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TRANSLATION

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It has been established that the sharp difference in structure of capsules and endosperms substantially effects not only absorption or extraction of moisture, but also physico-chemical processes which alter the density and structure of grain. In this, the basic effect is deterioration of the endosperm, a method of observation of which is propounded. It is shown that the intensity of physico-chemical processes in grain is determined by the intensity of internal moisture transmission. The nature of absorption and extraction of moisture by grain lots is established and explained; deepening of evaporation zones during dehydration of grain is demonstrated.

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Water plays a vital role in the processes of preserving and converting grain. All the properties of grain are related to the relative content of moisture, the reduction or increase of which unfailing causes their corresponding alteration.

It has been established that during absorption of grain in water, at first only the capsule is wetted, and it penetrates into the endosperm only with the passage of some time (1). A supposition was expressed that somewhere in the border between the capsule and the endosperm a special layer, which was called moisture-proof, obstructs the penetration of water into the center of the grain. The presence of this layer is confirmed without any discussion; only attempts to determine its placement are being undertaken. Hinton (2) attributes this function to the seed capsule of grain, and primarily to its pigment layer. However, elaborate analysis, of experimental data forces doubt of the existence of a moisture-proof layer in grain. First of all, it would have to resist absorption of water by the endosperm to the same degree as it does extraction. But during dehydration of grain it does not manifest itself in any way. Besides, in the presence of a barrier, absorption would have to penetrate by some other means (according to the type of washing of some obstruction by a stream). Finally, grain is a living organism, to the tissue of which free entry of water is essential. Consequently, the most correct supposition is that there is no such layer in grain. The special mechanism of absorption of water must have some explanation.

It is generally admitted that grain is a capillary-porous body. However, estimation of the capillaries shows that their dimensions are comparable to the size of the intermolecular spaces of natural high polymers composing grain: albumins and carbohydrates. The most probable diameter of capillaries for the endosperm of food grain is $2.5 \cdot 10^{-7}$ cm (3), and for maize $1.1 \cdot 10^{-7}$ cm. Thus, in the endosperm there are only microcapillaries (diameter less than $1 \cdot 10^{-5}$ cm). But capsules have large capillaries and pores, especially in the hollow layer. Consequently, the structure of grain can be represented thus: a solid body - the endosperm, in which there are only microcapillaries, surrounded by a thin layer - the capsule, having basically, macrocapillaries. Such a concept makes it possible to explain the peculiarities of the mechanics of wetting and dehydrating grain.

Since the rate of motion of water in a capillary is proportional to the square of its radius, if the diameter of endosperm capillaries is less than the capsule capillaries by only 100 times (in actuality much more), the rate of motion of water in the endosperm must be 10,000 times less. It is just thanks to this that on contact of grain with water, only the capsule becomes wet. This is observed not only with wetting with water, but also with sorption wetting and with converting grain by saturation or by superheated steam. Consequently, the mechanics of wetting grain does not depend on the method of wetting. But this condition is related not to the presence of some moisture-proof layer, but to the special structure of grain. In 1952 doubt of the existence of this layer was also expressed by E. D. Kazakov (4).

There is still another extremely important feature of wetting grain. It has been established (5, 6, 7) that penetration of water substantially alters the structural-mechanical properties of the endosperm, mechanically disrupts its integrity: microfissures are formed. Their dimensions and extend of formation change with time: at first larger ones appear, then smaller and smaller ones. Thus, the endosperm dissintegrates into parts, deteriorates. This phenomena can be given a satisfactory theoretical basis: fine layers of water (to several thousands of angstroms) displace the walls of the apertures in which they are enclosed, i.e., they manifest a wedging action.

