Agronomy Research **19**(S3), 1308–1317, 2021
https://doi.org/10.15159/AR.21.053

Evaluation of ozone influence on wheat grain quality during active drying

E. Straumite[1,*], A. Rucins[2], D. Viesturs[2], J. Kleperis[3] and A. Kristins[3]

[1]Latvia University of Life Sciences and Technologies, Faculty of Food Technology, Department of Food Technology, Rigas iela 22, LV-3001 Jelgava, Latvia
[2]Latvia University of Life Sciences and Technologies, Ulbroka Research Center, Instituta iela 1, LV-2130 Ulbroka, Latvia
[3]University of Latvia, Institute of Solid State Physics, Raina blv. 19-125, LV-1586 Riga, Latvia
[*]Correspondence: evita.straumite@llu.lv

Received: February 1st, 2021; Accepted: April 24th, 2021; Published: April 29th, 2021

Abstract. The aim of this study was to evaluate the effect of ozone on the quality of wheat grain during air ventilation drying process. After harvesting, the wheat grain was placed in two storage tanks. In one storage tank for grain drying was used air but in the other - ozone as the drying agent. The following quality parameters - moisture, water activity, gluten, starch and protein content, as well as the total plate count of microorganisms were determined during storage. Wheat grain quality parameters were analysed by taking samples from the top and bottom of the storage tanks. Two-year experiments showed that ozone treatment did not significantly affect ($P > 0.05$) the moisture content, water activity, gluten, starch and protein content of the analysed wheat grain, but all parameters were significantly affected ($P < 0.05$) by the sampling location - top or bottom of the storage tank. All samples taken from the top of the tanks throughout the drying process had higher water activity ($a_w < 0.800$). It should be noted that in both series of experiments it was found that there is a very large difference (up to 10%) in grain moisture between grain sampled at the top and bottom of the tanks. Favourable conditions for the development of microorganisms are increased moisture and free water available in the products and raw materials. According to the results obtained in the experiments, it can be concluded that the total plate count in the analysed wheat grain did not exceed the permissible norms (10^5 CFU g^{-1}).

Key words: grain safety, ozone treatment, wheat quality.

INTRODUCTION

According to statistics (Worldwide production of grain 2019/2020), in 2019/2020, wheat (*Triticum aestivum* L.) was grown 764.49 million tons, which is the second crop grown after corn (1,116.34 million tons). Of the total amount of wheat grown in 2019/2020, 80% was used for food. Wheat is mainly used in the production of bread, flour confectionery, pasta, as well as in daily meals (sauces, pancakes, etc.). Therefore, it is important to ensure grain and flour quality during storage and processing, because their quality is affected by many factors.

Ozone is widely used to ensure the quality of drinking water and the processing of food raw materials and products (fruit, vegetables, and cereals). The ozone treatment is considered as an alternative method to reduce the total number of microorganisms, pests and mycotoxins in food or raw materials, as well as to reduce the risk of mould, thus extending the shelf life of products (Tiwari et al., 2010; Jian et al., 2013; Rakcejeva et al., 2014; Zhu, 2018; Hutla et al., 2020). Additional studies showed that ozone treatment can reduce the content of mycotoxins in products and raw materials and it have harmful effects by toxigenic fungi (Savi et al., 2020; Nickhil et al., 2021). The efficiency of ozone treatment depends on raw material or food product used, the level of contamination, the time and duration of ozone treatment (Wang et al., 2016; Granella et al., 2018). Many studies have been done under laboratory conditions and with a small amount of grain or flour (Rakcejeva et al., 2014; Mei et al., 2016; Granella et al., 2018; Hu et al., 2020). In order to enable the assessment of the potential use of ozone for grain treatment by farmers, it is necessary to evaluate ozone treatment performance in real farm conditions. Such research has been started by Latvian scientists (Kleperis et al., 2019; Rucins et al., 2020), and research is still ongoing. There are relatively few studies on how ozone treatment affects grain quality and if ozone can be used as the agent to enhance active drying of grain.

The aim of this study was to evaluate the effect of ozone on the quality of wheat grain during air ventilation drying process.

MATERIALS AND METHODS

The experiments were performed in 2019 and 2020 on the farm Mazkalniņi, Tervete district, Latvia.

