GRAIN DRYING EXPERIMENTS WITH UNHEATED AIR

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Abstract. Grain drying is a very power capacious and expensive process. The prices of power resources being used in grain drying increase year by year. The solid or liquid fuel, electric power or the sun energy is usually used for grain drying in order to heat air. In order to reduce the great consumption of power resources and to slash the drying costs, grain drying technologies with small consumption of power should be applied. Using the new, low temperature technologies in grain drying the same effect can be achieved as using high air heating temperature oasts or hotoasts. One of such technologies could be grain layer drying at low air temperatures in ozone setting. Carrying out experiments in laboratory, it is apparent that carrying out moisture from grain is more effective if there is the active ventilation with ozonized air. The presence of ozone in the process of the grain active ventilation increases carrying out moisture. Power is educed when ozone decomposes transforming back into oxygen. The laboratory research approved the efficiency of the presence of ozone in the grain active ventilation process.

Key words: ozone, grain drying, grain active ventilation.

Introduction

The statistic data of the last years witness that reaches of croppers increase and in 2004 already more than 1 million tons of grain were harvested [1]. Not always the weather conditions are favourable during the time of grain harvesting, therefore the preservation of the grown grain crop with the least possible losses is one of the main tasks.

Harvesting grain in a dry summer, very often grain moisture is above 20% but in the wet weather it can exceed even 25%, for such moisture grain drying the consumption of much power and time is necessary. The consumption of fuel, drying grain with hotoasts, can change from 6 to 20 kg of derv per 1 ton of grain. The optimum term from grain harvesting to drying would be from one to two days. Very often for the economical purpose grain is not dried to condition moisture (or grain is not dried at all), what influences grain quality afterwards very essentially [4, 5].

As grain drying to optimum moisture is a very power capacious and expensive process, then it is possible to achieve the reduction of power resource consumption if the moist grain is dried at low temperatures. Usually heated air is used in grain drying. The solid or liquid fuel, electric power or the sun power are used for air heating. Using low temperature technologies in grain drying the same effect can be achieved as using high air heating temperature oasts or hotoasts. As one of such technologies could be the grain layer active ventilation at low air temperatures in ozone setting [2, 3]. To ascertain the influence of ozone in grain drying, the laboratory experiments were carried out.

Materials and Methods

In order to carry out the drying research, a laboratory equipment, the construction of which allows the simultaneous grain drying with ozonized air and without ozonized air (Figure 1), had been built in grain drying laboratory. The data of the experiment are measured and recorded by an electronic device REG-01 and GK-01.

This equipment consists of 10 grain cassettes, where in each cassette approximately 20 mm thick layer of grain has been evenly filled in, about 300 g. The grain has been weighed by electronic scales EW1500-2M with precision ($d = 0.01$ g). The moist grain has been dried with ozonized air 5 and without ozonized air 6. For drying the moist grain, air has been carried out by the help of ventilator 4 where the favourable air filtration speed, which has been controled by air flow speed controller TESTO 400 8, has been set by nonstep regulator. Ozone is being produced by ozone generator PRO 3.400 2. As grain drying takes place with unheated air, then for checking the temperature of the air flowing in, before a ventilator thermometer 1 and thermometer 3 have been used for checking temperature before the grain cassettes. By the help of retardation coil 7 the system has been balanced so that air filtration speed through the moist grain with ozonized air and without ozonized air would be equal. The flowing out air moisture and temperature have been controlled by grain active ventilation control-equipment GK-01 and by the help of temperature – moisture sensor 9. For recording the temperature of the interlayers of the process, the data recording electronic recording equipment REG-01 10 has been applied.

The moistened wheat had been used as the research object in the laboratory. The initial moisture of grain had been determined by grain moisture meter Wille-35. Grain drying time is 1 hour and the temperature of the drying agent is 21.0 ^{o}C ± 0.5 ^{o}C. After the the experiment had been finished for determining the amount of the carried out water in the grain layers, the electronic scales EW1500-2M (Δd = 0.01 g) had been used.

