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THERMALSTRUDING AS AN APPROACH TO GRAIN PROCESSING AND STORAGE

Abstract

The need to maintain the thermal stability of grain at the stage of its elevator, often many hours, drying and subsequent storage limits the possibility of intensifying these processes. Shaft, column, drum and other dryers, modern granaries are bulky and energy-intensive, weakly or not at all connected with the subsequent stages of grain processing, which, in turn, are lengthy and multi-stage, which often leads to a decrease in the quality of the final product. For a cardinal solution to this problem, it is proposed to deliberately violate its thermal stability already at the stage of post-harvest drying of field grain, using the method of thermal trudging - high-speed heating, drying and explosion (swelling) of grain during its high-temperature processing in oncoming jets for 3-5 seconds. The product of thermal trudging is strudate, a grain in which raw starch is converted into dextrins and sugars, while it is disinfected from harmful inhibitors while maintaining the microelement and vitamin composition. Thus, the process of elevator drying and expensive storage of grain is replaced by thermal trudging with simplified (without drying and ventilation) floor storage of grain and obtaining a finished product of high quality or a semi-finished product used in flour-grinding, alcohol, oil-fat, and other technologies. Implementation of a new approach to the processing and storage of grain is possible on the basis of the developed technology of thermal trudging. Pilot-industrial and industrial thermal struders of two types have been created - autonomous and satellite, re-equipped on the basis of the reconstruction of standard grain dryers. In the article, various modifications of thermostruders and the principle of their work are considered. Long-term operation of thermal struders operating on flue gas heat carriers, hot air, superheated water vapor with a previously unattainable temperature up to +600 °C (even without a special task of grain drying) showed high economic efficiency, which increases when field grain is burrowed with high humidity. The versatility of thermostruders allows the use of heat-labile modes of high-intensity drying for seed grains as well.

Key words: post-harvest drying, explosion, grain disinfection, counter-jet dryer-thermostruder, elevator, technologies for deep processing of grain, heat carrier - superheated steam.

Introduction

The article will focus on scientifically and practically substantiated cardinal innovations proposed for implementation at the elevator and subsequent stages of grain processing. The traditional approach in this industry, focused on Western European and American equipment and technology, does not change the situation about its insufficient efficiency. So, already the first stage of this approach - post-harvest processing of grain in elevators, aimed at preserving its original qualities, maintaining the thermal stability of grain during drying and storage, obviously implies low efficiency of drying processes, which are key for the economy of elevator production, and entails significant costs for high-quality storage. grains. There is an unjustified break in the chain, as it turned out, capable of combining and intensifying, interrelated sequential operations to obtain the final product. And at the subsequent stages of grain processing, which are weakly or not at all connected with the first, low efficiency, multi-stage, duration of technological processes need to be intensified and reduced in their number while improving the consumer qualities of products.

The proposed new approach to the processing and storage of grain can largely eliminate these shortcomings and improve production efficiency. The main concept of innovation consists in a controlled violation, already at the stages of elevator drying and storage, of the previously unshakable rule for maintaining the thermal stability of grain. It, with only minor adjustments for subsequent technologies, is supported even in industrial elevators that are directly connected with processors and manufacturers of final products. Indeed, the preservation of thermal stability, which provides for the transfer of moisture inside the grain only in the form of a liquid, is necessary for seed grain and in some other cases, for example, in the production of malt. But this share of the harvested crop, the drying of which will be discussed separately, is incomparable with the amount of grain used for food and feed purposes and in need of further technological processing. This processing provides for the transfer of starch for cereals into sugar and dextrins convenient for further production, while maintaining the vitamin and microelement composition of the grain in an acceptable form, and for legumes - maximum disinfection. This is achieved with varying degrees of efficiency at the post-elevator stages of grain processing in the food industry (oil and fat, flour and cereals, alcohol, etc.), in the feed industry. At the same time, everyone, even a small plant for deep processing of grain, has its own elevator.

With a low level of efficiency of drying processes in modern elevator shaft, column, tower, drum grain dryers, the intensification of grain drying, combined with a useful violation of its thermal stability, which fits into the further technological process, is unattainable. In these grain dryers, it is impossible to increase the grain and drying agent above the accepted temperatures, the filtration rate of the latter through a sedentary grain layer is no more than 0.5 m/s, regime restrictions associated with grain moisture are also required, its drying time reaches several hours.

Academician A.V. Lykov, prof. I.L. Lyuboshits, the creator of the first generation of recirculating grain dryers, etc.), were actively involved in heat and mass transfer processes in capillary-porous colloidal materials, which include grain. These developments contributed to an increase in the intensity of drying in recirculating grain dryers, compared to shaft dryers, by almost one and a half times. My main scientific direction is the theory and technology of high-intensity heat and mass transfer processes in apparatuses with counter-jet gas suspension [1, 2] associated with the drying of high-moisture materials, for example, with industrial, commercially available counter-jet installations of the SHS type for thermal drying of sewage sludge and other materials. I am co-author of the Counter Jet Dryers section of the International Guide to Dryers, ed. New York [3]. The super-high intensity of heat and mass transfer in counter-jet dryers, which is unattainable even in such high-speed apparatuses as fluidized beds and wind tunnels, is determined by the hydrodynamic conditions for carrying out processes associated with an increase in the local concentration and velocity of particles relative to the gas upon collision of counter flows of gas suspension organized in a certain way. On the basis of the studies carried out, a system of high-speed apparatuses with semi-annular and reversible counter jets was developed, oriented, among other things, to drying grain [2, 4, 5]. On the basis of these developments, I invented and experimentally proved (1989) the method of thermal trudging - thermal counter-jet dextrinization of grain or thermal counter-jet impact for legumes and grain [2, 4]. Its essence is the application of an almost instantaneous (several seconds) high-temperature thermal shock (thermal shock) to each grain with an explosion or swelling in gas or steam counter-jet flows with the transition of starch into dextrins and sugar while maintaining all the beneficial qualities of the grain [2, 4]. This applies to almost all types of grain. For legumes, such as soybeans, rapeseed, as well as cereals - rye and triticale, along with complete thermal disinfection from harmful inhibitors. This heat treatment is highly effective for oilseeds such as sunflower. Thermally embossed (embedded) grain is called strudate.

An important feature of the method is that thermal trudging occurs effectively at almost any initial grain moisture content (from 5 to 45%), and the higher the grain moisture content, the higher the temperature of the drying agent can be applied. At an initial humidity of more than 18-20%, the drying rate is in the range of 1.5-4% per second, at lower humidity it does not fall below 0.5-1%/s, i.e. in one cycle, calculated in seconds, the drying of wet field grain is guaranteed. The wide range of grain moisture levels used for trudging makes the method universal, both for waterlogged grain harvested in the rainy season, and for overdried grain that usually requires special moisture in the dry season.

Storage of labor data, as well as its transportation (logistics) are greatly simplified, because the dangers associated with maintaining the breath of grain, its possible damage from insect infestation, mold, and the influence of outside temperature are eliminated. It is also possible to restore the quality of such spoiled grain, which was not previously accepted by elevators, by trudging it. The time of safe storage of vtrudat without its forced ventilation in the now proposed floor version can be calculated in several years. In addition, using the method of thermal trudging, production elevators can be directly included in the technological process of grain processing enterprises, supplying ready-made hot work for subsequent operations, which further reduces or even makes the process of cooling and storing grain in this type of elevators unnecessary. Thus, thermal elastomer solves the issue of implementing a new approach to this important industry.

