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Informative article – comment
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ADVANTAGES AND DISADVANTAGES OF DIRECT AND INDIRECT DRYING OF MERCANTILE GRAIN AND SEEDS

PREDNOSTI I NEDOSTACI DIREKTNOG I INDIREKTNOG SUŠENJA MERKANTILNOG ZRNA I SEMENA

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ABSTRACT

The question again arises as to how to dry certain types of agricultural grain products and seeds. Should it be indirect or direct? The reason for this is the occasional fires that occur in dryers. It is often and unprofessionally stated that the cause of the fires is the use of a direct dryer. However, the causes of fires are multiple, and it is seldom due to the type of dryer. Two factors determine the differences between direct and indirect drying, and these are the nutritional and safety aspects. The ambition of this study is to clarify all the important differences between direct and indirect grain drying and to eliminate the established misconceptions on this issue. Drying of sunflower, oilseed rape and sorghum is especially delicate.
Keywords: *grain dryer, fire, direct and indirect grain dryers, sunflower.*

REZIME

Po ko zna koji put ponovo se postavlja pitanje kako sušiti pojedine vrste poljoprivrednih zrnastih proizvoda i semena. Da li da to bude indirektno ili direktno? Razlog ovome su povremeni požari koji se javljaju na sušarama, a tada se često i nestručno konstatuje da je razlog požara korišćenje direktne sušare. Međutim, razlozi požara su mnogostruki, a vrlo retko je to zbog tipa sušare. Dva faktora determinišu razlike između direktnog i indirektnog sušenja, a to su nutricionistički i bezbednosni aspekti. Presudni faktor pojava požara je nepažnja ili nestručna upotreba sušare. Suncokret se može sušiti i na indirektnim sušarama, ali se mora strogo voditi računa o adekvtanim merama bezbednosti i primerenoj tehnologiji. Požari se javljaju i na direktnim i na indirektnim sušarama. U radu se objašnjava mehanizam požara na indirektnim sušarama. Ambicija ove analize je da razjasni sve bitne razlike između direktnog i indirektnog sušenja zrna i da otkloni ustaljene zablude o ovom pitanju.
Ključne reči: *sušara za zrno, požar, direktne i indirektne sušare za zrno, suncokret.*

INTRODUCTION

Definition and description

Direct dryers are those dryers in which convective drying is performed with a mixture of air and combustion products (*Babic and Babic, 2012*). Thus, the products of combustion of fuel, used as an energy source, are present in the drying fluid (drying agent). Indirect dryers are characterized by convective drying in which the drying fluid is heated air without the presence of combustion products. Therefore, clean heated air.

Dilemmas and problems

Drying is the oldest preservation process of agricultural products. Even in the original community, the application of this technology began, so that meat and fish were dried in smoke by the fire. This was direct drying. Sun-drying was also present, which can be attributed to indirect drying because there was no contact with the combustion products. From then until today, both types of drying are used. In modern times, analyzes of the quality of food have begun, in the production of which the drying of raw materials has been applied. The presence of unpleasant odors was the first reason to eliminate the contact of smoke (combustion products) with the material being dried. However, it was later determined that heavier hydrocarbons and other organic compounds that appear in the products of incomplete combustion, if present in the dried product, can be the cause of cancer. The mass removal of direct drying as a type of drying began then due to the fear of disease. Such an approach has partially reached grain agricultural products. The professional public was divided on this issue in the 1960s when it came to grain. Namely, in then West Germany, the prevailing view was that grain agricultural products must be dried exclusively in indirect dryers. In Germany at that time, there was no corn and soybeans in production, they predominantly dried wheat, barley and oats. In France, as the leading producer of corn in Europe, and in the USA, as the leading producer of corn in the world, direct grain dryers were used. Interestingly, the division into supporters of direct and indirect drying was also present in SFR Yugoslavia. Serbia used direct grain dryers en masse, and Croatia exclusively indirect ones.

