed a variation in the contents of zinc in poultry litter applied soil in contrast to non-litter applied soil. Higher Zn contents in litter applied soil as compared to control were reported by⁴⁸. Other studies conducted by^{49,45} measured an increasing trend of zinc during the biodegradation of organic waste. Zinc is an essential trace metal and plays important role in reproduction and growth. A soil rich in organic matter with high nitrogen contents would be susceptible to a deficiency of zinc. The lower value of Zn reduces plant growth and crop yield but higher value has potentially toxic effects on plants and the food chain⁵⁰.

The sequence of metals in control was observed as Zn>As>Cu>Cd. Among compost group, in control compost the observed pattern was Zn>As>Cu>Cd, Zn>Cu>As>Cd for Aluminum Sulfate treated litter compost and Zn>Cd>Cu>As for Aluminum Chloride treated litter compost (Table 3). Recent results indicated that control, control compost, Aluminum Sulfate treated litter compost and Aluminum Chloride treated litter compost did not exceed the permissible limit for selected metals. So, it can be considered safe for the crop.

3.4 One-way Anova

Statistical analysis of one-way anova for control, control compost, Al₂SO₄ treated litter compost and Al₂Cl₃ treated litter compost showed a significant ($p = .000$) effects. Among litter the interaction was non-significant ($p = .744$) (Table 4). A significance difference for control and blended litter with Aluminum Sulfate and Ferric Chloride was also observed by²⁴.

Table 4: One-way ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Control	Between Groups	1337.688	3	1629.73	6.777	.000
	Within Groups	778.682	175	1038.80		
	Total	91176.177	179			
Control compost	Between Groups	636.676	3	15916.906	222.654	.000
	Within Groups	27812.511	173	78.717		
	Total	91761.771	175			
Al₂SO₄ treated litter compost	Between Groups	614.726	3	1633.282	32.852	.000
	Within Groups	176.177	195	421.006		
	Total	67811.129	197			
Al₂Cl₃ treated litter compost	Between Groups	614.726	3	1633.282	32.852	.000
	Within Groups	6.137	195	421.006		
	Total	5811.125	197			
Among litter	Between Groups	172.282	3	57.427	.413	.744
	Within Groups	29510.942	212	139.203		
	Total	29683.224	215			

4 Conclusion and Recommendations

The results of the physico-chemical analysis revealed that the chemical amendment of poultry litter compost is undoubtedly capable of producing a high nutrient organic fertilizer. Recent findings realized that composting conserves valuable nutrients from being lost. The overall results markedly indicated an increase in the nutritional value of both treated litter especially Al₂SO₄ treated-litter after composting. Thus, poultry litter amendment along with composting could be one of a way to improve litter quality for environmentally friendly sustainable agriculture management. However, less attention has been paid to the potential hazards of poultry waste constituents. Metals (As, Cd, Cu, and Zn) are used as nutritive and growth supplements in poultry. So, there is a potential for metal contamination in repeatedly litter amended soil and their bioavailability to crops. Therefore, further research is also needed on different amendment methods for sustainable utilization of poultry litter as fertilizer.

There is a need to develop a method for effective composting. Better utilization of poultry litter is one way to reduce its negative impacts on humans and the environment. So, environment friendly management techniques should be adopted to enhance the nutritional value of poultry litter. This will help in saving economic resources and sustainably reduce the burden on inorganic fertilizer. Modern strategies like chemical amendments in poultry litter are recommended to turn poultry litter into economically viable solutions for healthy agriculture.

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Vliv chemických přísad (koagulantů) na nutriční kvalitu kompostu připraveného z drůbežího steliva

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Abstrakt

Tato studie byla provedena za účelem zjištění nutriční kvality drůbežího steliva doplněného chemickými koagulanty po kompostování. Za tímto účelem byly ve vybraných drůbežích farmách aplikovány chemické koagulanty (tj. síran hlinitý a chlorid hlinitý v dávce 45 g/kuře). Tři typy drůbežího trusu (tj. ošetřené síranem hlinitým, chloridem hlinitým a neupravený odpad/kontrola) byly shromážděny pro kompost a charakterizovány pro různé makro a mikroživiny.

Bylo pozorováno, že pH, vodivost, organický uhlík byly sníženy, zatímco obsah dusíku byl zvýšen v chemicky ošetřených kompostech. Procentuální rozdíl v pH byl -6,5 %, -10,5 % a -11,3 %; -EC 6,1 %, -19,3 % a -15,6 %; organický uhlík -12,9 %, -20 % a -20 %, zatímco dusík byl +24,6 %, +28 % a +25,2 % pro kontrolní kompost, podestýlkový kompost ošetřený Al_2SO_4 a podestýlkový kompost ošetřený Al_2Cl_3 . Kromě toho srovnávací analýza ukázala sekvenci vysoké výživy jako kontrola > kontrolní kompost > kompost ošetřený chloridem hlinitým > kompost ošetřený síranem hlinitým. Zaznamenaný obsah kovů v kontrolních a kompostech byl v rámci přípustných limitů stanovených USEPA a považován za bezpečný pro zemědělství. Jednosměrná analýza rozptylu mezi kontrolní a kompostovou skupinou vykazovala významné ($p = 0,000$) účinky, zatímco interakce vykazovala nevýznamný rozdíl ($p = 0,744$). Rozsáhlá a pravidelná aplikace drůbežího steliva však může způsobit kontaminaci kovů. Proto, aby byly zajištěny její výhody jako půdního kondicionéru, bylo doporučeno zavést strategie managementu, jako jsou chemické úpravy drůbežího steliva, správné kompostování a pravidelné monitorování aplikace drůbežího trusu do půdy.

Klíčová slova: síran hlinitý (Al_2SO_4), chlorid hlinitý (Al_2Cl_3), drůbeží stelivo, kompost.

Retail Chains Under the Food Waste Spotlight: the Case Study Of the Czech Republic

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Abstract

Retail is an intermediary between food producers and consumers and can influence other actors in the agri-food chain. The authors explored the volume of wasted food in the large food stores in the Czech Republic as well as the retail chains' strategies and barriers to reduce it. At the same time, the main reasons for food waste in Czech households were examined. Consumer-oriented retail chain activities were confronted with the reasons for household food wasting and whether a parallel could be found between certain retail and household activities was discussed. Despite the fact that the share of food waste compared to food quantity sold is rather small, the total annual volume of lost food is enormous. The retail chains indicated strategies focused on internal processes as well as toward external entities. The most frequent reason for food wasting mentioned by consumers is over-purchase. Only a negligible portion of them indicated that the reason is purchases made under pressure, such as discounts or child demands. One can consider whether consumers are really not un-pressured when shopping, or if retail marketing policies are so sophisticated that customers buy more than they need without perceiving it. Unfortunately, reducing promotions and discounts as a means of waste reduction was not mentioned by retail chain managers. For further progress, adjustments in legislation are recommended, as well as media education aimed at civic responsibility to increase consumer cooperation.

Key words: *retail chains; food waste; prevention strategies; consumers attitudes*

Introduction

Food waste becomes a phenomenon in developed countries. Moral human values should lead to minimizing waste to the lowest acceptable level. In the EU the efforts to reduce food waste and to transit to sustainable food system are supported by several legislative acts. Based on the directive EU¹, member states should take measures to significantly promote the prevention and reduction of food waste throughout the food chain by 2030. Such a challenge should cover the responsibilities of all actors in the food system.

The methods of obtaining household food supplies have significantly changed over the last several decades in the Czech Republic. Following the previous political change, food assortment displays have been significantly enriched, the retail network expanded, and food purchase has thus been considerably facilitated. What was once a "sacred gift" and often produced by households themselves as recently as the 1980s, simply became one of many consumer categories.

Large food stores (LFS) such as hypermarkets, supermarkets and discount stores are the main food shopping destination for 70 to 90% of Czech consumers, depending on the assortment². Fruits and vegetables were preferably purchased by 90% of consumers in LFS in 2017, for bakery products the share reached 78%, while for meat and cheese the shares accounted for 72% and 90% respectively. All mentioned figures showed a 3 to 5 percentage point increase compared to the previous five years.

There is a rich literature focused on wasted food in households. The authors show that households generate a significant amount of loss – according to the Fusions project,³ about 52% of food waste from the entire food supply chain falls on households; according to Gustavsson et al.⁴ waste amounts to about 40% of food lost at the household level.

Although retail is an important part of the food distribution chain, information concerning food waste from this segment is rare. There are only a few studies which focus on food waste quantification at the retail stage of food supply chains in European countries (see for example Orr and Schmidt⁵ from Germany; Lebersorger and Schneider⁶ from Austria; Eriksson et al.⁷ from Sweden; Cicatiello and Franco⁸ from Italy). In the Czech Republic, so far as we know, the food waste in retail has not yet been quantified. We aimed to fill this gap by focusing our research on this segment. The goal of the study is to reveal the amount of food discarded in the main retail chains in the Czech Republic and to discover the chains' food waste prevention activities with a special attention to consumers related activities. The results should contribute to the understanding of the current state and help to define suitable strategies either for the government institutions or private companies to reduce food waste generated at the retail level.

Materials and methods

We aimed to obtain the data on the amount of food sales and food waste in the LFS of the most important retail chains in the country. After initial communication with their representatives, it turned out that companies considered these data confidential with respect to their marketing strategies and store operations and were not willing to pass them individually. Therefore, we used the traders' association as a communication intermediary, who persuaded some of their members to collaborate. At the meeting with the union and the national headquarters, including representatives of the collaborating chains, we discussed what type of data each company had in their records. Based on this information, we developed a survey of questions on the figures, activities and barriers related to reducing food waste.

The data were obtained from four retailer chains which make up almost 36% of the entire trade sector with fast moving consumer goods and almost 52% of so-called modern trade. Modern trade is formed by both international retail chains with fast moving consumer goods and cash-and-carry stores.

The data collected show the in-store waste recorded in the retailers' internal systems. Pre-store waste was not included, as it is wasted by a supplier, not the retailer (in accounting terms). Due to records limitations, similarly to other studies, we did not distinguish between avoidable and unavoidable food waste (see for example Eriksson et al.⁷; Orr and Schmidt⁵). Nevertheless, at the end we present an estimate of what part of the discarded waste could have been used by the chain representatives.

In addition, collected qualitative information helped us analyse the food waste behaviour of retailers, their waste management practices and their potential marketing activities aimed at reducing food waste production on the retail level.

All the data were anonymised under codes A, B, C and D. The ratio indicators were compiled and compared from those figures. The descriptions of the activities and barriers obtained were structured into several thematic parts and discussed. As background information, the wholesale and retail sectors characteristics were compiled.

Consumer-oriented chain strategies have been confronted with consumer responses on responsible food purchase and household food waste. The research addressed a panel of 1,000 consumers across the Czech Republic by an on-line survey, with an inquiry for the reasons for food waste in their household. The sample structure copied the socio-demographic structure of the Czech Republic and the number of respondents guaranteed the samples were representative for the country. We offered consumers nineteen different reasons in total, from which they were invited to choose up to the five most important. The offer of reasons was intentionally wide, so that consumers could identify themselves as much as possible with the options. Therefore, when processing the answers, the reasons were grouped into twelve thematic areas. Each individual reason indicated by each consumer was rated by one point. All indicated reasons from all consumers became the basis (100%) for calculating the share of each of the twelve areas on all responses.

Finally, the activities of chains and the most frequent reasons for household food wasting were compared and we discussed whether a parallel could be found between some activities in retail and households.

Results

Wholesale and retail sector in the Czech Republic

The share of the so-called modern market (which consists mainly of multinational chains) on the total retail market with fast-moving consumer goods in the Czech Republic accounted for more than two thirds in 2019⁹. The additional third was the so-called traditional trade (which consists mainly of Czech retailers with small stores).

The situation for the retail market in the Czech Republic is similar to those situations in the other 13 EU Member States (e.g. the Netherlands, Denmark, France, Germany), where the market share of the top 5 dominant retailing companies (not necessarily the same in each country) exceeds 60%³.

Czech modern trade is formed by eight large international chains, whose individual market shares fluctuate from 5% to approximately 13%. Three of these international chains have market shares larger than 10%, while another account for between 8-9 % and the rest have market shares around 5 – 6%. Market share is estimated based on annual revenues from 2019 (data are publicly available in the Czech commercial register).

Food waste volume

Data attributable to food waste from four different chains (three retailers and one cash-and-carry store) are introduced in Table 1. Supermarket and hypermarket sales formats predominate in all three retail chains.

The total revenues of the retail chains involved in our study are 181.79 billion CZK (= 7.08 billion EUR). More than half of the modern retail market was described (51.5%). The data represent the year 2019 (52 weeks) and were summarized for all operated branches by each retailer.

Table 1: Food waste in retail sector

Categories	Retail						Wholesale	
	Subject A		Subject B		Subject C		Subject D	
	tonnes	%	tonnes	%	tonnes	%	tonnes	%
Food sold [t]	918 052	100	984 101*)	100	617 488	100	479 111	100
Foods donated for human consumption "surplus" [t]	422.0	0.05	107.6	0.01	1 118.0	0.18	801.8	0.17
Food donated as feed "surplus" [t]	1 065.0	0.12	2 103.7	0.21	5 126.0	0.83	-**) .	.
Total food waste [t] Food that was not donated but was thrown away ***)	13 079.0	1.42	11 145.4	1.13	4 712.0	0.76	2 675.2	0.56
Estimate of the share of total food waste [%] that was discarded but which was potentially good for human consumption	3 923.7	30	1 671.8	15	1 036.6	22	Minimum	Minimum

Source: own research, 2020

*) Subject B was not able to provide such data, therefore this number was recalculated based on existing statistics which are publicly available.