Experimental design

Wheat grains were harvested in July 2019 and in August 2020. The wheat grain storage in 2019 was performed according to the procedure described by Rucins et al. (2020) and the location of ozone sensors in the grain storage tanks was designed as described Kleperis et al. (2019). Storage tanks were equipped with fans of equal 7,000 $m^3 h^{-1}$ capacity - one blowing only air from below, the other - air / ozone mixture (200 $g h^{-1}$). The ozone generator OPV-100.03 (ООО НПО 'Жемчужина Руси', RU) was connected to the fan (Fig. 1). The air flow above the grain layer was 0.05–0.06 $m s^{-1}$. From the experience of 2019, it was found that the fan productivity for a 5.5 m high wheat grain layer was insufficient and in 2020 the experiments were performed with a 3.0–3.5 m high wheat grain layer, which required about 10.8 t of wheat grain to fill each tank.

Drying with air active ventilation without and with ozone was performed for 185 h (2019) and 136 h (2020), approximately 7 and 6 h per day, respectively.

The ozone concentration at inlet was 15–18 ppm, while ozone concentration at the 5 m level was around 0.1 ppm in 2019, indicating that the majority of supplied ozone was absorbed at the lower levels. In the 2020 experiment, the inlet concentration remained at 15–18 ppm, but due to the reduced height of the grain layer, its concentration at the top was around 2.6–4.5 ppm.

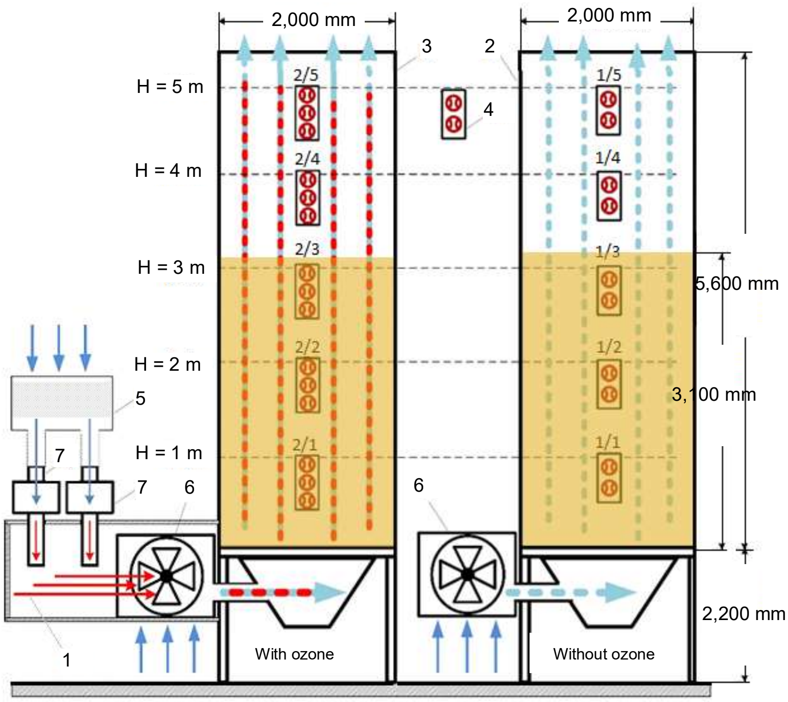

Figure 1. Experimental design of wheat grain storage tanks for year 2020.
The tank filling: to the height (coloured) to 3.2 m; 1/1–1/5; 2/1–2/5 – air humidity, temperature and ozone sensors; 1 – ozone; 2 – tank without ozone; 3 – tank with ozone; 4 – outside sensors; 5 – air dust filter; 6 – fans; 7 – the ozone generators.

Moisture content of wheat grain

Moisture content of wheat grain was determined according to AACC Method 44-15.02 Moisture - Air-Oven Methods, in the ULM 500 oven (Memmert, Germany).

Water activity of wheat grain

Water activity was determined with LabSwift-aw device (Novasina, Switzerland).

Chemical composition of wheat grain

Gluten, starch and protein content was determined using Grain Analyzer Infratec™ 1241 (FOSS, Denmark). For the analysis approximately 700 g of whole wheat grain were used.

Microbiological analysis of wheat grain

Determination of the microorganisms total plate count (TPC) was completed according to the standard ISO 4833-1:2003 Microbiology of the food chain - Horizontal method for the enumeration of microorganisms - Part 1: Colony count at 30 °C by the pour plate technique.

For the analysis (moisture content, water activity and microbiological analysis) were used approximately 100 g of ground wheat grain.

All parameters were analysed for wheat grain sampled from each storage tank (without ozone and with ozone) from the top and the bottom.

Statistical analysis

All analysis was done triplicate. In the experiments required data are given as average with standard deviation. Data were analysed Microsoft Office Excel 2016. ANOVA (one-way analysis of variance) and Tukey's test at a confidence level of 95% was used to estimate differences between means. Comparison of analysed parameters were calculated by *t-test* and significance between data was defined at $P \leq 0.05$.