Usually the diameter of water molecules are taken to be 3.0-3.2°A. Consequently, according to capillary diameter, 7-8 molecules of water can be embedded in a grain of wheat. In this case the distending action takes place in full. As a result of this, in only one hour after wetting, microfissures appear in the endosperm (5), dividing it into large parts and oriented basically perpendicularly to the longitudinal axis of the grain. With the passage of time the imcrofissures increase in number, but their size decreases. After 8-12 hours they gradually begin to disappear as a result of albumin swelling, although the ones formed at the very first do not vanish for 24 hours. During wetting, water penetrates the endosperm along these microfissures and disperses in it with great irregularity, especially in the first hours after wetting: particles of endosperm dislodged by microfissures remain drier a longer time than the walls of the fissures.

But the proposed methods (5, 6) of observing endosperm deterioration are complicated, laborious, and allow only qualitative evaluation of the process. A simple and reliable method is needed, allowing quantitative analysis of the intensity of the process.

Beginning with 1959 we experimented with a method of recording volimetric changes in grain. The curves obtained have principally one and the same form and therefore are easily subject to comparison, including quantitative.

In figure 1 is presented a graph of change in specific volume of a grain of wheat V_{ud}, type IV, subtype 3 (OD-16) during wetting with 13.8 to 16.7% of the dry weight (curve 1) and to 19.8% (curve 2), and also for a grain of coarse yellow corn, Bukovinskij hybrid 2: curve 3 corresponds to wetting at 16°C, and curve 4 at 40°C. The degree of wetting in these two cases is identical: from 12.6 to 22.5% of the dry weight. The specific volume is found to be an inverse value of density, determined pycnometrically in toluene.

The graphs shown can be called curve deterioration, since they define the path of deterioration of the original structure of endosperm. They evolve uniformly and register well changes of grain volume as well as the effect of stages of wetting and heating, i.e. visually express physico-chemical processes.

Thus, the structural-mechanical properties of grain depend not only on the degree of wetting, but also on the duration of the process of penetration of the endosperm by moisture. It must be constantly kept in mind that progress of moisture in the endosperm substantially effect these properties. Apparently, therefore, the degree of their change must depend on the intensity of movement of moisture in the endosperm, on the rate of flow.

For testing what has been stated from the form of yellow tooth-shaped corn Luch 55-52, obtained by threshing the cob by hand, after painstaking mixing taking 15 lots of 10 grains, placing them in glass containers and adding water. After the specified time the next lot was removed, the grains carefully dried with filter paper and weight. The density was found pycnometrically and converted to specific volume. The data for the first 9.5 hours is shown in figure 2: the graph of growth in dampness ΔW_c (curve 1) and changes V_{ud}* of the grain (curve 2).

* - specific volume

In the first quarter hour curve 1 rises sharply, which is explained by the saturation of the capsule with water; this is indicated by ΔW_c - 6.5% of the dry grain weight, which exactly corresponds to the moisture capacity of dry capsules. Further growth of moisture sharply slows down, but in 1 hour the curve once again steeply rises, as if forming steps. They appear in the graph both a second and third time, while their incline gradually decreases (they stretch out in time), but the value remains unchanged, about 5%.

Thus, increasing the moisture of grain by soaking in water in the liquid state takes place step-by-step, approximately in equal stages, it is interesting that their values are about equal to the total moisture capacity of the capsule. Apparently, after formation of the first microfissures, water quickly penetrates them. Then the rate of its saturation slows down as a result of filling the "existing capacity" of the microfissures. But this rate can increase again with the formation of new microfissures, which does take place - in curve 1 a new step appears. Here the capacity of the new microfissures each time is about equal to the original water content of the capsules.

The complex appearance of curve 2 also speaks of the presence of endosperm deterioration periods. Its rise coincides each time with the rise of curve 1, the maximums on curve 2 in time agree well with the completion of steps. In this way, the increase of grain capacity as a result of deterioration of the endosperm during the formation in it of microfissures is directly related to the penetration of water into the endosperm.

