Study of influence of average diameter and rolling friction of hawthorn fruits on moisture content during drying process

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Abstract. The method and technology were developed to study the influence of an average diameter, mass and rolling friction of hawthorn fruits on the moisture content during the drying process. It was established that the fruits of smoothed hawthorn (Crataegus oxyacantha L.) have a large unevenness in diameters of 11 mm - 21 mm and weight of 1.3 g - up to 4.2 g. The average diameter of hawthorn fruits decreases from 16 to 12.5 mm with a decrease in moisture content from 74.9 to 14%; the coefficient of rolling friction of hawthorn fruits on the surface of the working chamber increases from 0.12 to 0.31 with a decrease in moisture content from 74.9 to 14%. The results of these studies of hawthorn fruits can be used in the future when designing drying plants and improving drying technology.

1. Introduction
The use of dried fruits and berries of long-term storage, economically justified and technologically rational, when drying significantly, reduces the mass of raw materials, which reduces the cost of transportation, additional spending on containers, reduces the need for storage space, thus simplifying the storage processes. In a concentrated form, dried foods contain nutrients and do not require special storage conditions [1, 2].

Modern drying must meet three basic requirements: high product quality, low energy consumption and affordable cost of finished products.

Drying of fruits will reduce the moisture content of raw materials; increase its safety and quality, which will make it possible to supply the population with high-quality dried products, in a wide range of long-term storage, which are of great importance in human nutrition [3, 4].

To improve the drying technology and create new technical means for drying, it is necessary to conduct research that allows you to establish rational modes and settings for drying apparatus [2, 5, 6]. For the development of drum and vibratory dryers, it is important to determine the average diameter and rolling friction of the fruit on the surface of the drying chamber during the drying process, which will allow calculating the required productivity and energy consumption for drying.

2. Materials and methods
To study the effect of the average diameter, mass and rolling friction of hawthorn fruits on the moisture content during the drying process, we used equipment, devices and materials [7], shown in Figure 1.

These studies were carried out to achieve such goals as evaluating the intervals of variation of diameter, weight, moisture content, rolling friction coefficient of smooth hawthorn fruits and changes in these parameters during the drying process.
Figure 1. Equipment, devices and materials required to study the effect of the average diameter, mass and rolling friction of hawthorn fruits on moisture content during drying. 

For drying plant products, a TSh-902 convective drying oven is used, which is shown in Figure 1 a. It includes a drying chamber 1, electric thermal heaters 2 (3 pcs) located in rows inside the chamber, between which there are trays for drying raw materials, the cabinet is equipped with a switch for stepwise power control of heating elements, and temperature sensors are connected to a temperature controller 3 for autonomous maintaining the specified mode in the chamber. Inside the drying cabinet, natural convection occurs; in the upper part of the cabinet there are 4 holes through which air is removed.

The measurement of the mass of hawthorn fruits was carried out using a VL-500 laboratory balance (Figure 1 b), with an accuracy of 0.01 to 500 g. To avoid errors, these scales are installed on a stationary table that is not subject to vibrations. Turning the adjusting legs-support 3, we set the scales in a strictly horizontal position, controlling the horizontal position of the installation in terms of level. The product is placed on the weighing platform 1.

A baking sheet (Figure 1 c) is intended for distribution of hawthorn fruits inside the TSh-902 drying cabinet. It consists of a rectangular metal body 1 with a side of a certain height, a metal mesh 2 is stretched to the bottom. In experimental studies using the 3 strips, the baking sheet is divided into 9 equal parts. Hawthorn fruits were placed in all parts of the baking sheet 4. To measure the rolling friction coefficient, one hawthorn fruit was used, placed in each part of the baking sheet [8].

The device for determining the friction coefficient of hawthorn fruits (Figure 1 d) consists of a movable platform 4, to which a working perforated plate made of stainless steel 5, made of the investigated friction material, is fixed using the clamping bars. On the perforated plate 5, the studied raw material was placed. The movable platform 4 has the ability to move relative to the horizontal plane by means of the installed stand 3, and is fixed with an adjusting screw 2. The angle of elevation of the
movable platform 4 is determined using a protractor 1. The installation elements are mounted on a support frame 6, adjustment is carried out using adjustable supports 7.

