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Investigations of Solar Collector and Ozone in Grain Drying

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Abstract. The prices of energy resources used for grain drying are increasing year by year. In order to reduce grain drying costs, in the Research Laboratory of Grain Drying and Storing of the Faculty of Engineering, the LUA research into methods of energy – saving in grain drying is in progress.

In 2005 the equipment for experimental research into the materials of solar collectors was built. The construction of the equipment allows for simultaneous comparative studies of two materials. The experimental data are metered and recorded in the electronic equipment REG.

Cell polycarbonate PC (bronze) (henceforth referred to as polycarbonate) with absorbers steel-tinplate and black coloured wood was researched in relation to the polyvinylchloride film (henceforth referred to as a film). The researches were made with different air velocities. The air heating degree ΔT in the solar collector is dependent on solar radiation I and air velocity v in the solar collector. In the experimental equipment, the length of which is 1.5 meters, the air heated to $\Delta T = 6$ °C at the velocity $v = 0.5$ m s^{-1}.

Another type of low-temperature technologies in grain drying could be active drying in ozone medium. Laboratory experiments show that the carried out moisture from grain is more efficient if active drying is performed using ozonized air. Ozone when decaying to ordinary oxygen creates additional energy, which can be efficiently used in grain drying. Laboratory experiments prove the effectiveness of the presence of ozone in grain active drying process.

Key words: radiation, sun, air, grain, temperature, polycarbonate, film, ozone.

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 [Aboltins & Palabinskis,2005]. 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 during dry summer the moisture of grain quite often is over 20%, but in wet weather it can exceed even 25% (Chegev, 2006). For drying of grain having such moisture high consumption of energy and time is necessary. The optimal term from harvesting of grain till drying would be from one to two days.

As drying of grain till the optimal moisture is a very expensive process consuming much energy, it is possible to decrease the consumption of energy resources if wet grain is dried at low temperatures. Usually heated air is used in grain drying. For heating of air either solid or liquid fuel, electric or solar energy is used.

Grain drying as well as all costs of its first treatment and storage depend upon equipment, the balance cost of buildings, power supply systems, the amount of the drying material and its moisture content, the level of cleanness and energy carrier's prices, which are continuously rising.

Fuel is getting more expensive year by year but grain has to be dried in order that it can be stored. Nowadays more attention has been paid to environmental protection thus ways how to use alternative energy more widely are being explored. The sun is the most powerful heat generator, with which none of the heat sources created by mankind can compete with. Yearly the earth is reached by the solar energy 15000 times more than the power industry of the whole world can produce. It means that only a tiny part of solar energy is being used for the sake of mankind.

Increase in the utilization of solar energy is closely connected with research into solar collectors. The necessary amount of heat for grain drying with active ventilation from July to September can be obtained by making use of solar radiation. In Latvia at midday in this period of time the average solar radiation power on a horizontal surface is more than 600 W m^{-2}. The air heated this way is not toxic and electrically neutral. Solar collector efficiency is not high but it has simple construction and is cheap to produce and operate.

In grain drying applying the technology of low temperatures the same effect can be achieved as using high air heating temperature dryers or heat dryers. One of such technologies could be active ventilation of the grain layer at low air temperatures in ozone medium. In order to state the influence of ozone in grain drying, laboratory experiments were carried out. (Lauva et al, 2005).

MATERIALS and METHODS

The aim of the research is to find the optimal technical solutions, utilized materials, operation parameters and power possibilities for a solar collector. In the laboratory a 1.5 meters long experimental solar collector was constructed for research into the properties of roof materials. The keynote of the equipment is to conduct comparative studies of the utilized materials for the solar collector. The collector has been built so that it can be easy to use in a laboratory setting. The box-like frame of the collector is divided into two parts (Fig. 1)..