**) Shops of Subject D are donating food as animal feed but are not able to provide exact amounts because they do not record it.

***) this category does not include the weight of the packaging: subject C – by most categories; subject D – by most categories (such as dairy products, meat, sausages, fish and chilled food) while primary packaging (plastic foil) is included for other foods (dry + fruits & vegetables).

Reported food waste amounts in the retail sector are quite diverse, ranging from 4,712 tons of food waste in subject C to 13,079 tons of food waste in subject A. With regard to proportions of food sold, subject C also reported the lowest and subject A the largest share (while taking into account only retail chains). In the case of wholesale subject D, the proportion of food waste to food sold was quite low (0.56%) but is representative of a wholesale sector with another type of both customers and processes, compared to the retail sector. The total amount of discarded food among the four chains examined is about 31,612.4 tons.

Although in percentage terms, food waste appears to be minimal compared to total sales, in volume terms the importance of food waste is highly visible. To convey the idea of volume, we used a comparison with the weight of a consumer food basket. In the Czech Republic in 2020¹⁰, the total annual consumer food basket weighed 796.5 kg per capita, including waste. Considering a theoretical value without food waste of 720 kg, the discarded food among the four chains examined would cover the annual consumption of around 44,000 consumers. This is not only an incentive for thought but should also inspire the greatest possible effort to prevent food waste.

Food waste causes

The main causes of food disposal in the retail sector related to customer demand, logistic operations and replenishment practices. Specifically, high customer requirements regarding the quality and freshness of selected food categories (mainly fruit, vegetable and pastry) were mentioned in combination with difficulties in maintaining the freshness of fast-moving consumer goods (fruit and vegetables), human and system errors in the logistics chain and the short shelf-life of some food categories.

The most problematic categories of food which are thrown out are fresh food categories - most often fruits, vegetables and pastries, mostly due to more demanding supply chain processes and more complex handling practices, as well as efforts by retailers to offer customers fresh foods and pastries in the evening. Also dairy products, meat, fish and ready-meals were classified by retailers as problematic categories. Subject B also has problems with markdowns because of goods with missing / damaged labels, food with damaged packaging or incomplete information on the label. Goods with such flaws cannot be sold because of Food Law and therefore subject B is donating such food to a foodbank.

The chains indicate several specific periods when it is particularly difficult to estimate consumer demand and waste usually increases. These periods vary from chain to chain. This aspect of food waste behaviour is highly connected to stock-management practices, planning and forecasting of replenishments. For example, for subject A it is more difficult to adjust planning of orders in the summer, because some categories of food are grown by customers for their own use and the main holidays also take place in this part of the year – children are out of school and therefore their parents do not prepare snacks for children to such normal extents. For subject C, most problems occur at Christmas and Easter holidays. Subject D also perceived the Christmas period as relatively demanding, together with the following winter period up until spring. Spring months, on the other hand, were called "the lowest" in terms of food waste production by subject D.

Food waste prevention strategies

Retail chains undertake a relatively diverse range of activities to prevent food waste in this stage of food supply chain. We structured the activities preventing food waste into three areas – i) activities within the company, ii) activities focused on external companies or institutions and iii) activities focused on customers (consumers or gastronomy sector customers). In summary, food waste prevention strategies within the company include better cooperation among their own distribution centres, precise planning of orders and work with food assortment, waste measurement and staff information as well as staff trainings and others.

Strategies related to external institutions comprise, on the one hand, cooperation with suppliers and, on the other hand, donating food to food banks, farms and associations dealing with animals. Consumer (or customer) oriented strategies are based on marketing aimed at sales promotion of food approaching its expiration date (special discounts with call to customers for not wasting food) and the education of consumers, including waste reporting or even implementing training programs for customers in the B2B sector. Subject D, for example, introduced monthly reports in their stores of food waste and donations to

food banks. They also use a waste measuring indicator which affects the monthly remuneration of employees and other mainly internal activities preventing food waste. Surveyed chains also prepare training modules for their employees (subject C, D) or customers (subject D). A summary of activities preventing food waste occurrence in the retail sector is shown in Table 2.

Table 2: Summary of activities preventing food waste

Activities preventing food waste	Subject A	Subject B	Subject C	Subject D
Activities within the company	<ul style="list-style-type: none"> - <u>Work with assortment of goods</u> <ul style="list-style-type: none"> - identification of products for mark-downs, - adjustments of the baking plan, - adjustment of the assortment of goods according to stores needs, - optimization of the assortment with regards to minimizing damage 	<ul style="list-style-type: none"> - <u>Control</u> <ul style="list-style-type: none"> - Detailed control of freshness and quality of goods during receiving in the warehouse and control of stock at logistics centers - Close cooperation of logistics centers with departments of sales promotion and of purchase - Compliance with the cool chain 	<ul style="list-style-type: none"> - <u>Work with assortment of goods</u> <ul style="list-style-type: none"> - Using AI system for mark-downs before the expiration date - Prevention of surpluses by optimizing orders and supply - <u>Measurement of waste</u> <ul style="list-style-type: none"> - Transparent waste data and informing own employees - <u>Staff training</u> 	<ul style="list-style-type: none"> - <u>Work with assortment of goods</u> <ul style="list-style-type: none"> - The employees of the chain are led to adhere to the so-called pyramid of waste: sell goods for full price - sell goods for reduced price - donate goods to food banks/feed purposes - dispose of goods - <u>Control</u> <ul style="list-style-type: none"> - Use of automated ordering systems - Building a logistics networks within the Distribution Center - <u>Measurement of waste</u> <ul style="list-style-type: none"> - Use of indicator of the amount of waste in stores affecting monthly remuneration of employees - Setting up a monthly report about amounts of food waste and donations to food banks - Appreciation of stores which are most successful in minimizing food waste or surpluses - <u>Staff training</u> <ul style="list-style-type: none"> - Employee training (how to prevent food waste at home) - Each store has a named employee who is in charge of communication with food banks on a daily basis - Introduction of new position of sustainability manager at headquarters
External activities focused on other companies and institutions	<ul style="list-style-type: none"> - <u>Cooperation with suppliers</u> <ul style="list-style-type: none"> - Better cooperation and relationships with suppliers - <u>Donation</u> <ul style="list-style-type: none"> - Sub-optimal food to own employees or further processing of this kind of food at the point of sale. - Donation of surplus to food banks, donation of transport to food bank - Fresh food unsuitable for human consumption are donated to farms and - associations dealing with animals 	-	<ul style="list-style-type: none"> - <u>Cooperation with suppliers</u> <ul style="list-style-type: none"> - The chain works with a wide range of partners, including suppliers (FoodCloud, own suppliers) - <u>Donation</u> <ul style="list-style-type: none"> - donate goods to food banks/feed purposes 	<ul style="list-style-type: none"> - <u>Donation</u> <ul style="list-style-type: none"> - donate goods to food banks/feed purposes - dispose of goods - Coordinating cooperation with Czech federation of food banks in regions
External activities focused on customers	<ul style="list-style-type: none"> - <u>Discounts</u> <ul style="list-style-type: none"> - Sales promotion of products with approaching expiration date (stickers on product with information "Help us not to waste" with a 30% discount a 50% discount in the category of pastries used 2 hours before closing stores) - <u>Education</u> <ul style="list-style-type: none"> - Effort on better communication with customers, public education 	-	<ul style="list-style-type: none"> - <u>Education</u> <ul style="list-style-type: none"> - Transparent food waste data publication 	<ul style="list-style-type: none"> - <u>Discounts</u> <ul style="list-style-type: none"> - Sell goods for reduced price within the so-called pyramid of waste - <u>Training</u> <ul style="list-style-type: none"> - Training modules for customers from gastronomy sector (economics of operations, food waste prevention, proper food storage)

Source: own research, 2020

The C chain has a policy most open to the public and builds on the publicity of its activities. At the same time, according to the data of its own, it reaches the lowest share of the three examined chains. The B entity does not rely on publicity, while it is clear from the list of activities that it deals with the issue very intensively and, according to its own data, has minimal waste.

Barriers to food waste prevention strategies

The main problem, mentioned by all examined chains, is the constantly increasing demand of customers for freshness and appearance of fruits and vegetables. Other barriers relate to limited capacity of subjects in redistribution systems, especially with regard to chilled and frozen food (mentioned mainly by the D chain) or strict requirements of food laws concerning redistribution processes. The impossibility of improving the forecast of customer demand was also identified as a barrier, and methods for improving the situation were not explicitly mentioned. Either the improvement of the forecasting system is hindered in some control measurements (such as automatic ordering at the subject D) or this is considered a difficult problem to solve. For subject D, big difficulties arose from the Covid pandemics, as some customers were gastronomic establishments that were either closed because of restrictions, operated in restricted mode or have gone bankrupt – the situation was unpredictable, which complicated demand forecasting.

Some suggestions for system changes which might be implemented by state authorities were also mentioned. All the subjects would welcome simpler legal environments in the area of food donation, minimizing the bureaucracy involved and amendment of the tax law for food donated; state authorities could also establish databases of feed processors, associations of hunters, or other type of associations that might be interested in food surpluses.

Consumers attitudes

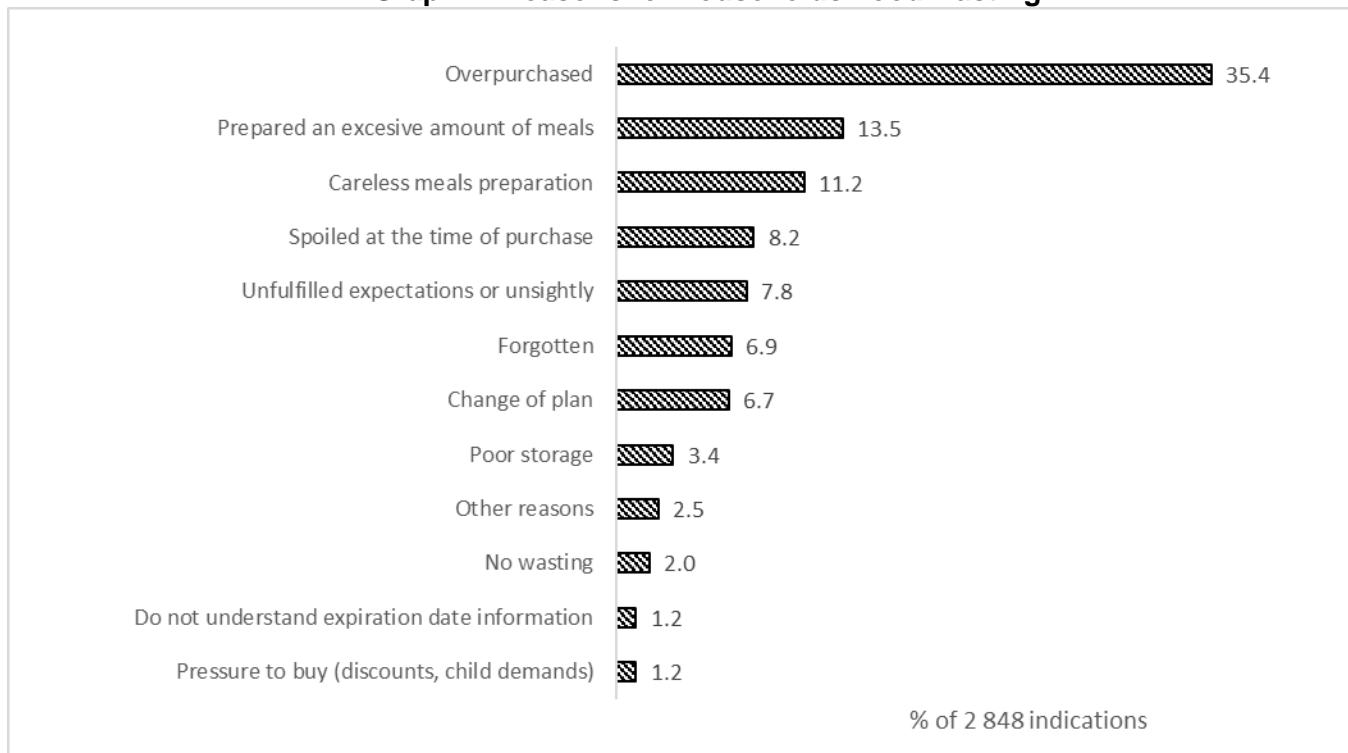
The retail chains policies have the potential to influence consumer behaviour. Therefore, we aimed to find common points in chain strategies and consumer behaviour, which give hope to a successful reduction of waste.

We examined consumers' answers to the question "*what is the cause of household wasting*" and looked for connections with retail chains. The reasons and their frequencies are recorded in Graph 1. The most frequent reason, mentioned in 35.4% of all 2,848 indications of any reason, is consumer over-purchase. This combines three response options: i) we bought more than we consumed; ii) food spoils before we can eat it, and iii) we throw away only what we don't consume right away, store it for the next time, and then find it spoiled. In fact, all three options mean that respondents bought more than they could store and consume. Those who chose the first answer are well aware of the wasting cause, but the share of this option in the reasons group was only 6.7%, while the second and third options accounted for 50.1% and 43.2% respectively. It is worth considering whether over-purchase stems from the retail chains efforts to maximise their sales, or poor shopping planning in households, or a combination of both factors. It is worth mentioning that only 1.2% of responses declared that the reason for food wasting is a purchase under pressure, such as discounts or children's demands. One can consider whether consumers are not really subject to pressure when shopping, or the retail chains marketing policies are so sophisticated that customers buy more than they want without perceiving it, and "*buying under pressure*" is in fact hidden in the "*overpurchased*" answers.

