PAPER • OPEN ACCESS

Heli-drying units for drying fruit and vegetable products under conditions of Uzbekistan

To cite this article: B Shaimardanov *et al* 2021 *IOP Conf. Ser.: Mater. Sci. Eng.* **1030** 012151

IOP Conf. Series: Materials Science and Engineering 1030 (2021) 012151 doi:10.1088/1757-899X/1030/1/012151

Heli-drying units for drying fruit and vegetable products under conditions of Uzbekistan

B Shaimardanov, Sh Abdurokhmonov, Sh Abdurokhmonova and G Ibragimova

Tashkent Institute of irrigation and agriculture mechanization engineers, Republic of Uzbekistan

E-mail: abduroxmonov.shavkatjon@bk.ru

Abstract. The article presents the results of research of solar drying plants for mechanization of preparation processes and organization of the drying process with a minimum energy consumption and maximum quality of finished products. The greatest effect is achieved when drying to low humidity, for example, drying fruit to a humidity of 2.5-3% is achieved in 4-16 hours, depending on the properties of the material to be dried. During vacuum drying, the rate of moisture evaporation increases, since the rate of moisture removal is proportional to the difference in water vapor pressure at the surface of the material and in the surrounding space. The efficiency of the process increases due to the lack of heat loss with the outgoing air.

1. Introduction

Devices for drying wet materials using solar energy by converting it to heat can be divided into two main groups: installations with a concentrating device, greenhouse solar dryers. In the first group of installations, solar radiation is supplied in different multiplicities of concentration, depending on the type of concentrating devices. These types of installations are used in high-temperature drying conditions. Their main disadvantages are: the high cost of hubs, the need to use expensive tracking devices, and low performance [3,4]. In the technology of drying pasty masses of fruit and vegetable products, it is used when the drying pressure is lower than atmospheric, followed by a sharp pressure drop. When the pressure of the material decreases, intensive evaporation itself occurs and a significant gradient of the total pressure occurs, due to which part of the moisture is removed in the form of a liquid. The pressure is lowered and increased several times until the required humidity is reached. This method of drying has been little studied. Along with other drying methods, vacuum drying is of great interest in terms of energy and technology. Vacuum, i.e., drying in a discharged medium is based on reducing the boiling point of water. This allows you to create a soft drying mode with improved quality of the finished product. The greatest effect is achieved when drying to low humidity, for example, drying fruit to a humidity of 2.5-3% is achieved in 4-16 hours, depending on the properties of the material to be dried. During vacuum drying, the rate of moisture evaporation increases, since the rate of moisture removal is proportional to the difference in water vapor pressure at the surface of the material and in the surrounding space. The efficiency of the process increases due to the lack of heat loss with the outgoing air.

Vacuum-contact drying of materials is a conductive drying under medium vacuum conditions (residual pressure 1.33– 13.3 kPa). This is one of the most advanced methods of drying, characterized by high intensity and sufficient economy, and allows you to get a good quality product. In contrast to other methods of thermal drying, vacuum-contact drying makes it possible to intensively conduct the process at lower temperature conditions. This is of paramount importance, since long-term and strong thermal effects on wet material lead to a decrease in its quality. Thus, vacuum contact drying combines the advantages of atmospheric contact drying and vacuum drying. Analyzing the above, we chose to dry the pasty mass of fruit and vegetable products vacuum drying with contact power supply. As a heat carrier, you can use hot water, as the most affordable type of heat carrier.

2. Putting the issue

The possibility of using solar energy is directly related to the natural and climatic conditions of a particular region. In particular, the temperature and humidity of the air, the intensity of solar radiation, and some other conditions are important for the practical use of solar drying plants [1,12].

Table 1. The beginning of maturation and the duration of fruit drying (sub-stage)

Name of produce	June			July			August			September			October		
	I	II	II	I	II	II	I	II	II	I	II	II	I	II	II
Cherry	+	+	+												
Apricot		+	+	+	+	+	+								
Apples			+	+	+	+	+	+	+	+	+	+	+		
Pear						+	+	+	+	+	+	+			
Fig						+	+	+	+	+	+	+	+		
Peach		+	+	+	+	+	+	+	+	+	+	+			
Plum					+	+	+	+	+	+	+				
Melon						+	+	+	+	+	+	+	+	+	
Grape						+	+	+	+	+	+	+	+	+	

Climatic conditions that affect the drying intensity in solar dryers are characterized by the temperature *t* and relative humidity *φ* of atmospheric air, its moisture absorption capacity *U*, and the intensity of solar radiation *E*. In addition, the duration of a sunny day and cloudiness greatly affect the drying intensity in solar dryers the height of the sun. Each of these parameters varies significantly during the season, and many of them are also subject to diurnal fluctuations.

