[1.]Mariana BÎRSAN, [2.]Petre CÂRLESCU, [3.]Ioan ŢENU, [4.]Adriana MUSCALU

CONSIDERATIONS REGARDING VERTICAL DRYERS FOR CEREAL AND TECHNICAL PLANT SEEDS

[1,4.]INMA Bucharest, ROMANIA
[2,3.]University of Agricultural Sciences and Veterinary Medicine "Ion Ionescu de la Brad", ROMANIA

Abstract: Drying seeds is done to avoid degradation due to high moisture they have to harvest and to be kept for a longer time. It is necessary that the drying operation to be carefully planned and managed to ensure the optimum drying temperature. This temperature depends on the subsequent destination of the dry product, so that the seeds intended for sowing be not affected as germination capacity. This paper presents a synthesis on the drying process of cereal seeds and technical plants using vertical dryers. This is a prerequisite for deepening the study of this type of machines, both constructively and in terms of the characteristic working process, in order to optimize the parameters.
Keywords: drying, seeds, vertical dryers

1. INTRODUCTION

Harvested crop products are used in important sectors of the economy. Thus, healthy grain seeds are used for sowing and for human or animal consumption. Agricultural products account over 90% of the raw material used in the food industry, where they are processed by various processes (*Casandroiu. 1993*).

Until their use for the population consumption, industrial processing or commercialisation, it is necessary to ensure preserving and storage for a long time and without loss.

In this regard, we are talking about subjecting agricultural products to a primary processing process, aiming to bring the product into a state characterized by a certain purity, humidity, temperature, etc.. in order to avoid its deterioration and to preserve its nutritional qualities.

The primary processing of the various seeds is carried out in specialized units equipped with technological lines in which the processes are mechanized and automated. Here, besides the operations in which the physical condition of seeds such as aeration, drying or cooling, is changed, other types of seed methods such as sorting, filtering, sedimentation, etc.. are also intended to degrade.

In the primary processing, the seeds mass pre-cleaning and cleaning obtained from the combine harvest, the impurities contained (vegetal, mineral and / or weed seeds) are essential. These operations are necessary to meet the requirements of national and / or European standards according to their destination (sowing, consumption, industrial processing, storage. etc.) (*Casandroiu, 1993; Voronov et al., 1955*).

Due to the fact that at harvest the agricultural products have higher moisture content than that required for a long life, it is necessary to dry them. This is one of the oldest conservation methods, where,due to a heat and mass transfer phenomenon, the water migrates from the interior of the product to the surface of the product, from which it evaporates (*Mohammed et al. 2010*).

Pre-storage drying for further processing substantially reduces the risk of mass-storage disturbances of the stored product and also allows for better storage management. The delay in performing this operation or incomplete implementation generate significant qualitative and quantitative losses (Gummert et al. 2004). It is recommended to dry seeds to the moisture limit that can guarantee good conservation. Thus, besides a high germination power and cessation of the seed degradation process, it is ensured by microorganisms and insects that act strongly when the humidity is high. Also, drying is required to ensure the moisture appropriate to the mechanical conditioning operation for sowing, because seeds with high moisture content can be easily damaged. (*Olaniyan and Alabi, 2014*).

The drying operation can be performed either naturally or artificially.

Natural drying can be accomplished by: solarisation (direct exposure to sunlight during the summer period and rigidity of the seed lot to increase the evaporation area); active aeration (air is introduced under pressure into the mass of stored products); handling with ventilation facilities (used for silos that are equipped with many dehumidifiers); passing batches of products through "cold" drying installations - without fuel consumption (through the column), using dry and warm air instead of the drying agent.

The sun-drying method is limited only to hot sun geographies and the dry atmosphere with strong winds, which do not characterize all the regions producing cereals (*Andritsos et al. 2003*). Also, in a solar dryer, cereal grains are often not protected from weathering (rain, storm, wind, dust) and insect pests, rodents etc., which can seriously affect their quality becoming even inedible. Artificial drying of cereal grains is a widespread operation, being the safest way to dehydrate them, because with it greatly reduces losses and the quality of the resulting product is significantly improved compared to solar drying (*Balbine et al.. 2015*).

This process also has important drawbacks because it is highly energy-intensive and may favour an increased degree of damage to the grain by cracking or breakage, due to the large internal stresses induced during its deployment. In order to eliminate these inconveniences, it is necessary to progressively dry the seeds by means of complex plants in which the thermal regime is automatically controlled depending on the nature, the seed moisture and the parameters of the drying agent.

