VOL V

Estudos em Ciências Agrárias e Ambientais

Eduardo Spers
(Organizador)

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2025

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PRÓLOGO

Este volume V de **Estudos em Ciências Agrárias e Ambientais** reúne oito contribuições que, em conjunto, delineiam um panorama atual e propositivo dos desafios na produção agropecuária e na gestão do meio ambiente. O volume está organizado em três eixos temáticos: *Ambiente: Monitoramento e Gestão de Riscos*; *Produção Vegetal: Insumos e Melhoramento*; e *Produção Animal e Saúde Veterinária*, com o objetivo de aproximar evidências científicas, soluções técnicas e impactos socioambientais, sempre com ênfase em rigor metodológico, transparência e aplicabilidade.

O primeiro trabalho do eixo **Ambiente: Monitoramento e Gestão de Riscos** apresenta uma investigação sobre monitoramento de emissões em processos industriais do setor agroalimentar**,** que valida, por medições em pontos críticos da linha de produção, a conformidade com padrões regulatórios e reforça a importância de sistemas confiáveis de rastreabilidade. Em seguida, uma experiência de educação ambiental voltada à redução de riscos de inundações e deslizamentos em contexto escolar rural demonstra, com avaliação pré–pós-intervenção, ganhos expressivos em conhecimento e atitudes, oferecendo um modelo replicável de formação comunitária para a gestão do risco.

O Eixo **Produção Vegetal: Insumos e Melhoramento** articula estudos do manejo de insumos e cultivares até o zoneamento produtivo em larga escala: um ensaio agronômico sobre o uso de silício em cafeeiros quantifica efeitos em crescimento, sanidade e qualidade sensorial, apoiando decisões de manejo nutricional; um estudo de zoneamento agroclimático com geotecnologias mapeia áreas de alto potencial produtivo para cultura energética sob irrigação, conectando planejamento territorial e bioenergia. Na sequência, uma análise de biofortificação de milho discute avanços em teores de micronutrientes e compostos bioativos, bem como desafios de adoção e oportunidades de mercado. Por fim, uma avaliação comparativa de variedades de soja sob irrigação atualiza o pacote tecnológico regional, apresentando indicadores agronômicos e de rendimento para recomendações de cultivares.

Produção Animal e Saúde Veterinária apresenta um estudo em nutrição de pequenos ruminantes e avalia a inclusão de subproduto agroindustrial fermentado na dieta, examinando consumo, conversão alimentar e perfis de fermentação ruminal, com implicações para sustentabilidade e desempenho produtivo. Encerrando o volume, um ensaio histórico sobre uma grande epizootia bovina no século XVIII revisita práticas precoces de contenção (como limpeza de instalações, isolamento e reentrada faseada de rebanhos) e evidencia a gênese de princípios de biossegurança que permanecem atuais.

A força deste volume reside na convergência entre método e pertinência: medições em processo, ensaios de campo, geoprocessamento, avaliações nutricionais e reconstruções históricas informam decisões públicas e privadas, da gestão de emissões e planejamento territorial à escolha de insumos, cultivares e dietas, passando pela formação de comunidades para prevenção de desastres. Essa convergência é intencional: a ciência agrária e ambiental cria maior valor quando quantifica, compara e comunica com clareza.

Agradecemos às autoras e aos autores pela confiança e pela qualidade técnica dos manuscritos; às instituições de origem, pelo apoio às pesquisas; e às leitoras e aos leitores, cuja atenção crítica dá sentido a esta série. Que os capítulos aqui reunidos inspirem novas perguntas, parcerias interdisciplinares e aplicações responsáveis, no campo, na indústria, na escola e no território.

Desejo a todos uma excelente leitura!