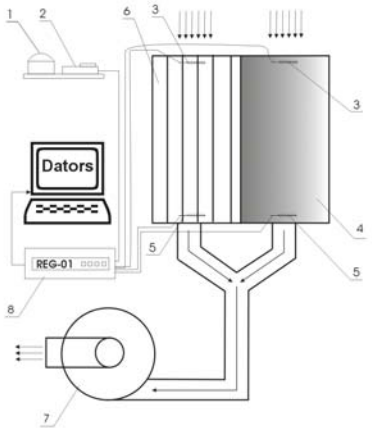

Fig. 1. Experimental equipment for research into the properties of solar collector materials:
1 – solar radiation meter (pyranometer); 2 – solar lighting meter; 3 – temperature transducers of incoming air; 4 – polyvinylchloride film; 5 – temperature transducers of outgoing air; 6 – researched material; 7 – fan; 8 – metering and recording equipment REG

One part is covered with a traditional material for solar collectors, i.e. a polyvinylchloride film, henceforth referred to as a film. The other part is used for the placement of the researched material compared to the polyvinylchloride film. In both channels of the experimental equipment equal conditions for the experiment are ensured. The experimental data are recorded by means of an electronic metering and recording equipment of temperature, radiation and lighting REG (REG, 2004). It is equipped with 16 temperature transducers and metering sensors of solar radiation and lighting. The information is stored in the form of a table and in case of need it is depicted as a graph.

Experimental laboratory equipment was made up for simultaneous drying of grain using ozonized air and not using ozonized air (Fig. 2). This equipment consists of ten grain cassettes; in each cassette a layer of wet grain of the density of approximately 20 mm is evenly refilled. The grain is weighed with electronic scales EW1500-2M with exactness (d = 0.01 g). The wet grain is dried using ozonized air (position 5) and without ozonized air (position 6). For drying of wet grain the air is fed by means of a fan (position 4), where the desired air filtration velocity that is controlled by an air flow velocity controller TESTO 400 (position 8) is set by a gradeless regulator.

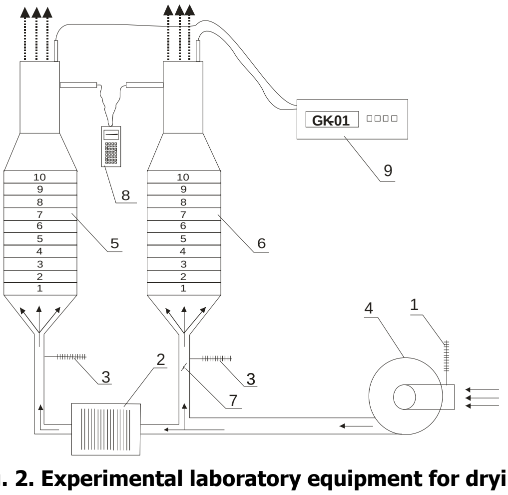

Fig. 2. Experimental laboratory equipment for drying grain with ozonized air:

1 - inflowing air thermometer, 2 – ozone generator, 3 – thermometer for control of air temperature before the grain cassettes, 4 – fan, 5 – grain cassettes (10 pieces), 7 – throttle, 8 – air- flow velocity controller TESTO 400, 9 – grain active ventilation control devices GK-01 with air temperature – moisture sensors.

Ozone is produced by the ozone generator PRO 3,400 (position 2); in our experiments the amount of the produced ozone is 7.7 mg m^{-3} of air. As drying of grain is done using cold air, for regulation of the temperature of the in-flowing air before the fan a thermometer (position 1) is used and for regulation of the temperature before the grain cassettes thermometers (position 3) are used. The system is balanced by help of a throttle (position 7) in order to make the air filtration velocity through the wet grain with ozonized air equal to that without ozonized air. The moisture and temperature of the out- flowing air are regulated by help of the grain active ventilation regulation equipment GK-01 and air temperature sensors (position 9).

Artificially humidified grain was used as the object of the research. The initial moisture of grain was determined by the grain moisture meter Wille-55. At the end of the experiment for stating the amount of the carried away moisture the electronic scales EW1500-2M (d = 0.01 g) were used.