The average monthly temperature t and relative air humidity φ for some points in Uzbekistan are shown in (Fig. 1.). An analysis of the dependences shows that the temperature regime during the study period is quite favorable, average

The air temperature is 28 ... 40 ° C. Relative humidity is quite low - 10 ... 40%. The purpose of the work is the analysis and determination of technology and technical means for solar drying of fruit and vegetable products at the lowest cost and high quality of finished products.

The purpose of the work is to analyze and determine the technology and technical means for solar drying of fruit and vegetable products with the lowest costs and high quality of dried products.

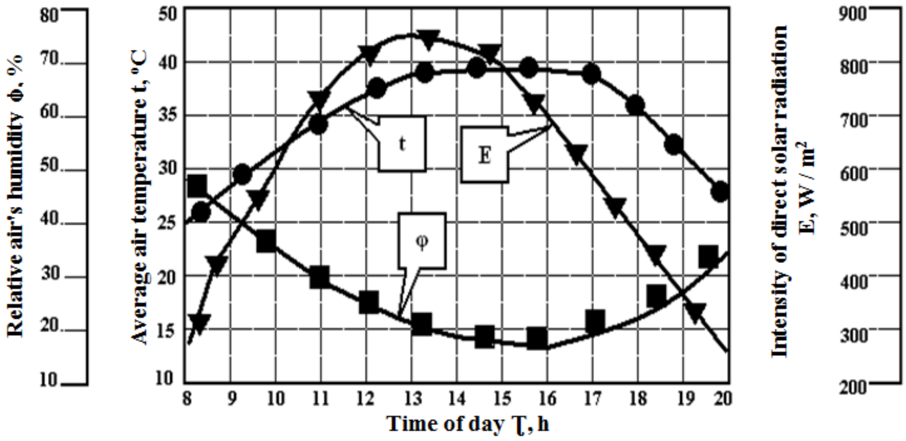

Figure 1. The average temperature t, relative humidity φ and the intensity of solar radiation E.

3. Solution method

Classification of solar dryers. Drying these materials undergoing complex biochemical transformations requires further development of research aimed at the creation of rational designs of solar dryers that meet the requirements of production, are simple and reliable in operation, and have economically viable indicators. In all these works, when choosing the type of solar dryers, they are based on only two criteria: reducing the duration of the process, improving the quality of the finished product, not organically linking the technological, energy and operational aspects with the types and volumes of the dried material. This leads to the imperfection and high cost of the adopted design schemes, the consequence is the relatively low efficiency of the applied solar technology principles, which further research should be aimed at improving the process technology while simplifying and reducing the cost of the design of solar dryers, which will allow them to be widely implemented in the agricultural complex [4,5].

Various designs of solar drying plants are used. According to the method of heat supply to the dried product, these installations are divided into chamber, radiation and combined.

In chamber solar drying plants, the product is placed in a drying chamber. The drying agent-atmospheric air-enters here through a system of helium-air heaters, in which it is heated to 60 – 70 degrees. Raw materials are not exposed to direct sunlight, drying takes place by convective method. In such installations, it is advisable to dry fruits and vegetables that have a light color (white kishmish, apples, pears, melons) to obtain a high-quality commodity type of finished products. The productivity of chamber solar drying plants is from 0.8 to 1.2 kg of finished products per day per unit ($1m^2$) of the radiosensitive surface.

In solar radiation drying plants (SRDP), radiation heat exchange prevails over convective, i.e. the solar installation and the drying chamber are combined in one unit, and the products to be dried are directly exposed to sunlight. The vapor-air mixture is removed either by the natural draft created by the inclined position of the installation to the horizon, or by the forced air circulation created by the fan. The performance of dryers of this type is 1.5 – 2 times higher than chamber ones. The results of studies of the drying process in SRDP showed that the heat carrier removed from them still has sufficient drying potential. This made it possible to develop a combined heliofructosushilny installation consisting of a collapsible solar-radiation drying part and a pre-drying chamber. Raw materials after pre-treatment are placed in a drying chamber, which receives a drying agent after SRDP, having a temperature of $40\text{-}50^0$. After removing the mechanically bound moisture (usually on the second day), the semi-finished product is transported to the SRDP, in which the temperature regime is higher compared to the chamber part, and it is dried to the final humidity. The combined method allowed to reduce the drying time by 1.5 times compared to drying in the SRDP.