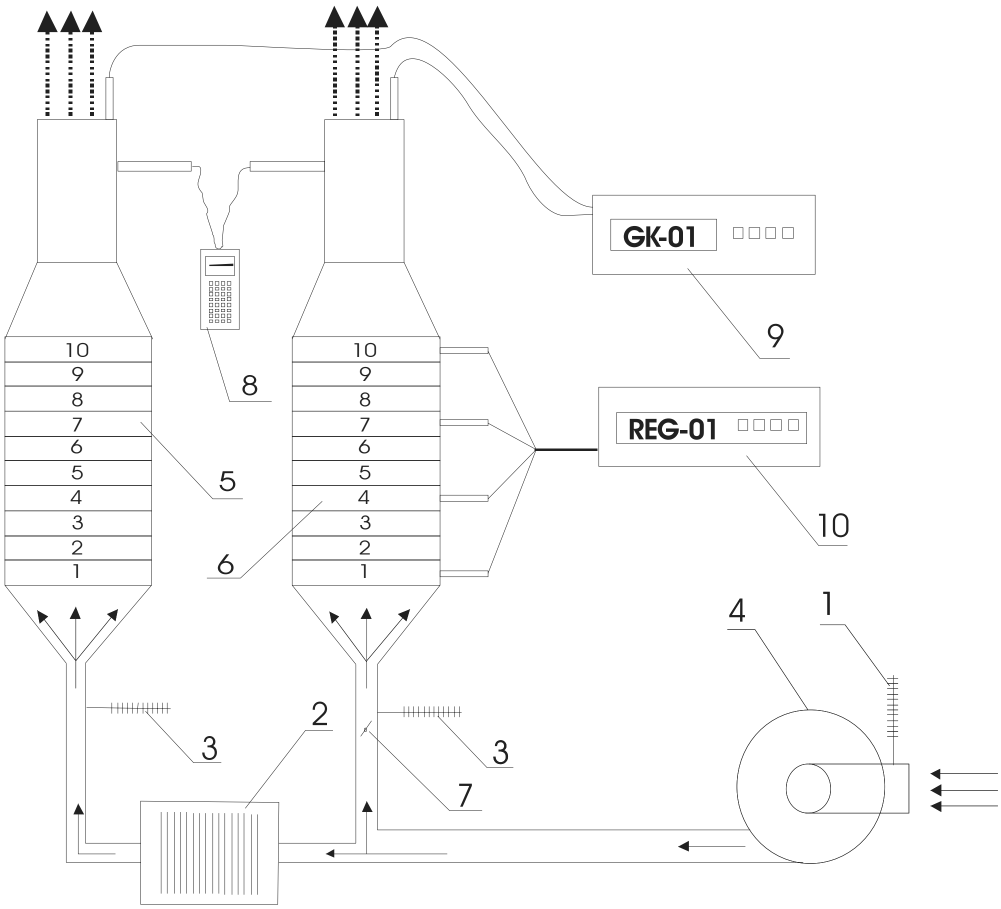

Fig. 1. **The laboratory experimental equipment for grain drying with ozonized air**: 1 – thermometer for measuring the entering air, 2 – ozone generator, 3 – thermometer for controlling air temperature before grain cassettes, 4 – ventilator, 5 – grain cassettes for grain drying with ozonized air (10 pieces), 6 – grain cassettes for grain drying without ozonized air (10 pieces), 7 – retardation coil, 8 – controller of air flow speed TESTO 400, 9 – grain active ventilation control-equipments GK-01 with air temperature – moisture sensors, 10 – data electronic recording equipment REG-01

Results and discussion

In the laboratory had been carried out grain drying experiments at various air filtration speeds: v = 0.1 m/s, v = 0.2 m/s, v = 0.3 m/s and v = 0.4 m/s, simultaneuosly drying grain both with ozonized air and with unozonized air. In the experiments there had been applied moistified wheat with the initial moisture W = 24.5% ± 1.5%. The length of grain drying experiments – 1 hour. The unheated drying agent's (air) temperature was 21.0 ^{o}C ± 0.5 ^{o}C and grain temperature 21.5 ^{o}C ± 0.5 ^{o}C.