Eduardo Eugenio Spers

SUMÁRIO

CAPÍTULO 1

MONITORING POLLUTANT SUBSTANCES RELEASED BY COMPOUND FEED FACTORIES

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ABSTRACT: Due to the intense competition currently present in the market, the main objective of compound feed factories is to achieve maximum efficiency. This can be accomplished by providing customers with high-quality finished products at the lowest possible cost. In this context, current European Union regulations require rigorous monitoring and control of the technological processes carried out in compound feed factories. This paper presents the analyses and experimental measurements conducted at various strategic points along the technological flow of compound feed production, emphasizing that the results obtained were consistently within the limits imposed by the legislation in force for the entire batch of the compound feed assortment. To clearly demonstrate the reliability of the working installation used, the production processes of two distinct assortments of compound feed were monitored, each with a different recipe composition and, consequently, specific technological parameters that needed to be set.

KEYWORDS: compound feed; chemical reactions; burning gas; pollutant emissions.

MONITORAMENTO DE SUBSTÂNCIAS POLUENTES LIBERADAS POR FÁBRICAS DE RAÇÕES COMPOSTAS

RESUMO: Devido à intensa concorrência atualmente presente no mercado, o principal objetivo das fábricas de rações compostas é alcançar a máxima eficiência. Isso pode ser obtido oferecendo aos clientes produtos acabados de alta qualidade ao menor custo possível. Nesse contexto, as regulamentações vigentes da União Europeia exigem um rigoroso monitoramento e controle dos processos tecnológicos realizados nas fábricas de rações compostas. Este trabalho apresenta análises e medições experimentais realizadas em diversos pontos estratégicos ao longo do fluxo tecnológico de produção de rações compostas, destacando que os resultados obtidos estiveram consistentemente dentro dos limites impostos pela legislação em vigor para todo o lote do sortimento de rações compostas. Para demonstrar de forma clara a confiabilidade da instalação utilizada, foram monitorados os processos de produção de dois sortimentos distintos de rações

compostas, cada um com uma formulação diferente e, consequentemente, parâmetros tecnológicos específicos que precisaram ser ajustados.

PALAVRAS-CHAVE: ração composta; reações químicas; queima de gás; emissões poluentes.

1. INTRODUCTION

The process of producing an assortment of compound feed is quite complex. The activities that take place during the technological flow in a compound feed factory include the reception and storage of raw materials, transport between different installations, mixing, processing, sterilization, packaging, storage, and delivery of finished products.

During the processing of raw materials, crumbling is first performed, after which the materials are mixed. Then, under a jet of steam generated by a steam generator, particles of different forms and dimensions are obtained. The steam plays a dual role: homogenizing the particles and sterilizing them. At the outlet of the steam generator, samples were collected, and various measurements were carried out to analyze the functional parameters of the installation. At this point, the emissions of burning gases resulting from the production of the steam jet – necessary for the homogenization of the raw material mass to obtain compound feed grains – were measured.

These analyses and measurements of burning gas emissions at the outlet of the steam generator were conducted with the aid of a TESTO 350 M/XL gas analyzer, over an interval of 100 minutes, which represents the minimum time required to produce a batch of compound feed grains.

2. MATERIALS AND METHODS

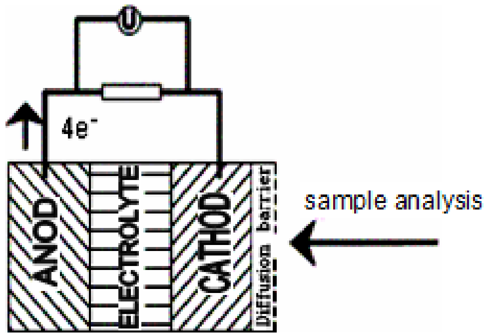
The experimental measurements carried out to monitor the pollutant substances released during the production of a compound feed assortment are based on a principle well known to chemical specialists: the intensity of the galvanic current generated by a galvanic cell changes when the properties of its electrolyte are altered after reacting with the gas component that needs to be detected and whose concentration must be measured (Gaceu, 2006; Mihaila, 2001).