RESULTS AND DISCUSSION

Grain quality after harvesting and storage may be affected by many factors (temperature, drying type, air humidity, storage conditions, raw material quality) (Granella et al., 2018). During storage moisture content, water activity, chemical composition and microbiological parameters were determined for wheat grain.

Moisture content

In Fig. 2 the experimental data on changes of the wheat grain moisture during active drying with and without ozone were collected.

In accordance with the Regulations of the Cabinet of Ministers of the Republic of Latvia No. 461 (12.08.2014.) for food quality schemes, procedures for their implementation, operation, monitoring and control, wheat must not have a moisture content higher than 14%, but the protein content not less than 12.5%. The moisture content of wheat grains, which does not exceed 14%, is optimal so that the grains can be stored for a long time and retain their quality.

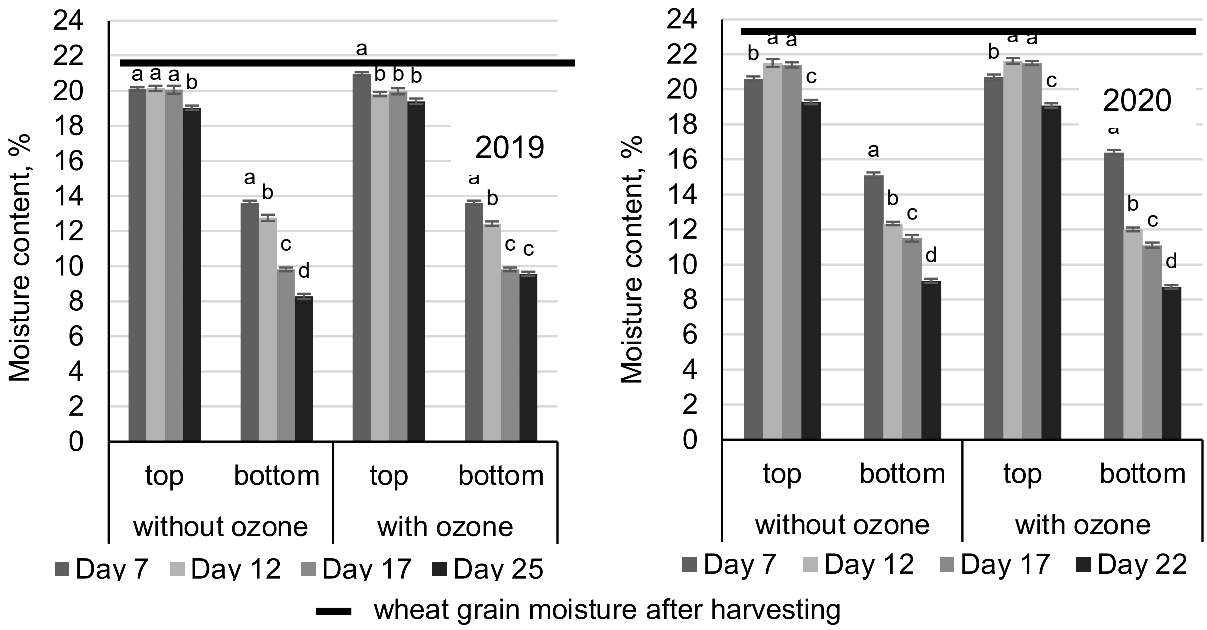

Figure 2. Changes of wheat grain moisture content during air and ozone active drying.
Different letters within sample groups indicate significant differences between samples ($P < 0.05$).

In both years of the experiment, the moisture content of wheat grain after harvesting was high - 22.97 ± 0.35% (2019) and 21.47 ± 0.22% (2020) (Fig. 2.). After seven days of active drying with and without ozone, the moisture content of the grain at the top of the storage tank was reduced by 1.87–2.77% ($P > 0.05$), but at the bottom of the storage tank - by 7.87–8.74% ($P < 0.05$). Active drying with air and ozone shows that during the first week of storage, more moisture is released from grain at the bottom of the storage tank. In the experiment performed in 2020, after seven days of active drying, the moisture of wheat grain, which was at the bottom of the storage tanks, was already below 14.0% and they are safe for long-term storage. In turn, in 2019, the moisture content of wheat grain at the bottom of the storage tanks, which is lower than 14.0%, was reached after 12 days of active drying. It must be acknowledged that for wheat grain taken from the bottom of the tanks for analysis, the moisture content at the end of drying was relatively low: 8.28 ± 0.16–9.07 ± 0.06% (without ozone, 2020 and 2019, respectively) and 8.73 ± 0.14–9.55 ± 0.25% (with ozone, 2019 and 2020, respectively), which could affect the baking properties of cereals. All analysed samples taken from the top of the storage tanks, regardless of the type of active drying - with or without ozone - were high (above 19.0%) even on the last day of the experiment. It should be noted that in both years of the experiments it was found that on the last day of the experiment there was a very large difference (up to 10.74%) in moisture of wheat grain for those sampled from the top and bottom of the storage tanks. Therefore, regardless of the storage tank filling (5.0 or 3.5 m), it is necessary to stir the grain during active drying to even out the moisture content of the wheat grain. From the obtained results it can be concluded that active drying with ozone didn't significantly affect ($P > 0.05$) the moisture content of wheat grain. However, moisture content of wheat was affected ($P < 0.05$) by the sampling location with a quicker reduction of moisture at the bottom of the storage tank.