As for sunflower, there was an opinion earlier that only indirect dryers should be used for its drying. In this case, the reason for such an attitude was the fire hazards, which were more pronounced in the case of sunflowers. At the faculties of technology, teachers educated technologists that indirect drying must be used for drying sunflowers as a safer drying method. This position, in the general case, is not correct and we will make a somewhat more detailed analysis and clarification of the matter later because there are different ways of indirect drying.

The dominant drying fuel was liquid fuel, extra light fuel oil (EL) and in a number of cases heavy oil.

Poor quality burners were the reason that with direct dryers there was a problem of incomplete combustion, i.e. the appearance of residues of heavy hydrocarbons (tar) on the dried grain.

Natural gas was available to a small number of grain dryers. The large increase in the price of liquid fuel has caused the need to look for cheaper solutions for the energy source. The expansion of the natural gas distribution network was the answer to this problem. At that time (from the eighties of the last century onwards), this fuel was significantly cheaper than liquid fuel. There have been valuable and creative attempts to use renewable energy sources and coal.

Biomass as a fuel has not been domesticated in large silo dryers due to a number of technical, safety and organizational problems of use. It was concluded that biomass as a fuel can be used relatively easily and rationally on smaller energy units, except in special cases, such as seed processing centers. There have also been attempts to use geothermal water in grain dryers and to use straw bales for vertical gravity grain dryers (Hungary).

MATERIAL AND DISCUSSION

The nutritional aspects

Combustion of natural gas is relatively simple and is realized, mainly, as complete combustion. Combustion products contain carbon dioxide and water vapor as a result of combustion. None of these components (substances) are toxic or contaminate the grain. Of course, it is known that the produced carbon dioxide is harmful due to the greenhouse effect, but it is not harmful to the grain. The expansion of the natural gas distribution network to silos has led to a gradual transformation of attitudes towards the use of direct dryers. There are a large number of newer direct-type dryers in Germany. The reason for this is the tendency to reduce drying costs. Namely, indirect dryers require more heat energy than direct ones by about 10 to 25%. This loss is directly related to heat energy losses with combustion products released into the environment through the chimney. Direct dryers are significantly cheaper to invest in (up to 30%). In addition to reducing fuel consumption and lowering investment costs, there is also the argument of reduced carbon dioxide emissions into the atmosphere. The responsible professional public accepted these arguments and enabled the mass construction of direct dryers on natural gas. Furthermore, driers for liquefied petroleum gas (LPG), compressed natural gas (CNG) and biogas should be added to this category.

The question is what to do about liquid and solid fuel. Older burners on older dryers have become technically obsolete because new generations of modern burners are better. They are better because they provide quality fuel spraying in the form of equal fog droplets. In addition, turbulent mixing with air enables very high quality and complete combustion. This is very important. If we have very high quality (complete) combustion of liquid fuel, then there are no heavy hydrocarbons (herbal tars) in the combustion products that later condense on the grain. So, in this case, too, there is no fear of harmful effects on the material. It should be noted that the ratio of combustion products (according to stoichiometric balance) and added air in order to obtain a drying fluid (agent) of a certain temperature is very small. There is 20 to 70 times more air than combustion products in that mixture of fluids that dry the grain (*Babić and Babić, 2012*). This ratio depends on the type of gaseous fuel and the set temperature of the drying agent.

As for heavy oil, the issue is quite specific. Combustible sulfur is present in heavy oil to a greater or lesser extent. It can be about 2% or more. Sulfur combustion produces gaseous sulfur oxides. They will subsequently, during the flow through the grain, cool and condense on the grain itself, but also on the equipment. The presence of SO2, i.e. sulfuric acid, can be ascertained on the grain. Although this is not forbidden, it should be taken into account when trading. There is much more damage to the equipment, which will corrode quickly. Therefore, fuel oil requires very good combustion, i.e. a very high-quality burner, but also, uses heavy oil with very low sulfur content (less than 1%). It should be known that the sulfur content in fuel oil depends on the composition of crude oil used in rectification, i.e. the production of derivatives (and fuel oil) in refineries. Sulfur mainly remains in heavy oil and bitumen.