Main part

The necessary data for the implementation of the technique and technology of thermal intrusion were obtained in the course of complex studies carried out earlier [2]. Comprehensive studies, in addition to scientific ones, included the creation of a series of thermostruder devices, their experimental and industrial tests. Biologists from academic and industrial institutes have developed methods for assessing the quality of wstrudate, and feed workers of specialized institutions have carried out large-scale tests of wstrudate to determine its effect on weight gain at different stages of growing cattle, pigs, and poultry (6-25%, depending on the proportion of wstrudate in compound feed). Departmental technical requirements for the inputs and standard recipes for introducing them into feed have been developed and approved. The payback of thermalstruders did not exceed one or several months with a high economic effect. From the 1990s until recently, feed mills operated thermal struders on superheated water vapor, practically analogues of the TV-3M semi-industrial thermalstruder created under my supervision [2].

With regard to the production of food products, including wstrudate, recipes have been developed and small industrial batches of confectionery products (kozinaki, sweets, sweet tiles) have been obtained in the factory. In the conditions of a small enterprise, semi-finished products, salted snacks, flakes from certain types and mixtures of strudates (wheat, barley, rice, rye, corn, flax, sesame) were produced and tasted, the trudging of full-fat soybeans, semi-finished dishes from food substitutes for meat products, was worked out.

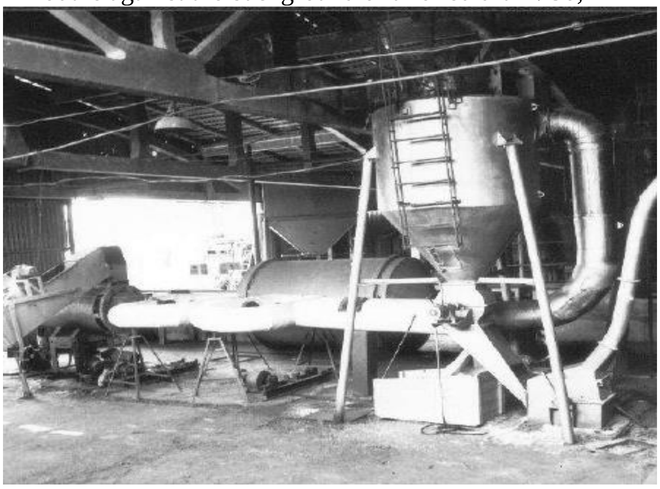
The scheme of processing and storage of grain (vstrudata) using technology and equipment for thermal trudging includes: grain drying, decontamination, husk separation, grain explosion, crushing/ flattening/ separation of the whole grain, cooling, storage, use as a semi-finished product in foodstuffs or input into animal feed.

Thermal embedding is recognized as one of the most effective methods of deep processing of grain [2]. So, notes that "thermal trudging is one of the most promising technologies for the heat treatment of grain raw materials and competes with methods such as extrusion, micronization, etc." However, it is not noted in the literature that in comparison with micronization, extrusion, explosion in a fluidized bed during thermal trudging, significantly lower maximum explosion temperatures are used under conditions of super-fast exposure time: for grain - +105-110°C, for decontamination of legumes - +90 -100°C [2]. This improves their fodder and nutritional qualities, while there are no restrictions on the moisture content of the initial grain intended for trudging, which makes it possible to simultaneously dry wet grain and explode it at any range of plant capacities, unlike other methods. The main provisions of the thermal trudging process are described in the literature [2, 6] and the German patent [4], which reflects the technological and design features of the method, and provides promising solutions for its further development.

Satellite thermalstruders.

The developed thermalstruders can be conditionally divided into two types: autonomous and satellite - attachments (separate modules) to existing agricultural dryers. For the second type, it is expedient to reconstruct both large elevator dryers (shaft, etc.) and drum dryers, which include, for example, in Ukraine grain dryers ASB-1, SESB-8A as part of the grain dryer complex KSZ-25B, universal dryers such as BSSH, AVM, etc. The still produced high-temperature pneumatic drum drying unit AVM-0.65 was taken as an object for fundamental reconstruction. Its main element is a dryer drum, where the drying of wet grain takes place in a dense layer mixed with blades. The drying time of grain varies within 30-40 minutes per pass with an allowable decrease in moisture content of not more than 5-8%. Combining it with an explosion is impossible due to the long stay of the grain in the drum at high temperatures of the coolant and the low intensity of the drying process. The reconstruction of the unit consisted in replacing a bulky, metal-intensive drum with a semi-annular two-stage modular struder, the weight of which is almost an order of magnitude less than the drum.

On Fig. 1 [2-4] shows a diagram of a reconstructed version of the AVM-0.65 dryer - a VSD - 0.8/1.2 thermalstruder and its photo (Fig. 1a) with a counter-jet module against the background of a rolled drum. So, in



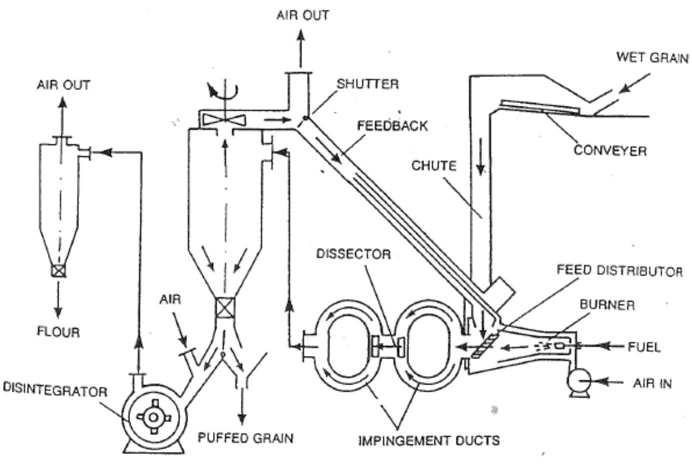


Fig. 1. Scheme of the VSD-0.8/1.2 thermal struder (reconstructed unit AVM-0.65)

Switzerland, for example, the well-known company SWISS Combi produces Dryer HTD units, an analogue of the units of the ABM series, which, like the drum dryers of the German company Stela and Rotary Dryers of the English company Alvan Blanch, can be reconstructed in a similar way.

The thermal strut module includes two stages of oncoming jets, made in the form of elongated toroids, flow dividers, a modified grain supply unit. It is possible to withdraw wstrudate in its entirety after a large cyclone or transfer it into flour after a disintegrator and a small cyclone, the fan of which is not shown in the diagram. At the request of the customer, the dryer can be equipped with a built-in peeler or a vtrudata conditioner. Energy consumption for grinding, flattening or peeling it is several times less than unexploded grain, and cooling is easier and faster due to an increase in the porosity and surface of the strudate by 1.5-2 times.