Viewing the exiting air moisture in Figure 2, various phases in carrying out of moisture can be observed. At a low ventilation speed v = 0.2 m/s, but at the ventilation speed v = 0.4 m/s, the moisture carrying out from intergrain space has already been carried out in four 4 minutes if the drying air temperature is equal. In further period of time it can be seen that the reduction of the amount of the carried out moisture is taking place and it can be concluded that all moisture from the intergrain space has been carried out. Next follows the carrying out of moisture from the surface of a grain. The moisture in intergrain space is in a liquid condition and it is easy to carry it out but in order to carry out the moisture from the surface of a grain, power is needed because evaporating is taking place. Heat has been consumed for evaporating and simultaneously the temperature is falling. The greater is the drying speed, the faster is occurring the drying process, the smaller is the ventilation speed, the longer is the drying time. After carrying out the moisture from the surface of a grain, the drying of a grain starts and simultaneously the temperature is falling. The drying front gradually is moving from the lower layers to upper layers. Grain drying being proceeded in the entire layer, the amount of the carried out moisture begins to increase.

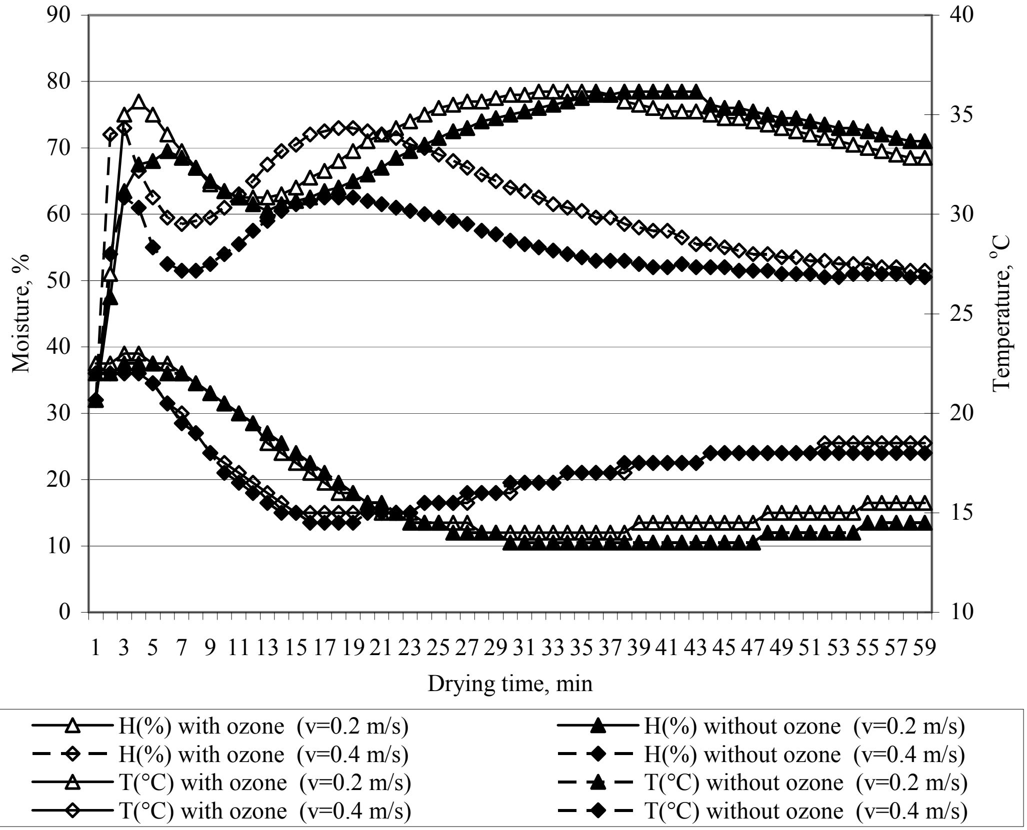

Fig 2. **Moisture and temperature of the exiting air**

Drying grain with ozonized air, the carried out moisture is bigger than drying with unononized air, because as a result of ozone decomposing, power is discharging what increases the temperature of the air flowing through. Ozone does not influence the initial process of grain drying essentially, while the moisture is being carried out but its influence starts to appear when moisture should be carried out from the surface of a grain and the grain itself should be dried. The presence of ozone fastens the drying of a grain as a result the power consumption reduces. The laboratory research ascertained the efficiency of the presence of ozone in the process of grain drying.