Vertical and horizontal dryers with continuous or discontinuous operation based on convective dehydration are used to dry seed crops.

Consistent with the current context regarding the reduction of energy consumption and environmental protection, this paper presents a synthesis of the technology of dehydration of cereal seeds and technical plants made in vertical dryers.

2. MATERIAL AND METHOD

The operating principle of tower dryers is generally based on heat recovery, especially that resulting from cooling the seeds. Thus, this paper presents some of the most efficient vertical dryers used worldwide.

The GSI Group produces three types of continuous flow tower dryers (Figure 1). The supply of each type of dryer is carried out through the upper part, the product reaching the reception room designed to reduce the impact of the fall on the berries and to ensure their uniform distribution.

After they pass through the reception room, the cereals reach the heating hopper between the two cylindrical walls, concentrically arranged. The high capacity of the hopper is an advantage as drying the product is slow, at low temperature.

In the middle of the heating section is the inverter system which moves the warm beans located near the inner wall of the hopper instead of the wet grains adjacent to the outside wall, thus ensuring uniform drying irrespective of the distance between the grain column and the wall from the heating chamber.

After leaving the heating zone, the cereals reach the bottom of the dryer, where they are cooled by the atmospheric air forced by the fans through the walls of the hopper. The same airflow is then reused to dry the grain in the hopper, being already heated by the heat absorbed from the cereals in the cooling zone. For this reason, the amount of fuel used by the burner is reduced to further heat it.

Depending on the size of the dryer, one to four fans are placed in line. They are mounted in the interior, designed to operate at low speed. Thus, noise and energy consumption are low. Fan motors also have a long life.

The dryer uses a computerized Vision control system.

In order to be in line with the European standards on processed grain quality, GSI's dryer burners work with natural gas or liquefied gas. In this way, the cereals are heated directly resulting in a high-quality product.

The dryer is equipped with walkways, ladders and protective grids made of high-strength materials, so that all dryer areas can easily be accessed for inspection, cleaning and maintenance.

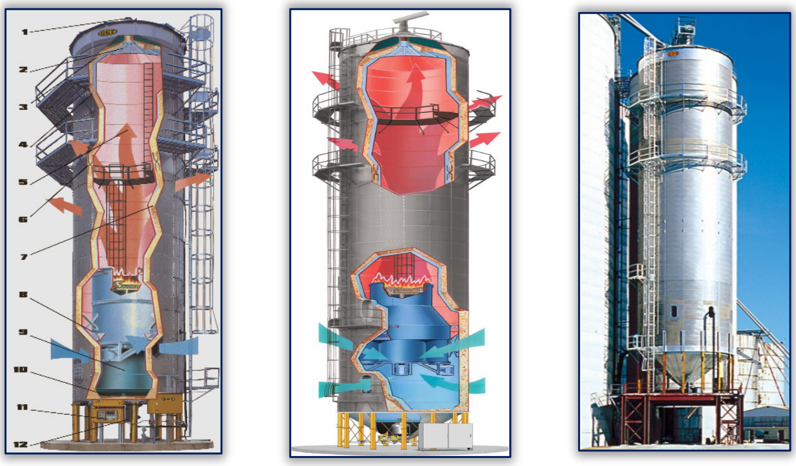


Figure 1 – Flow diagram of the GSI tower dryers [8]; 1 – feeding area; 2 – reception room; 3 – cereal level monitoring device; 4 bunker for heating; 5 – air flow that crosses the grain column; 6 – grain inverters; 7 – stainless steel panels; 8 – separator funnel; 9 –cooling zone; 10 – download area; 11 – Vision system; 12 – humidity control sensor.

The SG Feerum Dryer (Figure 2) is an equipment designed and manufactured in Poland by Feerum S.A., which allows the work in drying mode from feed to seed grain as well as fine-grained oilseeds. Feerum dryers are designed to maintain a stable strong work throughout the drying period. Their capacity is from 19 to 30 tons. As fuel sources for dryer can be used natural gas, liquid gas or diesel fuel.

The SG Feerum dryer is equipped with: centrifugal fans with dust collector; capacity to dry, which increases the capacity of the dryer by 25%; service platform for the air fans; the heat source as an integral part of the main air channel dryers; adjustment of air feed capacity can be changed depending on the grain type; device for real time control over grain moisture throughout the drying and cooling processes; real time air temperature monitoring and touch screen with PLC for full process control in local languages.