Tests and industrial operation of VSD-0.8/1.2 showed that the unit is efficient, simple and reliable in operation. It provides two options for grain processing. In the off-season (about 10 months of the year), grain coming from the elevator was trudged on it, and then it was sent, often still hot, to farms for feeding. During the harvest season, either a drum was re-installed (within two hours) for traditional seasonal drying of grass, grain waste, etc., or dry field grain was dried on a pilot scale at VSD-0.8/1.2, grass cutting, mechanically dehydrated agricultural products. At the same time, it was obtained from grain at a drying rate of up to 4%/sec. ready-made vstrudat [2], when drying high-moisture grass cutting alfalfa up to 9.5%/sec. - dry grass flour [2], when drying mechanically dehydrated potatoes up to 15% / sec. - dry potato flour [2], when drying meat and bone waste up to 7% / sec. — dry fodder meal. In all cases, the drying rate increased compared to the drum version, and the time decreased by about two orders of magnitude. As for grain, the main phase of its explosion took place in the stages of oncoming jets and ended with vertical ascending pneumatic transport in a pipe connecting the stages with the main cyclone, and a high degree of explosion (1.5-2.5) and dextrinization (30-50 %) of grain [2]. The consequence of this was increased feed intake and weight gain of young pigs up to 20-25%. If necessary, cooling of strudata, unlike grain, can be safely carried out in a struder-cooler to temperatures of + 20-25 °C higher than the outside air temperature, while replacing, for example, a drum cooler used in a mobile drum unit SZPB -2,5. The super-fast cooling of the wstrudate additionally reduces the moisture content of the grain and increases the degree of its explosiveness.

Another version of the developed module [7] used in the reconstruction of the AVM-1.5 unit is shown in Fig. 2.

A feature of the module of the reconstructed AVM-1.5 unit, which replaced the drum, was that the proposed design of the pneumatic tube is made sectional with parallel and horizontal placement of sections connected by semi-annular nozzles, and the sections are equipped with impact oncoming flow swirlers of a special design that provide oscillatory movements, swirling and braking grains in the flow of high-temperature coolant carrying them. As a result of such a complex effect

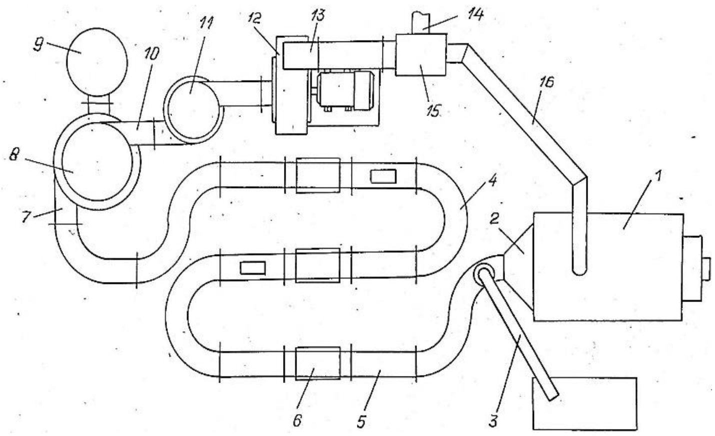


Fig. 2. Scheme of the installation for thermal trudging of grain UTZ-1 (reconstructed unit AVM-1.5): 1 - heat generator, 2 - outlet pipe, 3 - grain feeder with outlet pipe, 4 - semi-annular pipes, 5 - pneumatic pipe sections, 6 - unit with counter impact swirler, 7 - cyclone inlet pipe, 8 - cyclone, 9 - blasted grain - vstru-data, 10 - cyclone outlet, 11 - grain husk precipitator, 12 - fan, 13 - fan outlet, 14 - flue gas pipeline, 15 - control valve, 16 - recirculation pipeline

on wet grain, the difference in gas velocity with respect to particle velocities sharply increases, respectively, the intensity of interfacial heat and mass transfer increases, and the exposure of the process is sufficient for drying, heating, and explosion of grain. The UTZ-1 installation was successfully functioning, issuing industrial batches of labor for feeding livestock and other farms. Thus, the tests and operation of VSD-0.8/1.2 and UTZ-1 showed that both plants ensured the production of similar quality wood with approximately comparable fuel consumption per unit of finished product.

The possibility of high-temperature drying of coarse chips (2-3 mm) to a moisture content of 8-11%, revealed in experiments, can increase the efficiency of installations. Drying time was a few seconds. At the same time, an increase in the porosity of the chips was noted, which contributes to its more efficient combustion. Dry hot chips can be fed into the pellet press of now reconstructed units, obtaining pellets that serve as a relatively cheap fuel for heat generators during the processing of grain into wood.

Let us consider the real possibility of using satellite thermalstruders for the reconstruction of the most common class of elevator grain dryers, united by the presence of a dense, slow-moving falling layer of grain blown by a drying agent. These include mine, column, gas recirculation and some other grain dryers. In some cases, partial reconstruction, for example, of low-intensity mine grain dryers, is carried out by transferring them to gas recirculating grain dryers in order to increase their efficiency. Thus, the Tselinnaya 50 grain dryer was created on the basis of the reconstruction of the mine EAF-24 CH. On the other hand, historically gas recirculating grain dryers were the object of a partial reconstruction of the first generation of pneumogas recirculating grain dryers developed at ITMO ANB. Gas recirculating grain dryers differ from pneumatic-gas recirculating grain dryers by transferring grain heating and drying in the pneumatic transport mode to heating it in a heating chamber in a falling, mechanically inhibited grain layer in countercurrent to a high-temperature heat carrier. In practice, the heating of grain in the chamber does not exceed + 10-18 °C, and the drying of grain in it is limited to 0.1-0.25% per pass. With multi-cycle drying in one cycle lasting 10-15 minutes, the grain reduces moisture by about 2%, and the maximum temperature of the grain during the entire drying does not exceed + 40-60 °C. Despite this, such a transfer was economically justified for the conditions grain drying only. In the proposed variant of the combination of drying and trudging of grain, the implementation of which is impossible in grain dryers of the Tselinnaya type, the experience of research and operation of RS-10 pneumogas grain dryers is used. It studied the patterns of heat and mass transfer during vertical high-temperature pneumatic transport of grain, which are typical for such dryers. The re-equipment of drum dryers into struders (dryers-struders) proved the efficiency of drying and trudging grain by combining high-temperature treatment in pneumatic transport and counter jets. On this basis, a scheme of a satellite thermalstruder operating on the basis of the reconstruction of a pneumogas recirculating grain dryer, proposed for implementation, was developed and described in the patent [4] (Fig. 3).