The measurement cells consist of galvanic elements that generate a current proportional to the number of ions dissociated in the electrolyte solution as a result of the interaction with the studied gas (Vasile, 2020).

Analyzers built on this principle are much cheaper compared to infrared-based analyzers, but they may only be used for short or normal periods of time, usually in portable devices. With the aid of these instruments, it is possible to determine the concentration of any of the following gases: O_2, CO, H_2S, NO, NO_2, SO_2 (Ionel, 1994).

Figure 1 illustrates the operating principle of a twin-electrode sensor, specifically for detecting O_2. In this analysis, the sample gas diffuses through a membrane toward the alkaline electrolyte.

Figure 1: A simplified diagram for the twin-electrode sensor.



The following chemical reaction takes place on the cathode:

$$O_2 + 2H_2O + 4e^- = 4OH^- \tag{1}$$

The electrons necessary for the reaction (1) result from the oxidation of the material which the anode is composed of (the anode is made of Pb) under the following reaction:

$$Pb + 4OH^- = PbO_2 + 2H_2O + 4e^- \tag{2}$$

By combining reaction (1) and (2), we obtain the whole of the reaction (3). The result is lead oxidation inside the anode's twin-cell electrode, across the sensor's whole lifetime:

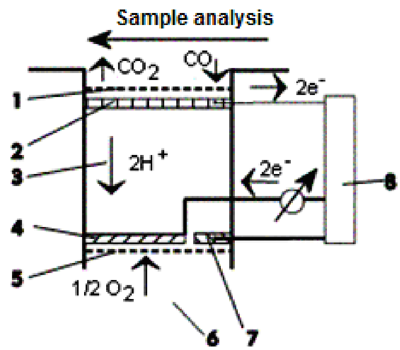
$$O_2 + Pb = PbO \tag{3}$$

The electrolyte is not consumed, though the lead anode will wear down over time and become depleted, shortening the sensor's lifespan to a duration of approximately three years.

The physical separation of reaction (1) and reaction (2) enables the generation of an electrical signal proportional to the concentration of oxygen in the mixture of gases that diffuse through the sensor's periphery (Ionel, 2004).

Figure 2 show a diagram of a three-electrode sensor's functions, normally used to detect the toxic gases NO, NO_2, CO, SO_2, given here as an example to demonstrate how to determine the concentration of CO.

Figure 2: Diagram of a three-electrode sensor. 1,5 – diffusion barrier, 2 - anode, 3 - electrolyte (H_2SO_4), 4 - cathode, 6 – reference gas, 7 – reference electrode, 8 – voltage regulator.



In addition to the anode (also known as an active electrode) and a counter electrode (the cathode), the device is provided with a reference electrode as well.

The analyzed gas sample will pass through the holes of the diffusion barrier and will suffer later a chemical decomposition on the anode, which also serves as a catalyst.

In order to determine the correct concentration of CO in the gas sample is presented the reaction (4) which takes place on the anode, then the reaction (5) which takes place on the cathode and finally the sum reaction (6). It is noted the advantage offered by the three-electrode sensor to the two electrodes as the electrodes are not consumed while they are subjected to aging.

$$CO + H_2O = CO_2 + 2H^+ + 2e^- \qquad (4)$$

$$1/2O_2 + 2H^+ + 2e^- = H_2O \qquad (5)$$

$$CO + 1/2O_2 = CO_2 \qquad (6)$$

A constant voltage regulator (continuous) provided between the active electrode (anode) and the reference electrode, is designed to prevent a potential modification of the active electrode due to the current generated by reactions (4) and (5).