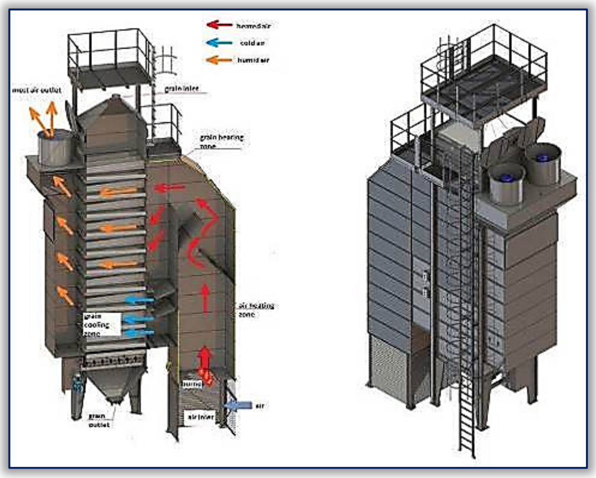


Figure 2 – Flow diagram of SG Feerum Dryer [9]

The Portuguese company Entriger made the Agi-Entriger Dryer (Figure 3) to achieve the grain drying, which works continuously or intermittently. In this system, the drying takes place by contacting the beans with the hot air during the passage through the drying tower located in the centre of the dryer and containing the cereals. Hot air is released in at least four points in each of the overlapping pipes. Perforated pipe columns thus allow, in addition to heat exchange with higher yield, better circulation and air contact with grains, which results in an effective level of moisture loss of the product and guarantees better quality of the product.

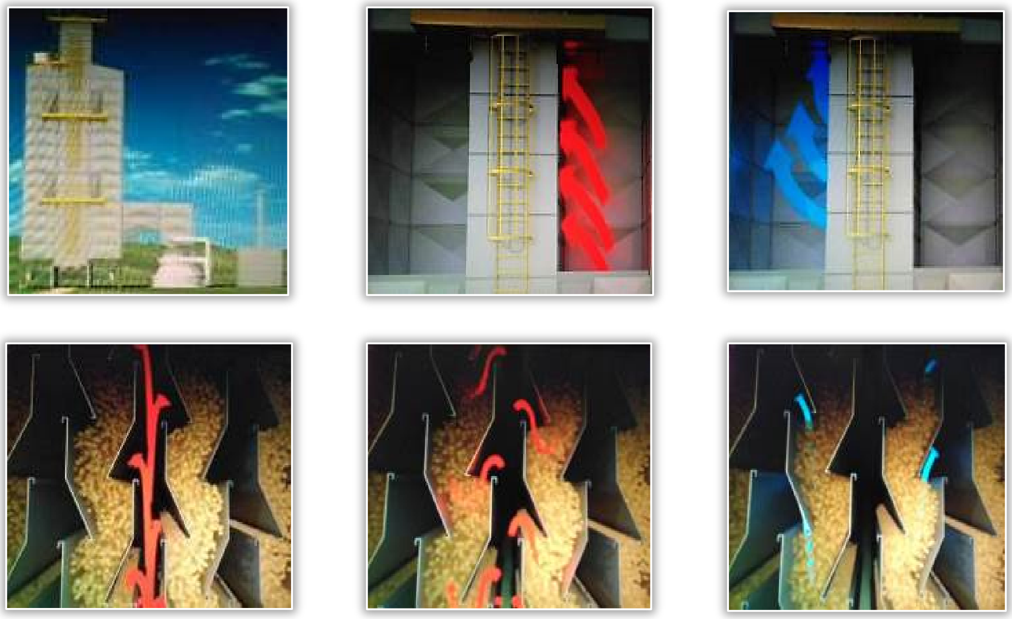


Figure 3 – Flow diagram of Agi-Entriger Dryer [10.11]

Italian company "Macmar" manufactured three models of tower dryers. In Figure 4 is shown the Tower Dryer of the RG series. The drying process is divided into 4 stages corresponding to a single operating configuration of the machine: loading, drying, cooling and discharge.

Figure 4 –RG Drying tower [12]

The products enter still wet and after going through the machine from the top to the bottom, they are dried and cooled. The recovered heat from the grain during the cooling phase significantly reduces fuel consumption. The cereals are subjected to a progressive decrease of the temperature, so that the grain does not receive any damage by sudden temperature changes, thus arriving in the discharge zone perfectly cleaned and cooled at room temperature. After this process the dried product it can be stored without any problem and in absolute safety. The Eco Master dryer (Figure5) made by the Cimbria group in Austria is used for drying cereals and other granular products. It has a modular design that increases the size of the unit, if the drying requirements increase later.