Solid fuel cannot burn with high quality on the heat air generators of the dryer. In this case, there are no dilemmas, the dryers must be indirect. When it comes to seed production, things are a little simpler. The seeds are not eaten or consumed for animal nutrition, so any residual tar on the grain (seed) is not so important. Here it is above all important to preserve germination. Germination is also important in beer barley. The temperature of seeds and beer barley must not exceed 42^{o}C. Everything previously analyzed concerned the nutritional aspects of direct grain drying.

The security aspects

The safety aspects of direct and indirect dryers will be considered here, i.e. the impact of the type of dryer on fires that occur in grain dryers will be analyzed. There are a large number of different technical solutions for indirect dryers. There are also differences in the type of heating medium in the technical solutions of the heat exchanger. Heating fluids can be warm and very hot. Warm heating media are all those with which we heat the air for drying, and whose temperature is lower than 200^{o}C. Examples are warm or hot water, dry saturated water vapor and thermal oil.

As for indirect grain dryers that use a warm heating medium, they are usually also factories that have a central power plant with the production of warm water, water vapor, or thermal oil. Typical places are oil factories, which produce water vapor for technological needs, and part of that co-saturated water vapor (usually 3-6 bar) is fed to tubular finned heat exchangers in which air is heated for drying. The ambient air, which is heated to obtain a drying agent, should not have dust or leaves in it, but even if it does, there is no great danger of ignition because the temperatures are lower than the ignition temperature (exothermic reaction). When the building of dryers in oil factories began, it was concluded that dryers should be indirect and that was the correct position, but only if the energy for heating the air for drying is realized with a warm heating medium. However, it should be noted that there are known cases of fires in such dryers (*Radmilo, 2005*). However, if the temperature of the heating medium is higher, usually over 500 ^{o}C, then it is a matter of very hot heating media.

Heating media in these cases are the products of combustion. What is the situation in such cases from the aspect of safety, i.e. possible occurrence of fire? Applied exchangers in which the air is heated by means of a heating medium are a drum, pipe, or combined system (drum exchanger + pipe exchanger). In all these cases, there is a zone in which the exchange surface is of a very high temperature. The inner sheath of the multi-pass drum exchanger (Fig. 1) is usually red-hot. The situation is the same with a simple drum firebox with a mantle for heating the air. The material of these mantles is either fire-resistant stainless steel or less often boiler sheet steel. It is important to notice that a flammable particle, leaf, husk, etc., which comes from outside, can touch the red-hot sheet metal and that will be the cause of ignition and the formation of sparks that formed in clean air. That is important to understand. The question is often asked why a fire broke out in an indirect dryer if it is safe. Similarly, a fire occurs in the case of other types of exchangers, because there are always parts of the exchanger that are heated to a very high temperature where the husk or a piece of a leaf with the surrounding air can reach. An indirect dryer with very hot