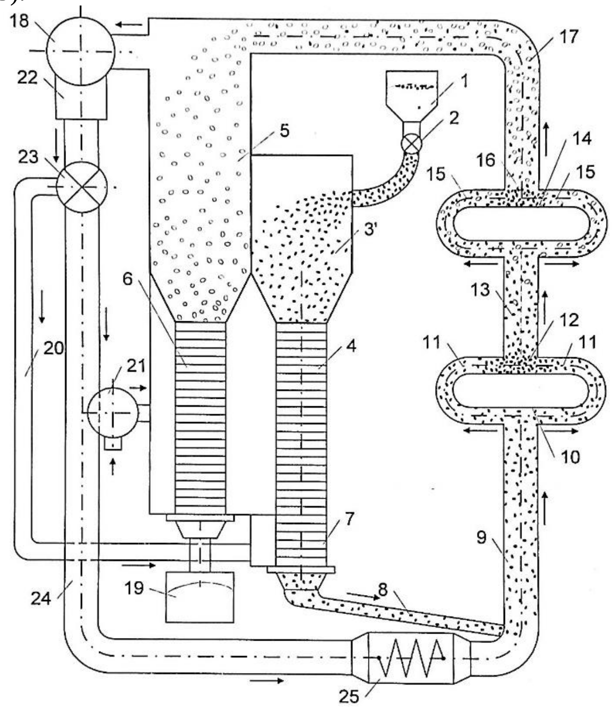


Fig. 3. Scheme of a thermal struder (reconstructed version of a pneumogas recirculating dryer): 1 - initial grain feeder, 2 - auger, 3 - first (small) expander, 4 - shaft of falling initial grain, 5 - second (large) expander, 6 - vtrudat shaft, 7 - lower section of shaft 4, 8 - elevator, 9 - vertical pneumatic tube, 10 - lower stage of oncoming jets, 11 - accelerating tubes, 12 - jet meeting chamber, 13 - first outlet pipe, 14 - second stage of oncoming jets, 15 - accelerating pipes of the second stage, 16 - the second chamber of the meeting of the jets, 17 - the second outlet pipe, 18 - the main fan, 19 - the bunker of the finished product (vstrudata), 20 - the heat carrier pipe to section 7 of shaft 4, 21 - the second fan, 22 - pressure pipe fan 18, 23 - control valve, 24 - recirculation pipe, 25 - heat generator

Two-stage counter-jet pipes are mounted in a vertical pneumatic pipe, which provides the necessary degree of drying and explosion of grain preheated in the mine during 4-6 seconds in the high-temperature and high-intensity mode of the process. or, respectively, heating, drying and disinfection of legumes. The contact heat and mass transfer chamber now loses its function, turning, if necessary, into a holding chamber, where the grain explosion intensifies. The chamber is divided by a partition into two expanders. Raw grain enters the small one for pre-heating in the shaft from the heat of the cooled hot strudate, deposited before that in a large expander. In the lower section of the shaft, the original grain is heated due to the heat from contact with the part of the recirculating coolant removed from the installation. Both shafts are combined in one housing and are blown sequentially with outside air.

Another promising version of a satellite thermal struder operating on the basis of the reconstruction of a pneumogas recirculation dryer is also described in the patent [4]. Its peculiarity is that pre-heating and drying of raw grain is carried out by means of a cooling hot strudate in a contact heat and mass exchanger, and to separate a mixture of grains differing in specific gravity and volume, vibrating screens are used, for example, pneumosorting tables of the SPS series by OLIS. The installation turns out to be less energy- and material-intensive, but it requires a more significant reconstruction of the Tselinnaya grain dryer. With such a reconstruction, pneumogas dryers-struders cease to be recirculating, with the exception of the heat treatment of high-moisture corn in them. In this case, it is possible to use a repeated cycle of its heat treatment by moving the finished product from the bunker with a recirculating elevator to the feeder to complete the drying and explosion of the grain. The variant of this recirculation can also be used for heat-labile modes of drying seed grain.

Thus, the advantages associated with the use of satellite thermal struders are a sharp increase in the intensity of drying, a reduction in the technological chain for turning grain into a finished product of added quality, a reduction in energy costs and an increase in the efficiency of the reconstructed grain dryers. At the same time, it is necessary to take into account the increase in the productivity of the now dryer-struders, the reduction in the cost of cleaning the grain supplied for drying, the guaranteed uniformity of processing of each grain, the increase in fire safety, the simplicity and reliability of the installation control. Due to the simplified storage of vtrudat, it is possible to use cheaper floor-type granaries. The implementation of the proposed innovations will lead to a significant reduction in the payback period for elevators, which now reaches 8-12 years.

Autonomous thermal struders.

Another (non-satellite) autonomous type of thermal struders is also important for the further implementation of the new approach to grain processing. Autonomous thermal struders with semi-annular and reversible counter jets were developed, researched and patented in due time, using hot air and superheated water vapor as environmental coolants [2, 4]. It is known that many Western countries are already refusing to use direct contact of grain with flue gases, using intermediate heat exchangers, despite the decrease in efficiency. Another option for generating a "clean" coolant - hot air - is used in the VSD-0.15/0.2 thermostruder.

On fig. 4 shows a simplified diagram of an autonomous thermostruder VSD 0.15/0.2 with a capacity of 150-200 kg/h (heat carrier - hot air), and in fig. 5 - his photo. In the center of the photo is the cylindrical-conical body of the thermal struder 3 itself. Inside it, in the cylindrical part, semi-annular multi-stage counter channels are located, below which there is a conical settling chamber. The operation of such a compact thermal struder is as follows. The air entering the fan 6 is heated in the electric heater (heating heater) 7 to a temperature of + 250-350 °C, it is sent through the pipeline 9 to be mixed with raw grain from the feeder 10 and in the form of a gas suspension goes to the sequentially installed sections of the accelerating channels of the thermal strut 3. Dried and exploded grain (strudat), partially or in a full chamber, and is removed from the struder through the gate 2, which can be made in the form of a gate-crusher. The exhaust air is sent through pipeline 4 through the husk precipitator 5 to the fan 6. This enlarged experimental thermalstruder was used to test the modes and produce batches of grains and legumes of various crops, on the basis of which experimental series of food were created products.

A more efficient version of the stand-alone thermalstruder KTDZ-500 in hot air with a capacity of up to 500 kg/h (Fig. 6) was produced in Odessa under my scientific supervision by the NPO Demetra enterprise. Its peculiarity is the use of semi-annular accelerating pipes

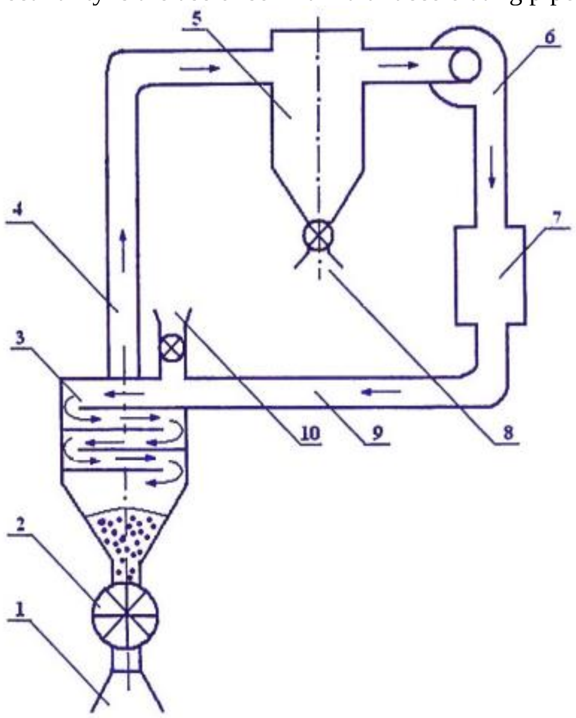


Fig. 4. Scheme (simplified) of an autonomous thermalstruder VSD 0.15/0.2: 1 - outlet pipe of the finished product (vstrudata), 2 - shutter-crusher, 3 - block of channels of oncoming jets, 4 - recirculation pipeline, 5 - grain outlet cyclone husks, 6 - fan, 7 - heat generator, 8 - outlet valve of the grain husk cyclone, 9 - heat transfer pipeline, 10 - raw grain feeder

