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REDUCTION POSSIBILITIES OF GAS EMISSION FROM MEAT PROCESSING COMPANIES: A REVIEW

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Abstract
Every year the ecological situation in the world is getting worse. Modern enterprises in their daily activities should provide not only high-quality and safe products, but also strive to improve environmental performance. The meat industry occupies a leading position in terms of the level of environmental pollution in the food industry. The main indicators of the meat chain have an impact on environmental aspects, the production process, the heat treatment of the product has the highest indicators from the slaughter of the animal to the transportation of the finished product. This article looks into possible ways to reduce emission into the atmosphere during the meat processing as smoking and evaluates the effectiveness of possible ways to reduce emission into the atmosphere, highlighting the most effective ways to achieve an environmentally friendly balance. During this research it was revealed that a more optimal and cost-effective method to achieve the desired result is the installation of CAB (Catalytic afterburner).
Key words: environment, ecological aspect, meat industry, impact, environmental situation.

Introduction

The environmental situation in the world is getting worse every year, and it is also gaining momentum in attracting the attention of government agencies and prompting adjustments to tighten tax rates on emission into the atmosphere in order to encourage manufacturers to take measures and introduce practices, as well as to look for methods to reduce emission. This is due to the fact that the ecological situation in the world is deteriorating and growing exponentially every year, which incredibly affects the climate, human health and, in general, the comfortable existence of human civilization (Djekic *et al*., 2016). Modern enterprises in their daily activities should provide not only high-quality and safe products, but also strive to improve environmental performance (Lazarus, McDermid, & Jackuet, 2021). 'Industrial Ecology' is a term whose main goal is to create a balance between enterprises and the environment, that is, to minimize its negative impact (Hyland *et al*., 2017). During the heat treatment processes, carbon dioxide emission is released into the atmosphere, as a result of which the biosphere is damaged and subsequently a greenhouse effect occurs. Such damage provokes global warming of the planet (Kuzlyakina, Yurchak, & Baskhamdgieva, 2019). According to the (FAO, 2019) Food and Agriculture Organization, the meat industry occupies a leading position in terms of environmental pollution in the food industry.

The meat and dairy industry accounts for 14.5% of global greenhouse gases (Gerber *et al*., 2013). This type of production contributes to global warming by generating substances that destroy the ozone layer, and is also distinguished by its high consumption of water and energy, which provokes increased waste and wastewater discharge (Zhernosek & Strukova, 2021).

The production of the meat chain at each stage has an impact on environmental aspects − transport, storage, slaughter, deboning, production and sale. Of all these processes, the most important are the indicators of slaughter and the production process, the heat treatment of the product (Kuzlyakina, Yurchak, & Baskhamdgieva, 2019). During the production of meat products, the frequent technological operation is the smoking process, as a result of which the product acquires a presentable appearance, a specific aroma and antiseptic properties of smoky smoke, which increases the safety of the product during storage (Alimov, Lykasova, & Mizhevikin, 2020). The consumption of smoked meat products is high (Kim *et al*., 2021). Manufacturers are experimenting by trying to give products more and more different and richer flavours using different types of wood and smoking technologies (Nazarov & Majorov, 2020). In the smoke formed during the pyrolysis of wood, more than 200 different groups of chemical compounds were found in the composition, as well as solid, gaseous smoke particles that passing the product chamber through the chimney and enter the atmosphere in such a way that the surrounding environment is cut off (Valdovska, Miculis, & Plotina, 2010). There are a number of methods of air purification from carbon dioxide, the main of which can be divided according to the phase principle into 'gas − solid' and 'gas − liquid' (Bhuyan *et al*., 2018).

The purpose of the present review is to study certain techniques with the ability to simultaneously reduce the impact on the environment into the atmosphere during the heat treatment of meat products during smoking and increase the efficiency of technological and economic processes. Also, its purpose is to determine the most effective method as well as to consider possible ways of smoke filtration during meat smoking in terms of efficiency and economy, in order to determine the most profitable method.

Materials and Methods

The monographic method was used to summarise and analyse the latest information and research articles dedicated to possible emission reduction into the atmosphere during the heat treatment of meat products during smoking. Information published from 2005 till 2022 in total 37 full text research articles, books and databases were analysed and summarised. For statistical analysis FAO databases were used. To select and analyse full text research articles and books Scopus, Web of Science, ScienceDirect and ResearchGate research databases were used. To find relevant information, previously mentioned constituents and processing technologies as keywords in research databases were used.