The reasons "*spoiled at the time of purchase*" and "*unfulfilled expectations or unsightly*" might reflect some shortcoming on the part of retail chains or at least some discrepancy between supply and expectation. Together 16.0% of all indications contained the first or the second reason. These statements express customers somehow doubting the quality of what they bought; either they consider it poor, or their choice was not well made. Whether the quality was in fact good or not, consumers perceive it as inadequate. This is in line with the retail chain statements that customers' expectations on quality and freshness are high and arrangements to meet them without food wasting are a real challenge for operational managers.

On the other hand, a high proportion of consumers declared their willingness to reduce food wasting. When answering the question "*do you mind the food wasting?*" 74% of respondents chose the option '*yes*' and '*I'd like to reduce it*', while 9 % didn't mind wasting and 16 % thought that the reduction of food wasting was not possible in their household.

Graph 1: Reasons for households' food wasting



Note: results of multiple choice

Source: own research, 2019

Discussion

The volume of food waste in the examined retail chains ranged from around 0.76% to 1.42% of the weight sold and slightly less (0.56%) in cash-and-carry chains. These figures are in line with findings of Katajajuuri et al.¹¹ who quantified the average amount of food waste in the retail sector in Finland at 1 - 2% and identified the most sensitive products to be fruits and vegetables, as well as bread, followed by dairy products, fresh meat, fish and convenience foods. Beretta et al.¹² estimates the share of unsold food in retail chains in Switzerland at 2.2% on average, while in individual food categories the unsold volume ranges between 0% and 12%. For vegetables, in-store waste accounted for 8% – 12%, while the out of store processes, such as logistics centres, plus sorting due to inadequate quality and transport, show about 0.4%. Both authors also experienced a reluctance on the part of retail chains to communicate waste data. The percentage values from the Czech Republic are lower than those from Switzerland. The reason may not only be well-set processes, but it should be noted that the more the composition of the assortment is shifted to perishable foods, the more difficult it is to reach low waste. Increasing consumer demands for food freshness are likely to push the retail offer for this type of food in the future, which would make waste reduction even more difficult.

Our research showed that retail managers focus on controlling and optimizing goods flows, waste measurement, staff training, consumer education, discounts and redistribution to prevent wasting. Similar strategies have been found by other authors such as Cicatiello et al.¹³ for Italy, Hermsdorf et al.¹⁴ for Germany, Filimonau and Gherbin¹⁵ for the United Kingdom. While implementation of measures focused on internal food waste causes are controllable, external causes depend on the agri-food chain stakeholders. Identified external barriers originate partly at the consumer side (especially in their high expectations) and partly in legislation (mainly concerning conditions for redistribution).

Gruber et al.¹⁶ emphasises that retail is a good policy target, especially for its high concentration. This tendency of regulation of both retail and wholesale sectors could also be seen in the Czech Republic as, for example, Czech retail or wholesale stores larger than 400 square meters are obliged by Czech food law to provide surplus food to food banks or other charities (see Act no. 110/1997). However, retailers perceive this measure as incomplete and they propose to amend the legislation towards better

conditions for the obligation implementation. The biggest barrier to redistribution systems was the regulatory framework dealing with redistribution system or Food law in general. It is in line with findings presented by Hermsdorf et al.¹⁴ who identified the same problems in redistribution systems in Germany.

Customers high expectations on quality and freshness were identified as one of the food waste causes and barriers. This cause of food waste was also identified by Teller et al.¹⁷ and Mena et al.¹⁸. In our questionnaire, almost every sixth consumer declared his dissatisfaction with quality or unfulfilled expectations as the reason for the waste. It is possible to point out the long-term need for consumer education towards sustainable behaviour. It is also to question the role of the retail chain and the government in this process.

Is it necessary to continue raising standards according to growing customer requirements or to look for a reasonable solution? De Hooge et al.¹⁹ points out that traders can set aesthetic food standards, such as product weight, size and shape that determine consumer expectations and thus effect wasting. The basic standards for selected types of commodities (such as fruit and vegetables, wine, dairy products and others) at the EU are defined by the EU Regulation²⁰ establishing the common organization of the markets and marketing standards. We can assume that the adjustment of standards to reasonable levels and their adoption could affect the reduction of waste in the store, as well as subsequently in other parts of the agri-food chain.

More than one third of the reasons for household wasting is over-purchase. There is no consensus among the authors about the positive relation of marketing policy and consumer food waste. Schmidt²¹ says that, based on research by German consumers, shopping at promotions is an antecedent of food waste. Ganglbauer et al.²² claims for Austrian and British consumers that buying more at a lower price will result in more waste in homes. A similar positive relationship has been shown by research in Finland (Silvennoinen, et al.)²³, Italy (Setti et al.)²⁴ and in other countries.

On the contrary, in the research in Sweden (Williams et al.²⁵), Canada (Parizeau et al.²⁶) or Katajajuuri et al¹¹ the relationship has not been confirmed. Tsalis²⁷ concludes that about half of the authors found a positive relationship between promotions and household waste, while the other half did not confirm this. At the very least, the finding by some authors that promotions have an unfavourable effect on wasting, is a reason to consider those strategies the retailers should focus upon in order to mitigate wasting. Unfortunately, the topic of reducing promotions and discounts as a means of waste reduction was not mentioned by managers. From a purely economic point of view, against the efforts for food waste minimization, there arose the need to withstand competitive pressure, attract customers and offer them the best shopping convenience even in perishable food.

Conclusions

Our results show that the share of food waste on the quantity sold is rather small but the annual volume of lost food is enormous. Retail chains indicated that the most sensitive foodstuffs are fruits, vegetables and pastry, followed by meat and meat products as well as dairy products.

For traders, food waste is not only an ethical issue, but of course also an economic loss. One can imagine that an economist will calculate whether it is advantageous to reduce customer convenience (e. g. by limiting the offer before the end of working hours) and herewith reduce fruit, vegetable or pastry waste, or whether full customer convenience generates more shoppers and higher profits to cover related economic loss.

From a social point of view, however, such a situation is no longer acceptable. The continuing visibility of environmental issues deepens its social acceptance and requires the retail chains to market on eco-friendly policies. Thus, promotions should emphasize their contribution to the environment and food waste reduction. Companies going down this path would, in fact, change the commercial service by offering an additional service to consumers - a contribution to the conservation of resources and the sustainability of agriculture and food production.

For this policy retail chains need the cooperation of external actors. Research has shown which government measures the chains would be able to use. Also, a significant part of consumers declared their willingness to reduce food wasting. Retail chains are continuing to build their environmentally friendly policies, and with the support of legislative measures, together with media education and consumer cooperation, further progress in food waste reduction can be accomplished.

Acknowledgement

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Maloobchodní řetězce ve světle plýtvání potravinami: případová studie České republiky

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Souhrn

Maloobchod je prostředníkem mezi výrobci potravin a spotřebiteli a může ovlivňovat další aktéry v zemědělsko-potravinářské vertikále směrem nahoru i dolů. Autoři se zabývali objemem plýtvání potravinami ve velkoplošných prodejnách maloobchodních řetězců v České republice, a strategemi i bariérami maloobchodních řetězců ke snížení plýtvání. Současně byly prověřeny hlavní důvody plýtvání potravinami v českých domácnostech.

Spotřebitelsky zaměřené strategie a aktivity obchodních řetězců byly konfrontovány s důvody vyhazování potravin v domácnostech a bylo diskutováno, zda lze najít paralelu mezi některými aktivitami v maloobchodě a domácnostmi. Přestože podíl potravinového odpadu na prodaném množství potravin je poměrně malý, roční objem ztracených potravin je enormní. Strategie obchodních řetězců je zaměřena na interní procesy i směrem k externím subjektům.

Nejčastějším důvodem plýtvání potravinami u spotřebitelů je nákup nadměrného množství. Jen zanedbatelná část spotřebitelů však uvedla, že důvodem plýtvání potravinami je nákup pod tlakem, jako jsou slevy nebo přání dětí. Je třeba se zamyslet nad tím, zda spotřebitelé při nakupování skutečně nepodléhají tlaku, nebo je marketingová politika obchodních řetězců natolik propracovaná, že zákazníci nakupují více, než chtěli, aniž by to vnímali. Bohužel téma omezování akcí a slev jako prostředku snižování odpadu manažeři obchodních řetězců nezmínili. Pro další pokrok se doporučují úpravy legislativy a mediální edukace zaměřená na občanskou odpovědnost ke zvýšení spolupráce spotřebitelů.

Klíčová slova: maloobchodní řetězce; potravinový odpad; preventivní strategie; přístupy spotřebitelů, plýtvání.

Utilization of Solid Waste from Landfill Passive Zone to Treat Leachate Through A Combination of Leachate Recirculation and Bulking Agent

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Abstract

Real evidence of the Municipal Solid Waste (MSW) decomposition process is the emergence of pollutants as leachate, which has a chemical composition that is difficult to degrade (recalcitrant compounds) and causes pollution of water bodies. On the other hand, waste from the passive zone landfill is not utilized at all. The aim of this study was to determine the effect of adding solid waste from landfill passive zone as bulking agent to treat fresh leachate with a combination of the recirculation process. MSW + bulking agent (70%: 30%, v/v) was recirculated using fresh leachate with a flow rate of 1 L/min for 30 days. Reactor without recirculation and bulking agent was used as control. The leachate quality was analyzed on days 0, 3th, 7th, 14th, and 30th, while the MSW composition was controlled after being left for 365 days. The outcome of the results obtained from the experiment showed that the addition of bulking agent + recirculation accelerated the increase in leachate pH and the increment of COD reduction. On day 30th, the lowest TDS level presented 63,813.8 mg/L, the conductivity was 111,457.5 µS/cm, and the ammonia showed 72.5 mg/L produced from R3 (MSW + bulking agent + recirculation). The addition of bulking agents from passive landfill zones can reduce COD, TDS, conductivity and ammonium. On the 365th day, the water content of MSW in R3 was 76.8%, pH value get 7.7, EC value presented 43.4 mS/cm and volatile solid achieved 94.99%. The same increase occurred in the total Nitrogen at R3 from 0.23% to 0.95%. Meanwhile, the levels of P-Total and K-Total did not change significantly.

Keywords: leachate; recirculation; solid waste; bulking agent; COD, landfill, MSW

1. Introduction

At pandemic COVID-19, researchers have become increasingly interested in municipal solid waste treatment. Unsustainable waste management in many developing countries makes them more vulnerable to the possible spread of the coronavirus through waste management practices. Although, the impact of the COVID-19 pandemic on the waste management system has not been still well understood¹. The problem is exacerbated by an increase in waste products as a result of population growth and urbanization². Most countries globally, including Indonesia, have chosen the sanitary landfill method³ to treat solid waste produced by residents. Sanitary landfills are very economical in terms of exploitation and costs. On the other hand, sanitary landfills have a significant drawback in leachate production which has a chemical composition that is difficult to degrade (contains recalcitrant compounds) and causes pollution of water bodies^{4,5}. The strict quality standards, required by the ministry of environment and local governments regarding environmental protection and sustainable development, emphasize the elaboration of the strategy for processing leachate to be thorough.

The landfill as a large anaerobic reactor, abundant in solid waste takes the function of a plentiful and sustainable source of methane gas⁶. For this, researchers and academics are continuously exploring various optimization strategies to increase the efficiency of anaerobic processing^{7,8}. However, most of these strategies require a lot of energy and a complicated operating process. Leachate that is wasted

has high levels of Chemical Oxygen Demand (COD). On the other hand, the recirculation of this COD, as a source of nutrients for methanogens, increases the contact time between bacteria and organic matter (waste), and increases methane production from MSW⁹⁻¹¹.

Currently, the leachate in Jatibarang Landfill comes from active zone 1 and 2. Zone 3 is the current passive zone. Managers closed the passive zone area and planted green plants on the surface³. COD leachate levels in Indonesia vary between 3,500 – 12,000 mg/L depending on the season. The rainy season produces lower COD, but the amount is quite abundant. For example, the Rembang TPA (final processing site) produces 40.82 m³/day of leachate with a total active zone area of 1.4 ha and a rainfall of 2,449 mm/year. The leachate management system in Indonesia mostly consists of stabilization tanks, biological treatment and aeration¹². In Indonesia, a leachate management system by recirculation has not been still developed. This has great potential to implement this system because several countries by now have implemented it. According to Rahmawati (2018), the characteristics of solid waste composition in Indonesia are different from other countries, so it needs a thorough and systematic investigation.

This study aims to process leachate using a combination of leachate recirculation and bulking agent based on this background. The bulking agent used comes from the passive landfill zone that is no longer operational. The quality of leachate is evaluated in-depth and systematically.

2. Method

The research was conducted at the Environmental Engineering Laboratory, Diponegoro University using an anaerobic reactor. The anaerobic reactor is made of acrylic material with a capacity of 25 liters, cylindrical shape and dark color. The reactor is equipped with leachate inlet and outlet holes, as well as with gas emission outlets. The inlet hole provide the function to enter the leachate into the reactor using a pump with a 1 L/min discharge. The leachate outlet hole (\varnothing 5 mm) serves for leachate sampling. Gas emission will exit through outlets with a diameter of 2 mm. The gas outlets were closed during the research process and opened once a day to prevent an explosion.

In this study, solid waste and leachate were created artificially with a composition equivalent to the composition of solid waste in the active zone of the Jatibarang landfill. This is an effort to anticipate the spread of COVID-19 through Municipal Solid Waste. Bulking agents are taken from the passive landfill zone in Jatibarang, Semarang, Central Java, Indonesia. Artificial samples of inorganic substances are manually separated to ensure an average particle size of 1.0 – 1.5 cm. The percentage of each component was calculated (wt%).