Water activity

During the active drying of wheat grain with and without ozone, its water activity, which characterizes the amount of free water in the products, was analysed. In the Fig. 3. the changes in wheat grain water activity during storage using active drying with and without ozone are summarized.

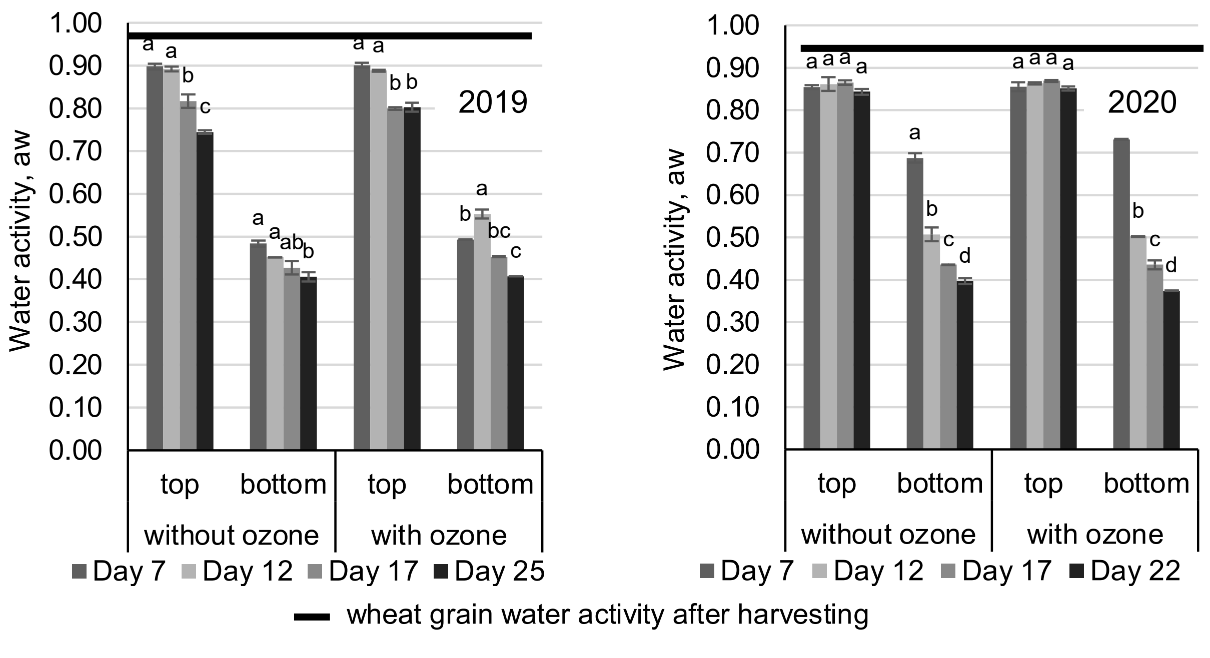

Figure 3. Changes of wheat grain water activity during active air and ozone drying.
Different letters within sample groups indicate significant differences between samples ($P < 0.05$).

The water activity of wheat grain after harvesting was very high - above 0.900, which indicates a large amount of free water available to microorganisms that can promote grain moulding process. For wheat grain harvested in 2020, the water activity was high ($a_w > 0.800$) during the whole period of active drying (22 days). Similar results were obtained in the 2019 experiments, when only after 25 days of active drying; the water activity of the samples taken from the top of the storage tank was below 0.800, which is high value. The wheat grain of 2019, after seven days of active drying, reached an $a_w < 0.500$, which is sufficient not to promote the development of microorganisms. In turn, in 2020 $a_w < 0.500$ was reached after 12 days of active drying. Analysing the results obtained in the study 2020, it can be concluded that active ozone drying didn't significantly affect ($P > 0.05$) the water activity of wheat grain, but it was significantly affected ($P < 0.05$) by the sampling location - the top or bottom of the storage tank.