This widens the stability and the measuring sensor. The voltage between the active electrode and the reference, as well as a proper choice of the electrode and the electrolyte, provides an adequate selectivity of the sensor. [1, 2]

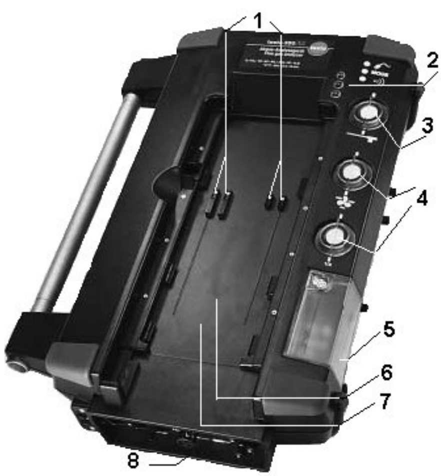
The gas analyzer TESTO 350 M/XL is a powerful equipment which determines the gas emissions from the burning gases, their determination is obtained in special cells, as the result of some electro-chemical reactions type Peltier. Analyzed gases are: SO_2, CO, CO_2, O_2, NO and NO_2 (Roden et al., 2006).

This device, used in the analyzers of the study of compound feed factory consists of three main parts: the unit of analysis, the control unit and gas sampling probe (Bollen et al., 2014; Franke et al., 2006; Heinsohn et al., 1999).

The analysis unit contains reaction cells, battery pack, filters for retaining solid impurities in the flue gas and air, settling for condensation and electro-pneumatic connections, as shown in figure 3.

The gas drawn through the probe is inserted in the reaction cells when the gas pump is started manually or automatically. However, before the analyzed gas is suddenly cooled at 4÷8°C, taking place the precipitation of the condensate with low absorption of NO_2 and $SO_{2,}$ condensate which is evacuated at regular intervals by a condensate pump.

Figure 3: Analysis Unit. 1-electical contacts; 2- control LEDs; 3-solid particles filter; 4-filters for retaining particles from air aspiration; 5-condensate collecting; 6-analysis cells; 7-intergrated system for speed determination and gas pressure; 8- connections.

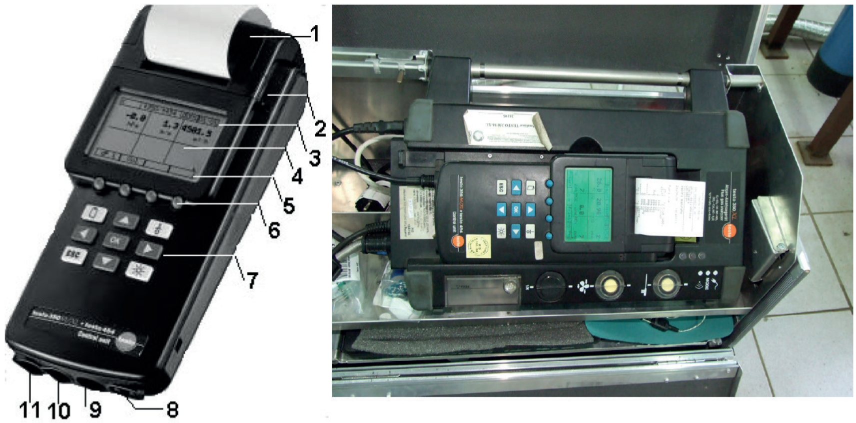


After Peltier reactions are emitted, an electrical signal is sent and processed in the control unit, displaying the concentration values of the analyzed gases. The gas excess is continuously discharged.

The control unit (figure 4) is a measurement device which can be used either by keyboard, or with the help of a touch-pen. In addition to the values of the measured data, there are also displayed information like the system configuration and the location of the activity.

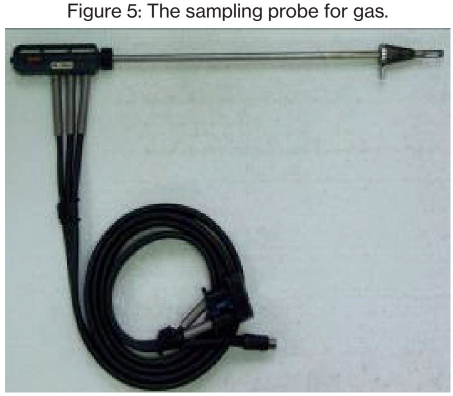
By connecting the device to a PC, this can be used for long-term measurements (days, even weeks), being controlled by a special program called TESTO Easy Emissions (Vasile, 2020).