In comparison of the process intensity (figure 3): wetting of grain $\frac{dW}{d\tau}$ (curve 1) and the deterioration of the endosperm $\frac{d(\Delta V)}{d\tau}$ (curve 2) explains that $\frac{d(\Delta V)}{d\tau}$ is in direct dependency on $\frac{dW}{d\tau}$, i.e. on the rate of water penetration into the endosperm. In this way, during wetting the degree of deterioration of the endosperm is determined by the intensity of motion of moisture in the grain. The same thing is also observed during soprtion wetting of grain. It is essential to constantly consider that deterioration of the endosperm, the formation in it of microfissures must take place, regardless of the method of wetting. This explains the reduction of vitreousness during wetting, and also the reduction of vitreousness and density of grain in harvesting periords during alternate wetting by dew or rain.

Apparently, structural differences of endosperm and capsule must be expressed also in the dehydration of grain. Evaporation of moisture from the capsule must take place much more intensely than the arrival of it from the endosperm. Therefore right from the very beginning of dehydration, the zone of evaporation must move to the border between the pistil and seed capsules and possibly even deeper.

In figure 4 is shown the experimental test of this assumption. Curve 2 shows moisture change W_c of wheat grain type I in a process of active ventilation at 20°C, curve 1 moisture change of capsules (indicated by electro-moisture meter VE-2m). Active ventilation was realized in drying chamber SESh-3 with heater turned off, the lots of grain (20g) placed in reticular containers.

The graph shows that during dehydration the moisture of the capsules immediately sharply drops and then remains below the grain moisture. After about 2.5 hours in curve 1 a repeated rapid reduction as a result of change of the zone of evaporation deeper, beneath the capsule. This phenomena is observed after removal of about 5% of the moisture (by dry weight), which corresponds to the content of it in the capsules during complete saturation.

And where during evaporation of moisture from the capsules the rate of drying of the grain is high, after deepending of the zone of evaporation after change to removal of moisture from the endosperm it rapidly falls. In this way, the process of dehydration of grain also has its own features, related to the difference in structure of capsule and endosperm.

Simultaneously in this experiment the volumetric changes of grain were also measured pynometrically and a complex curve was obtained. Apparently, this also must be related to intensive moisture transfer in the grain. Shown in figure 5 are graphs of the rate of dehydration (curve 1) and intensity of volumetric changes (curve 2) develope uniformly, which supports this supposition.

Consequently, both during wetting and of grain the sharp difference in structure of capsules and endosperm significantly effects not only the absorption or extraction of moisture, but also physico-chemical processes, changing the volume of the grain and its endosperm structure. Here it is important that the intensity of penetration of the processes determines the rate of moisture transfer in the grain. In other words, along with the increase of parameters of the system of wetting of drying there will be observed also an increase of changes in the structural-mechanical properties of the grain. This phenomenon must be studied from all aspects, insofar as the relationship of the degree of change of structural-mechanical properties of grain to the amount of action on it, i.e. to the method of hydrothermal processing, has the foremost significance in practice.

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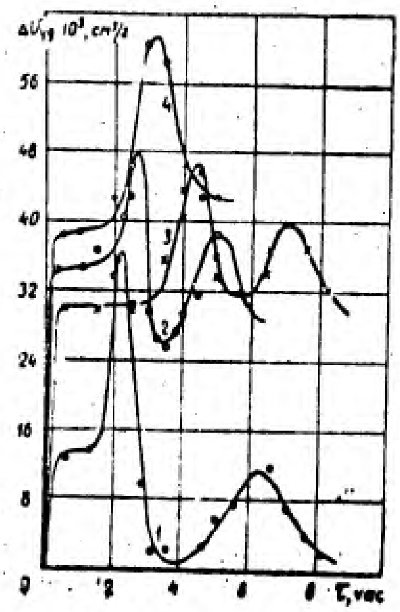