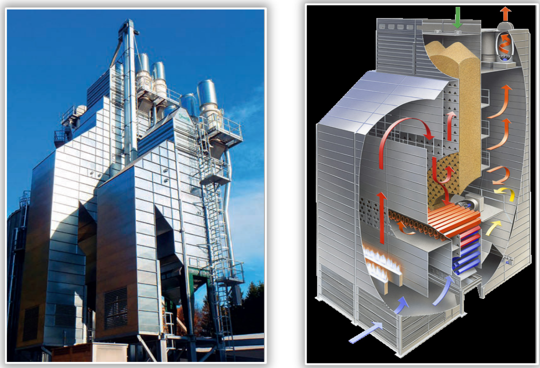
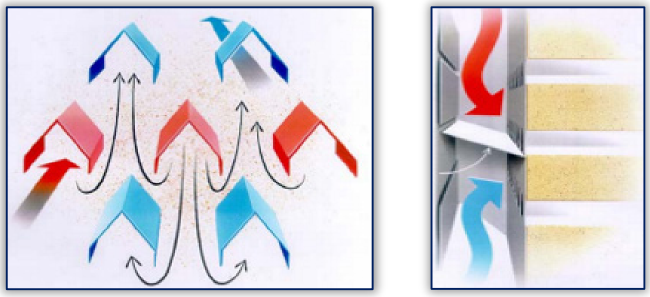


Figure 5 – The Eco Master Dryer [13]

The dryer is designed for industrial use and the drying and cooling sections are therefore built in 2 mm galvanized plates with inclined and conical air ducts to ensure high durability and homogeneous air and grain distribution - a pre-requisite for maintaining product quality without undesirable energy loss.

Cimbria drying sections (Figure 6a) are build from triangular air ducts mounted between two walls. The ducts are alternately tapered against both walls and open in the tail end. The alternate ducts are respectively connected to the hot air and the exhaust chamber, through which the air is distributed in the drying column. In addition the ducts are displaced in relation to each other. Thus, each hot air duct is surrounded by 4 exhaust ducts and reverses with the exhaust ducts. The cereal moves slowly down between the hot air and exhaust ducts and is ventilated from different directions.



a. b.

Figure 6 – Principle sketch from Eco Master Dryer [13]: a. Air Streams; b. Cooling Shutter

The mutual stream between the cereal and the air ensures that the product is exposed to a changing airflow. This alternating exposure to hot- and cold air ensures a gentle treatment and a homogenous drying of the grain and the speed of the cereal flow through the column is controlled by the discharge.

The Cimbria drying column is suitable for both drying and cooling purposes (Figure 6 b). The Cimbria dryer enables a varying cooling zone that makes it possible to configure the dryer to the exact drying and working conditions at all times. This zone is regulated with a shutter placed in the bottom part of the hot air duct.

By using air and energy in the best way possible, the costs are reduced and the capacity is optimized. The Dry line (Figure 7) manufactured by the Swiss group Buhler operates in continuous flow and is used in reception, storage and manufacturing facilities.