Combining recirculating leachate and bulking agent aims to accelerate waste degradation, reducing leachate processing volume and improving leachate quality. This study used three reactors, namely reactor 1 (R1), as the control, where this reactor contains 5,000 g of solid waste, and no recirculation was carried out. Reactor 2 (R2) contains 5,000 g of solid waste, and the leachate was recirculated every three days. The reactor 3 (R3) contains solid waste + bulking agent with a ratio of 70%: 30% (v/v) to the total volume 5,000 g. R3 is recirculated once every three days. Once every three days, the leachate of each reactor was taken for the analysis of physical and chemical parameters. The leachate collected from R2 and R3 was recirculated with a discharge of 1 L/min until all the leachates enter back into the reactor. The study performed leachate recirculation during the study period of 30 days. During the operation, all holes were closed to ensure that the reactor conditions take place anaerobically. The quality of leachate was analyzed based on the efficiency of COD removal, TDS, conductivity, nitrate, ammonia and pH.

The leachate pH was measured using a pH meter (Walklab TI 9000, Singapore) with an accuracy of 0.01. Leachate pH measurements were carried out in the three reactors on day 1th, 3th, 7th, 14th and 30th. The closed reflux method was used to determine the COD leachate concentration. Measurement of COD and nitrate concentration was provided by using a UV vis spectrophotometer (Thermoscientific Genesys 10, USA). The concentration of NH₄⁺-N was determined using the Nessler method. Total Dissolved Solid (TDS) and conductivity were tested using conductivity-TDS-salinity meter HC9021 (Walklab, Singapore).

3. Results and discussion

The results and the most important biological reaction that occurs in the solid waste decomposition process was the conversion of organic matter to gas and leachate. The most important chemical reactions were the dissolution and suspension of MSW materials and products of biological processes as well as oxidation reduction reactions that affect the solubility of metals and metal salts¹⁴.

3.1. The effect of leachate recirculation on pH.

Anaerobic decomposition generally goes through four stages. First, a decrease in pH due to the production of volatile fatty acids (VFA) during the hydrolysis and acidogenesis processes¹⁵. In this study, the pH value decreased from the third day, both in the reactors R1, R2 and R3 (Figure 1 a). This was an indication that the process of hydrolysis and acidogenesis had taken place¹⁵. On the third day, the pH value at R1 was 5.9, R2 of 5.8 and R3 6.23. The presence of the recirculating leachate + bulking agent as much as 30% in R3 produces a higher pH than the ones with and without recirculation. The bulking agent functions as a leachate buffer for the pH not to drop drastically. These results indicate that the bulking agent had a larger buffer capacity to maintain the pH value¹⁶. Cooked and stable compost can be used as a pH buffer because it increases nitrogen availability¹⁷.

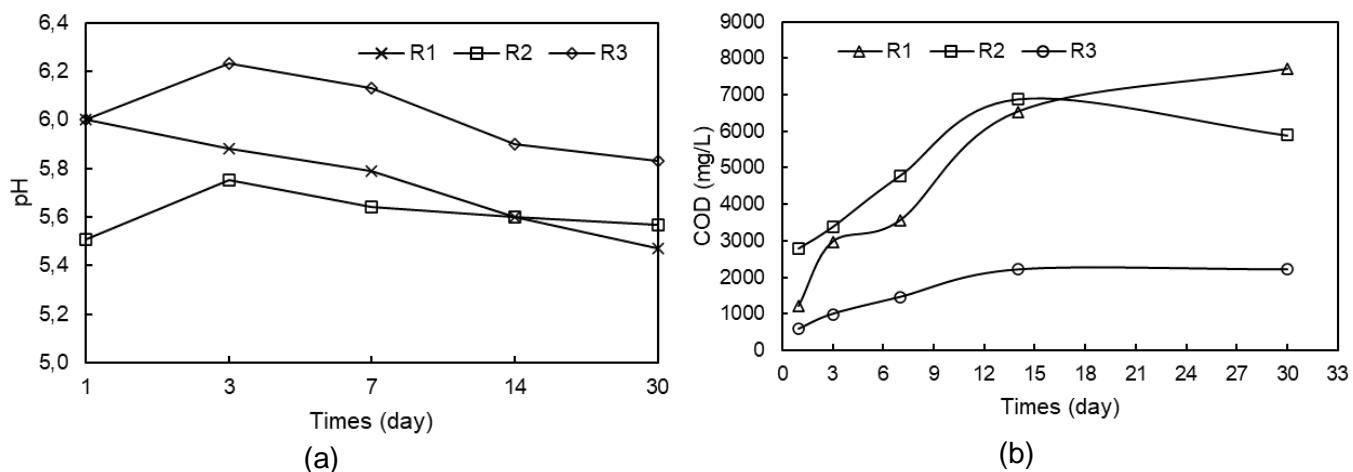


Figure 1: The pH values (a) and COD concentrations (b) of leachate generated from R1, R2, and R3 at 30 days

3.2. Effect of leachate recirculation on COD concentration.

COD is an important parameter for determining the amount of organic and inorganic material in water. COD concentration is used to estimate oxygen demand through oxidative degradation of the organic compounds presented in the leachate. This oxidative degradation was carried out chemically using a strong oxidizing agent such as dichromate or permanganate¹⁸. The results showed that the COD value increased significantly from the third day to the 14th day and was stable in the 14th to 30th day range. On the 30th day, COD concentration in R3 was much lower than in the other reactors (Figure 1b). The COD in R3 was 2,216.7 mg/L, while R1 was 7,700.0 mg/L and R2 was 5,891.7 mg/L. The presence of a bulking agent significantly reduces COD levels in the leachate.

3.3. Effect of leachate recirculation on TDS concentration and conductivity.

A high TDS concentration is usually associated with a high ion concentration, which increases the conductivity of the liquid. Sulfate and chloride anions are the main anionic contributors to TDS¹⁹. TDS levels and conductivity are shown in Figures 3a and 3b. TDS levels and conductivity have increased from day to day. R3 produces a lower TDS and conductivity levels than both R1 and R2. The lowest TDS level was 63,813.8 mg/L and the lowest conductivity level was 111,457.5 µS resulting from R3.

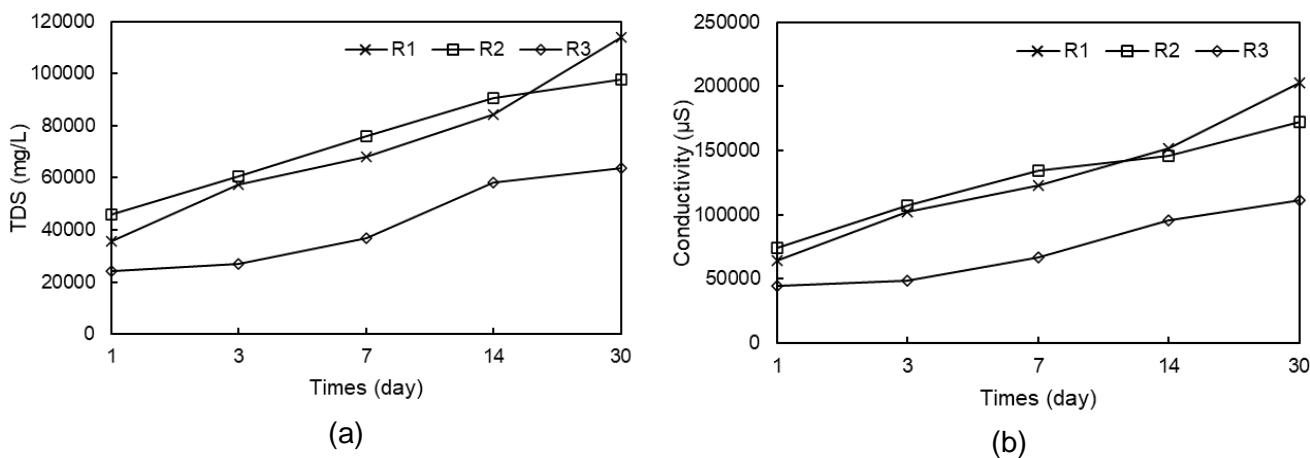


Figure 2: The concentration of TDS (a) and conductivity (b) of leachate generated from R1, R2, and R3 at 30 days

3.4. Effect of leachate recirculation on ammonia and nitrate concentrations.

Based on Amlinger and Top^{20,21} The presence of N-NH₄⁺ in leachate comes from the MSW ammonification process, namely the transformation of organic nitrogen compounds (humus-R-NH₂) into N-NH₄⁺ (stage 1), then ammonification stage 2, where NH₃ becomes N-NH₄⁺ based on equation (1) and (2).

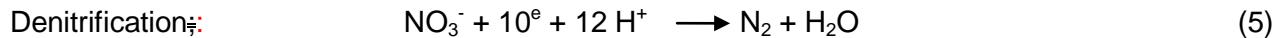


Figure 3a is a graph of ammonia and nitrate levels in R1, R2 and R3 generated during the 30 days of the study. On the first day, R1 did not undergo recirculation resulting in ammonia levels of 262.7 mg/L, while R2 and R3 experienced one-time recirculation to produce leachate with ammonia levels of 286.0 mg/L and 143.7 mg/L, respectively. Based on this value, the bulking agent in R3 was able to reduce ammonia levels in the leachate. The pattern of ammonium levels was almost the same in all reactors. The increase in ammonia occurred from the third to the 14th day, while on the 30th day it decreased compared to the 14th day. At the end of the study, the lowest ammonia level was produced by R3 at 72.5 mg/L. Based on Figure 3b, R3 produced a leachate with nitrate levels of 56.5 mg/L, while R1 and R2 get a production of 135.8 mg/L and 127.1 mg/L, respectively. The increase in nitrate was quite sharp from R3 on day 14th, where the nitrate level reached 563.0 mg/L. At the end of the study, the lowest nitrate level was produced by R2 with 35.0 mg/L.

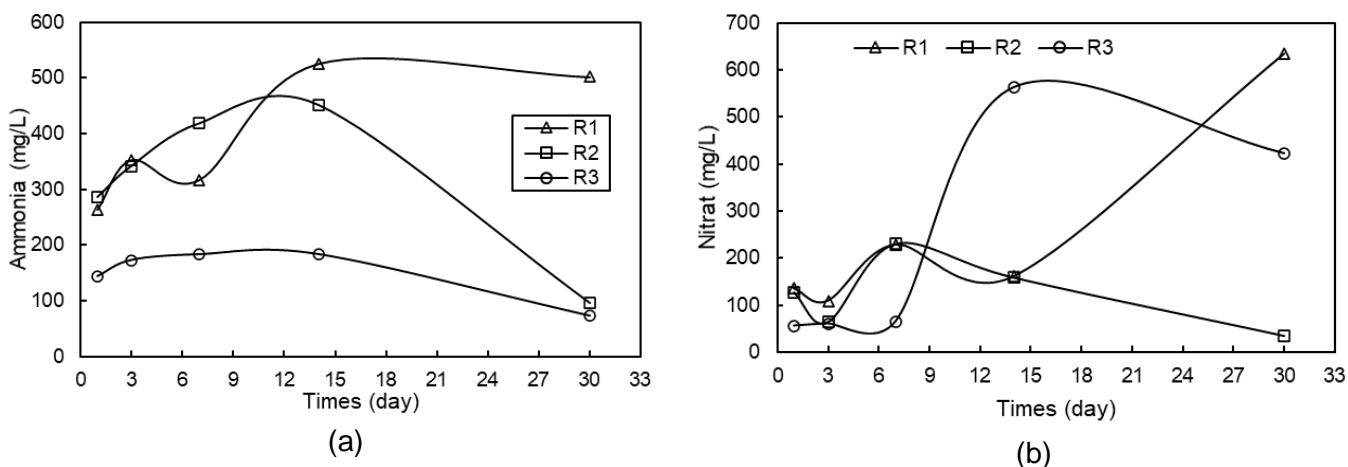


Figure 3: Ammonia (a) and nitrate (b) concentrations of leachate generated from R1, R2, and R3 at 30 days

3.5. Long term quality of municipal solid waste

This research analyzed changes of long-term MSW composition after being left for a period of 365 days. The characteristic of municipal solid waste at 365 days are shown in Table 1. The water content showed a largest increase in R3 from the initial water content of 32% to 76.8%. This increase was due to the leachate recirculation process and the addition of the bulking agent. We take samples at the bottom of the reactor. The increase in water content comes from water bound to solid waste at the top. As a result of the decomposition process, the water undergoes leaching and flows through the MSW by gravity. As a result, there is a buildup of water at the bottom of the reactor. This is in accordance with other studies ²², where the recirculation aims to increase the water content of solid waste. The pH of the waste on day 365th ranged from 7.1 to 7.7. The EC value multiplied a significantly increased from 6.9 mS/cm to 13.8 mS/cm, 35.8 mS/cm, 43.4 mS/cm for R1, R2 and R3 respectively. Volatile solids (VS) are the solid fraction remaining after sample dried, weighed and ignited at 600°C ²³. The volatile solids experienced a significant increase, especially in R3, where the value raised from 54.3% to 94.99%, while VS in control reactor were 62.10%. This indicated that the amount of volatile solids on R3 was more than in R1. Danlami Yavini et al. ²⁴ stated that the VS content is an indication of the level of degradation. Meanwhile, Rukmini ²⁵ stated that the changes in volatile solids content indicate the speed of organic matter conversion. So, the organic matter conversion rate at R3 was greater than that of R1 and R2. The same increase occurred in the total nitrogen at R3 from 0.23% to 0.95%. Meanwhile, the levels of K-Total did not change significantly, P-Total increased significantly.