Figure 4: The control unit. 1- the printer, 2 - touch pen, 3 - the system information bar, 4 - showing the values measured, 5 - information about functioning bar, 6 - operating functioning tastes, 7- keyboard, 8 - connecting pressure probe, 9 - connection sample, 10 - connection of analysis unit, 11- serial interface.



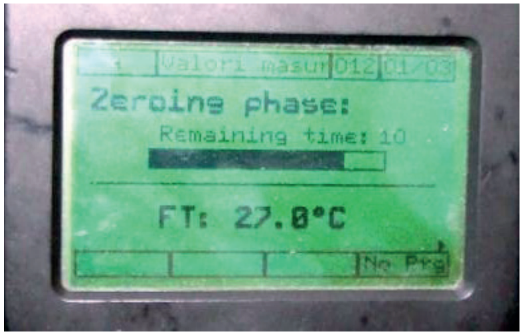
The machine can be equipped with several gas sampling probes, but those can be different regarding the characteristics of the sampled gases which have been taken. In figure 5 we can see the sampling probe for gas, which has its tub at 180 degrees, which operates at maximum temperature of 1200°C.

Figure 5: The sampling probe for gas.



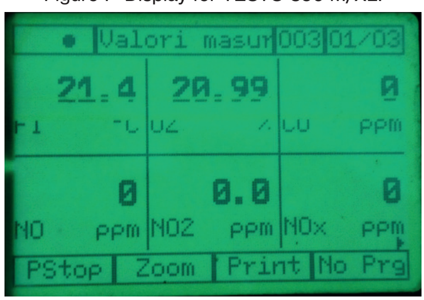
After interconnecting the three elements of the gas analyzer (the control unit, the analysis unit and the probe) the device is started either by connecting it to the mains supply of 220 V or its own battery. At this point the machine automatically enters in the procedure of „zero calibration" and washing the reaction cells (figure 6). Also, at this point of „zero calibration" the probe of device should not be inserted into the duct of the combustion gases.

Figure 6: Zero calibration for TESTO 350 M/XL.



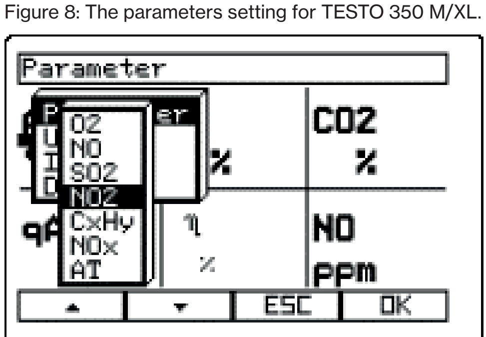
After the device (the gas analyzer) enters in the normal operating mode, it must be programmed to acquire and display that data, which presents interest for the one who analyzes the gas sample (figure 7).

Figure 7- Display for TESTO 350 M/XL.



It is obligatory to set the machine for the right type of fuel, from the database of the machine (figure 8). After we set the parameters which we want to measure, the probe is due to be introduced in the canal of the gases and the activity of measuring the size starts.

Figure 8: The parameters setting for TESTO 350 M/XL.



3. RESULTS AND DISCUSSION

The recipe and thermodynamic parameters of the working installation for the production of combined fodder for "Dairy cows" are characterized by:

a) Recipe:

- Maize: 20%,
- Wheat: 21%,
- Sunflower goats: 32%,
- Bran: 24%,
- Supplementary premix with vitamins: 3%

b) Thermodynamic parameters:

- Steam temperature in the installation: 160°C;
- Thermal agent temperature: 180°C;
- Nominal steam pressure: 8 bar.