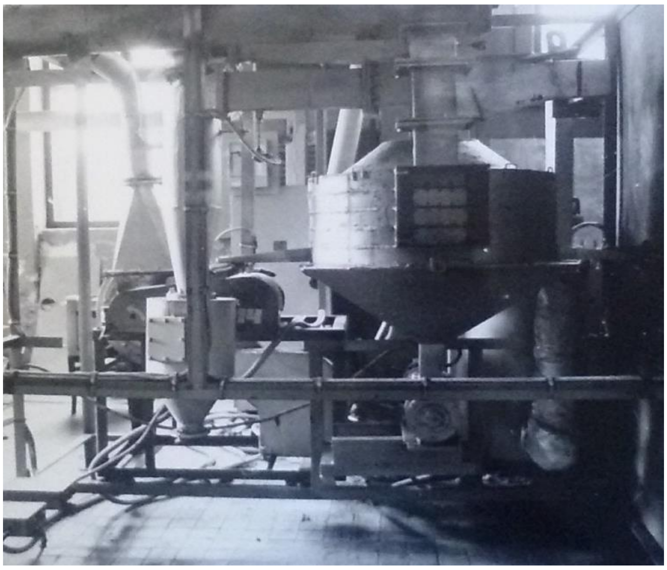


Fig. 5. Photo of an autonomous thermostrude VSD 0.15/0.2

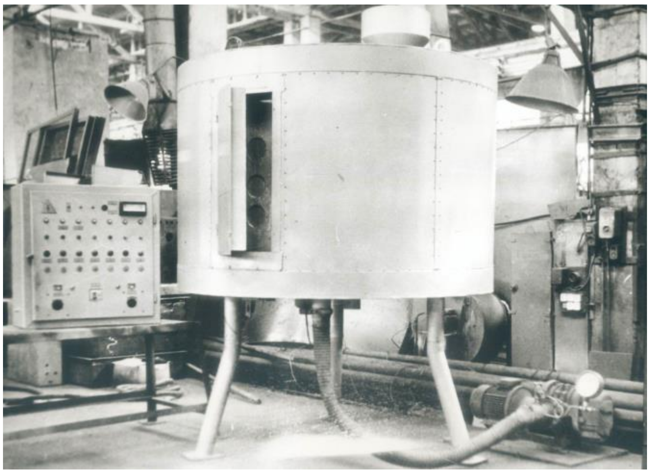


Fig. 6. Photo of the autonomous installation KTDZ-500

of circular cross section and the presence of a heat exchanger-recuperator. These thermalstruders functioned in several farms of the Odessa region. Both variants of autonomous thermalstruders can be easily scaled up without a significant increase in dimensions in installations with increased productivity and in this case, for example, are used in farm elevators.

The heat carrier is superheated water vapor. Growing requirements for the quality of grain products in the food industry, and more recently in the feed industry, combined with the need to increase the efficiency of grain dryers and subsequent grain processing devices, can be largely resolved by using the most environmentally and economically most efficient "clean" heat carrier — superheated water vapor [2, 4]. Compared to another "pure" heat carrier - air, not to mention flue gases, superheated steam has a number of obvious advantages: higher heat transfer coefficients between superheated steam and grain, higher specific volumetric heat capacity of steam, the possibility of using increased initial temperatures of the coolant, which allows reduce the dimensions of the installations, reduce the consumption of the drying agent. The speed of grain drying in the environment of superheated steam increases significantly, which leads to an increase in its nutritional and fodder qualities. In addition, there is very low environmental pollution. A particularly important factor is the possibility of increasing the temperature of the coolant. In our experiments, it was possible to increase it to +550-600°C, achieving a superfast grain explosion. Such an increase in the temperature of superheated steam under conditions of high-speed drying is possible due to the absence of an oxidizing environment that degrades the quality of the processed grain. So, during thermal trudging of grain in the environment of flue gases or air, the maximum allowable initial temperature of the coolant did not exceed +350-400°C. In addition to these factors, the basis for the practical use of superheated steam in grain embedding technology is its successful application in other technologies (beet pulp and pulp drying), as well as proven standard operations for the food and feed industries (devices for loading and unloading grain processed steam). In the West, the production of drum dryers operating on superheated steam has already been mastered (SWISS COMBI, W.Kurz Drytec AG, etc.).

For the first time in 1990, the efficiency of drying and embedding grain in an environment of superheated water vapor was proven using the patented universal thermostruder OS-6 [2]. Thermal struder connected to the steam and air systems of the plant, operating according to the scheme of Fig. 4, made it possible to obtain batches of strudat using both hot air and superheated steam as a heat carrier. At the same time, high-intensity drying of wet meat and bone raw materials was also tested to obtain dry fodder meal and peat and fat additives, which are especially sensitive to drying in an oxidizing environment (air). At the Ekomol feed mill, a TV-3 thermostruder was installed (Fig. 7) [2] with a productivity of up to 1 t/h, and then a TV-3M thermo-struder with a productivity of up to 2 t/h, which replaced it, which produced on an industrial scale strudat for more than ten years and

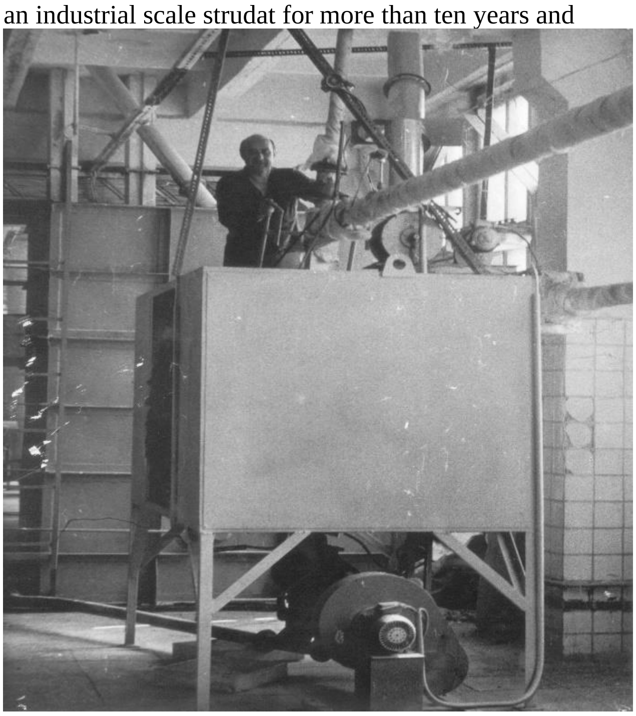


Fig. 7. Photo of the factory experimental industrial thermostruder TV-3

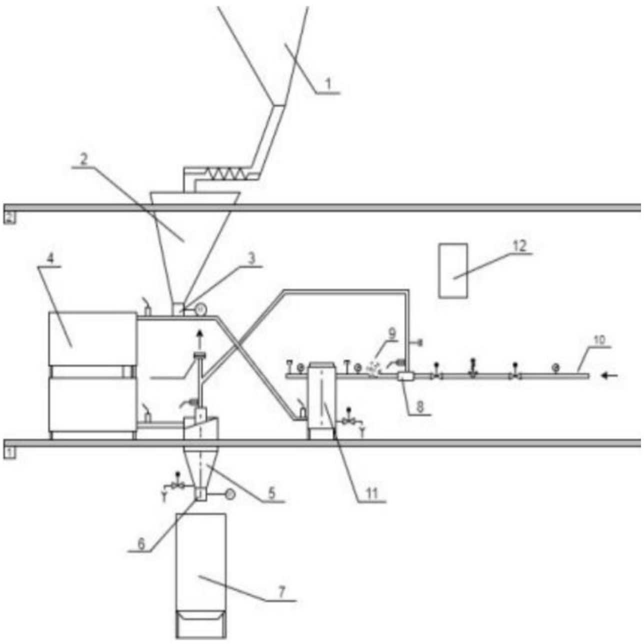


Fig. 8. Scheme of the factory experimental industrial thermalstruder TV-3M: 1-network hopper with a screw feeder, 2 - grain input hopper, 3 - sluice gate, 4 - thermalstruder, 5 - cyclone, 6 - sluice feeder, 7 - cooling chamber , 8 - ejector, 9 - fan, 10 - steam line of the factory network, 11 - electric heater, 12 - control panel.