Table 1: Characteristics of municipal solid waste at 365 days

No	Parameters	Unit	Result			
			A	R1	R2	R3
1	Water content	%	32.0	44.2	63.2	76.8
2	pH	-	5.8	7.1	7.7	7.38
3	EC	mS/cm	6.9	13.8	35.8	43.4
4	Volatile Solids	%	54.3	62.10	72.70	94.99
5	Organic C	%	12.5	5.49	7.49	25.93
6	N-Total	%	0.23	0.38	0.408	0.952
7	P-Total	mg P ₂ O ₅ /100 g	0.003	0.007	0.027	0.031
8	K-Total	mg K ₂ O/100 g	0.012	0.017	0.014	0.036

A - Sample of solid waste at 0 days

R1 - Sample of solid waste without recirculation at day 365th

R2 - Sample of solid waste+recirculation at day 365th

R3 - Sample of solid waste+recirculation+bulking agent at day 365th

4. Conclusions

The aim of this study was to determine the effect of adding solid waste from landfill passive zone as bulking agent to treat the fresh leachate produced in the landfill with a combination of recirculation processes. The pH value was decreased from the 3th day, both in reactors R1, R2 and R3. On day 30th, R3 produced a higher pH than R1 and R2. The bulking agent on R3 functioned as a pH buffer, so that the pH value of the leachate did not drop drastically. The bulking agent had a larger buffer capacity to maintain pH value. The COD concentration in R3 was much lower than in the other reactors (2,216.7 mg/L), while R1 was 7,700 mg/L and R2 showed 5,891.7 mg/L. At the end of the study, the lowest TDS level was 63,813.8 mg/L, the conductivity get a value of 111,457.5 µS, and the ammonia level was 72.5 mg/L in R3. The addition of a bulking agent from the landfill passive zone can reduce levels of COD, TDS, conductivity and ammonium. Municipal solid waste parameters increased for a long time. Water content in R3 increased from the initial water content from 32% to 76.8%. The pH on day 365th ranged from 7.1 to 7.7. EC value increased from 6.9 mS/cm to 13.8 mS/cm, 35.8 mS/cm and 43.4 mS/cm for R1, R2 and R3, respectively. Volatile solids in R3 increased significantly from 54.3% to 94.99%. The same increase occurred in the total Nitrogen at R3 from 0.23% to 0.95%. Meanwhile, the levels of P-Total and K-Total did not change significantly. The implication of this research is that MSW in the landfill passive zone can be used to treat fresh leachate. Leachate will not come out into the water body, so that pollution to the environment due to leachate can be minimized.

5. Acknowledgment

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Využití pevného odpadu z pasivní zóny skládky do upraveného výluhu kombinací recirkulace výluhu a objemového činidla

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Souhrn

Skutečným důkazem procesu rozkladu tuhého komunálního odpadu (TKO) je vznik znečišťujících látek ve formě výluhu, který má chemické složení, které se obtížně odbourává (odolné sloučeniny) a způsobuje znečištění vodních útvarů. Na druhou stranu odpad z pasivní zóny skládky není využíván vůbec. Cílem této studie bylo zjistit účinek přidání pevného odpadu z pasivní zóny skládky jako objemového činidla pro úpravu čerstvého výluhu s kombinací procesu recirkulace. TKO + objemové činidlo (70 % : 30 %, obj./obj.) bylo recirkulováno pomocí čerstvého výluhu s průtokovou rychlosí 1 l/min po dobu 30 dnů. Reaktor bez recirkulace a plniva byl použit jako kontrola.

Kvalita výluhu byla analyzována ve dnech 0, 3, 7, 14 a 30, zatímco složení TKO bylo analyzováno po ponechání po dobu 365 dnů. Výsledky získané z experimentu ukázaly, že přidání plnidla + recirkulace urychlilo zvýšení pH výluhu a zvýšilo pokles CHSK. V 30. den byla nejnižší hladina TDS 63813,8 mg/l, vodivost byla 111457,5 S/cm a amoniak byl 72,5 mg/l vyrobený z R3 (TKO + plnidlo + recirkulace). Přidání objemových činidel ze zón pasivních skládek může snížit CHSK, TDS, vodivost a ammonium. V 365. den byl obsah vody v MSW v R3 76,8 %, pH bylo 7,7, EC hodnota byla 43,4 mS/cm a těkavá pevná látka byla 94,99 %. Ke stejnemu nárůstu došlo u celkového dusíku na R3 z 0,23 % na 0,95 %. Mezičím se hladiny P-Total a K-Total výrazně nezměnily.

Klíčová slova: výluh, recirkulace, TKO, CHSK, skládka

Posúdenie možnosti valorizácie kávového oleja prítomného v kávovom odpade na produkciu bionafty

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Abstrakt

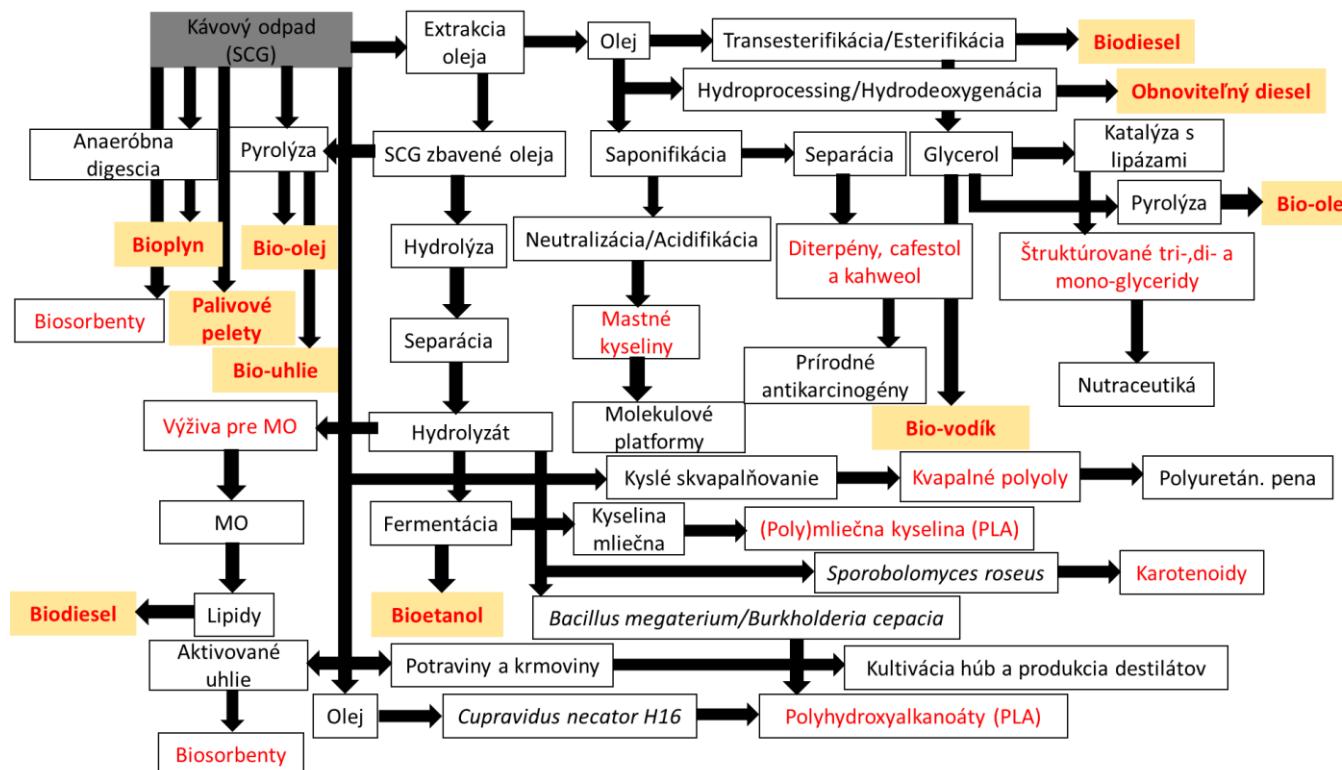
Kávový odpad vzniká po príprave expressa alebo pri výrobe instantných rozpustných káv. Zvýšenou konzumáciou kávových nápojov dochádza k zvýšenému generovaniu kávového odpadu, pričom väčšina tohto bioodpadu putuje na skládky alebo do spaľovní. Kávový odpad má potenciál výroby látok s vyššou pridanou hodnotou, teda je možné ho zhodnotiť a znížiť tak jeho skládkovanie. Kávový odpad obsahuje prieomerne 15 % kávového oleja, resp. lipidického podielu, ktorý môže byť valorizovaný na produkciu bionafty.

Cieľom tejto práce je posúdiť možnosť produkcie bionafty z kávového oleja extrahovaného z kávových usadenín, a to nepriamo analýzami kávového oleja a porovnaním s olejmi komerčne používanými na produkciu bionafty. Vykonané analýzy a experimenty preukázali potrebu purifikácie kávového oleja, resp. odstránenia nezmydeliteľných látok prítomných v oleji v množstve takmer 15 %. Z hľadiska profilu mastných kyselín je kávový olej vhodný na produkciu bionafty, pričom najviac zastúpenými mastnými kyselinami sú kyseliny C18:2 (linolová) a C16:0 (palmitová), ktoré tvoria ~75 % zloženia mastných kyselín (resp. viac ako 60 % zloženia kávového oleja). Ďalší výskum bude zameraný na produkciu bionafty z kávového oleja. Cieľom projektu, ktorého súčasťou je tento výskum, je komplexná valorizácia kávového odpadu na látky s vyššou pridanou hodnotou.

Kľúčové slová: kávový olej, kávový odpad, biodiesel, bionafta, valorizácia

Úvod

Káva je druhou najväčšou obchodovateľnou komoditou po rope¹. Spotreba kávy v Európe v roku 2019 bola 53,316 mil. kusov 60 kg vriec, čo predstavuje takmer 3,2 mil. ton kávy². Zvyšujúca konzumácia kávových nápojov má za následok aj zvýšené generovanie odpadu. Kávový odpad, ktorého ročná produkcia je približne 6 miliónov ton SCG ročne (SCG – spent coffee grounds), vzniká pri použití mletej zrnkovej kávy na prípravu expressa alebo iných druhov kávy, ako aj pri výrobe instantnej rozpustnej kávy, ktorá predstavuje 50 % svetovej produkcie kávy³. Aktuálne najčastejším spôsobom nakladania s takýmto bioodpadom je jeho spálenie, alebo skládkovanie. Avšak, v dôsledku prítomnosti organických látok sa kávový odpad definuje ako vysoko znečisťujúca látka, ktorá taktiež vykazuje čiastočnú toxicitu (dôsledok prítomnosti kofeínu, tanínov a polyfenolov)⁴. Preto je cieľom preskúmať možnosti komplexného spracovávania a valorizácie kávového odpadu na látky s vyššou pridanou hodnotou, čím sa zároveň dosiahne redukcia odpadu na skládkach, resp. v spaľovniach. Doteraz bolo preskúmané použitie SCG ako paliva (20,9 MJ/kg), na výrobu biopalív (bionafty a bioetanolu), bioplynu, prípravu enzymov, ako sorbent pre odstraňovanie kovov a mnoho ďalších (obrázok 1)⁵.



Obrázok 1: Možná valorizácia kávového odpadu v biorafinériách¹¹

Chemické zloženie SCG je variabilné, dôsledkom odlišností v odrodách kávy, rôznych pestovateľských podmienok a procesov spracovania kávy (sušenie, praženie a extrakcia). Zložky SCG môžeme rozdeliť do troch hlavných skupín – sacharidický podiel (45,3 % hmot._{DS}), olejová zložka (7,9 – 26,4 % hmot.) a ostatné zložky (napr. alkaloidy, proteíny, polyfenoly, fytosteroly a ī.). Sacharidy prítomné v SCG sú polymerizované do celulózových a hemicelulózových štruktúr, pričom najviac zastúpeným polysacharidom je manán. Profil sacharidov detegovaný v SCG bol 46,8 % manózy, 30,4 % galaktózy, 19 % glukózy a 3,8 % arabinózy. Priemerný obsah proteínov v SCG sa pohybuje okolo 13,6 % z celkovej biomasy. SCG má tiež antioxidačný potenciál (DPPH antioxidačná aktivita – 20.0 µmol TE/g DSCG), za ktorý sú zodpovedné najmä fenolové zlúčeniny. Obsah lipidov v SCG je rôzny, v priemere sa uvádzaj približne 15 %. Zloženie lipidov v SCG je premenlivé v závislosti od zdroja, avšak všeobecne 80 – 90 % oleja extrahovaného z SCG tvoria glyceridy^{3, 6, 7}. Vo všeobecnosti sú najviac zastúpenými mastnými kyselinami kyselina palmitová (C16:0) a linolová (C18:2)⁶.

Pre produkciu bionafthy z kávového odpadu je potrebné extrahovať olej prítomný v kávovom odpade. Extrakcia sa môže vykonávať mnohými procesmi, najčastejšie Soxhletovou extrakčnou metódou⁹. Kávový olej sa extrahuje organickým rozpúšťadlom s nízkou teplotou varu, ako sú hexán, éter, dichlórometán a ī.⁷ Okrem extrakcie rozpúšťadlom sa môže použiť superkritická CO₂ extrakcia, ktorej výhody sú chemická inertnosť, či extrakcia bez zvyšku rozpúšťadla⁸. Získaný výťažok oleja vo všeobecnosti závisí od rôznych metód varenia kávy, typu kávy (Arabica, Robusta a ich pomeru), vlhkosti SCG a veľkosti častic SCG, no taktiež od množstva a polarity rozpúšťadla, použitej extrakčnej metódy a doby jej trvania⁹. Caetano et al. (2014) preukázali, že vyextrahovaný obsah lipidov je pri použití DSCG vyšší (približne dvojnásobne) v porovnaní s použitím mokrých SCG s vlhkosťou ~ 66 %²². Z doposiaľ zistených štúdií sa najvyššie výťažky oleja extrahovaného z SCG dosiahli pri použití izopropanolu (21 % hmot.), resp. pri použití zmesi hexán/izopropanol v pomere 1:1 (21,5 % hmot.)¹⁰.