Results and Discussion

Catalytic afterburner (CAB)

The method of catalysing smoky smoke using a catalyst system (CAB) (Figure 1), which provides the ability to preserve the taste, colour, smell that natural smoke creates for the product while being able to control and minimize emission of harmful substances (Swaney-Stueve *et al.*, 2019). The smoke catalysis system combines heat treatment and a catalyst with which it safely removes harmful substances from the smoke (Sullivan, Kafka, & Ferrari, 2012). The operation of the system is based on the afterburning of smoky smoke, when leaving the chamber with a temperature of 500 to 800 °C, then passes through the catalyst, causing a chemical reaction − which eliminates harmful emission leaving water and CO_2 (Emis, 2020a). The system can be installed to any camera, it runs on gas as well as electricity (Hevia, Ordonez, & Diez, 2005).

This system is already used in the world for more complex solutions in such campaigns as the production of synthetic fibres, metallurgy, fuel production, to reduce emission of organic compounds into the atmosphere, allows achieving efficiency results of up to 99% (Dopshak, 2009).

The system has great advantages due to its simple design and low metal consumption, as well as its competitiveness in investment and operating costs.

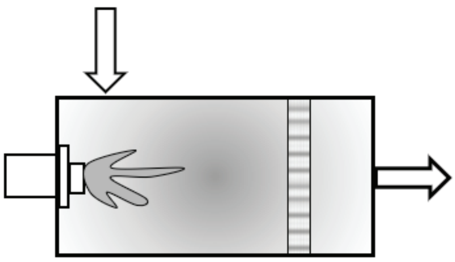

Figure 1. Catalytic afterburner (CAB) (Image created by the author after Emis, 2020a).

Scrubber

Scrubber is industrial equipment that is used to clean emission from dust and gases based on wet filtration. The equipment is a column (Figure 2) in which the main retention or neutralization of impurities is carried out using water or an absorbent. The gas mixture enters the equipment, where it is directed in the right direction with the help of fans, a liquid reagent is supplied from the sprayers installed at the top, thus neutralizing and separating dust and gases. After turbulent mixing, the medium enters the lower part of the scrubber and then into the drain pipe (Pronin *et al.*, 2015). The principle of operation of this system is always the same, the gas comes into contact with the medium (water, reagent), which is sent out using nozzles.

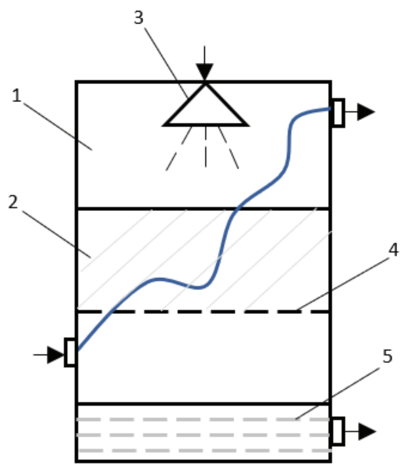

Figure 2. Scrubber scheme (Image created by the author after Pronin *et al.*, 2015); 1 – corps; 2 – filling from porous material; 3 – liquid reagent atomizer; 4 – support grid; 5 – collection of liquid reagents.

This equipment has long been known in Europe. The purpose of using this equipment may differ depending on the specifics and specifics of production (Samokhvalov & Zykova, 2019).

Companies that process meat waste into offal use this equipment to reduce volatile organic compounds (VOC) as well as odours, and also use it to reduce solid gas fractions, dust. This system, depending on the composition of the gas, can reduce it to 100%, more complex ones from 20 to 64% (Kastner & Das, 2011). Also, studies from Nordström show that large particles from gas vapor can be separated by 60-70% using a scrubber (Gerber *et al.*, 2013). The system is characterized by high mobility of the pile structure, limitations of possible leaks, as well as its unique ability to filter gaseous impurities and mechanical fractions. Among the disadvantages, we can note the high need for a stable installation of electrical energy saving (Wang *et al.*, 2020).

Bio bed

The system is based on filtration (Figure 3) of the gas stream using biological purification. The gas stream passes through biological material (peat, trees), which creates a thin water film with microorganisms (Omri *et al*., 2013). Fillers such as wood chips, sawdust, shavings and others are also added to the biofilter to increase porosity (Maia *et al*., 2012). Due to this, substances in the gas stream are absorbed in the filtering material and further decomposed with the help of microorganisms that have settled in the filter material, which also serves as a supplier of essential nutrients for microorganisms (Affek *et al*., 2021). The advantages of decomposition in the filtration process are − sulphates, carbon dioxide and others. The filter material is periodically moistened with the help of air flow treatment, for the functionality and maintenance of the vital activity of microorganisms (Emis, 2020c).