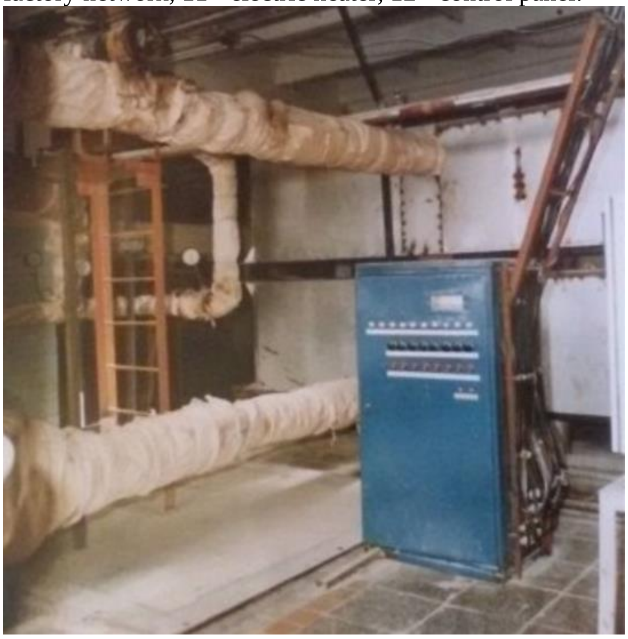


Fig. 9. Photo of the factory thermostruder TV-3M

served as a close, almost copied prototype to industrial thermal struders. The scheme of the TV-3M thermostruder is shown in Fig. 8, a fragment of its general view in Fig. 9.

In the diagram - a "semi-satellite" thermalstruder, partially using the infrastructure of the plant. The installation works as follows. The grain is fed into the network hopper 1 with a screw feeder, from where it is portionwise fed into the hopper 2 and is introduced into the steam pipeline using a sluice feeder 3. The resulting vapor suspension is sent to the first counter-jet stage of the thermalstruder 4 and sequentially passes through its four stages. During the movement of the vapor suspension in the mode of oncoming jets, an explosion or swelling of grain occurs, disinfection of legumes. After the thermalstruder 4, the vapor suspension enters the cyclone 5, where the finished product is separated from the steam and enters through the sluice feeder 6 into the cooling chamber 7, from where it is sent to the factory storage bins and further to the preparation of compound feed. Cooled steam from cyclone 5 branches into two streams. A smaller part of it is thrown out of the plant and used for the technological purposes of the plant. The main part of the steam is sucked into the discharge line of the installation through the ejector 8 or the fan 9 (their joint operation is possible). After the fan, the cooled steam enters the electric heater 11, where it overheats to the technologically specified temperature and then goes to the feeder 3. The operation of the installation is controlled by the operator using the remote control 12.

The features of the TV-3M unit include: a semi-closed coolant circulation system, a multi-stage counter-jet system using accelerating channels of circular cross section located at an angle to the horizontal, an original design of the superheater, grain inlet and outlet units, a reconstructed fan for pumping high-temperature superheated steam, now equipped with remote bearings and a water jacket. On the TV-3M plant, the modes of industrial strutting technology for cereals - barley, wheat, rye, triticale, legumes - soybeans, rapeseed, as well as rapeseed meal were worked out (for corn, rice, sunflower, the conditions for trudging were determined on other types of thermalstruders). The main characteristics of the technological process are summarized: the trudging time is 3-5 seconds, the average temperature of the type carrier - superheated water vapor is +300-450°C (the initial temperature reached +550°C), the degree of grain explosion is 1.5-2.5 (for legumes - decrease in bulk density by 1.1-1.4 times), the degree of dextrinization is 35-50%, the degree of reduction in the content of trypsin inhibitors in legumes, rye and triticale is up to 85-100%, and the content of glucosinalate is up to 80% [2].

It should be noted that grain with a moisture content of about 14% comes from the technological elevator to the feed mill, in this case with the task of trudging, during trudging it drops by 5-6% (drying due to the explosion of grain) and under these conditions the process of trudging is economically justified. If you combine the simultaneous drying of field grain and its trudging in TV-3M, solving the issue of moisture drop to the technologically specified, and so the high economic effect increases significantly. Instead of feed mills, with some adjustment for the peculiarities of technologies, distilleries, oil refineries, flour and cereal enterprises can be involved.

Successful grain embedding in a steam environment justifies the possibility of replacing the drum in foreign dryers operating on superheated water vapor with satellite "inserts". In particular, technical proposals were prepared for the Swiss company SWISS COMBI, which produces Drum Dryer ecoDry (SSD) dryers, which can be easily reconstructed without violating the well-established infrastructure associated with the specific use of superheated steam.

In the future, it is proposed to consider the possibility of replacing flue gas coolants or even hot air with superheated water vapor in thermalstruders based on reconstructed pneumogas and recirculating dryers. The closed circuit of superheated steam circulation, carried out by the main fan 18 (Fig. 3), will provide an increase in the drying rate and quality of the wood, fire safety and the absence of grain dust emissions into the atmosphere, reduce the dimensions of the installation and increase its productivity, which will more than compensate for the problems associated with the development new infrastructure. Moreover, taking into account the existing practice of transferring mine grain dryers to Tselinnye, it may be justified to reconstruct mine grain dryers into thermalstruders already on the basis of pneumo-gas recirculating grain dryers with superheated steam as a coolant.

In Ukraine, one of the options for implementing the technology of thermal trudging can be, due to the experience, elevators at feed mills. For example, the enterprise SOOO "Promin" located in the Nikolaev region, where the elevator is connected to the plant by a straight line. On the basis of raw grain embedding, an economically beneficial, deeper combination of the functions (infrastructure) of the elevator and the plant will occur.

Reversible thermalstruders. In the technology of thermal trudging, the quality of the workpiece is of great importance. Semi-annular direct-flow thermalstruders allow you to control the temperature and speed of the coolant, however, their design features limit the time the grain stays in the installation, which does not always make it possible to achieve its optimal quality. The problem is solved by the reverse version of counter jets, which provides high-temperature heat treatment of grain for an adjustable (arbitrarily long) time in a given mode [4-6]. Its essence consists in timed recirculation of grain between two zones (chambers) of oncoming jets alternating with the help of a flow switch. The scheme of the pilot industrial thermalstruder (dryer-struder) UVS-5 with a capacity of 200 kg/h is shown in Fig. 10.