Vlastnosti a parametre oleja majú vplyv na produkciu bionafthy, ako aj na kvalitu a stabilitu výslednej bionafthy. Na základe niektorých parametrov oleja vieme posúdiť, či olej bude/nebude vhodný na následnú produkciu bionafthy, resp. vieme predpokladať potrebné rafinačné kroky pre splnenie požiadaviek kvality a stability bionafthy. Dôležitými parametrami oleja sú najmä číslo kyslosti a množstvo esterov, resp. podiel zmydelnítejnej zložky v oleji. Číslo kyslosti určuje množstvo voľných mastných kyselín (FFA) v oleji, ktoré negatívne ovplyvňujú výťažok a čistotu produkovej bionafthy¹³. Množstvo

esterov (zmydelniteľnej zložky bionafthy) je rovnako dôležitý z hľadiska výťažku a nepriamo aj kvality bionafthy. Nezmydelniteľný podiel rastlinného oleja vo všeobecnosti môžu tvoriť látky (napr. fytosteroly v rôznych formách, tokoferoly, karotenoidy), ktoré v prípade, že sa z oleja neodstránia, môžu znižovať kvalitu a stabilitu bionafthy, a tým spôsobovať problémy spojené s prevádzkou vozidla poháňaného bionafhou^{14,15}. Taktiež bolo preukázané, že profil mastných kyselín prítomných v oleji ovplyvňuje nízkoteplotné vlastnosti výslednej bionafthy. Lepšie nízkoteplotné vlastnosti boli vyhodnotené v bionafte, ktorá bola produkovaná z oleja s vyšším obsahom a stupňom nenasýtených mastných kyselín, a väčšou dĺžkou reťazca¹⁶. Analýzu obsahu fosforu v oleji je potrebné sledovať z dôvodu, že fosfolipidy prítomné v oleji môžu spôsobiť zníženie efektivity katalyzátora v transesterifikačnej reakcii pri produkciu bionafthy, a tiež vplývajú na separáciu glycerolu od bionafthy. Tento efekt skúmali Van Gerpen a Dvorak (2002), ktorí preukázali zníženie výťažku o 3 – 5 % pri obsahu fosforu v oleji vyššom ako 50 mg/kg²⁶. Obsah síry je potrebné sledovať hlavne v bionafte, nakoľko norma STN EN 590, upravuje maximálny obsah síry v bionafte 10 mg/kg, a to z hľadiska emisií pri používaní paliva. Z hľadiska skladovej stability je však síra prospešná, nakoľko pozitívne ovplyvňuje oxidačnú stabilitu bionafthy²⁷. Anorganické kontaminanty, napr. K, Na, Ca, Mg, musia byť v bionafte kontrolované z dôvodu vplyvu na výkon motora a možného vytvárania usadenín v systéme vstrekovania paliva. Obsah kovových kontaminantov v bionafte je taktiež limitovaný európskymi normami²⁸.

Materiál a metódy

Kávový odpad sa vyzbieral z kaviarní Fresh Corner. Pred sušením kávového odpadu sa stanovil obsah sušiny v kávovom odpade pomocou sušinových váh. Na plochu misky sa rozprestrel približne 1 g vzorky a nechal sušiť do konštantnej hmotnosti pri teplote 105 °C. Obsah sušiny sa po skončení merania odčítal z meracieho zariadenia. Sušenie zozbieraného mokrého kávového odpadu prebiehalo pri teplote 105 °C do konštantnej hmotnosti, pričom úbytok hmotnosti predstavoval 58 % z celkovej hmotnosti; výsledkom bolo 5 kg suchého kávového odpadu.

Následne sa vyprodukovaný suchý kávový odpad (5 kg) podrobil extrakcii, s výsledným objemom približne 600 ml extrahovaného kávového oleja. Extrakcia kávového oleja z kávového odpadu prebiehala v extrakčnom systéme podobnom Soxhletovej extrakcii s tým rozdielom, že sa vzorka extrahovala rozpúšťadlom pri laboratórnej teplote. Ako rozpúšťadlo sa použil hexán. Stĺpec kávového odpadu vysoký 5 cm sa pomaly premýval hexánom až do času, keď rozdiel medzi obsahom extrahovaných triglyceridov (TAG) v extrakte a obsahom TAG na začiatku extrakcie bol nižší ako 1 %. Dlhšia extrakcia nebola žiadúca, nakoľko by mohla spôsobiť narastajúce množstvo polárnejších látok prítomných v lipidickom podiele kávového odpadu. Takto pripravený olej sa podrobil analýzam, na základe ktorých sme predpokladali nepriame určenie využiteľnosti kávového oleja z kávového odpadu na produkciu bionafthy.

Základná analýza kávového oleja a kávového odpadu

Obsah oleja v kávovom odpade – stanovenie množstva oleja sa vykonávalo extrakčnou metódou s návažkom približne 1 – 2 g suchého/mokrého kávového odpadu. Olej sa zo skúšobnej vzorky extrahuje na prístroji VELP SCIENTIFICA SER 148 s hexánom. Extrakčný prístroj používa dvojstupňový postup. V prvom kroku je patróna ponorená do vriaceho extrakčného činidla v extrakčnej banke. Po určitom definovanom čase je patróna z extrakčného činidla zodvihnutá a visí pod chladičom, z ktorého odkvapkáva kondenzované extrakčné činidlo a extrahuje vzorku. Po skončení extrakcie a odstránení rozpúšťadla sa extrakt zváži. Výsledok je uvedený ako priemer troch hodnôt.

Číslo kyslosti – číslo kyslosti sa určovalo titračnou metódou. Navážená vzorka (približne 10 g) bola rozpustená v zmesnom rozpúšťadle (dietyléter s etanolom v pomere 1:1) a titrovaná 0,1M etanolickým roztokom KOH, na indikátor fenolftaleín do ekvivalentného bodu titrácie. Číslo kyslosti sa následne vypočítaло pomocou vzorca: $\text{ČK} = \frac{\text{sp} * \text{f} * \text{c} * 56,1}{\text{n}}$, kde ČK je číslo kyslosti v mg KOH/g, sp je spotreba 0,1M etanolického roztoku KOH v ml, f je faktor 0,1M etanolického roztoku KOH, c je koncentrácia etanolického roztoku KOH, n je navážka vzorky v g a 56,1 je molekulová hmotnosť KOH v g/mol. Výsledok je uvedený ako priemer troch hodnôt.

Prvky – obsah P, Ca, Mg, Na, K, S sa stanovil emisnou spektrometriou s indukčne viazanou plazmou (ICP) na prístroji SPECTRO Genesis FES. Vzorka sa zriedila petrolejom v pomere 1:1 (hm.), štandard sa zriedil s petrolejom. Pripravený roztok sa uviedol vo forme aerosolu do indukčne viazanej argónovej plazmy. Obsahy jednotlivých prvkov sa následne stanovili porovnaním vo vzorke a štardarde pri vlnovej dĺžke 177 a 495 nm. Výsledok je uvedený ako priemer troch hodnôt.

Obsah vody v oleji – obsah vody v oleji sa stanovil pomocou coulometrickej titračnej metódy podľa Karla Fishera. Na stanovenie sa použilo cca 0,2 g vzorky, ktorá sa so striekačkou s ihlou vstrekla do titračnej nádoby. V titračnej nádobe coulometrického titrátoru Karla Fishera (Coulometer 831 KF) je jód generovaný coulometricky na anóde. Stitrovaním celého množstva vody vo vzorke sa nadbytok jódumu deteguje elektrometrickým detektorm. Na základe stechiometrickej reakcie jeden mól jódumu reaguje s jedným mólom vody, takže množstvo vody je priamoúmerné celkovému integrovanému prúdu podľa Faradayovho zákona. Po ukončení titrácie sa obsah vody vo vzorke v % odčítal z titrátoru. Výsledok je uvedený ako priemer troch hodnôt.

Celková analýza majoritných látok v kávovom oleji

Pre analýzu majoritných látok v oleji sa zvolil postup silanizácie vzorky s derivatizačným činidlom 1,1,1,3,3-hexametyldisilazánom (HMDS), aby sa derivatizovali kyslé vodíky nachádzajúce sa v kaboxylovej, hydroxy resp. amino skupine. Tako silanizované látky sa následne analyzovali s použitím prístroja Network GC System 6890 N (Agilent Technologies) pomocou vysokoteplotnej plynovej chromatografie s FID detektorm, ktorá umožňuje merať látky do veľkosti C80. Na separáciu látok bola použitá kapilárna kolóna DB-1. Metódou, ktorú sme použili, je možné separovať voľné mastné kyseliny, steroly, mono-, di- a triacylglyceridy, vosky, fosfolipidy príp. ďalšie nepolárne látky. Na spoľahlivú identifikáciu jednotlivých látok v kávovom oleji sa dodatočne použila analýza silanizovanej vzorky pomocou GC-MS. Vzhľadom na obmedzenia teplotného rozsahu merania pri použití GC-MS, nebolo možné potvrdiť identitu TAG.

Analýzy profilu (esterov) mastných kyselín

Profil (esterov) mastných kyselín bol stanovený dvoma spôsobmi, aby sme zároveň porovnali rozdiely medzi jednotlivými analýzami. Ako prvé sa na úpravu vzorky použila bázická transesterifikácia pomocou metanolátu sodného. Týmto spôsobom je možné analyzovať prítomné mastné kyseliny nachádzajúce sa vo forme esterov triglyceridov, diacylglyceridov, monoacylglyceridov, fosfolipidov, voskov a esterov mastných kyselín so sterolmi. Voľné mastné kyseliny týmto postupom nie je možné analyzovať. Na analýzu sa použil prístroj Network GC System 6890 N (Agilent Technologies). Na separáciu jednotlivých metylesterov sa použila chromatografická kolóna s polárnou stacionárnou fázou DB-23 a na detekciu FID detektor (vzorka označená „COFO (analýza 1)“). Druhý spôsob, ktorý sa aplikoval na analýzu (esterov) mastných kyselín slúžil na presné stanovenie zloženia lipidov vo vzorke. Vzorka kávového oleja sa zmydelnila a esterifikovala podľa STN EN ISO 12966-2 a následne analyzovala podľa STN EN 14103 (vzorka označená „COFO (analýza 2)“).

Kyslá esterifikácia kávového oleja – nepriame overenie prítomnosti diterpénov

Esterifikácia prebiehala v sklenenom miešanom reaktore s objemom 1 L. Na kyslú esterifikáciu sa použilo 50 ml COFO, 16 ml metanolu a koncentrovaná kyselina sírová (5 ml). Podmienky kyslej esterifikácie: teplota 70 °C, 800 rpm, tlak 0,9 bar, doba reakcie 2 hodiny. Po zbehnutí reakcie sa k reakčnej zmesi pridal n-hexán (predpoklad: hexánom sa extrahujú vzniknuté metylestry). Z hexánového extraktu bol odparený hexán na vákuovej odparke a vzorka esterov bola analyzovaná podľa STN EN 14103.

Výsledky a diskusia

Základná analýza kávového oleja a kávového odpadu

Priemerná počiatočná sušina kávového odpadu pred sušením bola 49,70 %. Vzorka po vysušení obsahovala 90,18 % sušiny. V kávovom odpade bol stanovený obsah oleja. Pre zistenie vplyvu vlhkosti (vody) prítomnej v kávovom odpade sa realizovala extrakcia oleja zo suchého (DSCG) aj mokrého (WSCG) kávového odpadu (Tab. 1). Rovnako ako v štúdii Caetano et al. (2014), sa potvrdilo zníženie efektivity extrakcie, resp. zníženie výťažku extrakcie oleja vplyvom vody prítomnej v kávovom odpade. Výťažok po extrakcii oleja z DSCG bol o 56 % vyšší v porovnaní s extrakciou oleja z WSCG. S cieľom extrakcie kávového oleja z SCG s čo najlepším výťažkom, bola následne extrakcia vykonávaná zo suchého kávového odpadu.

Tabuľka 1: Priemerné množstvo oleja v mokrom a suchom kávovom odpade

Vzorka	Sušina [hm. %]	Obsah oleja [hm. %]
WSCG	49,70	6,2
DSCG	90,18	9,7

Extrahovaný kávový olej (COFO) sme podrobili analýzam určujúcich základné parametre oleja (tabuľka 2). Parametre COFO sme následne porovnali s parametrami surového repkového a kukuričného oleja, ktoré sa komerčne spracovávajú na výrobu FAME. Najdôležitejším z týchto parametrov je číslo kyslosti, ktoré nepriamo určuje množstvo voľných mastných kyselín. Počas transesterifikácie sa voľné mastné kyseliny menia na mydlá a ich zvýšený podiel v oleji spôsobuje problémy pri produkcií FAME, preto sa oleje pred samotnou transesterifikáciou upravujú destiláciou voľných mastných kyselín tak, aby rafinovaný olej vstupujúci do transesterifikácie obsahoval menej ako 1% FFA (ČK < 2 mg KOH/g). Z uvedeného vyplýva, že výrobu FAME z kávového oleja je možné efektívne vykonať po úprave čísla kyslosti alebo primiešaním COFO do olejov s nižším množstvom FFA.