In Figure 3 there has been shown the amount of the carried out water Q (g/kg %) after one hour drying. In order to compare the carried out water at various grain initial moistures, we introduce a rate Q (g/kg %) which reflects the amount of the carried out water in grams from one kilogram of moist grain to one grain moisture percent.

This variable is necessary in order to compare the amount of the carried out water at various initial grain moistures because at the bigger initial grain moisture the amount of the carried out water is bigger. In our experiments the initial grain moisture is W_1 = 24.5% ± 1.5%.

After one hour drying it can be concluded that at a low ventilation speed v = 0.1 m/s, the total amount of the carried out water is less than at a greater ventilation speed v = 0.4 m/s. The amount of the carried out water after one hour drying in the first cassette does not differ essentially from the ventilation speed, however, at greater ventilation speed, the drying front moves faster and the upper layers of grain have been also dried more. From the third figure it is seen that at the same ventilation speed drying with ozonized air the amount of the carried out water is bigger, $\Delta Q \sim 0.11 - 0.25$ than drying without ozonized air. It should be marked that at great ventilation speeds the efficiency of ozone is falling and the difference of the amount of the carried out water is $\Delta Q \sim 0.04 - 0.10$. The biggest effect appeared at drying speeds $v \sim 0.15 - 0.25$ m/s.

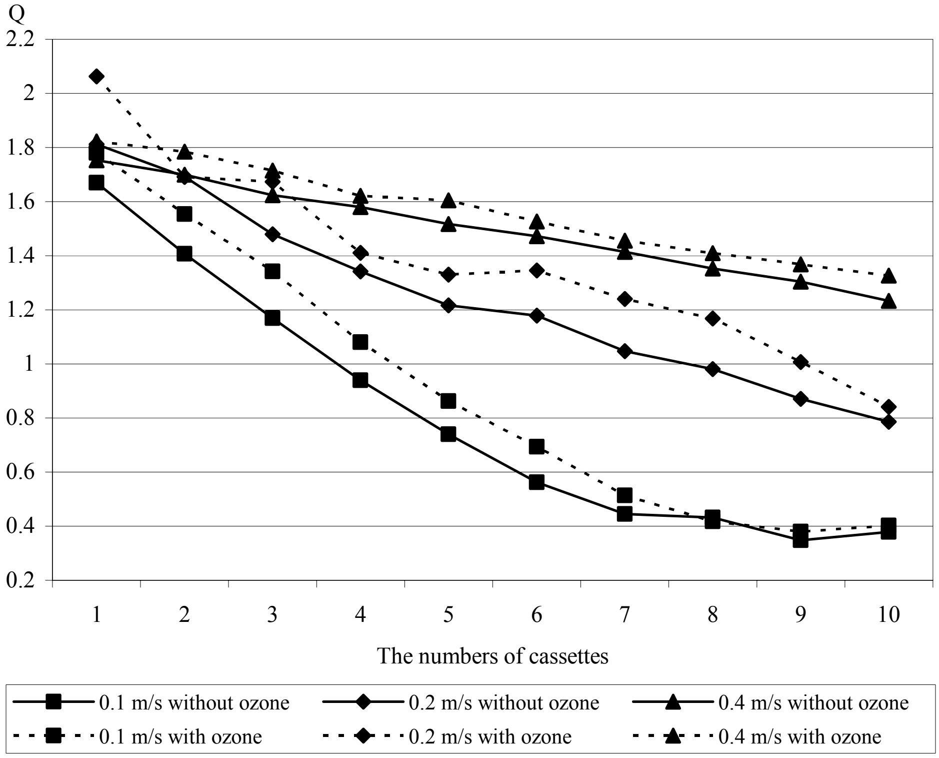

Fig. 3. **Carrying out of water from grain through cassettes at various ventilation speeds**