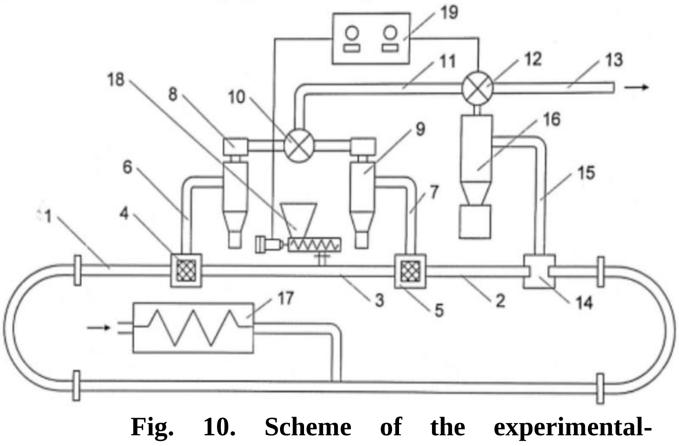


Fig. 10. Scheme of the experimental-industrial reversible thermostruder UVS-5: 1.2 - peripheral accelerating pipes, 3 - central accelerating pipe, 4.5 - jet meeting chambers, 6.7 - outlet pipes, 8.9 - cyclones, 10 - switch flows, 11 - branch pipe, 12 - second flow switch, 13 - outlet line, 14 - non-lattice jet meeting chamber, 15 - outlet pipe, 16 - additional separator, 17 - heater, 18 - grain feeder, 19 - control panel

The chambers for meeting the jets in combination with switches provide a predetermined time for the circulation of the next portion of moist unhulled grain in the heat carrier flow, a large cyclone - the release of the finished product, and small cyclones - the continuous removal of the husk formed due to the collision of the grains with each other and with the working surfaces. Desquamation is intensified in the case of heat shock on the grain (almost instantaneous drying and chipping of the shell of some types of cereals and legumes). The mode of heat treatment of grain in a reversible thermal studio is continuous-batch.

About the heat treatment of wet corn. Proven in practice, as well as promising options for reversible thermalstruders are described in the patent [4].

Like semi-circular, they are effective for drying, disinfecting, explosion of any kind of cereals and legumes, but are especially suitable for heat treatment of wet corn, the large size of the grains of which and the presence of a dense shell, lengthen the drying time by several times compared to other types of cereals. A high-intensity reversible version of thermalstruders, which has common features with a fluidized bed, but is much more efficient, requires time for its development and industrial development. In terms of a new approach to corn processing, it is proposed as an option to convert the fluidized bed dryers used in Ukraine to corn explosion drying. These include the previously operating grain dryers "Tselinnaya 100" and the currently used "Ukraine 1", a series of installations "MIG", imported ones - "Alvan Blanch" (dense, easily transferred to a fluidized bed of grain), the DF series of the company "Petkus".

The effectiveness of such a transfer, which does not require a large reconstruction of installations, is confirmed by many years of experience in the use of a fluidized bed for grain explosion (without a drying task) in the Jet Sploder installations of a large American company California Pellet Mill Co., which has shown interest in thermalstruders as an alternative to " Jet Sploder" (business contacts with a firm with a joint patent proposal). As noted, recirculating thermalstruders based on a pneumogas grain dryer can serve as another option for effective drying and explosion of corn, which can also be used for thermolabile drying of seed grain using storage in a large expander hopper (Fig. 5). The high intensity of heat-labile drying of seed grain was also proved in reversible thermalstruders, which is an order of magnitude higher than that in fluidized bed installations [2, 4]. This makes it possible to dry such grain even with air of external temperature at its humidity not exceeding 70% or at thermolabile temperatures of the heat carrier not exceeding the external one by 20-30°C. In addition, reversible thermalstruders dry seed grain in a pulsating mode in terms of temperature and speed of the coolant with high-frequency grain resting in a dense layer, alternating with the movement of grain in oncoming jets. At the same time, no decrease in seed quality of grain was noted.

Once again about the advantages of thermal trudging. The new approach to grain processing makes it possible not only to dramatically increase the efficiency of the first post-harvest stage, to organically include new types of elevators in the structure of enterprises, but also to obtain a higher quality end product. Vtrudirovanie, as noted, has significant advantages over the most commonly used high-temperature extrusion and micronization, at which the product temperature reaches +180-200°C, the total processing time is calculated in minutes, the moisture content of the initial grain should be within narrow limits, and the productivity of the plants is limited. When trudging, the grain processing time is reduced by about an order of magnitude, its maximum temperature decreases by + 50-80 °C, any initial humidity is acceptable, which means that strutting can be carried out already at the stage of drying (harvesting) of field grain, including in large-scale plants. performance. In addition, due to the processing of grain calculated in a few seconds, the highest temperature of the heat carrier is applied. So, for superheated steam, it reaches +550-600°C, which is economically and environmentally beneficial. At the same time, the destruction of nutrients and lysine, which is sensitive to temperature and pressure increase, and the denaturation of fatty acids do not occur in the strudate. Technologies have been developed for the use of vtrudat in the feed industry and, partially, in the food industry [2].

On new structural technological schemes for obtaining products.

Flour and cereal industry

On Fig. 11 shows a diagram of the production of food products from composite grain mixtures. Long-term hydrothermal treatment (HTT) of grain, divided into a number of independent processes (Bühler, OLIS technologies, etc.), is replaced by combined in time and performed in one unit operations of mixing the components of the grain mixture, drying, disinfection, trudging, partial or complete peeling, which occurs when wet grains collide in the oncoming jets of the thermalstruder and in the shelling device built-in, if necessary, into the strudate precipitator.

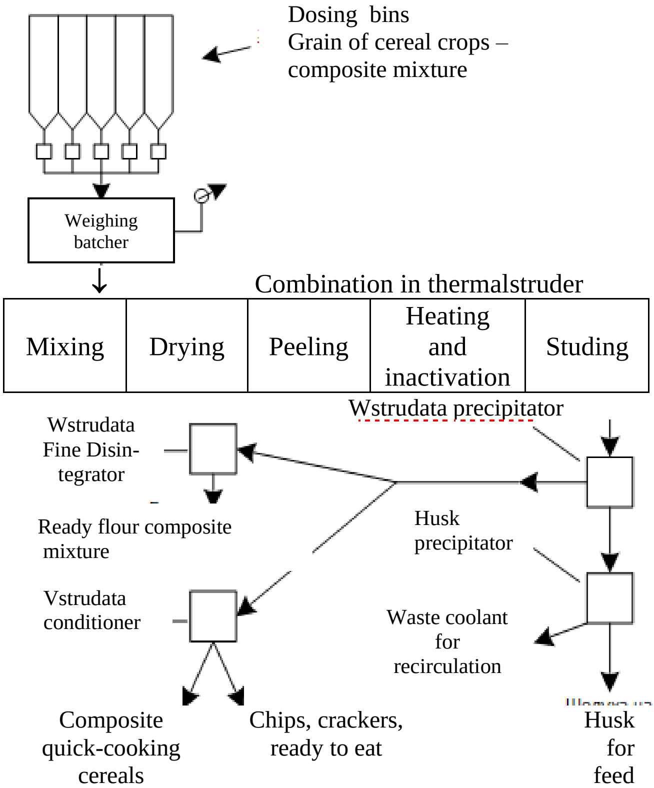


Fig. 11. Structural scheme for obtaining food products of high quality from composite grain mixtures

The time of these operations (no more than 10-20 seconds) is two orders of magnitude less than the standard GTO. An additional advantage for flour milling is the refusal to pre-grind each component separately before feeding it to the dosing bins. Now the low-cost grinding of already a mixture of embedded components takes place in the disintegrator. The mixing of the mixture components in a thermalstruder, as in an apparatus with counter jets [1], occurs an order of magnitude faster than in modern mixers (Bühler, Ukrainian mixers of the ST K, DST type).