Before the start of the experiment, the installation was fixed at a level, then a sample of the raw material under study, previously selected from the general batch according to certain parameters, was placed on the working plate 5. Then slowly raised pad 4, parallel to the support frame 6, until the moment when the sample under study begins to roll on the plate 5. Next, platform 4 was slowly raised, parallel to the support frame 6, until the moment when the test sample began to roll on plate 5. At the moment the test raw material began to slide along the surface of the working perforated plate 5, the lifting of the movable platform 4 was stopped, and the position was fixed using the adjusting screw 2 platform 4 to the rack of installation 3, and the angle of rolling friction was determined from the readings of the protractor. The average size of the fetus was determined using a caliper [6, 9].

To continuously measure the current temperature of the heating agent inside the drying chamber throughout the entire drying process, a standard multimeter was used (Figure 2), which is a device with a temperature sensor and a digital display, where the current temperature inside the drying chamber is constantly displayed. This device allows you to determine and control the temperature of the heating agent inside the drying chamber in order to avoid the appearance of overheating of the product due to a sharp jump in temperature.

The process of drying hawthorn fruits was carried out at a temperature of 60 °C. Measurements to determine the mass, size and coefficient of friction of hawthorn fruits were recorded every 60 minutes, during the observation process, 12 measurements were made, the period was 11 hours.

To determine the moisture content of the product, the device was used - The "EVLAS-2M" (moisture content analyzer is presented in Figure 3), designed for the express definition of thermogravimetric method in the laboratory of the mass share of moisture in agricultural products and its processing products, food and confectionery products, chemicals, pharmaceutical and construction materials [9].
Sampling of plant raw materials was carried out according to the current regulatory and technical documentation and methods GOST 28561-90, GOST 3852-93. For point measurements, samples of smoothed hawthorn fruits were taken, crushed and evenly distributed over the bowl of the moisture analyzer (Figure 4).

**Figure 4.** Even distribution of the sample on the particle of the humidity analyzer

3. **Result study of the influence of the average diameter and rolling friction of hawthorn fruits on the moisture content during the drying process**

The data obtained from measurements of hawthorn fruits before drying are presented in a graphical form, approximated using the law of normal distribution.

The graph (Figure 5) shows the definition of the average diameter of the fruits of smoothed hawthorn (Crataegus oxyacantha L.).

**Figure 5.** Graph for determining the average diameter of the fruits of smoothed hawthorn (Crataegus oxyacantha L.)

From the graph (Figure 5), it can be seen that the average diameter of hawthorn fruits is 16 mm.
The graph (Figure 6) shows the definition of the average fruit weight of the smoothed hawthorn (Crataegus oxyacantha L.).

![Graph showing average fruit weight](image)

**Figure 6.** Graph for determining the average weight of fruits of smoothed hawthorn (Crataegus oxyacantha L.)

From the graph (Figure 6) it can be seen that the average weight of hawthorn fruits is 2.75 g. Hawthorn fruits have a large irregularity in diameter 11 mm - 21 mm (Figure 5) and weight 1.3 g - up to 4.2 g (Figure 6).

Then a number of experiments were carried out, according to the results of which the following dependencies were obtained (Figure 7): changes in the diameter of hawthorn fruits on moisture content; changes in the coefficient of rolling friction from the moisture content of the fruit.

![Graph showing dependencies](image)

**Figure 7.** Dependences of changes in the average diameter and rolling friction of hawthorn fruits on their moisture content at a temperature of 60 °C
The average diameter of fruits of smoothed hawthorn decreases with a decrease in moisture content (from 74.9 to 14%) from 16 to 12.5 mm, the rolling friction coefficient of fruits of smoothed hawthorn on the surface of the working chamber increases from 0.12 to 0.31 with a decrease in moisture content from 74.9 to 14%.

4. Conclusion

According to the research results, it was found that:

1. Hawthorn fruits have a large irregularity in the diameter of 11 mm - 21 mm and weight of 1.3 g - up to 4.2 g.
2. The average diameter of hawthorn fruits decreases from 16 to 12.5 mm with a decrease in the moisture content from 74.9 to 14%. The rolling friction coefficient of hawthorn fruits on the surface of the working chamber increases from 0.12 to 0.31 accompanied by a decrease in the moisture content from 74.9 up to 14%.

The results of these studies of hawthorn fruits can be used in the future when designing drying plants and improving drying technology.

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