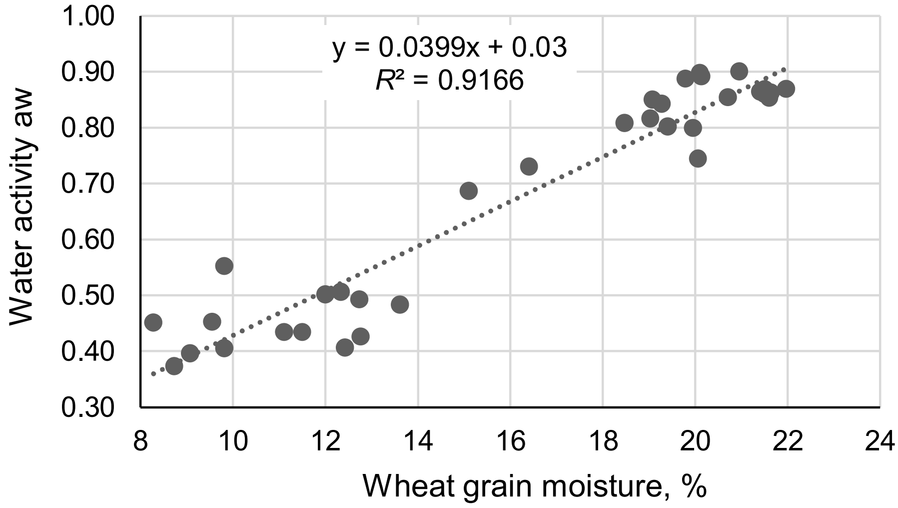

Figure 4. Correlation between wheat grain moisture and water activity during active air and ozone drying.

The results of experiments demonstrated strong linear correlation ($r = 0.957$) between wheat grain moisture and water activity (Fig. 4.) - the lower the wheat grain moisture content, the lower grain water activity.

Chemical composition

In the Table 1 wheat grain protein, gluten and starch changes during active drying are summarized.

The protein content of wheat grain ranged from 7.00 to 20.00 g 100 g^{-1}, but the optimal protein content for good baking properties is 12.00 to 14.00 g 100 g^{-1}. The analysed wheat grain of 2019 had a protein content of 15.89 ± 0.72–16.41 ± 0.17 g 100 g^{-1} (Table 1), which is relatively high. In turn, the analysed wheat grain in 2020 had 14.87 ± 0.31–13.28 ± 0.41 g 100 g^{-1}, which is optimal for obtaining good quality bread. In this research we didn't find that the protein content of wheat grain was significantly affected ($P > 0.05$) by active drying with and without ozone and the sampling place (top or bottom), but the protein content was significantly affected ($P < 0.05$) by the year.

Table 1. Wheat grain chemical composition changes during active air and ozone drying