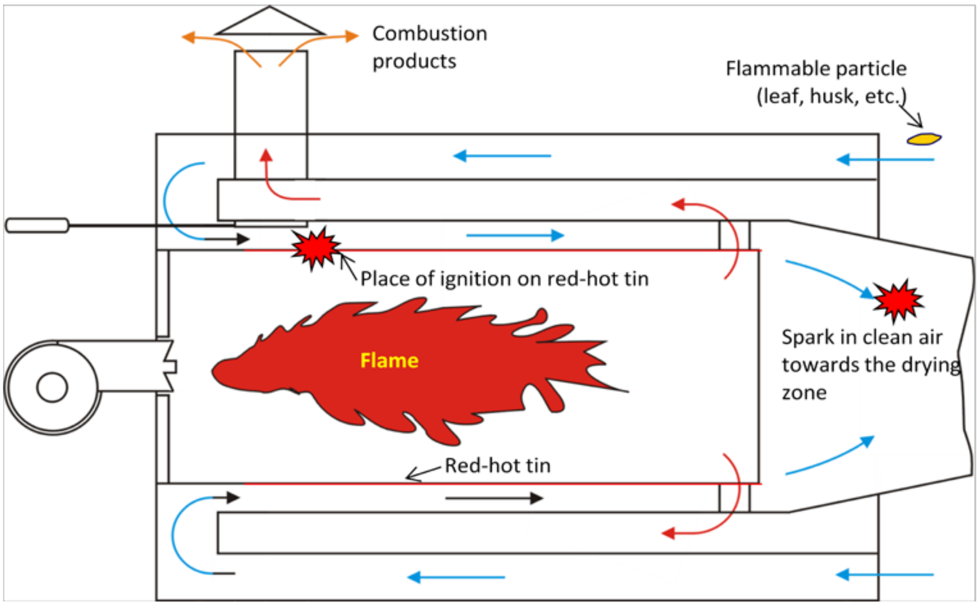

Fig 1. Demonstration of spark formation in a drum-type exchanger on an indirect dryer

heating media is almost as dangerous for fires as a direct dryer (*Poljak, 2000*).

Fire can also occur in the case of pipe exchangers, which are rare in the case of hot heating media because they are expensive and occur in combined heat exchange (example of the indirect dryer of former Serbian factory "Cer" based on combustion products).

Contemporary European dryers are almost all with partial recirculation of drying fluid (Fig. 2). In addition to them, there are two-stage dryers with air heating after the first pass by an open flame. Their safety is based on the elimination of husks in the recirculated fluid based on the closure of the airflow during the period of movement (discharge) of the grain into the bunker under the dryer (*Babić et al., 2007*). At that point, the presence of organic dust (and chaff) was reduced to less than 25 mg / m3. It is relatively safe, but in the case of sunflowers, the recirculation of the drying fluid is excluded and the dryer works as a single-pass. In this way, the possible occurrence of inflammation of the sunflower shell, which can be found in the recirculated air, is prevented. The dryer will be less energy efficient but will be safer to operate.

In addition to general safety measures, in the case of sunflowers, additional technical, technological and organizational measures are required, which are also important