To implement each of the above methods of drying, different designs of solar dryers can be used, which differ in their parameters. Depending on the method of heat supply to the material, solar dryers are divided into chamber, radiation and combined.

Chamber. Atmospheric air is heated in a helium-air heater and then enters the drying chamber, where the product to be dried is placed.

Radiation. The solar installation and the drying chamber are combined in one installation, i.e. the material to be dried is a ray-receiving surface (a type of radiation drying installations can be a solar dryer with a backup in the form of an IR generator).

Combined. The product to be dried is located both in the solar installation and in the drying chamber, i.e. the drying potential of the agent is used to the maximum.

After analyzing various types of solar installations, we can draw the following conclusions. All solar drying plants reduce the duration of drying of fruit and vegetable crops by 2-4 times compared to air-solar drying in open areas. The productivity of SRDP, where the product is exposed to direct sunlight, is 1.5-2 times higher than that of chamber-type dryers. However, light varieties of fruit and vegetable crops should be dried in vacuum chamber-type dryers to obtain finished products with high commercial qualities [6,7,8].

Principle of operation. One of the technical solutions for the complex mechanization of the solar drying process is the use of a mechanized complex to perform the main work on the solar drying of products. They are economically justified for processing volumes of 50 tons of dried products or more. The proposed technical solution is designed for farms with a volume of 300 tons of dried product per year, but due to its modularity, it can be used in farms with a volume of 50 to 500 tons.

In Fig. 2 the scheme MCLGS, helio drying consisting of four modules: a technological line of preparation of raw materials to drying, technological lines of processing of dried products, plot feeding, area of discharge of the dried product and two sections of intermediate discharge products.

Solar drying modules. According to the principle of operation and design solution, all four solar drying modules are identical to each other. However, in the technological process, they make up two separate technological cycles in pairs (modules I and III, modules II and IV). In turn, each cycle is divided into two parts: drying of fresh product (modules I and II); drying of semi-finished products (modules III and IV). This separation is dictated based on the high content of free moisture content of the material and their relative shrinkage during the drying process.

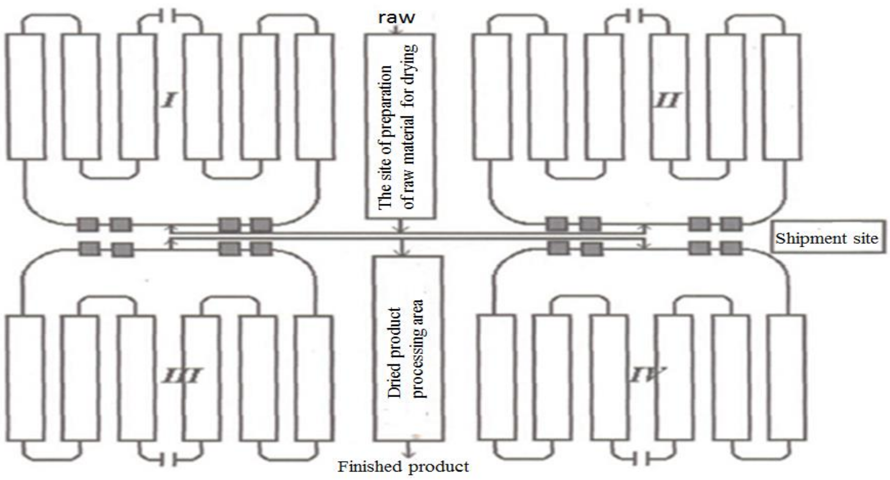

Figure 2. Mechanized production line of helio drying (MPLHD)

In Fig. 3. is a schematic diagram of a single solar module. The technical solution to the mechanization of solar drying is based on a cart conveyor corresponding to GOST 15517-77, as well as blocks of solar radiation drying plants (SRDP). The conveyor consists of a closed chain drive 1, through which the trolleys circulate in a continuous stream 2. The dried product in mesh trays is laid in several tiers on trolleys 2. The raw materials are heated and dried under the action of solar radiation in the SRDP 3. Steam-air the mixture from the SRDP blocks is removed through the exhaust hatches 7 through the main duct 8 laid in the ground due to the vacuum created by the centrifugal exhaust fan 9.