Analýza obsahu prvkov preukázala, že v kávovom oleji sa nenachádzajú kovy so zvýšeným obsahom, ktoré by mohli negatívne ovplyvniť produkciu bionafy alebo kvalitu bionafy. Jediným zvýšeným parametrom v kávovom oleji v porovnaní s olejmi používanými v priemyselnej výrobe bionafy je síra. V štúdii He et al. (2009) bolo pozorované, že síra je významne redukovaná v procese rafinácie oleja a výroby bionafy, a vo väčšine prípadov (s výnimkou kukuričného oleja) je jej obsah v bionafte redukovaný pod 10 mg/kg¹².

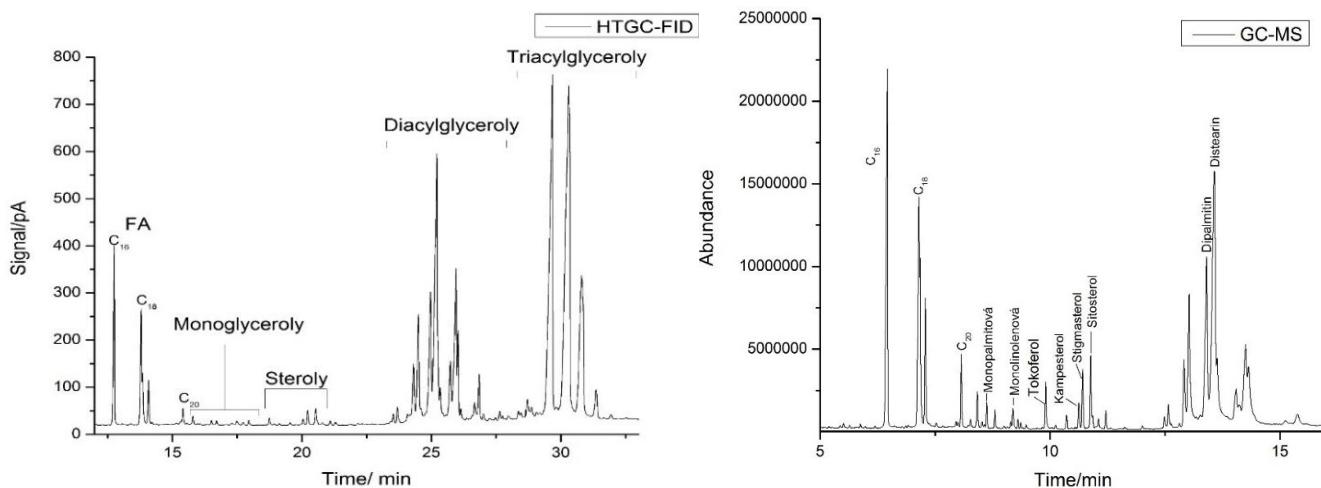
Tabuľka 2: Základné parametre kávového, repkového a kukuričného oleja.

Vzorka	Kávový olej (+odchýlka)	Repkový olej*	Kukuričný olej*
Číslo kyslosti (mg KOH/g)	4,8 ± 0,02	1,6	22,3
P (mg/kg)	14,4 ± 0,025	406,1	12,7
Ca (mg/kg)	2,3 ± 0,025	73,1	0,2
Mg (mg/kg)	4,4 ± 0,025	28,9	1,3
Na (mg/kg)	0,7 ± 0,025	0,7	2,9
K (mg/kg)	3,1 ± 0,025	111,7	9,3
S (mg/kg)	33,1 ± 0,025	20,7	14,9
Obsah vody (hm. %)	0,3 ± 1,8	0,06	0,4

*priemerné hodnoty parametrov olejov používaných v priemyselnej výrobe bionafy

Celková analýza majoritných látok v kávovom oleji

Z dôvodu obavy možnej prítomnosti hydroxykyselín (oxidovaných mastných kyselín), ktoré môžu vznikať pri pražení kávy, bola v kávovom oleji analyzovaná prítomnosť majoritných zložiek spolu s identifikáciou niektorých konkrétnych produktov (obrázok 2).



Obrázok 2: GC-FID chromatografický záznam získaný z vysokoteplotnej analýzy po silanizácii vzorky kávového oleja pre zistenie majoritných zložiek vzorky (vlavo) a GC-MS chromatogram získaný meraním silanizovanej vzorky kávového oleja pre identifikáciu niektorých konkrétnych produktov (vpravo)

Z výsledkov vyplýva, že vo vzorke sa jednoznačne potvrdila prítomnosť voľných mastných kyselín, sterolov, mono-, di-, a tri-glyceridov (tabuľka 3) a nebola potvrdená prítomnosť oxidovaných mastných kyselín, voskov a fosfolipidov. Vosky a fosfolipidy eluujú v oblasti di-acylglyceridov, čo sťaže ich identifikáciu. V danej oblasti sa namerala niekoľko neznámych látok, ale nakoľko išlo o retenčný prekryv s DAG, nebolo možné určiť ich štruktúru. Taktiež vzorka obsahuje nezvyčajné vysokú koncentráciu DAG (cca 35 %).

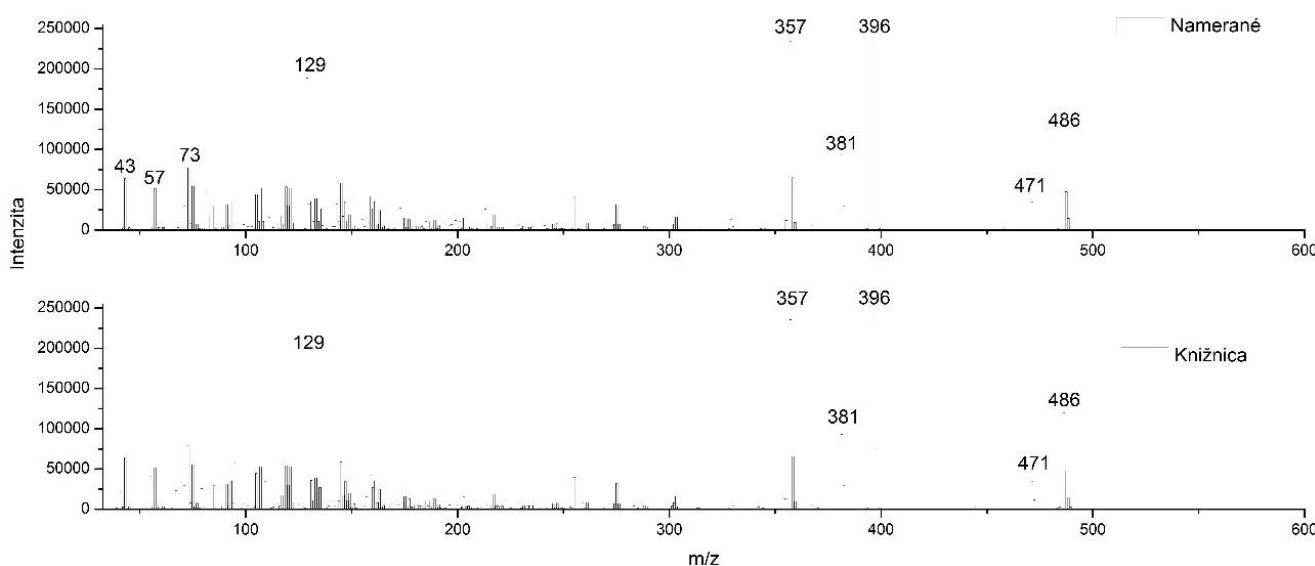
Tabuľka 3: Výsledky analýzy majoritných látok v kávovom oleji

Zložka	Percentuálne zastúpenie zložky %
FFA	7,59
MAG	0,79
Steroly	1,47
DAG	35,21
TAG	54,95

Štúdia Campos-Vega et al. (2015)⁶ uvádzá prítomnosť 84,4 % TAG, 12,3 % esterov diterpénov, 1,9 % sterolov, 1,3 % polárnych látok, a 0,1 % sterolesterov. Medzi diterpény prítomné v kávovom oleji patria dve hlavné látky, a to kahweol a cafestol. Kahweol a cafestol môžu byť v oleji prítomné vo forme esterov s alkoholmi alebo mastnými kyselinami v množstve až 7 – 20 % hm. Tieto zlúčeniny podliehajú termálnej degradácii počas praženia kávy, pričom môžu vznikať rozkladné produkty, akými sú dehydrocafestol, dehydrokahweol, cafestol a kahweol¹⁷. Kvantifikácia diterpénov, hľavne ich esterov s mastnými kyselinami a alkoholmi, vyžaduje efektívnu separáciu týchto látok od majoritných zložiek kávového oleja, nakoľko môžu interferovať s DAG a TAG¹⁸. Prítomnosť esterov diterpénov by mohla byť zodpovedná za vysokú koncentráciu DAG v analyzovanej vzorke. Potvrdenie, resp. vyvrátenie prítomnosti týchto látok v kávovom oleji bude skúmané v ďalšom výskume riešeného projektu.

Poznatkom, zisteným v tejto časti meraní, je prítomnosť fytosterolov a tokoferolov v kávovom oleji. Najviac zastúpeným fytosterolom vo vzorke kávového oleja je sitosterol, ktorého potvrdenie prítomnosti vo vzorke kávového oleja je znázornené na obrázku 3. Ďalšími fytosterolmi prítomnými vo vzorke kávového oleja boli kampesterol a stigmasterol. Prítomnosť fytosterolov v kávovom oleji extrahovanom z SCG nebola doposiaľ v štúdiach zaznamenaná, avšak analýzy fytosterolov v kávovom nápoji (štandardnom talianskom espresse)¹⁹ a v kávovom odpade²⁰ potvrdili prítomnosť fytosterolov, pričom rovnako bol najviac zastúpeným fytosterolom sitosterol; ďalšie prítomné fytosteroly boli kampesterol, stigmasterol a cykloartenol^{19,20}.

Prítomnosť týchto látok nie je žiadúca pre produkciu bionafty, pretože môžu spôsobovať problémy pri transesterifikácii oleja na bionaftu (hlavne diterpény a ich estery), alebo spôsobovať zrazeniny pri skladovaní bionafty (fytosteroly, sterylglykozidy).



Obrázok 3: MS spektrum píku eluujúceho v čase 10.88 min a porovnanie so spektrom sitosterolu v databáze NIST

Analýzy profilu (esterov) mastných kyselín

Analýzou profilu mastných kyselín v kávovom oleji sme chceli overiť vhodnosť kávového oleja pre transesterifikáciu (výrobu bionafty), a to porovnaním zloženia mastných kyselín v olejoch používaných priemyselne pre produkciu bionafty. Výsledky analýz a porovnanie s inými olejmi sú uvedené v tabuľke 4. Podľa výsledkov oboch analýz má v kávovom oleji extrahovanom z SCG najväčšie zastúpenie kyselina C18:2 (linolová) a C16:0 (palmitová), ktoré tvoria ~75 % zloženia mastných kyselín (resp. viac ako 60 % zloženia kávového oleja). Kyselina linolová je rovnako zastúpená vo vyššom množstve v kukuričnom (CO), sójovom (SBO) a slnečnicovom (SFO) oleji. Kyselina palmitová je zase najviac zastúpená v palmovom oleji (PO). Mastné kyseliny v kávovom oleji tvorili 85,85 % zloženia kávového oleja, z čoho vyplýva, že takmer 15 % kávového oleja extrahovaného z SCG tvorí nezmydeliteľný podiel, nevhodný pre produkciu bionafty, ktorý podľa štúdií môžu tvoriť najmä spomínané diterpény a ich estery, fytosteroly a látky polárneho charakteru²². Takéto množstvo doposiaľ neznámych zložiek v analyzovanej vzorke kávového oleja môže spôsobiť problémy pri produkcií bionafty alebo znížiť kvalitatívne parametre výsledného paliva.

Tabuľka 4: Výsledky analýz (esterov) mastných kyselín vo vzorke kávového oleja a porovnanie percentuálneho zastúpenia mastných kyselín v olejoch používaných pri výrobe bionafty

Mastné kyseliny (% hm.)	COFO (analýza 1)	COFO (analýza 2)	RSO*	CO*	SFO ^{23,24,25}	SBO ^{24,25}	PO ²⁴
C8:0	0,2	0,01	<0,1	<0,1	-	-	0,04 - 0,12
C10:0	0,02	0,01	<0,1	<0,1	-	-	0,01 - 0,11
C12:0	0,07	0,06	<0,1	<0,1	0,02	0,08 - 0,22	0,07 - 0,65
C14:0	0,10	0,10	0,1	<0,1	0,00 - 0,10	0,00 - 0,36	0,47 - 1,79
C16:0	31,97	33,64	4,6	12,8	4,73 - 7,97	9,74 - 13,26	39,13 - 45,49
C16:1	0,13	0,03	0,3	0,2	0,00 - 0,14	0,00 - 0,38	0,05 - 0,29
C17:0	0,11	0,12	-	-	0,02	0,00 - 0,09	0,00 - 0,12
C18:0	7,44	7,73	1,7	2,1	2,77 - 4,07	3,31 - 4,91	3,34 - 5,20
C18:1	10,37	10,43	64,5	28,4	15,26 - 28,00	21,54 - 25,46	38,16 - 43,64
C18:2	43,65	42,15	18,7	53,9	61,23 - 73,93	50,79 - 55,87	8,28 - 11,86
C18:3	1,25	1,16	7,7	1,3	0,00 - 0,40	4,66 - 8,86	0,08 - 0,48
C20:0	2,7	2,89	0,6	0,4	0,05 - 0,39	0,09 - 0,55	0,15 - 0,47
C20:1	0,37	0,38	1,2	0,3	0,00 - 0,22	0,00 - 0,44	0,10 - 0,22
C20:2	0,09	0,05	-	-	-	-	-
C20:3	0,12	0,14	-	-	-	-	-
C20:4	0,03	0,01	-	-	-	-	-
C22:0	0,02	0,59	0,3	0,2	0,38 - 0,94	0,05 - 0,49	0,00 - 0,09
C22:1	-	0,10	0,1	<0,1	-	0,00 - 0,20	-
C23:0	-	0,10	-	-	-	-	-
C24:0	-	0,26	0,1	0,2	0,15 - 0,35	0,01 - 0,25	0,00 - 0,10
C24:1	-	0,01	0,3	0,2	-	-	-

*priemerné hodnoty zloženia olejov používaných v priemyselnej výrobe bionafty

Kyslá esterifikácia kávového oleja – nepriame overenie prítomnosti diterpénov

Kyslá esterifikácia oleja je súčasťou dvojkrokovej transesterifikácie, a používa sa v prípade, že olej má vyšší obsah FFA, resp. vyššie číslo kyslosti²¹. Po pridaní kyseliny sa pôvodne hnedá farba COFO zmenila na tmavomodrú a vznikli tmavé častice s veľkosťou do 0,1 mm. Podobné pozorovanie sú publikované v štúdii Jenkins et al. (2014)²², ktorý pozoroval tvorbu modro-zelených nezmydeliteľných precipitátov počas transesterifikácie pri použití kyslého katalyzátora. Tieto precipitáty môžu vznikať z rôznych zlúčenín, akými sú napr. steroly, terpény a organické kyseliny. Dve z hlavných nerozpustných zlúčenín prítomných v esterifikovanom kávovom oleji, ktoré boli v štúdii Jenkins et al. (2014) pozorované, sú cyklické terpény bežne sa vyskytujúce v kávovom oleji – kahweol a cafestol²². Zvyšok vzorky po extrakcii s n-hexánom bol podrobnený extrakcii s acetónom. Po odparení acetónu z extraktu vznikla tmavá tekutina, ktorá po ochladení stuhla (obrázok 4). Je zrejmé, že pre úspešnú (trans)esterifikáciu je potrebné nezmydeliteľný podiel z extraktu vylúčiť.