RESULTS and DISCUSSIONS

In the experiment, the researched material was compared to the polyvinylchloride film, which in most cases is used as a solar collector material. Cell polycarbonate PC (bronze) was used as the researched material. This material has gained immense popularity due to such properties as safety, mechanical resistance, translucence and high UV radiation stability. It is easy to bend polycarbonate PC plates and they do not need previous treatment. As the experiments demonstrate, with high solar radiation I value the usefulness of solar collector is essential for rising air temperature up to $\Delta T = 7$ °C, which increases as the air movement velocity v decreases. There is no substantial difference in the outgoing air temperature T_2 as well as the heating degree ΔT between the film and polycarbonate collectors. With solar radiation of $I < 100$ W m^{-2}, the air heating degree does not exceed $\Delta T = 1$ °C.

The research results of this material are described (Lauva et al., 2006, Palabinskis, J et al., 2007). These results were obtained with absorber – black coloured wood. The results of the investigations of PC with absorber steel-tinplate are as follows (Fig. 3 and 4).

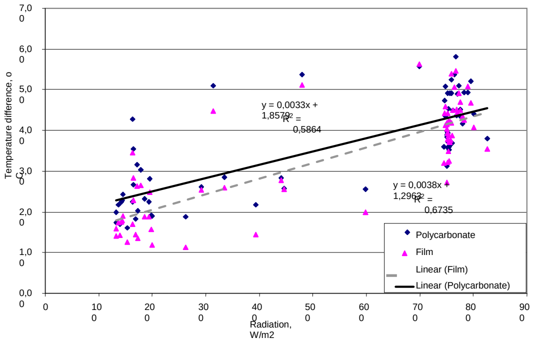

Fig. 3. Air heating temperature difference ΔT of film and polycarbonate with black coloured wood absorber depending upon solar radiation I at air velocity $v = 0.5$ m s^{-1}.

The experiments show that absorber steel-tinplate works more effectively than black coloured wood with polycarbonate plate cover (Fig. 3 and 4).

There is no important difference of temperature heating degree of solar collector covered by polycarbonate and film (fig.3). The heating degree ΔT increases with growing radiation of sun.

The researchers tried to find a correlation between the heated air temperature difference ΔT of the collector and two kinds of material – the polyvinylchloride film and the polycarbonate plate with different absorbers (Fig. 3 – 4).

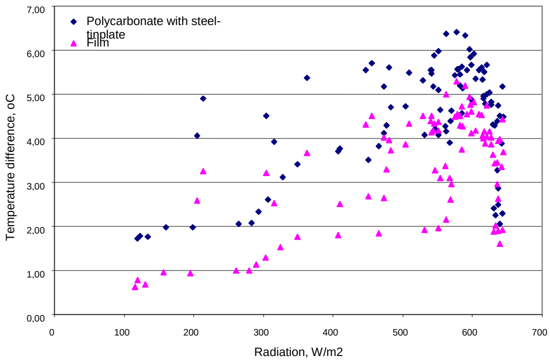

Fig. 4. Air heating temperature difference ΔT of film with black coloured wood absorber and polycarbonate with steel-tinplate absorber depending upon solar radiation I at air velocity $v = 0.5$ m s^{-1}.

By comparing the effectiveness of usage, it is obvious that the air heating degree does not change substantially at low air velocities v and it is directly dependant on solar radiation I volume. The heating degree ΔT (°C) is directly proportional to the radiation level I with sufficiently high correlation factors.

We compared temperatures of ambient air, temperatures of the end of collector covered by film and translucent roofing slate depending of sun radiation with different air velocities (Fig. 5-6).

It can be seen that the effectiveness of translucent roofing slate is higher that using the film. With small velocities the effectiveness is higher that with large velocities. The correlation of dependents (from experimental data) is high $r \in (0.65; 0.85)$. At lower air velocities $v = 0.75$; 0.95 m s^{-1} the correlation is lower. The experimental results show that heating degree of the solar collector depending on the air velocity is higher with lower velocities.