In the table 1 are presented the values of the experimental measurements for the concentrations of the pollutant substances analyzed from the combustion gases during the production of the combined fodder assortment for dairy cows. But the legislation in force stipulates that for stationary combustion installations operating with LPG, reporting is done for a reference oxygen value of 3% (marked with * in the table). Also, the values that are obtained from the analysis of the working installation of the compound feed factory, will be compared with the limit values that are in the legislation in force for the analyzed burning installation.

Table 1. Results of experimental measurement for the "Dairy cows" assortment.

Time [min]	CO [mg/m^3_N]	NOx [mg/m^3_N]	SO2 [mg/m^3_N]	CO2 [g/m^3_N]	CO* [mg/m^3_N]	NOx* [mg/m^3_N]	SO2* [mg/m^3_N]	CO2* [g/m^3_N]
1	62.50	16.42	0.00	170.85	74.01	19.44	0.00	202.32
2	62.50	16.38	0.00	170.85	74.01	19.39	0.00	202.32
3	62.34	16.35	0.00	170.26	73.59	19.23	0.00	201.74
4	61.25	18.47	0.00	168.43	73.50	22.17	0.00	200.06
5	61.25	18.51	0.00	168.43	73.50	22.36	0.00	200.06
6	61.02	18.49	0.00	167.59	72.43	22.31	0.00	199.47
7	61.25	18.47	0.00	168.43	73.50	22.17	0.00	200.05
8	61.38	16.31	0.00	170.61	73.89	19.28	0.00	201.98
9	62.50	16.42	0.00	170.85	74.01	19.44	0.00	202.32
10	62.50	16.45	0.00	170.87	74.50	19.57	0.00	203.46
Average	61.85	17.23	0.00	169.72	73.69	20.54	0.00	201.38

*) values relative to the reference oxygen 3%.

The duration of the production process of the assortment of combined fodder for dairy cows was 100 minutes, and the values of the experimental measurements shown in table 1 were read at regular intervals of 10 minutes. At the end of the table are presented the average values of the pollutant substances eliminated during the production cycle.

In figure 9 are presented graphically the measured values for the types of pollutant substances released into the air by the working installations, and in the figure 10 are presented the average concentrations of these pollutant substances during the production of the combined fodder assortment for dairy cows.

Figure 9: The measured values for the pollutant substances analyzed at the production of the assortment „Dairy cows".

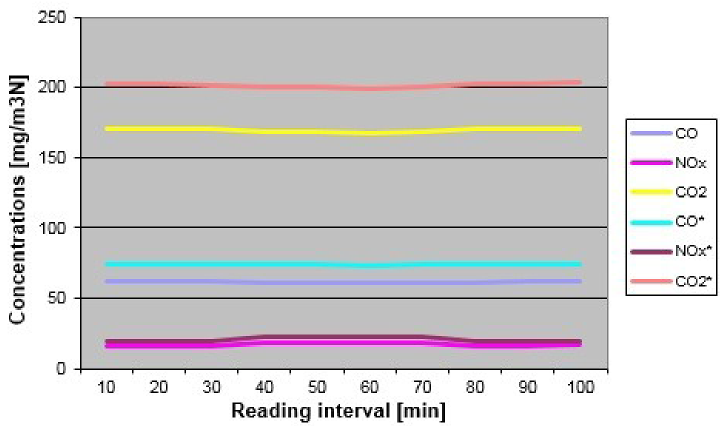
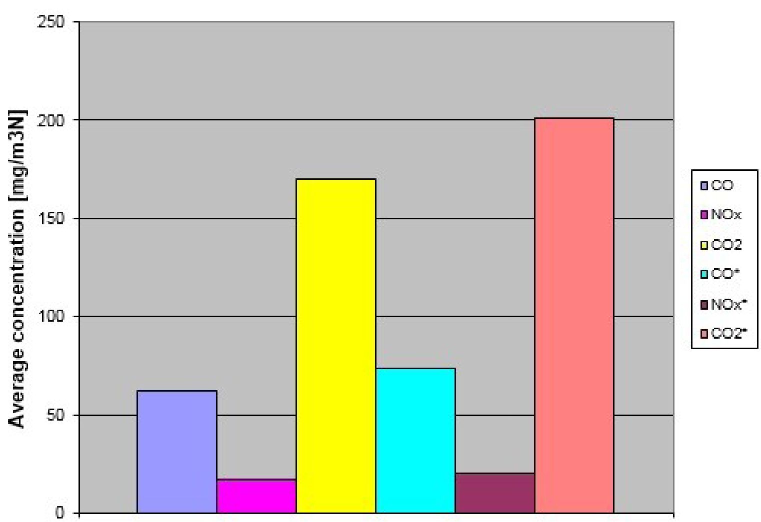