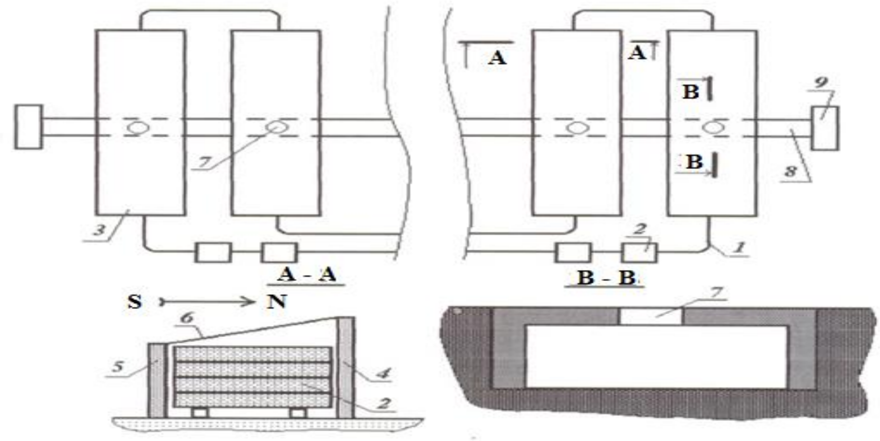

Figure 3. Schematic diagram of a single module: 1-chain transmission; 2- product trolley; 3 - block SRDP; 4,5 - thermally insulated side walls; 6 - light transparent fence; 7 - exhaust hatches; 8 - main air duct; 9 - fan.

The traction chain 1 is mounted to one of the side walls, and if the chain is attached to the north wall in odd blocks, then to the south wall in the next even blocks. GOST 15517-77 also provides for the installation of a chain along an axial line or buried in the ground.
The main air duct is laid across the axis of the SRDP blocks at an equal distance from both ends. Studies have established that the effective use of the potential of the drying agent occurs on a site 25 m long. Therefore, the distance from the ends of the SRDP to the duct should be 25 m, then the total length of the SRDP will be 50 m. The end walls serve to enter a fresh air stream into the unit as well as the entry and exit of product carts.
Section A-A shows a cross-section of the SRDP unit, which consists of heat-insulated side walls 4 and 5 and a transparent fence 6. Due to the difference in height between the south 5 and 4 walls, the light-transparent fence 6 is inclined to the horizon at an angle of 30 °, which contributes to an increase in the absorbed heat flux of direct solar radiation. The inner surface of the north wall 4 is covered with a reflective coating, increasing the irradiation of the dried product.
The main duct 8 is an internal cavity of an inverted reinforced concrete tray (section B-B). In the bottom of this tray, holes of 7 certain sizes are hollowed out, satisfying the condition of uniform air flow in all blocks of the control system.
Mesh trays. As mesh trays, you can use commercially available incubator trays with a size of 800x600x100 mm. The number of tiers of mesh trays placed on one trolley is: in the drying modules of the fresh product (I and II) - 4 tiers; in drying modules (III and IV) - 2 tiers.
Block SRDP is a hot box type solar installation, the walls of which are laid out from burnt clay bricks. The upper part of the control system is made in the form of a metal glazed frame. Joints are coated with 51-G-3 or 51-G7 sealant, and joints between the frame and side wall are cemented.
Fan equipment. In modules I and II, it is necessary to install fans with a capacity of 4000 m/h, and for modules III and IV - fans with a capacity of 2000 m/h. Then, the flow velocity of the drying agent will be, respectively, 1.1 m/s and 0.55 m/s. These parameters are optimal for the drying process of agricultural products.
The main pipeline. Its cross section should be 0.8 ... 0.9 m^2. It is most convenient to use the cavity of the reinforced concrete irrigation tray. [8,10].