The material contains a sufficient number of different bacteria in order for harmful substances to decompose during filtration, but also in the case of more complex substances, it is possible to add special cultures to the filter, and also to increase the efficiency and speed of the system, it is necessary to nutrients, oxygen level, pH, moisture content of the filter material (Tiwari *et al*., 2019). For the formation and existence of various bacterial cultures, several layers of filter media are usually used, and the second layer serves as an additional barrier for gases with more complex decomposability. The filter material needs to be serviced periodically from 1 to 5 years. The term of the use of the material depends on the composition of the emission as well as the out of the filler itself (Emis, 2020c).

The efficiency of the biofiltration system also depends on the composition of the gas; the purification of impurities varies from 30 to 100% (Melse & Hol, 2017; Tiwari *et al*., 2019). This system is used in the production of gelatine to remove odours with an efficiency of 70-93%, in the processing of chocolate to remove odours with an efficiency of 99%, in the food industry with an efficiency of about 93% (Nesaratnam *et al*., 2014).

The energy consumption of the biofilter itself is small. The energy consumption is determined primarily by the ventilators which compensate for the pressure reduction (Emis, 2020c).

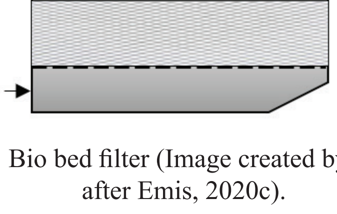

Figure 3. Bio bed filter (Image created by the author after Emis, 2020c).

Thermal afterburner (TAB)

The smoke flow with a certain amount of air is brought to high temperatures of 750 to 1200 °C. Gases are kept at a similar temperature for a long time, as a result of which substances are oxidized with oxygen and destroyed. The chamber is also equipped with automatic removal of combustion ash (Bujak, Sitarz, & Pasela, 2021). The efficiency of this system (Figure 4) depends on the afterburning time, temperature, oxygen and turbulence. For simpler organic compounds, a temperature of 750 to 1000 °C is sufficient, but for toxic compounds affecting the environment, it is necessary to provide a temperature of 1000 to 1200 °C for the destruction of compounds (Brinkmann *et al*., 2016).

With the correct implementation of the system for the specifics of production, setting the time and their circulation, the system can achieve 99% efficiency, depending on the composition of gas mixtures (Bujak, Sitarz, & Pasela, 2021). Such systems (Figure 4) are considered one of the eco-friendly methods of air purification, which provides high rates of various types of pollution of gaseous to solid particles in comparison with scrubbers and biofilters and other systems, but the disadvantage is the high cost of energy spent in maintaining a given temperature with fuel costs (Emis, 2020b).

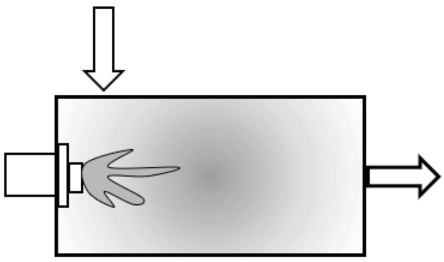

Figure 4. Thermal afterburner diagram (Image created by the author after Emis, 2020b).

Analysing all four types of possible methods and systems (Table 1) to reduce harmful emission into the atmosphere, each identified its advantages and disadvantages. All the described methods relate to difficult solutions to the problem on the part of the resources spent. The systems are not miniature and need installation and further maintenance, they also cannot be treated as budget installations and when choosing a solution to the problem, you need to consider the costs, resources and the result that is needed.

All these methods perform their function to a lesser or greater extent, depending on the composition of gaseous substances.

When choosing a previously studied necessary technique, two things should be considered: the result to be achieved and the economic part.

In this published analysis, four systems were compared from the point of equipment efficiency to parameters which are described below:

TOC – total organic carbon contained in an organic compound, the substance easily settles and accumulates in the soil and further in the water (European environment agency, 2019).

CO – carbon monoxide is a gaseous toxic substance that has no colour taste or smell.