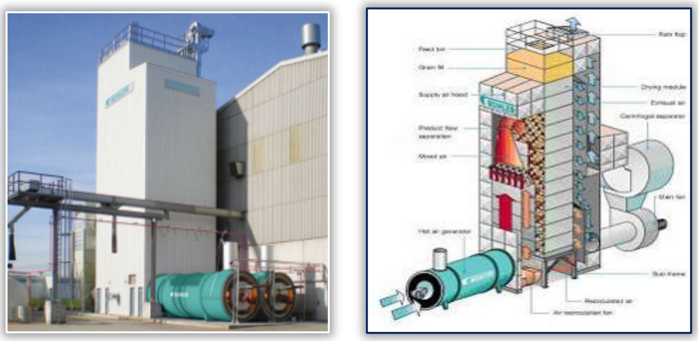


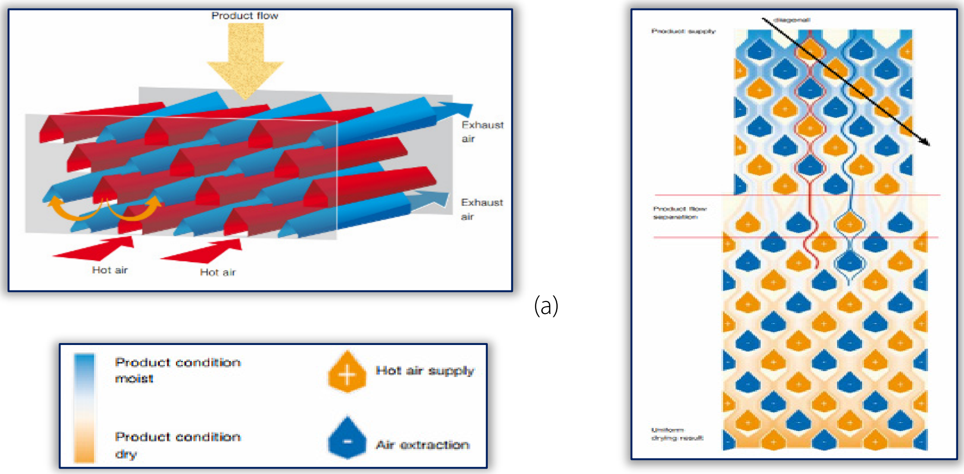
Figure 7 – The Eco Dry Dryer [14]

The ambient air is sucked in by the main fan and heated by a hot air generator. Heat can be produced from conventional sources (oil, gas) as well as from alternative energy sources (biomass). The positioning of the main fan on the suction side produces negative pressure inside the dryer and transports the air from the hot air generator through the drying column and the downstream de-dusting before it is discharged through the rain flap. After hot air drying in the upper section of the drying column, the product is cooled in the lower section of the column. To increase the energy efficiency of the system, the hot air and cooling air heated by the cooled product is reused, adding to the hot air given by the generator to ensure high durability and homogeneous air and grain distribution - and pre-requisite for maintaining product quality without undesirable energy loss.

The drying column of this dryer line, Eco Dry has a special and patented feature, namely conical piping arranged diagonally. The pipes are V-shaped and open at the bottom. The air comes from the heat source by opening the pipes (red) to the product and escaping through the exhaust ducts (blue). Thus, the product is heated and releases moisture into the warm air, which absorbs and cools through evaporation.

The conical shape of the pipes allows for more capacity columns and a uniform air distribution in the dryer and also prevents unintentional product discharge through the channels.

The diagonal layout of the pipes makes the product alternate from hot to cold, which leads to increased energy efficiency and reduced thermal stress on the product by almost 50%. Separation of the product flow ensures easy handling of the product, the drying process being extremely mild. This dryer can be combined with an Eco Cool dry cooler, contributing to a significant reduction in operating costs.



(a) b)

Figure 8 – Scheme of drying column of Eco Dry dryers [14]: a. airflow through conical pipes; b. Layout of pipelines

3. RESULTS

Technical and functional characteristics of dryer's type manufactured of Feerum are the only ones presented below in table 1, because producing / manufacturing companies give little technical details about their equipments.

Table 1. Technical and functional characteristics of SG and DG Feerum Dryers [9]

Type/Continuous operation SG Dryers	Model				
	Unit	SG 6	SG 10	SG 12	SG 16
Filling volume – grain	t	13	19	21.8	29.5
Drying sections	pc.	0-6	7/8	9/10	12/13
Cooling sections	pc.	6-0	3/2	3/2	4/3
Heat power	kW	500	1100/1200	1400/1500	1750/1920
Dryer airflow	m^3/h	27000	4400	53000	71000
Installed max. electrical power - fans	kW	13.8	~22.0	~26.6	~40.5
Installed max. electrical power – cycle-ventilators	kW	-	-	-	-
Device height	m	8.8	11.25	12.5	15.64
No. of buffer sections	pc.	2	2	2	3
Buffer volume	t	4.3	4.4	4.4	6.3
Grain column volume	t	8.7	14.5	17.4	23.2
LPG gas consumption	l/t/%	2.25	2.22	2.22	2.22
Natural gas consumption	$m^3/t/\%$	~1.9	~1.9	~1.9	~1.9
Oil consumption	l/t/%	1.5-2.0	1.5-2.0	1.5-2.0	1.5-2.0
Corn – efficiency for drying from 30% to 14.5% grain humidity					
Ambient air temperature	°C	5	5	5	5
Drying air temperature	°C	80-110-130	100-130	100-130	100-130
Relative humidity of outside air	%	85	85	85	85
Efficiency for moist grain	t/h	2.17	3.3	5.6	7
Efficiency for moist grain	t/day	52	80	135	168
Rape – efficiency for drying from 14% to 7% grain humidity					
Ambient air temperature	°C	15	15	15	15
Drying air temperature	°C	90	90	90	90
Relative humidity of outside air	%	65	65	65	65
Efficiency for moist grain	t/h	3.25	4.3	7.3	9.1
Efficiency for moist grain	t/day	78	104	175.5	218.4
Wheat – efficiency for drying from 18% to 14% grain humidity					
Ambient air temperature	°C	15	15	15	15
Drying air temperature	°C	100	100	100	100
Relative humidity of outside air	%	65	65	65	65
Efficiency for moist grain	t/h	4.3	10	16.8	21
Efficiency for moist grain	t/day	104	240	405	504