Figure 10: Average concentration for the pollutant substances analyzed at the production of the assortment „Dairy cows".



The recipe and thermodynamic parameters of the steam generator at the production of combined fodder for “Rabbits” are characterized by:

a) Recipe:

- Maize - 20%,
- Wheat - 18%,
- Goats of sunflower - 7%,
- Bran - 12%,
- Lucerne flour - 40%,
- Complete premix - 2,5%;

b) The thermodynamic parameters of the steam generator are:

- Steam temperature in the installation: 180°C;
- Thermal agent temperature: 190°C;
- Nominal steam pressure: 9 bar.

And during the production of the compound feed assortment for rabbits, experimental measurements were made of the pollutants eliminated into the air by the work installation. Table 2 shows the results of measurements for pollutant emissions during the production of compound feed for rabbits. As in the case of the previous assortment, the production interval of an assortment of compound feed was 100 minutes and during this time were maked 10 experimental measurements at a distance of 10 minutes between them.

Table 2. Results of experimental measurement for the “Rabbits” assortment.

Time [min]	**CO [mg/m^3_N]**	**NOx [mg/m^3_N]**	**SO2 [mg/m^3_N]**	**CO2 [g/m^3_N]**	**CO* [mg/m^3_N]**	**NOx* [mg/m^3_N]**	**SO2* [mg/m^3_N]**	**CO2* [g/m^3_N]**
10	63.75	18.47	0.00	170.85	77.53	22.47	0.00	207.79
20	63.48	18.43	0.00	171.24	77.46	22.29	0.00	208.45
30	62.71	17.59	0.00	170.83	78.15	21.03	0.00	207.64
40	62.49	17.31	0.00	170.85	78.06	20.85	0.00	207.79
50	62.06	16.42	0.00	169.34	77.98	20.64	0.00	206.28
60	61.73	16.28	0.00	169.02	77.53	19.97	0.00	205.92
70	60.92	17.04	0.00	168.71	77.21	19.32	0.00	204.81
80	58.75	16.41	0.00	168.93	71.45	18.78	0.00	204.97
90	59.37	16.19	0.00	170.44	71.94	19.02	0.00	207.25
100	62.50	16.63	0.00	170.86	76.53	20.88	0.00	207.94
Average	61.78	17.08	0.00	170.11	76.38	20.53	0.00	206.88

*) values relative to the reference oxygen 3%,

Also, in figure 11 are presented graphically the measured values for the types of pollutant substances released into the air by the working installations, and in figure 12 are presented the average concentrations of these pollutant substances during the production of the combined fodder assortment for rabbits.

Figure 11: The measured values for the pollutant substances analyzed at the production of the assortment „Rabbits".