Obrázok 4: Zvyšok po esterifikácii vzorky kávového oleja

Závery

Výsledky štúdie potvrdili vplyv vody/vlhkosti kávového odpadu na extrakciu kávového oleja z kávového odpadu, ktorý bol prezentovaný v štúdii Caetano et al. (2014)¹⁰. Výťažok po extrakcii oleja z DSCG bol o 56 % vyšší v porovnaní s extrakciou oleja z WSCG, z čoho vyplýva potreba sušenia kávového odpadu pred samotnou extrakciou oleja, pre získanie čo najvyššieho možného výťažku extrakcie. Analýzou základných parametrov kávového oleja bolo zistené zvýšené číslo kyslosti (4,8 mg KOH/g oleja). Je potrebné pred samotnou transesterifikáciou upraviť olej tak, aby sa dosiahla hodnota pod 2 mg KOH/g oleja, alebo vo vhodnom pomere zmiešať s olejmi s nižším číslom kyslosti. Celková analýza majoritných látok preukázala prítomnosť FFA, TAG, DAG, MAG a sterolov, pričom nebola identifikovaná prítomnosť oxidovaných mastných kyselín, voskov a fosfolipidov. V oblasti, kde eluujú DAG sa namerala niekoľko neznámych látok, avšak z dôvodu prekrytie s DAG nebolo možné určiť ich štruktúru. Z pozorovaní v literatúrach by sa mohlo jednať o diterpénové zlúčeniny, presnejšie estery diterpénov kahweolu a cafestolu. Estery týchto zlúčenín by eluuovali v tom istom čase ako DAG (nastalo by prekrytie spektier látok), čo by vysvetlovalo zvýšené analyzované množstvo DAG v kávovom oleji.

Kávový olej obsahoval najväčšie zastúpenie kyselín C18:2 (linolová) a C16:0 (palmitová), ktoré tvorili ~75 % zloženia mastných kyselín (resp. viac ako 60 % zloženia kávového oleja). Celkovo tvorili mastné kyseliny v kávovom oleji 85,85 % zloženia kávového oleja, z čoho vyplýva, že takmer 15 % kávového oleja extrahovaného z SCG tvorí nezmydelniteľný podiel, nevhodný pre produkciu bionafthy. Medzi nezmydelniteľný podiel kávového oleja sa zaraďujú aj identifikované fytosteroly. Podľa štúdií môžu nezmydelnitelné podiel tvoriť aj spomínané diterpény a ich estery a látky polárneho charakteru. Pri vykonávaní kyslej esterifikácie kávového oleja vznikali po pridaní kyseliny precipitáty/časticie, ktoré sú pre výrobu bionafthy nežiaduce, nakoľko by mohli spôsobovať problémy pri samotnej transesterifikácii, alebo by mohli znižovať kvalitu výslednej bionafthy. Pre úspešné využitie kávového oleja na produkciu bionafthy je preto potrebná úprava kávového oleja, odstránením nezmydelniteľného podielu kávového oleja.

Ďalší výskum sa bude zameriavať na identifikáciu zložiek v nezmydelniteľnom podiele kávového oleja a možnosti jeho odstránenia z kávového oleja. Na odstránenie týchto látok v laboratórnom meradle sa bude testovať použitie degummingu, kolóny so silikagéлом a tiež bieliaca hlinka. Dôležité bude taktiež prevedenie nečisteného aj čisteného kávového oleja na bionaftu. Zámerom je tiež určiť potenciál látok v kávovom oleji na výrobu látok s vyššou pridanou hodnotou. Cieľom projektu, ktorého je táto štúdia súčasťou, má za cieľ kompletné spracovanie a valorizáciu kávového odpadu na látky s vyššou pridanou hodnotou, akými sú napr. karotenoidy, polynenasýtené mastné kyseliny, enzymy a ī.

Zoznam skratiek

SCG	kávový odpad
DS	sušina
DSCG	sušený/suchý kávový odpad
WSCG	mokrý/vlhký kávový odpad
FAME	fatty acid methyl esters – metylestery mastných kyselín
FFA	free fatty acids – voľné mastné kyseliny
TE	transesterifikácia
TAG	triglyceridy
DAG	diglyceridy
MAG	monoglyceridy
COFO	kávový olej extrahovaný z kávového odpadu
RSO	repkový olej
CO	kukuričný olej
SBO	sójový olej
SFO	slnečnicový olej
PO	palmový olej

Podakovanie

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Assessment of the extracted coffee oil valorisation to biodiesel

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Summary

Spent coffee grounds are generated after coffee brewing or instant soluble coffee production. An intensified consumption of coffee beverages leads into increased generation of spent coffee grounds. Mostly this biowaste is disposed into landfills or burned in incinerators. Spent coffee grounds have the potential to be transformed into value-added compounds with their subsequent recovery while having the positive impact on reduction of landfilled SCG amount at the same time. Spent coffee grounds contain on average 15 % of oil, meaning that 15 % of lipidic share can be potentially valorised into biodiesel. Aim of this work is to investigate suitability of oil extracted from spent coffee grounds (SCG oil) for biodiesel production, by comparison of analyses of SCG oil and oils commercially used for biodiesel production. Results of performed analyses have determined the need for SCG oil purification, or additional removal of unsaponifiable matter (almost 15 % of oil content) present in the oil. In terms of fatty acid profile, SCG oil is suitable for biodiesel production, with the most abundant fatty acids being C18:2 (linoleic acid) and C16:0 (palmitic acid), together representing ~ 75 % of the fatty acid composition (more than 60 % of the SCG oil composition, respectively). Further studies will focus on the transformation of SCG oil to biodiesel. The aim of the project is to provide comprehensive insight into valorisation of spent coffee grounds into value-added compounds.

Keywords: coffee oil, spent coffee grounds, coffee waste, biodiesel, valorisation

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ODPADOVÉ FÓRUM

16. ročník symposia, jehož plný název je „**Výsledky výzkumu a vývoje pro průmyslovou a komunální ekologii**“, pokračuje ve svém rozšířeném záběru na celou oblast průmyslové a komunální ekologie. Znamená to, že vedle příspěvků z oblasti odpadového hospodářství a sanací ekologických zátěží mají zde prostor i téma související s vodním hospodářstvím a emisemi škodlivých látek do ovzduší. V souvislosti s přípravami na přechod k oběhovému hospodářství je navíc součástí i oblast **Věda a výzkum pro oběhové hospodářství**.

VODA	OVZDUŠÍ
<input type="checkbox"/> Čištění průmyslových odpadních vod <input type="checkbox"/> Získávání cenných látek z odpadních vod <input type="checkbox"/> Recyklace vody <input type="checkbox"/> Nakládání s kaly, kapalné odpady	<input type="checkbox"/> Čištění odpadních plynů a spalin <input type="checkbox"/> Snižování a měření emisí <input type="checkbox"/> Doprava a lokální zdroje <input type="checkbox"/> Kvalita ovzduší a zdravotní dopady znečištění ovzduší
ODPADY	VĚDA A VÝZKUM PRO OBĚHOVÉ HOSPODÁŘSTVÍ
<input type="checkbox"/> Systémové otázky odpadového hospodářství <input type="checkbox"/> Materiálové, biologické a energetické využití <input type="checkbox"/> Nebezpečné odpady, odstraňování odpadů <input type="checkbox"/> Sanace ekologických zátěží a následků havárií	<input type="checkbox"/> Šance a bariéry cirkulární ekonomiky <input type="checkbox"/> Nové zdroje surovin a energie <input type="checkbox"/> Inovativní technologické postupy a technologie <input type="checkbox"/> Nové materiály a jejich aplikace (bio- a nanomateriály)

KLÍČOVÉ TERMÍNY

CENY VLOŽNÉHO

Přihlášky příspěvků	31. 7. 2022	Plné vložné	4 900 Kč
Zaslání plných textů do sborníku	31. 8. 2022	Dvoudenní vložné	4 350 Kč
Přihlášky účasti	2. 9. 2022	Jednodenní vložné	3 800 Kč
Termín konání	20. – 22. 9. 2029		

OHLÉDNUTÍ ZA POSLEDNÍMI ROČNÍKY

	2019	2020/2021 (*covid-19)
Počet účastníků	190	135
Počet přednášek	64	60
Počet vývěsek	17	12

PŘIHLÁŠKY PŘÍSPĚVKŮ A PREZENTACE PŘEDNÁŠEK

Příspěvky na TVIP mohou mít povahu přednášky v odborné sekci (15 min. přednáška a 5 min. diskuse) nebo vývěsky. Vývěsky mohou být až do formátu A0 na výšku, větší rozměry je třeba konzultovat s pořadateli.

Termín přihlášek příspěvků je **31. 7. 2022**. Přihlášky je možné zasílat výhradně prostřednictvím elektronického formuláře na www.tvip.cz. Pořadatel potvrzuje přijetí přihlášky a vyhrazuje si právo konečného rozhodnutí o přijetí příspěvku, formě jeho prezentace a zařazení do konkrétní sekce a programu.

Po uvedeném datu je možno přihlásit příspěvek buď po výzvě přípravného výboru, nebo do naplnění kapacity (sestavení konečného programu). Jednací jazyk je čeština a slovenština. Zahraniční přednášející (i posluchači) jsou vítáni, ale tlumočení nezajišťujeme. Komerční prezentace na konferenci je možná, více na www.tvip.cz.

PLNÉ TEXTY PŘEDNÁŠEK

Autory všech příspěvků, přednášek i vývěsek žádáme o včasné předání konečného, graficky upraveného plného textu příspěvku v elektronické podobě v MS Word nejpozději do **31. 8. 2022**. Požadavky na grafickou úpravu textů do sborníku jsou uvedeny na internetových stránkách TVIP, kde je rovněž i vzorová šablona pro psaní textů. Sborník TVIP je vydáván v elektronické formě s označením ISBN.

PUBLIKACE VE WASTE FORUM

Časopis WASTE FORUM, který je dlouholetým mediálním i odborným garantem TVIP, je od roku 2017 indexován v databázi SCOPUS. V případě zájmu o publikaci příspěvku ze symposia v časopisu je toto možné. Publikační jazyk je angličtina, čeština a slovenština. Redakční uzávěrky jsou pravidelně 8. 1., 8. 4., 8. 7. a 8. 10. Text je třeba upravit podle redakčních zvyklostí (více na www.wasteforum.cz/ v sekci Pro autory). Příspěvky jsou posuzovány minimálně dvěma nezávislými recenzenty. Hotové číslo bývá vystaveno na internetu zhruba 10 – 11 týdnů po redakční uzávěrce. Všechna čísla časopisu (aktuální i archivní) jsou volně ke stažení na stránkách www.wasteforum.cz.

PŘIHLÁŠKY ÚČASTI

K účasti na TVIP se přihlašuje prostřednictvím formuláře na www.tvip.cz. Jeho součástí je i specifikace objednávaného ubytování a rozsahu stravování. Bližší informace na stránkách internetu. **Termín pro přihlášení je 2. 9. 2021.** K účasti se přihlašují (a platí vložné) i autoři příspěvků, přednášky nejsou honorované. Za neodpřednášenou přednášku či za nevystavený poster fakturujeme poplatek 1000 Kč za zařazení příspěvku do programu a uveřejnění textu ve sborníku.

DRUHÝ CIRKULÁŘ A DALŠÍ INFORMACE

Druhý cirkulář s předběžným programem bude rozesílán v polovině srpna. Veškeré, průběžně aktualizované informace k TVIP naleznete na internetových stránkách www.tvip.cz. Konkrétní dotazy a připomínky adresujte buď na níže uvedené garnty, nebo na společnou adresu tvip@cemc.cz.

POŘADATEL

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www.tvip.cz, tvip@cemc.cz
Tel.: (+420) 274 784 417
IČO: 45249741, DIČ: CZ45249741
Číslo účtu: 27534061/0100

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