Development of an optical method for determining the glassiness of brewing wheat for the production of environmentally friendly beer

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Abstract: A method has been developed for the objective assessment of the vitreousness of barley using computer vision technologies. An algorithm has been developed for determining the total glassiness of a barley sample based on the analysis of its digital images. The influence of the orientation of objects on the results of the algorithm is evaluated. The repeatability of the results for the same orientation of objects is estimated. For the first time, the function of evaluating the evenness of samples by the indicator "glassiness" has been implemented.

1. Introduction
Barley is one of the most important agricultural crops and ranks second in terms of gross crop harvest in the Russian Federation after wheat [1-7]. Barley is used for the manufacture of flour, cereals, mixed feed, and some of the specialized varieties have found their application as the main raw material for brewing. Depending on environmental conditions, many plants change their qualities during growth and maturation [1-3, 8-13]. In the context of the deterioration of the ecological situation in the world [13-19], various harmful effects are exerted on various plants. Starting with radiation, rains with chemically hazardous elements, ending with electromagnetic radiation from nearby objects [16-27]. This changes their physical structure and chemical composition, which affects the quality of agricultural products [3, 9, 13, 28].

Of all the quality indicators of malting barley, vitreousness is one of the most important. This indicator is widely used by malt producers to assess the evenness of samples, in addition, glassiness, as an indicator reflecting the peculiarities of the internal structure of grain, is associated with protein content. At the same time, the method of assessing the vitreousness is exclusively organoleptic control, since the presence of dense fruit shells of barley grains significantly weakens the transmitted optical radiation, and therefore makes it impossible to use standard equipment - diaphanoscopes. The use of NMR spectrometers and relaxometers [5, 6, 12, 28-33] does not allow testing products in large volumes. Sample tests only. The use of electromagnetic radiation [34, 35] leads to a change in the gustatory quality of barley, which affects the further quality of products made from it, for example, beer. Another feature of the analysis of the vitreousness of barley is the need for preliminary daily soaking and subsequent drying at a low temperature. This operation is performed prior to the analysis of the grain by an expert,
since the sample may contain grains with false vitreousness, which look like glassy, but differ in density and internal structure. Thus, there is a need to develop a reliable quantitative express method for assessing the vitreousness of malting barley and equipment for its implementation.

2. Description of the experimental setup and research methods
For experimental studies, a device was used, a sectional view of which is shown in Figure 1. The device contains two radiation sources, upper and lower, operating in the visible and infrared (IR) ranges, respectively, a scattering plate, a transparent cassette for placing the studied grain samples in the analysis zone and a television camera with a lens.

![Figure 1. Diagram of the experimental setup: 1 - upper illumination module; 2 - registration unit; 3 - cassette for placing samples, 4 - light scattering plate, 5 - bottom illumination module (IR)](image)

The experimental procedure was as follows: before the start of measurements, the photometric, colorimetric, and metric calibration of the system was performed. These calibrations are very often used in various photometric devices and quantum devices [36–44]. The studied grain samples were placed in a special cassette for 100 cells (Figure 2), illuminated with a lower light source, after which images of the grains were obtained in the "transmission" mode. The resulting images were converted to grayscale, segmented and processed by an algorithm for calculating the total vitreousness.

![Figure 2. Placing barley samples in a cassette](image)

The algorithm for processing the results of the study of samples (determination of glassiness) was implemented in the MATLAB software environment. After processing the images of the samples,
information on the amount of glassy, partially glassy and powdery grains in the sample was displayed on the monitor screen.

3. Description of the algorithm for determining the vitreousness of a barley sample based on the analysis of digital images of grains

The algorithm for determining the vitreousness is based on calculating the integral transmittance of each grain component and comparing it with the values obtained by industry experts for the samples used in the work. An image of the samples under study obtained in the shooting mode with an increased exposure time was taken as the initial one. For a given image in each area of interest, the average pixel intensity was calculated, then the resulting value was compared with the established threshold intensity values corresponding to glassy and mealy grains. This technique is often used in algorithms to process various optical images [42–45]. Upon completion of the algorithm, the total glassiness \( T \) was calculated using the formula (1):

\[
T_v = F_v + \frac{P_v}{2}
\]

where \( T \) – total vitreous, \( F_v \) - the number of fully vitreous grains, pcs, \( P_v \) - number of partially vitreous grains, pcs.

After adding threshold values of transmittance to the program (transmittance more than 0.53 - high glassiness, less than 0.48 - no glassiness, 0.48-0.53 - partial glassiness), it became possible to classify grains by glassiness and perform the final calculation of the "total glassiness". As a result of the program, the images of the sample with the transmittance coefficients corresponding to the caryopsis, the value of the total glassiness, and also the histograms of the distribution of grains by the transmittance were displayed (Figures 3-4).

![Figure 3](image_url)  
**Figure 3.** Example of results for variety O3. In the Figure, the color indicates: red - vitreous, green - partially vitreous, blue - not vitreous.
Figure 4. Example of results for variety O3. Grain distribution histogram by transmittance.

The obtained distributions can be used by industry experts to assess the evenness of the sample, since grains with different vitreousness are characterized by a different ability to absorb moisture and the rate of germination.

The influence of the orientation of the samples on the results of calculating the total glassiness was estimated using the coefficient of variation. The coefficient of variation was 4.6%. Thus, when making measurements, it is important to keep in mind that this factor can give a discrepancy in the measurement results within 5%, which lies within the values indicated for repeated measurements of the vitreousness.

4. Conclusion
An algorithm for determining the total glassiness of a barley sample based on the analysis of its digital images has been developed, which allows obtaining more reliable information than previously used methods. The influence of the orientation of objects on the results of the algorithm was evaluated; the coefficient of variation was 4.6%. The repeatability of the results for the same orientation of objects is estimated. The deviation in the values was no more than 1.1%. The function of evaluating the evenness of samples by the indicator “glassiness” has been implemented.

It should be noted that the developed method will significantly reduce the time for analyzing the quality of barley grain to obtain a reliable result.

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