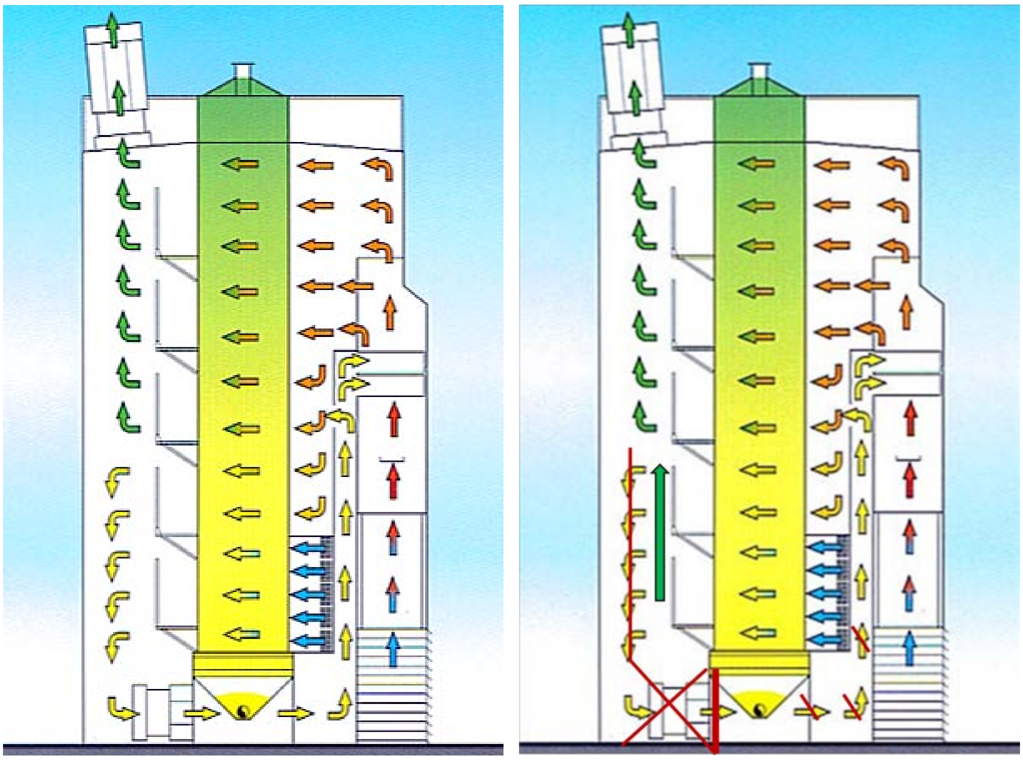

Fig 2. Direct dryer with partial recirculation of drying fluid (left - partial recirculation reduces fuel consumption and is used for all crops except sunflower; right - in case of sunflower drying partial recirculation is blocked to increase the safety of the dryer)

for the safe operation of the dryer (*Babić and Babić 2018*):

1) Use reduced airflow (grain must not be carried out into the dryer duct);

2) Turn off the recirculation fans in case of sunflower drying;

3) It is necessary to use especially low air (medium) temperatures for drying: max 65 °C. (best up to 60 °C)

4) Never fill the dryer with a sunflower that has started to ferment; the fermentation process develops a highly flammable gas. Such sunflowers should be actively ventilated beforehand;

5) Before starting the burner, the fan should run at least 45 minutes;

7) Increase the cooling time of the dryer to at least 60 minutes after drying;

8) Avoid downtime with a full sunflower dryer. If this happens, every 3 hours turn on the ventilation to work for at least 30 min. If the dryer will not work for more than 12 hours, then by recirculating the grain, dry all the sunflower present and send it to storage dried in this way;

9) Raw sunflower must be well cleaned before drying on a good grain cleaner with sieves and air separation;

10) Stop the dryer every 3-4 days (or maximum one time per week) and clean it (this is done in several hours or one shift);

11) The air entering the dryer must be clean, and for this purpose, there should be wire nets that stop leaves, husks and other larger impurities. Pay attention to the constant cleaning of these nets because they can get dirty quickly ("choke") and thus reduce the airflow, i.e. the capacity of the dryer;

12) The environment of the dryer must be clean;

13) Drying instrumentation, i.e. sensors, hardware and software must be constantly correct and checked before and during the drying season;

14) Workers must be well trained by a combination of theoretical instruction and practical work.

This applies to both direct and indirect dryers! Also, these tips should be applied to a greater extent in the case of drying other granular agricultural products.

The development of modern sensors and intelligent control reduces fire hazards. Timely registration of all important operating parameters on the dryer, but also the speed of parameter changes can shorten the time from the occurrence to the moment of noticing the accident situation (Dai et al., 2018; Dai et al., 2019). design of equipment and fire-fighting activities in case of fire (Xie et al., 2020)

CONCLUSION

There are major misconceptions about the role of direct and indirect grain drying in fire formation. Unfortunately, any fire that occurs in practice is abused by unfair competition by attributing the fire to the type and manufacturer of the grain dryer.

The analysis showed that the main causes of the fire were the technical condition of the equipment and the training of the dryer operator.

The type of dryer, i.e. whether the dryer is direct or indirect, can also participate in the danger of fire to some extent. Fires, however, occur in both dryers.

The installation of good and adequate sensors, which is an integral part of dryer automation, reduces the risk of fire. Such control systems must be fully operational at all times to ensure a high level of fire safety.

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