	Protein content, g 100 g^{-1}				Gluten content, g 100 g^{-1}				Starch content, g 100 g^{-1}			
	without ozone		with ozone		without ozone		with ozone		without ozone		with ozone	
	top	bottom	top	bottom	top	bottom	top	bottom	top	bottom	top	bottom
2019												
after harvesting	16.42 ± 0.24^{a}				36.46 ± 0.46^{a}				65.36 ± 0.84^{a}			
Day 7	16.34 ± 0.36^{a}	16.42 ± 0.39^{a}	16.30 ± 0.12^{a}	16.27 ± 0.53^{a}	36.02 ± 0.38^{a}	36.71 ± 0.53^{a}	35.79 ± 0.76^{ab}	35.6 ± 0.65^{ab}	64.87 ± 0.59^{a}	63.99 ± 0.19^{b}	64.15 ± 0.43^{a}	64.98 ± 0.41^{ab}
Day 12	16.25 ± 0.42^{a}	16.30 ± 0.07^{a}	16.21 ± 0.58^{a}	16.01 ± 0.74^{a}	36.14 ± 0.75^{a}	35.09 ± 0.49^{ab}	34.54 ± 0.34^{b}	35.15 ± 0.41^{b}	64.62 ± 0.71^{a}	63.78 ± 0.65^{b}	64.97 ± 0.47^{a}	64.12 ± 0.23^{bc}
Day 17	16.41 ± 0.17^{a}	16.25 ± 0.41^{a}	16.14 ± 0.23^{a}	16.21 ± 0.08^{a}	35.95 ± 0.65^{a}	34.91 ± 0.18^{b}	32.87 ± 0.34^{c}	32.54 ± 0.76^{c}	63.98 ± 0.45^{a}	63.98 ± 0.27^{b}	64.23 ± 0.46^{a}	63.87 ± 0.14^{c}
Day 25	16.37 ± 0.32^{a}	16.22 ± 0.29^{a}	16.10 ± 0.71^{a}	15.89 ± 0.72^{a}	35.52 ± 0.96^{a}	34.81 ± 0.28^{b}	32.45 ± 0.76^{c}	32.41 ± 0.51^{c}	63.64 ± 1.09^{a}	63.21 ± 0.36^{b}	64.74 ± 0.37^{a}	63.76 ± 0.43^{c}
2020												
after harvesting	13.67 ± 0.23^{a}				28.03 ± 0.65^{a}				68.73 ± 0.46^{a}			
Day 7	13.57 ± 0.37^{a}	14.87 ± 0.31^{a}	13.77 ± 0.04^{a}	13.80 ± 0.24^{a}	26.30 ± 0.14^{b}	31.00 ± 1.10^{b}	25.470 ± 0.23^{b}	28.80 ± 0.98^{a}	68.90 ± 0.54^{a}	65.53 ± 0.87^{b}	68.33 ± 0.98^{a}	67.07 ± 0.78^{ab}
Day 12	13.73 ± 0.21^{a}	14.00 ± 0.29^{a}	13.83 ± 0.28^{a}	13.63 ± 0.09^{a}	26.23 ± 0.78^{b}	30.07 ± 0.78^{b}	25.170 ± 0.69^{b}	29.20 ± 0.48^{a}	68.83 ± 0.36^{a}	65.53 ± 0.45^{b}	68.50 ± 0.65^{a}	65.57 ± 0.34^{b}
Day 17	13.60 ± 0.09^{a}	13.80 ± 0.19^{a}	13.80 ± 0.39^{a}	13.60 ± 0.21^{a}	25.70 ± 0.43^{b}	29.90 ± 0.54^{b}	25.700 ± 0.97^{b}	28.70 ± 0.54^{a}	69.00 ± 1.01^{a}	65.10 ± 0.69^{b}	68.90 ± 0.39^{a}	65.40 ± 0.23^{b}
Day 22	13.73 ± 0.15^{a}	13.93 ± 0.56^{a}	13.28 ± 0.41^{a}	13.59 ± 0.18^{a}	25.37 ± 0.21^{b}	30.10 ± 0.72^{b}	25.560 ± 0.51^{b}	28.76 ± 0.87^{a}	67.73 ± 0.69^{a}	65.66 ± 0.45^{b}	68.08 ± 0.65^{a}	65.36 ± 0.18^{b}

Values marked with the different letters in the columns per year are significantly different ($P < 0.05$).

Gluten content is an important quality indicator for the use of wheat grain in bread making. The minimum gluten content for making good quality bread is 23%. In 2019, after harvesting, the gluten content in wheat grain was 36.46 ± 0.46 g 100 g^{-1}, but in 2020 - 28.03 ± 0.65 g 100 g^{-1}, which allows to conclude that the gluten content in wheat grains was significantly affected ($P < 0.05$) by harvesting year - there were different weather conditions that could have affected the gluten content. The analysed wheat grain samples had a gluten content of more than 23% (irrespective of the year of harvest, active drying and sampling place in storage tanks), so they correspond to good quality grain that can be used for bread production. (Mei et al., 2016) found that 1.5–2.0 h of ozone treatment significantly affected ($P < 0.05$) wet gluten content. This is inconsistent with our study, but it could be related to the fact that 18.5 t and 10.6 t of wheat grain were used and active drying with ozone occurred for 185 h (2019) and 136 h (2020).

The starch content of wheat grain can be 60–70% of grain mass (Broberg et al., 2015). The analysed wheat grain of 2019 after harvest had a starch content of 65.36 ± 0.84 g 100 g^{-1} (Table 1), which did not change significantly during the active drying of wheat grain at the top of the storage tank. On the other hand, for wheat grains taken from the bottom of the storage tank, the starch content decreased by about 2.00% as a result of 25 days of active drying. In turn, in 2020, the starch content of wheat grain after harvesting was 68.73 ± 0.46 g 100 g^{-1}, which differs significantly ($P < 0.05$) from the 2019 harvest. For changes in starch content of active drying with and without ozone in 2020 were observed similar trends as in 2019.

The study showed that the protein, gluten and starch content of wheat grain was not significantly affected ($P > 0.05$) by the active drying with ozone. Our results are in accordance with the study of (Zhang et al., 2021), who reported that ozone treatment of wheat didn't affect the main chemical composition of milled flour.

