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Vibrating moistening of wheat grain

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Abstract The article experimentally established the influence of amplitude, frequency and duration of processing on the efficiency of vibratory wetting of wheat. With increasing amplitude and frequency of oscillations, as well as the duration of processing, the increase in moisture in the grain increases nonlinearly. With oscillation amplitudes of 10 and 20 mm and constant frequency of 10 Hz and processing duration of 8 min., Wheat grain increased moisture by 2.1%. Processing time more than 8 min. does not increase the moisture content of wheat. The largest increase in moisture in wheat was observed at an oscillation frequency of 12 Hz and an amplitude of 20 mm and a treatment duration of 5 min. Increasing the oscillation frequency more than 12 Hz did not lead to an increase in wheat moisture. It was found that the load does not affect the efficiency of moistening wheat grain.

Keywords: wheat, moisture, amplitude, frequency, vibration.

1. Introduction

Moistening grain is one of the urgent scientific problems of flour production. In flour milling, "cold" conditioning of wheat is used, the purpose of which is to change the properties of wheat grain to facilitate the process of separation of shells and endosperm during grinding [1–5]. One of the directions of intensification of grain moistening is based on the use of vibrations, which accelerate the internal mass transfer of moisture inside the grain [6–8].

Both the world's leading grain processing companies and researchers from various research institutions are involved in the creation of new or improvement of existing methods and ways of moistening wheat grain before grinding [9]. Development of devices of intensive moistening of wheat grain by the leading companies of the world is directed on increase of process efficiency of grain hydrothermal processing and increase of their capacity [10].

To increase the capacity of the mill without additional costs, the German company Muehlenbau Wittenberg Technologie has developed and mass-produces a vibrating method of grain moistening, which is carried out in the equipment «Vibronet» [11, 12]. Operating modes (amplitude and frequency of oscillations, duration of stay of grain in the device) of this equipment are unknown, however it is claimed that this equipment allows to increase wheat grain moisture to 10% [13]. Significant increase in moisture in the grain is interested in the vibratory method of moistening wheat grain, as a large increase in moisture indicates a high efficiency of moistening wheat grain in comparison with traditional devices for intensive moistening [14]. The use of vibrations can significantly reduce the process duration of grain moistening and reduce the volume of the hoppers for grain resting [10, 13, 15].

According to the company data, the acceleration of wheat grain moistening is due to the fact that the vibrational energy removes the surface tension of water, which forms a film of water that envelops the grains. Due to the surface tension of water droplets always try to take the formula of the ball. On a microscopic scale, these small balls are much larger than the capillaries in the grain and therefore penetrate into the middle of the grain mainly through the germ. Using high vibrational energy, vibration destroys the surface tension of microscopic water balls, turning water into a film that envelops the entire surface of the kernel and easily enters the small capillaries of the grain. Vibrating energy "forces" water to penetrate more evenly and quickly through the outer shells to the endosperm, which leads to more efficient moistening of the grain, which takes two to six hours [13].

Martseniuk was the first to investigate the effect of vibration on the moistening efficiency of wheat grain [16, 17]. He concluded that the change in the amplitude of oscillation from 1.68 to 2.91 mm does not

significantly affect the degree of transformation of the structure of wheat grain during vibration moistening. When the oscillation frequency changed from 0 to 400 Hz, the increase in moisture increased by 0.5% compared to moistened wheat, which was not subjected to vibration treatment. Moisture increase by 3.5% was achieved in 30 s of grain treatment in the experimental device.

Scientists [6] studied the effect of low-frequency vibrational oscillations on the increase in soybean seed moisture at an oscillation amplitude of 5 mm and the frequency of oscillations of seed containers with water 144 Hz for 120 – 125 s. Under such conditions, the increase in moisture in soybean seeds was 17%, namely from 8.0% to 25.0% [6].

Significantly different research results from different researchers require further studies of the effect of vibration on the efficiency of wheat moistening. Requires verification of the statement that the amplitude of oscillations does not affect the efficiency of grain moistening. The optimal modes of vibration moistening of wheat grain are not fully investigated and remain unknown. There is a practical expediency to investigate the efficiency of moistening wheat grain in "cold" conditioning with other amplitudes and oscillations, as well as the process duration. The load can affect the efficiency of the process, which also requires research.