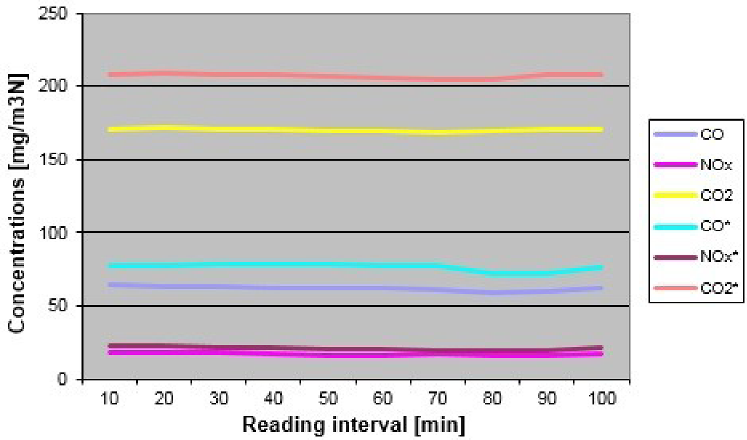
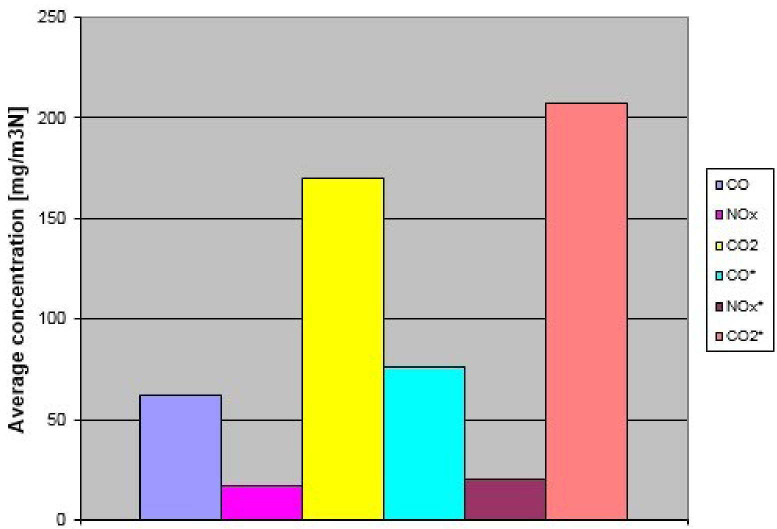


Figure 12: Average concentration for the pollutant substances analyzed at the production of the assortment „Rabbits".



4. CONCLUSIONS

By analyzing the pollutant emission samples collected and sent to the gas analyzer during the production process of the compound feed assortments for dairy cows and rabbits, whose experimental values are presented in tables 1 and 2, it can be observed very easily that they do not exceed the permissible limits imposed by national and European legislation, which means that they fall perfectly within the limits imposed by the legislation in force regarding environmental protection:

- the values of the emissions of CO are between 58,75 mg/m^3_N and 63,75 mg/m^3_N, that means do not exceed the maximum value, which is permitted by100,00 mg/ m^3_N
- the emission values of NOx are included between 16,19 mg/m^3_N and 18,51 mg/ m^3_N, meaning no more than the limit threshold of 35 mg/ m^3_N
- the emission values of CO_2 are between 167,59 mg/m^3_N and 171,24 mg/m^3_N, that means do not exceed the limit threshold t of 200g/ m^3_N.

It should also be mentioned the fact that a major advantage of the analyzed working installation, which is associated with the burning of LPG fossil fuel in the steam generator, is the lack of the SO_2.

Based on all the analyses and experimental measurements carried out, it can be highlighted, from the point of view of the automation of the production process, the fact that the working installation presented optimal operating parameters and its use in compound feed factories (CFF) is highly recommended.

Analyzing all the experimental results presented in this paper, it can be easily concluded that in order to meet the European Union rules regarding the production of animal fodder, it is necessary for the compound feed factories to be equipped with modern, high-performance equipment, with a high degree of mechanization, automation and computerization, which allow obtaining high productivity with low specific consumption.

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