Microbiological parameters

In the Fig. 5 the changes of microbiological parameter during storage using active drying with and without ozone are summarized.

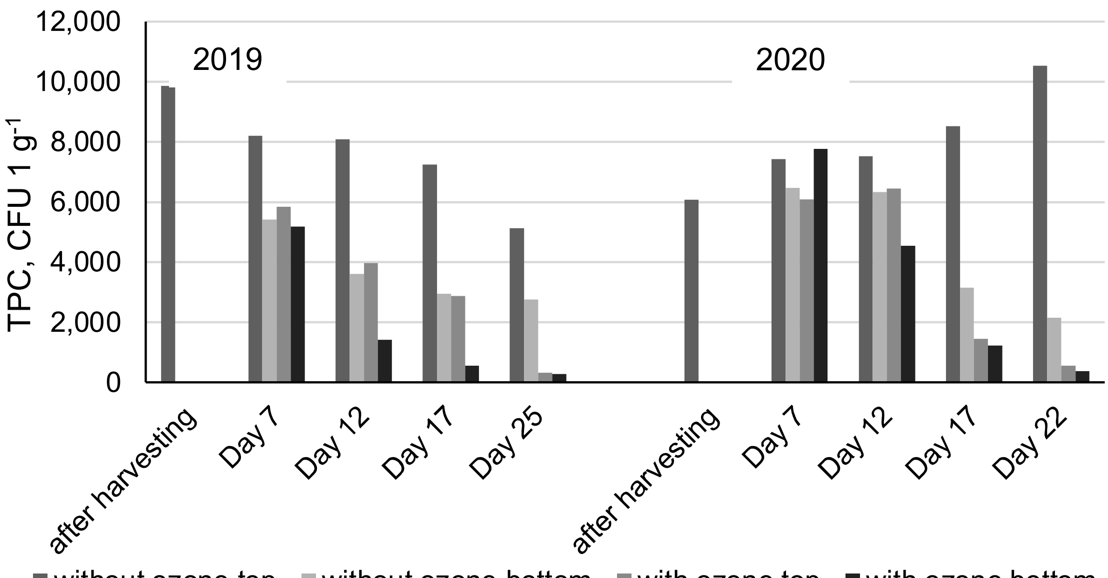

Figure 5. Total plate count (TPC) in wheat grain during active air and ozone drying.

European Commission Health & Consumer protection directorate has indicated that safe amount for consumers in the food product of microorganisms total plate count (TPC) is < 10^5 CFU g^{-1} (European Commission, 2012). Then, based on the results of the study, it can be concluded that the TPC in the analysed wheat grains didn't exceed the permissible norms. Active drying with ozone of wheat grains can significantly ($P < 0.05$) reduce the total amount of microorganisms (Fig. 5). What coincides with Hu et al. (2020) results, who found that in the buckwheat based composite flour total amount of microorganisms decreased significantly ($P < 0.05$). In year 2020, after 22 days of active drying, the TPC at the top of the storage tank increased significantly, which could be due to the high moisture content of the wheat grain analysed, which significantly contributed to the development of microorganisms. Jian et al. (2013) have found that ozone can reduce the count of microorganisms in grain, but this depends on the amount of ozone and the processing time with ozone.

The results obtained in this study showed that the application of ozone significantly ($P < 0.05$) reduced total microorganism count compared to the processing without ozone. However, the height of grain layer - 5.0 m in 2019 or 3.5 m in 2020 did significantly affect ($P > 0.05$) TPC. Savi et al. (2020) found similar trend in the storage of rice, and they recommend ozone treatment as antifungal agent.

CONCLUSIONS

The results obtained in the study showed that ozone treatment of wheat grain 15–18 ppm and treatment time of 185 h (2019) and 136 h (2020) did not significantly affect ($P > 0.05$) the moisture content and water activity of grain, but these parameters were significantly affected ($P < 0.05$) by the sampling location – the top or the bottom of the storage tank. Active drying with ozone significantly ($P < 0.05$) reduced the total plate count, but it was not observed that it would be significantly affected ($P > 0.05$) by the height of grain layer (2019 and 2020). The study proved that the protein, gluten and starch content of wheat grain was not significantly affected ($P > 0.05$) by the active drying with ozone.

In order to ensure a more efficient wheat grain active drying process in large quantities (more than 10 tons), it is necessary to find a solution that at least once a week grain in the storage tank is stirred.