The purpose of this research is to establish the efficiency of the moistening wheat process in conditions of vibration moistening of wheat grain at different frequencies and amplitudes of oscillations.

2. Materials and methods

2.1. Preparation of grain for research

Experiment before the research, wheat grain was cleaned with a Carter-Day dockage tester (Carter-Day Co., Minneapolis, MN) [21, 22]. Large fraction was obtained from the retained material on sieve 2.4 × 20 mm, and the passed fraction was sent to impurities. Light impurities were separated in a laboratory aspiration channel with a channel width of 60 mm.

After cleaning, wheat quality indicators were determined by standard methods: grain moisture [18], weight of 1000 grains [19] and its bulk density [20].

Wheat with the following quality indicators was used for the study of grain vibration moistening: grain moisture – 11.6 ± 0.05%; mass of 1000 grains – 30.9 ± 1.04 g; bulk density – 752 ± 3.0 g/l; glassiness of wheat - 65 ± 1.7%.

2.2. Investigation of the influence of oscillation amplitude on the wheat moistening efficiency

Vibration moistening of wheat grain was carried out on an experimental vibrating installation, which is shown in Fig 1. Vibrating installation consists of a container (1) in which wheat grain was filled and a calculated amount of water was added, a vibrating rod (2), which connects the container to the eccentric mechanism (3). The eccentric mechanism (3) is connected to the electric motor (6) by means of a rotating flexible shaft (4). When the electric motor shaft (6) rotates, the rotary motion is transmitted through the flexible shaft (4) to the eccentric (3). The eccentric (3) transforms the rotational movement into a reciprocating movement of the rod on which the container with grain is attached. The vertical rod together with the grain container moves in a vertical plane. In this way, low-frequency mechanical vibrations were created without the influence of temperature and other environmental influences. The research was conducted at a temperature of 23 °C.

Vibrating installation allows to change amplitude and frequency of oscillations. Oscillation frequency was changed by changing the speed of the motor shaft using a frequency converter (7). Speed measurements were performed using non-contact tachometer Testo 460.

Oscillation amplitude was set at 10 and 20 mm. Amplitude was provided by different eccentrics, which converted the rotational motion of the motor into the oscillating motion of the system.

The study of the effect of the of vibration moistening duration at different oscillation amplitudes was carried out at a current load of 17 kg/m^2. Wheat grain of 0.085 kg was filled into the container and the estimated amount of water was added. Then the container with grain and water was connected to the vibrating rod of the laboratory installation. Simultaneously with switching on of the electric motor of installation time counting by means of a stopwatch began. Oscillation frequency was constant of 10 Hz. Processing duration was varied from 1 to 12 minutes.