4. CONCLUSIONS

In the vertical drying columns, the seeds move from top to bottom through the space between the walls, drying more intensely at the top of the dryer compared to the bottom. Although a significant amount of energy is being recovered, consumption remains high because dryers have high capacities.

It is still necessary to optimize the performance of these systems in order to obtain dried seeds of superior quality with unimpaired germination capacity to reduce the energy consumption for the drying process, to reduce the drying time, to reduce the construction costs of a dryer, to reduce the length of the drying column or the size of the dryer, so that the process is carried out as evenly as possible.

Acknowledgement: This work was supported by a grant of the Romanian National Authority for Scientific Research and Innovation. CNCS/CCCDI – UEFISCDI, project number PN-III-P2-2.1-PED-2016-1357, within PNCDI III, contract 18PED/2017.

Note: This paper is based on the paper presented at ISB-INMA TEH' 2017 International Symposium (Agricultural and Mechanical Engineering), organized by University "POLITEHNICA" of Bucharest – Faculty of Biotechnical Systems Engineering, National Institute of Research-Development for Machines and Installations Designed to Agriculture and Food Industry – INMA Bucharest, Scientific Research and Technological Development in Plant Protection Institute (ICDPP), National Institute for Research and Development for Industrial Ecology – INCD ECOIND, Research and Development Institute for Processing and Marketing of the Horticultural Products "HORTING" and Hydraulics, Pneumatics Research Institute INOE 2000 IHP, University of Agronomic Sciences and Veterinary Medicine of Bucharest (UASVMB) – Faculty of Horticulture and Romanian Society of Horticulture (SRH), in Bucharest, ROMANIA, between 26 – 28 October, 2017.

References

[1] Andritos N., Dalampakis P. and Kolios N. (2003). Use of Geothermal Energy for Tomato Drying. Geo-Heat Centre Bulletin. 8-13;
[2] Balbine M., Edoun M., Kuitche A. and Zeghmati Belkacem (2015). Experimental Evaluation of the Thermal Performance of Dryer Airfow Configuration. International Journal of Energy Engineering. 5(4):80-86;
[3] Căsăndroiu Tudor. (1993). Equipment for primary processing and storing of agricultural products. Course / Utilaje pentru prelucrarea primară şi păstrarea produselor agricole. Curs. Vol I. Univ. Politehnica Bucureşti;
[4] Gummert M., Rickman J.F. and Bell M. (2004). Drying Systems. Rice Fact Sheets. International Rise Research Institute Bulletin. Manila. Philippines;
[5] Mohamed M.A., Gamal G.R. and Keshek M.H. (2010). Drying Characteristics of Okra by Different Solar Dryers. Misr Journal of Agricultural Engineering. 27(1):294-312;
[6] Olaniyan A.M. and Alabi A.A.(2014). Conceptual Design of Column Dryer for Paddy Rice including Fabrication and Testing of Prototype. International Journal of Basic and Applied Science
[7] Voronov I.G., Kojuhovski I.E. et al. (1955). Seed cleaning and sorting (Curatirea si sortarea semintelor). State Agro-Silvica Publishing House. Bucharest
[8] http://www.grainsystems.com/products/conditioning/continuous-flow-dryers/gsi-commercial-tower.html
[9] https://www.feerum.pl/eng.suszarnie-zbozowe-cyklu-ciaglym.html
[10] http://www.entringer.com.br/produtos/3/secador-de-cereal
[11] http://www.beatsloop.com/video/vzHWi2umZOE
[12] http://www.mecmargroup.com/en/catalogue/tower_dryers-1/mais_corn-4
[13] http://www.cimbria.com/products/drying/continuous-flow-dryer
[14] http://www.buhlergroup.com/global/en/process-technologies/drying.htm#.WdXYWY-Czcs

ISSN 1584 - 2665 (printed version); ISSN 2601 - 2332 (online); ISSN-L 1584 - 2665