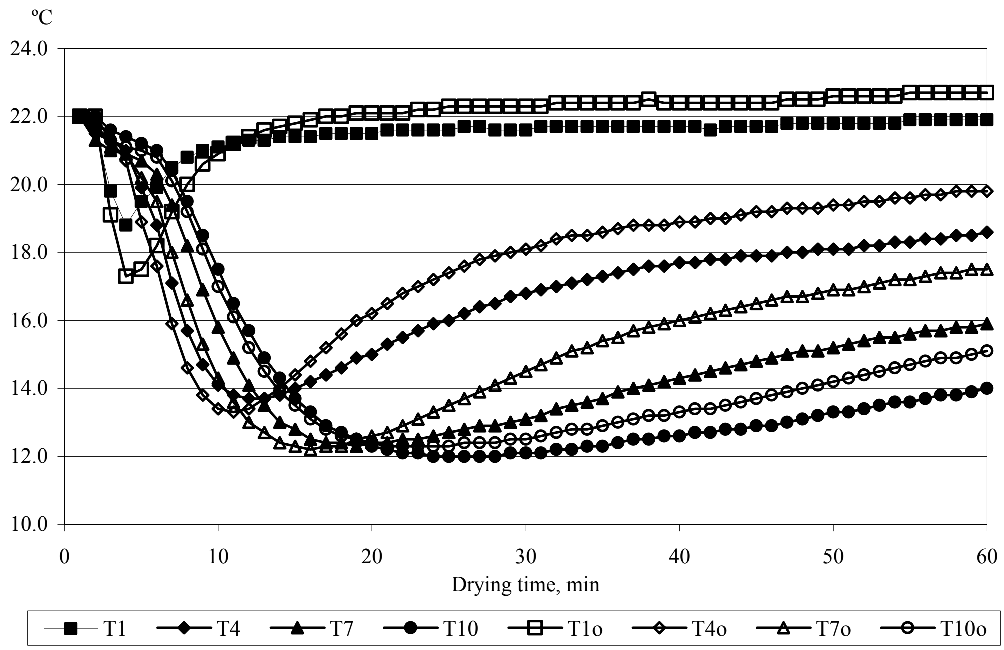

Fig. 4. **Grain interlayer temperature distribution through cassettes at ventilation speed v = 0.2 m·s^{-1}**: T_i – temperature in the cassette without ozonized air; T_{io} – temperature in the cassette with ozonized air, i – the number of a cassette (Fig. 1)

From Figure 4 it is seen that in the first cassette temperatures in the grain layer are rapidly falling in the first five minutes, that means, that the free moisture from the intergrain space and the surface of a grain is rapidly being carried out. Starting with the 6th minute begins the drying of the first grain layer and carrying out of moisture is not so intensive any more and the temperature of the entering air begins to warm up the first grain layer and to dry it intensively. The same effect has also been observed in the next grain layers, only with smaller intensity because every next layer has been dried with lower temperature and bigger moisture therefore in cassette 4 (T_{4o} and T_4) the grain starts already with the 10th minute.

Conclusions

1. In the experiments it was proved that the presence of ozone in the grain drying process increases carrying out of moisture.
2. Ozone does not influence the initial grain drying process essentially while moisture, that is in the intergrain space, is being carried out. Ozone being destructed back into oxygen, an additional power has been obtained and this circumstance allows in the ventilable air to use this power in grain drying.
3. At great ventilation speeds the efficiency of the application of ozone falls because during grain drying it has been carried out quickly through the grain layer and it does not manage to decompose and deliver its power.
4. The presence of ozone during grain drying increases the grain storing time, the grain germinating ability improves, the process of grain afterswelling occurs more intensively.

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