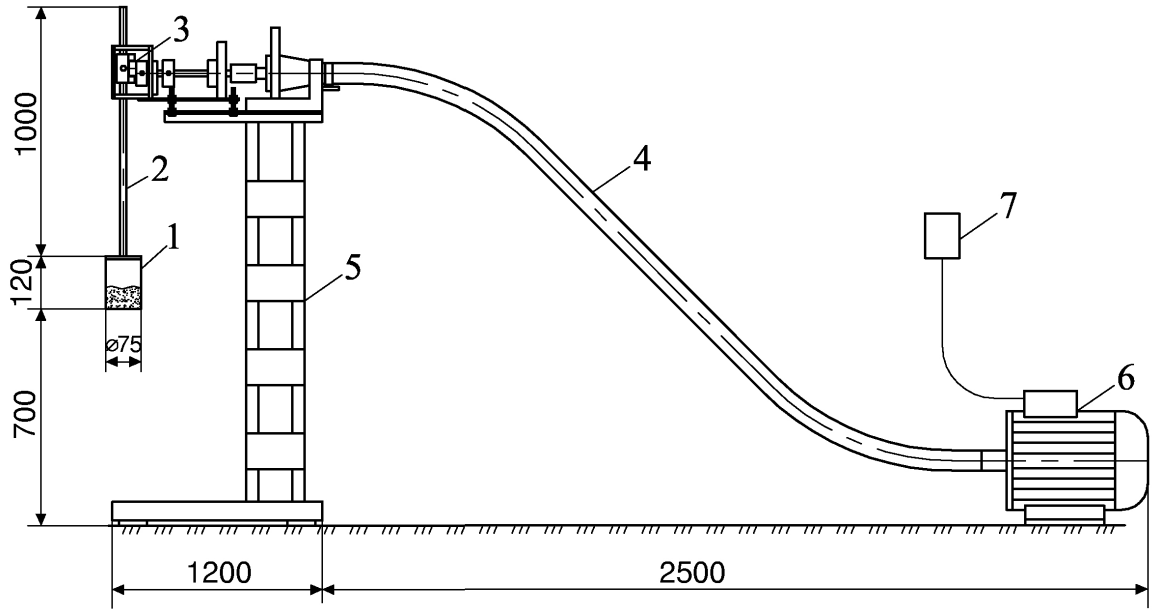

Figure 1. Scheme of vibration installation: 1 – container for grain and water; 2 – vibrating rod; 3 – eccentric mechanism; 4 – flexible shaft; 5 – supporting structure; 6 – electric motor; 7 – speed converter.

After completion of the experiment, grain moisture was determined according to standard methods [18]. The studies were performed in four replicates, the final result was taken as the average value of four replicates.

The amount of added water to the dry grain was determined by the formula:

$$M_g = M_w \left(\frac{100-W_a}{100-W_b} - 1\right), \quad (1)$$

where M_w, M_g – respectively, the mass of water and grain, g; W_a – the grain moisture is initial, %; W_b – the grain moisture is set, %.

The set moisture was taken equal 15.0 %.

The efficiency of moistening was taken as the increase in moisture in the grain after vibration moistening, which was calculated by the formula:

$$\Delta W = W_c - W_a, \quad (2)$$

where W_c – actual grain moisture, %.

Investigations of the effect of oscillation frequency were performed at oscillation amplitudes of 10 and 20 mm. Duration of wheat treatment and the current load were unchanged. The treatment duration was 5 min and the specific load was 17 kg/m^2.

2.3. Investigation of the effect of load on wheat moistening efficiency

To determine the effect of load on the efficiency of vibratory moistening of wheat grain under all the same conditions, a study was conducted in which the current load varied from 20 to 240 kg/m^2 in steps of 30 kg/m^2. Amplitude of oscillations was 20 mm, frequency of oscillations – 10 Hz, duration of grain treatment – 5 min.

3. Results

3.1. Influence of oscillation amplitude on moistening efficiency

Studies have shown that the amplitude of oscillations affects the rate of moisture absorption by wheat grain. With an increase in the amplitude of oscillations from 10 to 20 mm, the moisture content of wheat grain increased in a curvilinear relationship. When the duration of vibration treatment up to 1 min, the increase in grain moisture at different oscillation amplitudes is mostly the same, and from 1 min to 8 min there was a nonlinear increase in wheat grain moisture at different values of oscillation amplitude. When the duration of vibration moistening from 8 min, the increase in moisture content stops and becomes constant regardless of oscillation amplitude. Research results are shown in Fig. 2.

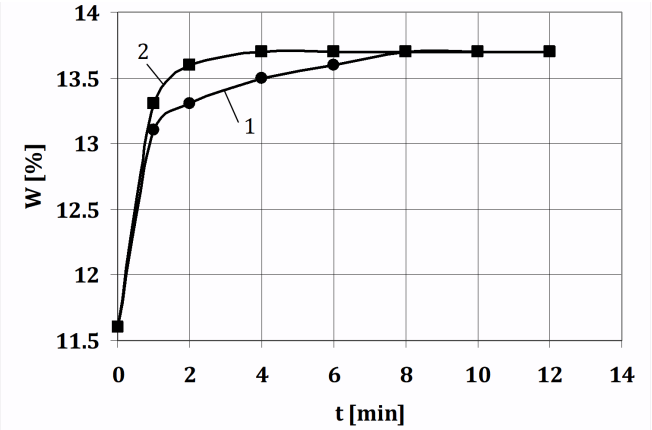

Figure 2. Influence of duration of vibration treatment of wheat grain on increase of its moisture at different oscillation amplitude: 1 – amplitude 10 mm; 2 – amplitude 20 mm.