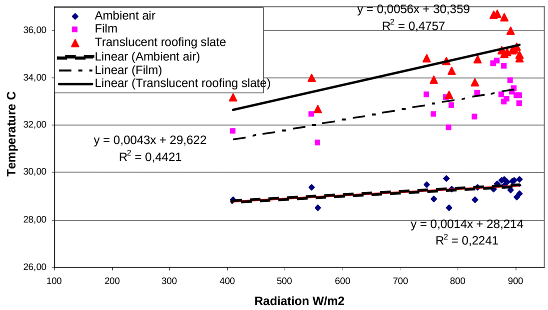

Fig. 5. Ambient air temperature, collector heating temperature covered by film and translucent roofing slate dependence from solar radiation I at air velocity $v = 0.75$ m s^{-1}.

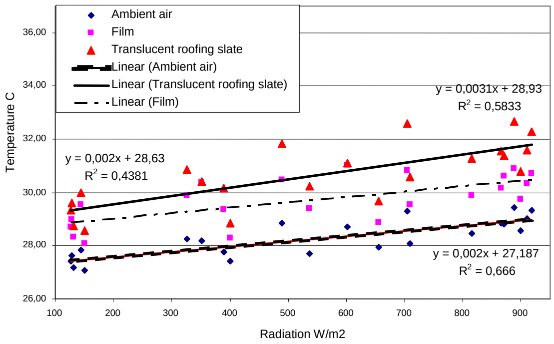

Fig. 6. Ambient air temperature, collector heating temperature covered by film and translucent roofing slate dependence on solar radiation I at air velocity $v = 1.34$ m s^{-1}.

For future investigations we made one man movable solar collector (fig. 7-8)

In order to state influence of ozone in grain drying laboratory experiments had been carried out 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 without ozone. In the experiments there had been applied moistified wheat with the initial moisture $W = 24.5\% \pm 1.5\%$. 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.

Figs 7-8. Movable solar collector.

Viewing the exiting air moisture in Figure 9, 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.

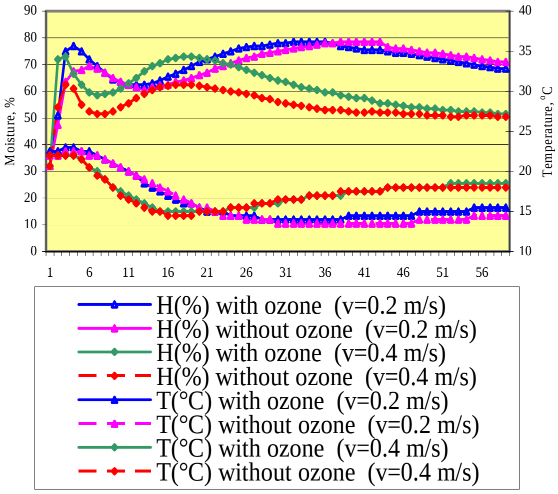

Fig 9. Moisture and temperature of the exiting air

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 10 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 $W_1 = 24.5\% \pm 1.5\%$.

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. 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.

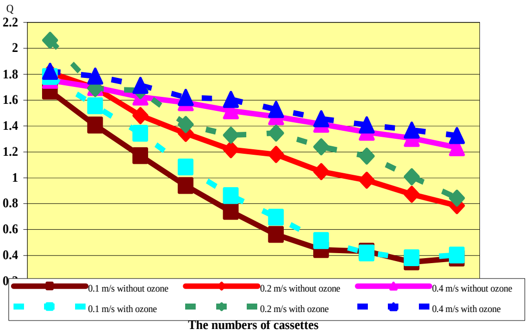

Fig. 10. Carrying out of water from grain through cassettes at various ventilation speeds