ACKNOWLEDGEMENTS. This research is supported by Support Service project No l8-00-A01620-000003 'Technology development of grain drying with active ventilation using ozone'.

REFERENCES

AACC Method 44-15.02 'Moisture – Air-Oven Methods'. AACC Approved Methods of Analysis, 11th Edition.

Broberg, M.C., Feng, Z., Xin, Y. & Pleijel, H. 2015. Ozone effects on wheat grain quality e A summary. *Environmental Pollution* **197**, 203–213.

European Commission. 2012. *Working Document on Microbial Contaminant Limits for Microbial Pest Control Products*. September, 24.

Granella, S.J., Christ, D., Werncke, I., Bechlin, T.R. & Machado Coelho, S.R. 2018. Effect of drying and ozonation process on naturally contaminated wheat seeds. *Journal of Cereal Science* **80**, 205–211.

Hu, J., Li, X., Jing, Y., Hu, X., Ma, Z., Liu, R., Song, G. & Zhang, D. 2020. Effect of gaseous ozone treatment on the microbial and physicochemical properties of buckwheat-based composite flour and shelf-life extension of fresh noodles. *Journal of Cereal Science* **95**, 103055.

Hutla, P., Kolarikova, M., Hajek, D., Dolezal, P., Hausvater, E. & Petrackova, B. 2020. Ozone treatment of stored potato tubers. *Agronomy Research* **18**(1), 100–112.

ISO 4833-1. 2013. 'Microbiology of the food chain – Horizontal method for the enumeration of microorganisms – Part 1: Colony count at 30 °C by the pour plate technique'. International Organization for Standardization, Geneva, Switzerland.

Jian, F., Jayas, D.S. & White, N.D.G. 2013. Can ozone be a new control strategy for pests of stored grain? *Agricultural Research* **2**(1), 1–8.

Kleperis, J., Kristins, A., Veinbergs, J., Gvardina, I., Viesturs, D., Rucins, A., Straumite, E., Sloka, B. & Buveris, J. 2019. Applicataion of ozone in grain drying: Autonomous sensor system construction and pecularities. In *Proceedings of the 9th International Scientific Conference Rural Development 2019*, pp. 34–39.

Mei, J., Liu, G., Huang, X. & Ding, W. 2016. Effects of ozone treatment on medium hard wheat (Triticum aestivum L.) flour quality and performance in steamed bread making. *CYTA - Journal of Food* **14**(3), 449–456.

Nickhil, C., Mohapatra, D., Kar, A., Giri, S.K., Tripathi, M.K. & Sharma, Y. 2021. Gaseous ozone treatment of chickpea grains, part I: Effect on protein, amino acid, fatty acid, mineral content, and microstructure. *Food Chemistry* **345**, 128850.

Rakcejeva, T., Zagorska, J. & Zvezdina, E. 2014. Gassy ozone effect on quality parameters of flaxes made from biologically activated whole wheat grains. *International Journal of Nutrition and Food Engineering* **8**(4), 378–381.

Rucins, A., Viesturs, D., Kristins, A. & Bruveris, J. 2020. Investigations in intensification of grain drying by active ventilation applying ozone. In *Engineering for Rural Development* 2019, **19**, 231–237.

Savi, G.D., Gomes, T., Canever, S.B., Feltrin, A.C., Piacentini, K.C., Scussel, R., Oliveira, D., Machado-de-Avila, R.A., Cargnin, M. & Angioletto, E. 2020. Application of ozone on rice storage: A mathematical modeling of the ozone spread, effects in the decontamination of filamentous fungi and quality attributes. *Journal of Stored Products Research* **87**, 101605.

Tiwari, B.K., Brennan, C.S., Curran, T., Gallagher, E., Cullen, P.J. & O' Donnell, C.P. 2010. Application of ozone in grain processing. *Journal of Cereal Science* **51**(3), 248–255.

Wang, L., Shao, H., Luo, X., Wang, R., Li, Y., Li, Y., Luo, Y. & Chen, Z. 2016. Effect of ozone treatment on deoxynivalenol and wheat quality. *PLoS ONE* **11**(1), 1–13.

Worldwide production of grain 2019/2020, by type 2021. *https://www.statista.com/statistics/263977/world-grain-production-by-type/*. Acessed 28.01.2021.

Zhang, W., Li, L., Shu, Z., Wang, P., Zeng, X., Shen, W., Ding, W. & Shi, Y. C. 2021. Properties of flour from pearled wheat kernels as affected by ozone treatment. *Food Chemistry* **341**, 128203.

Zhu, F. 2018. Effect of ozone treatment on the quality of grain products. *Food Chemistry* **264**, 358–366.