Data of Fig.2 show that the use of vibration does not allow for 8 min to reach a grain moisture of 15.0% in accordance with the added amount of water.

Intensification of the moisture absorption process by wheat grain occurs in the first 4 min at amplitude of 20 mm, and at amplitude of oscillations of 10 mm intensification of the process has doubled to 8 min, after which vibrational oscillations do not affect the acceleration of moisture (Fig. 3). These data suggest that amplitude of oscillations is one of the factors influencing the efficiency of moistening wheat grain.

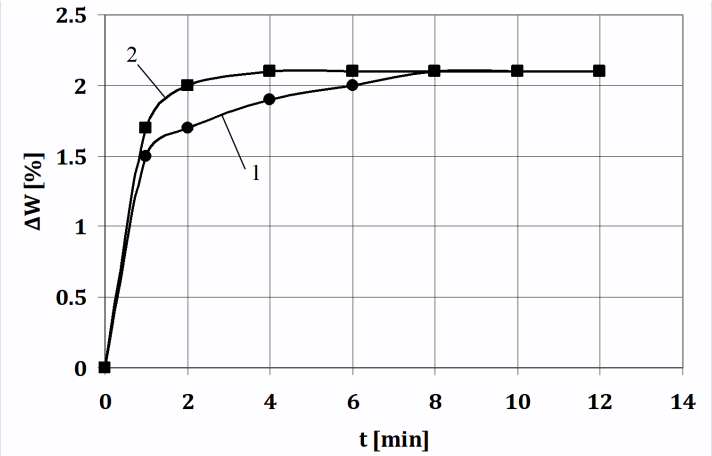

Figure 3. Influence of treatment duration on increase in wheat grain moisture at different oscillation amplitude: 1 – amplitude 10 mm; 2 – amplitude 20 mm.

Influence of oscillation amplitude on the increase in wheat grain moisture can be explained by the fact that with increasing amplitude increases the intensity of mixing of grains and water in the container, which contributes to better absorption of moisture by grain. Thanks to intensive mixing of grain and water, effective moistening of grain occurs in traditional devices of intensive moistening and modern vortex moisturizer. [12]. Author [17] concluded that the amplitude did not significantly affect the moistening efficiency of wheat, it is likely that this conclusion was made due to the low amplitude values that were used in the study, resulting in no intensive mixing of grain and water.

Data of Fig. 3 indicate that at vibration amplitudes of 10 and 20 mm and a constant oscillation frequency of 10 Hz, wheat grain can be moistened by only 2.1% for 8 min. Achieve a greater increase in grain moisture, as indicated in the works [6, 13] failed.

3.2. Influence of oscillation frequency on the efficiency of wheat grain moistening

Studies of the effect of oscillation frequency on the increase in wheat grain moisture, found that the oscillation frequency also significantly affects the intensification of wheat grain moistening process, regardless of treatment duration and oscillation amplitude. The wheat grain moistening process varies curvilinearly. Research results are shown in Fig. 4.

From the data of Fig. 4 it can be seen that at oscillation amplitude of 20 mm at constant treatment duration, the increase in grain moisture occurs at oscillation frequency of 12 Hz to the value of grain moisture of 14.0%. With the same treatment duration and oscillation amplitude of 10 mm, the increase of wheat grain moisture stops at oscillation frequency of 4 Hz and reaches the value of only 13.6%. Comparing the results of the studies shown in Figs. 2 and 4, we can conclude that there is a combined effect of amplitude and frequency of oscillations on the efficiency of grain moistening in the "cold" conditioning of wheat.