Fig. 1

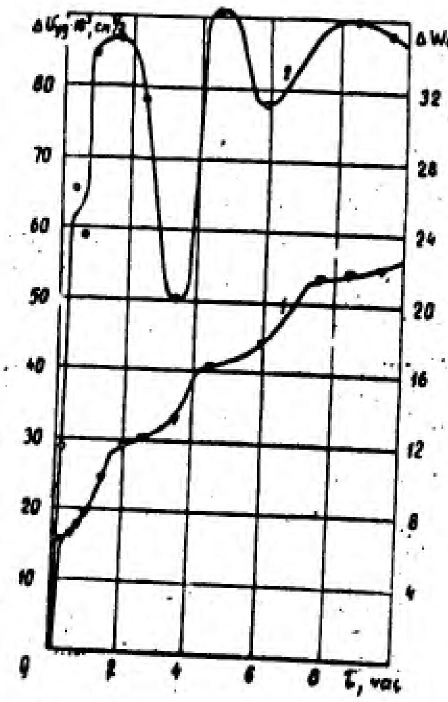

Fig. 2

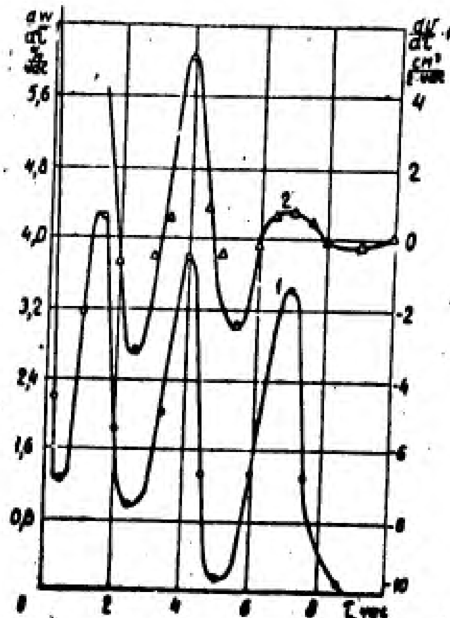

Fig. 3

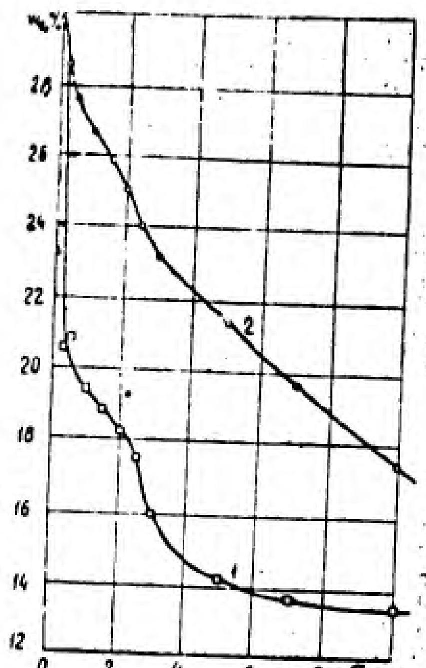

Fig. 4

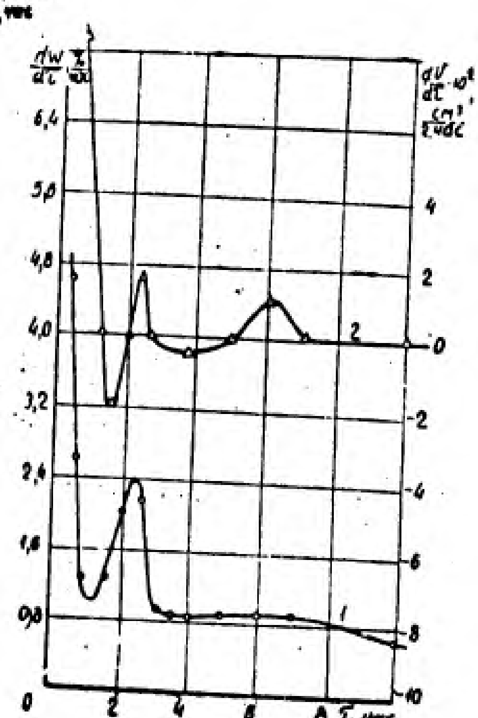

Fig. 5