From Figure 11 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

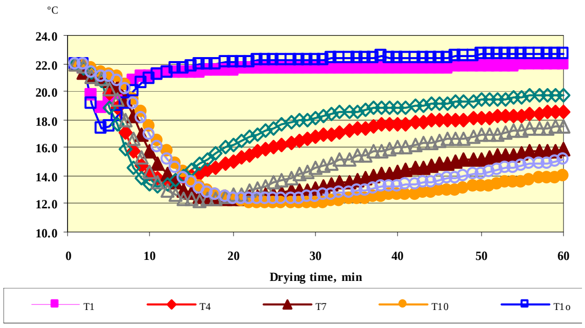

Fig. 11. Grain interlayer temperature distribution through cassettes at ventilation speed *v* = 0.2 m·s^{-1}:
T_i – temperature in the cassette without ozonized air;
T_{io} – temperature in the cassette with ozonized air, *i* – the number of a cassette (Fig. 2)

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, every next layer has been dried with lower temperatu-re and bigger moisture therefore in cassette 4 (T_{4o} and T_4) the grain starts already with the 10th minute.

Similar research has been carried out in Russia and Belarus (Trockaja 1997, Golubkovich et al 2005), (Krivopishin 1988), (Bogatova 2005, Golubkovich et al., 2005).

CONCLUSIONS

1. The air heating degree ΔT in the solar collector is dependent on the solar radiation I and the air velocity v in the solar collector. In the experimental equipment, the length of which is 1.5 meters, the air heated to ΔT = 6 °C at the velocity v = 0.5 m s^{-1};
2. The air heating degree ΔT in the polycarbonate collector did not significantly differ from the film collector by black colored wood absorbent, but it is significantly higher using absorbers of steel-tinplate;
3. The translucent roofing slate as a sun collector material is more effective than the polyvinylchloride film;
4. 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.
5. The presence of ozone during grain drying increases the grain storing time, the grain germinating ability improves, the process of grain after swelling occurs more intensively.

REFERENCES

1. Aboltins A, Palabinskis J.(2005) Research of grain drying (cooling) process in Latvia. Jubilee Scientific Conference with International Participation "State of the Act and Problems Of Agricultural Science and Education" Plovdiv. Bulgaria p. 207 – 214.
2. Chegev.(2006) Ozonizing of Grain and other Sifting Products.http://www.mediasecurity.ru/Chegev/OzonZerno.htm.
3. Lauva A., Aboltins A., Palabinskis J. (2005) Grain Active Drying Using Ozonized Air. Proceedings of the International Conference „New technological processes and investigation methods for agricultural engineering". No.10. Raudondvaris p. 322 – 326.
4. REG (2004) Technical description and using instruction, 11 pp. (in Latvian).
5. Lauva, A., Aboltins, A., Palabinskis, J., Karpova-Sadigova, N. (2006) Comparative studies of the solar material collector //Proceedings of the 5th International Scientific Conference "Engineering for Rural Development" – Jelgava, p.90-94.
6. Palabinskis, J., Lauva, A., Āboltiņš, A., Skujans, J., Iljins. U. (2007) The Material Investigations of Solar Collector. 6th International Scientific Conference„ Engineering for Rural Development", Jelgava, Latvia, p 18 – 23.
7. Trockaja, T. P. (1997) Energy Saving Technology of Drying Agricultural Materials in Ozone – Air Medium. Predprint, Minsk, BelNIIMSH, 750 pp.
8. Golubkovich, A. V., Vigodskij J. N., Bigodskaja N. J. et al. (2005) Efficiency of Using Ozone Air Mixtures in the Process of Drying Grain. Moscow, www.media-security.ru/, 04.2005
9. Krivopishin I. P. (1988) Ozone in Industrial Poultry Breeding. 2nd edition, revised and supplemented.- M., Rosagro-promizdat., 175 pp.
10. Bogatova Tatyana. (2005) Ozone-oxidizer. http://www.ng.ru/science/2005-0622/15_ozon.html.