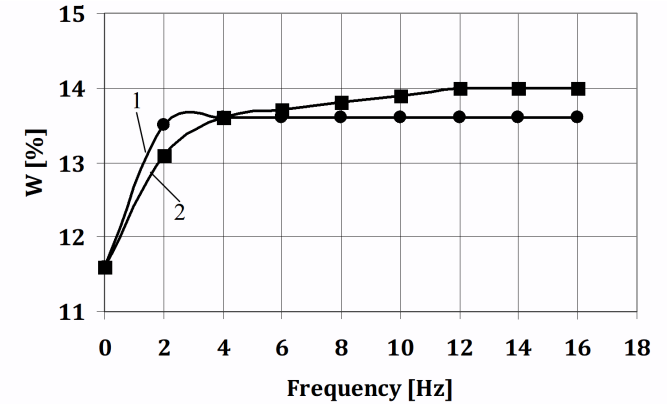

Figure 4. Influence of oscillation frequency on increase of wheat grain moisture at different oscillation amplitude: 1 – amplitude 10 mm; 2 – amplitude 20 mm.

Under the same conditions, without vibration treatment, wheat grain was moistened only to 13.1% for 5 min. Vibration treatment allowed to increase moisture growth by 0.5…0.7% compared to wheat grain, which is moistened without the use of vibrations.

Moisture growth in wheat grain at amplitude of 10 mm stops at an oscillation frequency of 2 Hz, and at oscillation amplitude of 20 mm moisture growth in wheat stops at oscillation frequency of 12 Hz. Results are shown in Fig. 5. These results indicate a combined effect of frequency and amplitude of oscillations on the efficiency of wheat grain moistening.

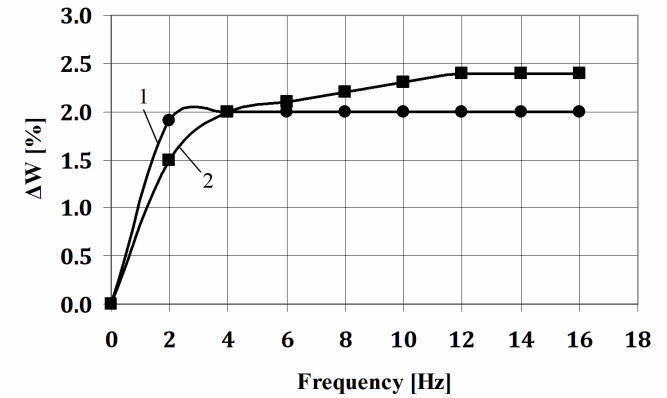

Figure 5. Influence of oscillation frequency on moisture growth in wheat grain at different oscillation amplitude: 1 – amplitude 10 mm; 2 – amplitude 20 mm.

Low moisture growth in wheat grain compared to the results obtained by scientists [6] for soybeans, can be explained by the low frequency of vibrational oscillations. Obtained results indicate the need for additional studies of the combined action of the amplitude and frequency of oscillations, as well as the treatment duration.

3.3. Influence of load on efficiency of wheat grain moistening at constant modes of oscillations

Studies of the effect of load on the efficiency of wheat grain moistening at amplitude of 20 mm and oscillation frequency of 10 Hz showed that the load does not affect the efficiency of wheat grain moistening. When changing the load of wheat grain from 20 to 240 kg/m^2 under all other conditions, the moisture

content of wheat grain was in all cases 13.9%. From these research results it was concluded that the load does not affect the efficiency of wheat grain moistening in the "cold" conditioning.

4. Conclusions

Research results indicate that the amplitude of oscillations affects the efficiency of moistening, but the accepted parameters of vibration oscillations did not increase the moisture content of wheat to 10%.

With increasing amplitude and frequency of oscillations, as well as the treatment duration, the moisture growth of grain increases nonlinearly. With oscillation amplitude of 10 and 20 mm and constant frequency of 10 Hz and treatment duration of 8 min., Wheat grain increased moisture by 2.1%. Treatment duration more than 8 min does not lead to the increase in wheat moisture. The largest wheat moisture growth was observed at oscillation frequency of 12 Hz and amplitude of 20 mm and treatment duration of 5 min. Increasing the oscSillation frequency more than 12 Hz did not lead to an increase in wheat moisture. Found, that the load does not affect the efficiency of wheat grain moistening.

The obtained research results indicate the expediency of further studies of the efficiency of wheat grain moistening at wider parameters of vibrational oscillations.

Additional information

The author(s) declare: no competing financial interests and that all material taken from other sources (including their own published works) is clearly cited and that appropriate permits are obtained.

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