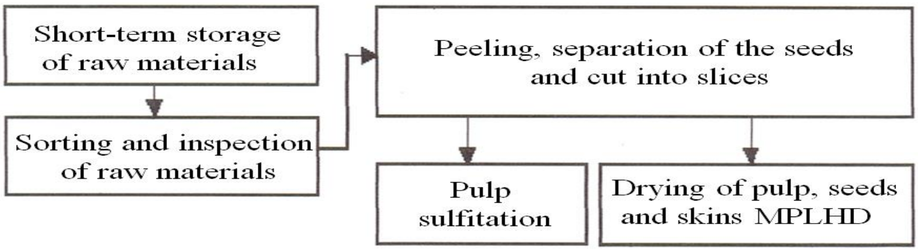

Figure 4. Technological line for the preparation of raw materials for drying MPLHD

4. Results and Samples

The product we offer for drying is melon. On the usefulness of melon for humans, we examined in the first chapter. In our work, we will dry the melon mass with jam. From one ton of melon, 300-350 kg of melon mass is obtained. The resulting mass is considered natural, since it does not add crystalline sugar, contains about 60-70% of dry matter, of which 40-50% is sugar. Color - yellow, orange and dark orange.

Description of the technological process:

Acceptance of raw materials - raw materials are transported from the field in tractor carts and collected around the proposed mini workshop. For the reception of raw materials, the organoleptic characteristics of the raw materials are determined. Organoleptic indicators are determined in the following sequence: appearance, color, smell, texture and taste.

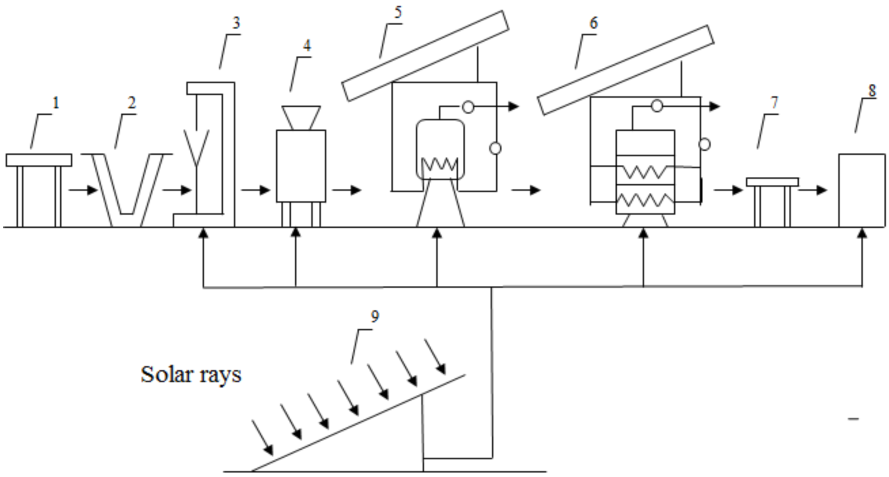

Figure 5. The technological scheme of the process of solar drying.

Cleaning, sorting, inspection of raw materials - we offer tray water conveyors for washing raw materials. In them, raw materials are cleaned of sand and other harmful substances. After cleaning, the raw materials are sorted.

The most labor-intensive technological operations in melon processing technology are peeling of the fruits with subsequent isolation of seeds and separation of the pulp. For this purpose, special designed machines are used at low energy costs (3.2...3.5 kW h/t). The machine allows you to process up to 7 t/h of fruit.

The resulting pulp is converted into a homogeneous dispersion using a homogenizer. This process is very beneficial for us since bound water loses its strength and is easily dehydrated.

The dispersion mass is placed in the evaporator and remove moisture and harmful substances. We offer the scheme of the evaporator operates due to solar energy. Water is heated to 70 ° C and enters the evaporator through a heat exchanger.
We put the resulting mass in hot condition on special pallets and put in a dryer with helio vacuum. To rationalize the energy supply, it is supposed to use preliminary heating of the material before turning on the vacuum. In this case, the temperature of the heaters should not exceed 50 ° C in order to avoid the activation of oxidative processes.
To improve the drying process, we use a vacuum pump, which will improve the quality of the dried product and the drying process. In the dryer, pasty masses are dehydrated up to 10%.
Dried products are packed in special airtight containers and finished products are sent to storage [10,13,17,18,19,20].