NO – nitric oxide, a poisonous gas that is formed at high temperatures by the combination of nitrogen with oxygen. Dust particles, which are also part of the emission and accumulate in the soil (Nathani *et al*., 2019). Formaldehyde is a colourless gas that is released from wood at high ignition temperatures, which is associated with the thermal decomposition of polysaccharide in wood.

The amount of substance release depends on various factors: wood species, humidity, air temperature and storage time (Salem & Böhm, 2013).

PAH – stands for polycyclic aromatic hydrocarbons whose organic compounds are characterized by the presence of several benzene rings in the structure. The connection is formed in the process of cellulose pyrolysis. In the process of emission, it easily accumulates in the soil and in the plants themselves (Yakovleva, Gabov, & Beznosikov, 2019).

Each of the above parameters in Europe has a set limit in the general administrative regulations of the Federal Law on Emission Control (Air Pollution Control Technical Instructions, 2021).

In the published analysis, the smoking process was carried out with the same parameters and raw wood chips (beech). In the process, the methods are compared with each other and the established limits. The indicators differ in different parameters. The smoke afterburning systems and the thermal catalysing system during the experiment do not exceed any of the established limits on parameters. The scrubber exceeds the limit of carbon monoxide and nitrogen oxide. The biological filter exceeds the limit on three indicators: carbon monoxide, nitrogen oxide and formaldehyde. Organic carbon and dust particles in the smoke were close to the limit, and there was only one indicator in the green zone − polycyclic aromatic hydrocarbon. From the point of view of energy consumption, the largest energy consumption is necessary for the smoke afterburning system (TAB), as well as the biological filtration system (Fesmann, 2020).

The economic part (Table 2) plays an important role in choosing a suitable method of solving the problem of emission. Not only the purchase of this equipment, but also its maintenance, costs, resources and necessary disposal costs must be considered in order to achieve an economic and environmental balance. The most expensive is a scrubber (~150 000-200 000 EUR) and a smoke afterburning system (100 000-150 000 EUR) (Emis, 2020a), but it is also worth considering further investments and maintenance of systems. For example, for a biofilter, there is a need to replace the filter material at a cost (~50 000 EUR /750 m^3) (Emis, 2020c). From the point of view of maintenance, this is needed for all systems practically equally. It is also important to consider the recycling process of biofiltration and scrubber systems that have the requirement to replace and clean up waste. The medium accumulating with the reagent enters the scrubber into the lower part of the system and then into the drain pipe, which periodically requires cleaning.

These substances from the scrubber and the filter material of the biofilter must be sealed by composting or contamination. All these techniques are installed

Table 1

Comparison of emission reduction systems (Table created by the author after Fessmann, 2020)

	Parameters	Thermal afterburner	Cartalytic afterburner	Scrubber	Bio-bed	Limit *
Smocking smoke	Total organic carbon	✚	✚	✚	●	50 mg m^{-2}
	Carbon monoxide	✚	✚	✖	✖	100 mg m^{-3}
	Nitric oxide	✚	✚	✖	✖	100 mg m^{-3}
	Part. matter	✚	✚	✚	●	20 mg m^{-2}
	Formaldehyde	✚	✚	✚	✖	10 mg m^{-2}
	Polycyclic aromatic hydrocarbon	✚	✚	✚	✚	50 mg kg^{-1}

*Air Pollution Control Technical Instructions (2021, August). New edition of the First General Administrative Regulations of the Federal Law on Emissions Control.

✖ Above the set limit; ● the result is equal to the limit; ✚ below the set limit

Table 2

Comparison of emission reduction systems with economic efforts
(Table created by the author after Fessmann, 2020)

	Parameters	Thermal afterburner	Catalytic afterburner	Scrubber	Bio-bed
EUR	Investment	●	✚		✚
	Energy	✖	✚	✚	●
	Maintenance	●	●	●	●
	Disposal	✚	✚	●	●

✖ the highest level of costs ● the medium level of costs ✚ the low level of costs

to furnaces, due to which they allow achieving the desired result without affecting the products of their colour, smell or taste of natural smoking (Fessmann, 2020).

Conclusions

Catalysis systems can be attributed to the optimal choice of a system for solving environmental and economic problems. It has shown a good result of effective filtration to reduce emission, and is also optimal in terms of maintenance, costs and dimensions.

Biofiltration has the least result, gas purification is less effective, and there is also a need for constant maintenance. But each system is suitable for certain functions. It is necessary to consider the result to be reached, the type of production, the composition of gas, the dimensions of production, economic opportunities, company policies, location.

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