Oil processing industry

According to the developed schemes for obtaining oil from legumes, options for the implementation of the process are proposed: one-stage using the trudging method and two-stage using double pressing: at the first stage - thermal trudging (instead of extrusion) with hot forepressing and at the second stage - extrusion with final pressing. In both versions, the preparation of the extraction of oil from legumes is carried out by combining peeling, drying of the beans, swelling and heating them with inactivation in the thermal shock mode in a thermalstruder with a heat carrier of high-temperature superheated steam. The grinding of the strudate is carried out preferably in a steam environment. Thermal trudging is carried out on modes that guarantee the absence of re-disinfection of cake and meal before their use.

Alcohol industry

A technological scheme for the implementation of a complex technology for the production of ethyl alcohol from grain raw materials has been developed. The proposed technology provides for a cost-effective combination of grain preparation for cooking (heating, trudging, peeling, grinding) with mechanically dehydrated stillage drying and mixing it with husks in one apparatus (the disintegrator is built into the thermalstruder). High-temperature superheated steam is used as a heat carrier. In addition to the explosion (trudging) of the grain, a repeated explosion of the already boiled mass of the batch is carried out. The technology will provide a more active effect of enzymatic preparations, a reduction in the fermentation period and an increase in the alcohol yield by approximately 10%. Drying bards and husks in a non-oxidizing environment will increase their digestibility and nutritional value.

Brewing industry

According to the proposed technological scheme, the heat-labile drying of raw barley grain is carried out in a universal thermalstruder, which, by changing the processing modes, is able to dry germinated grain (malt) with an initial moisture content of 41-48% to a final moisture content of 4-5%, to roughen (roast) it, at the same time separating the sprouts (instead of a special sprout separator) in the counter-jet flow of the thermostruder coolant. Exploded grain is crushed to a state of coarse flour with significantly reduced energy consumption. With the combined use of malt and unmalted grain, which is subjected to trudging, the biochemical effect of malt enzymes on biopolymers is enhanced. This technology will improve the economy and quality of the final product.

Feed industry

Figure 2 shows one of the developed schemes of thermal struder dryers for obtaining compound feed for cattle, pigs and poultry directly from field wet grain. The use of such schemes will provide even higher economic efficiency of feed production, which is currently based on the trudging of grain dried in an elevator. Thermostruder dryers are especially advantageous for farms.

Related industries

Innovative schemes have been developed in the integrated technology for the production of beet sugar, alcohol and compound feed (drying in a steam struder stillage, molasses and pulp, thermolabile drying of crystalline sugar). In the starch-treacle production of grain and potato starch - drying of starch, grain germ in a thermalstruder with superheated steam without an intermediate heat carrier. A scheme of co-drying, mixing and thermal trudging of fodder grains, plant wastes with a dense fraction of mechanically dehydrated manure with their subsequent pelletization and use in the form of feed is proposed.

Conclusion

The successes of Ukraine and other countries in the field of increasing the yield of grains and legumes are largely leveled due to their losses and spoilage during processing and storage. This problem is associated with the food security of mankind and the question of its innovative solution is raised at international forums, in the programs of the FAA (a special UN organization). Meanwhile, progress in this area is hampered by the impossibility noted by experts to significantly intensify the low-efficiency and long-term processing of grain in elevator dryers and at subsequent stages of storage and processing.

A new innovative approach to the processing and storage of grain has been proposed and developed, based on high-temperature short-term and super-intensive drying in the counter-jet mode, first of all, of raw field grain (the issues of drying seed grain are solved along the way). Drying is accompanied by an explosion, disinfection of grain (now vstrudata), its conversion into easily digestible forms, which are then used as a final product or semi-finished product in a number of grain processing technologies. If necessary, these operations can be supplemented with high-speed peeling or crushing of grain, mixing of components of processed grain composite mixtures. All these operations, according to the developed technology of thermal embossing and its hardware design, are performed in one installation. Thermalstruders are designed in autonomous and satellite versions, they can use flue gases, hot air, superheated water vapor as a heat carrier. The latter makes it possible to carry out heat treatment of grain at super-high temperatures, which provide an additional improvement in the quality of the product, environmental friendliness and cost-effectiveness of the process. The creation of satellite dryers-struders based on the reconstruction of existing elevator (mine, gas recirculation, drum) grain dryers will allow combining the functions of an elevator and enterprises for the subsequent processing of grain. This will simplify and thereby dramatically reduce the cost of grain storage and processing. In particular, its long-term multi-stage processing is replaced by a single-stage one (in one unit). The self-contained semi-circular and reversible struder dryers, developed and proven in practice, serve the same purpose, universal in use, for example, in farms.

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ТЕРМОВСТРУДУВАННЯ ЯК ПІДХІД ДО ПЕРЕРОБКИ ТА ЗБЕРІГАННЯ ЗЕРНА

Анотація

Необхідність підтримки термостійкості зерна на етапі його елеваторного, часто багатогодинного, сушіння та подальшого зберігання обмежує можливості інтенсифікації цих процесів. Шахтні, колонкові, барабанні та інші сушарки, сучасні зерносховища громіздкі та енерговитратні, слабко або взагалі не пов'язані з *наступними етапами переробки зерна, які, у свою чергу, тривалі та багатостадійні, що часто призводить до зниження якості кінцевого продукту. Для кардинального вирішення цієї проблеми пропонується вже на етапі післязбирального сушіння польового зерна цілеспрямовано порушити його термостійкість, застосувавши метод термовструдування - високошвидкісного нагріву, сушіння та вибуху (спучування) зерна при високотемпературній обробці його у зустрічних струменях протягом 3-5 сек. Продуктом термовструдування є вструдат — зерно, в якому сирий крохмаль переведений у декстрини та цукри, при цьому здійснено його знезараження від шкідливих інгібіторів при збереженні мікроелементного та вітамінного складу. Таким чином, процес елеваторного сушіння і дорогого зберігання зерна замінюється термовструдуванням зі спрощеним (без досушування та вентилювання) підлоговим зберіганням вструдата і отриманням готового продукту підвищеної якості або напівфабрикату, що використовується в борошномельно-круп'яній, спиртовій, олійно-жировій та інших технологіях. Реалізація нового підходу до переробки та зберігання зерна можлива на основі розробленої технології термовструдування. Створено дослідно-промислові та промислові термовструдери двох типів - автономні та сателітні, переобладнані на основі реконструкції стандартних зерносушарок. В статі розглянуто різні модифікації термовструдерів та принцип їх роботи. Тривала експлуатація термовструдерів, що працюють на теплоносіях димових газах, гарячому повітрі, перегрітій водяній парі з раніше не досяжною температурою до +600°С (навіть без спеціального завдання сушіння зерна) показала високу економічну ефективність, яка зростає при вструдуванні польового зерна високої вологості. Універсальність термовструдерів дозволяє застосовувати термолабільні режими високоінтенсивного сушіння і для насіннєвого зерна.*

Ключові слова: післязбиральна сушка, вибух, знезараження зерна, зустрічноструминна сушарка-термовструдер, елеватор, технології глибокої переробки зерна, теплоносій - перегріта пара.

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