5. Conclusion

1. For drying agricultural raw materials undergoing complex biochemical transformations, further development of research is required aimed at creating rational designs of solar drying plants that meet production requirements, are simple and reliable in operation, and have economically justified indicators.
2. The combined modular solar dryer is more productive than solar radiation and chamber, and in it you can get high-quality products. It can be built both for the production of a large number of dried fruits (approximately 100-150 tons per season), and for small (3-5 tons), i.e. use in horticultural teams.
3. The above analysis of solar dryers will help you choose the design of the installation for drying a particular product, depending on the conditions of its processing, the amount of processing, etc.

References

[1] Adewuyi OB, 1. Shaimardanov B.P. "Technological basis and justification of the parameters of mechanization for waste-free processing of melon fruit." Tashkent 2000
[2] Technological equipment of food products / B.M. Azarov, H. Aurich, S. Dichev and others. Ed. B.M. Azarova.- M.: Agropromizdat, 1988. -463 p .:
[3] Shaimardanov B.P. Melon fruits as an object of technical processing // Vestnik TashGTU, No. 1,2008, pp. 85-87.
[4] Umarov G.G. Shaimardanov B.P., Classification of Gel Dryers. // Solar engineering. 1988.-№1.P. 71-73.
[5] Umarov G.G., Kikodze R.O., Shaimardanov B.P., Bangna Alpha. Industrial solar drying systems for drying fruits, grapes and vegetables. // Solar engineering. 1988.-№2.S.80 -83.
[6] Umarov G.G. Shaimardanov BP, Calculation of the kinetics of helio-drying of agricultural products. // Solar engineering. 1988.-№8.P. 81-83.
[7] Shaimardanov B.P. Waste-free production line of melons and melons. // Solar engineering. 1996 -№2. S.77-78.
[8] Umarov G.G. Shaimardanov B.P., Mechanized agrotechnology of primary processing of melon fruits. // Storage and processing of agricultural raw materials 2004. No. 1, p. 25-26.
[9] Shaimardanov BP, Shaburyan S., Korsun A.I. A Device for isolating seeds, cutting fruits into halves, extracting and grinding the pulp of various melon fruits. RU patent FAP 00195. B.I. No. 6 2004, p. 55.
[10] Babych M., Korobka S., Skrynkovskyy R., Korobka S., Krygul R. justification of the economic efficiency of using a solar dryer in the conditions of private farms // Eastern European journal of advanced technologies. 2016. Vol. 6. No. 8 (84). Pp. 41-47.
[11] Korobka S., Babych M. Justification of design and technological parameters of the fruit solar dryer // Eastern European journal of advanced technologies. 2017. Vol. 1. No. 8 (85). Pp. 13-19.

[12] Shaimardanov B.P. The use of a solar dryer for processing agricultural raw materials // Republican scientific-practical conference on "Problems of the preparation of highly qualified personnel for the production of rural and Water Resources", Part 1, 133-136. Tashkent, 2008.
[13] Shaimardanov B.P., Kamilov A., Usmonov K.E., Melon processing technology. // Agricultural science. –M., 2005, No. 1. p.22.
[14] Korobka S., Babych M., Krygul R., Tolstushko N., Tolstushko M. Research of the technological process of convective drying of fruit in a solar dryer // Eastern European journal of advanced technologies. 2017. Vol. 3. No. 8 (87). Pp. 55-63.
[15] Nanka O 2014 *Agrotechnics and energy supply* **1 (1)** 204-209.
[16] Knaga J., Tatomyr A., Babych M., Korobka S. Justification of the efficiency of using a flat mirror concentrator in a solar dryer // Eastern European journal of advanced technologies. 2017. Vol. 5. No. 8 (89). P. 10-15.
[17] Shaimardanov B.P., Netkachev D.I. Processing of agricultural products in farms. Technology for storage and processing of agricultural products. Tutorial. Copyright august 1999 by Tacis services DG Ia European Commission, 881/06 Rue d'Arlon, B-1040 Brussels.C.18
[18] Alijanov D, Abdurokhmonov Sh, Jumatov Y and Bozorboev A 2020 *IOP Conf. Series: Materials Science and Engineering* **883** 012155
[19] Alijanov D, Abdurokhmonov Sh, Umirov N 2020 *IOP Conf. Series: Materials Science and Engineering* **883** 012117
[20] Alijanov D, Abdurokhmonov Sh**,** Makhatov Sh 2018 European science review Journal. **5–6** May–June Vienna 251-257.