Vegetable semi-finished products consistency produced by hydromechanical dispersion using MAH-50 apparatus

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Abstract. The paper discusses the influence of the chemical composition of raw materials and the parameters of the rotary-pulsation apparatus MAH-50 on the formation of the consistency of vegetable pasty semi-finished products. The analysis shown that it is necessary to regulate the hydromodule, temperature and processing duration to change the components of raw materials, which contributes to producing a product with a homogeneous consistency.

Rotary-pulsating apparatus are currently the most versatile machines for dispersing products. This is confirmed by the increased demand of industry enterprises for similar machines that successfully fit into existing technological lines, displacing less efficient pieces of equipment. The use of RPA as the main grinding device of universal capacitive devices such as grinders-mixers is a promising direction for obtaining enriched products of various types [1].

By using RPA, homogeneous sedimentation stable products can be produced. The SFSCA RAS has developed technologies for the production of semi-finished products and food products using the MAH-50 rotary-pulsating apparatus (figure 1). For MAH-50, the important operating parameters are the hydromodule, the process temperature, and the duration of exposure. It is necessary to understand the degree of influence of each technological parameter on the quality characteristics of products.

Figure 1. Rotary-pulsating apparatus MAH-50:
1-table, 2-leg, 3-tank, 4-disperser, 5-bearing unit, 6-disperser drive, 7-plate, 8-clamps, 9-mixer, 10-mixer drive, 11-funnel, 12-lid, 13-outlet valve, 14-thermometer, 15-thermometer bracket, 16-clamp, 17-drain nipple, 18-union nut, 19-lock bolt, 20-nipple, 21-branch, 22-oiler.
The mechanoacoustic homogenizer (MAH), developed by Alt-A, is intended for the production of: curd creams, processed cheeses, cream cheeses, spreads, condensed milk, reconstituted milk and other similar products.

Through the hopper, the raw material requiring processing enters the bowl, after which it enters the rotary-pulsating drum, where the raw material is dispersed. The device has a complex effect on raw materials: mechanical, hydrodynamic, acoustic. The mechanism of cavitation formation under the influence of ultrasonic waves is shown in figure 2.

MAH-50 performs the following technological operations: dispersion, homogenization, kneading, pasteurization, cooling.

When product particles enter from the low pressure area into the high pressure area, they are destroyed with the formation of a large amount of crushed fraction.

![Figure 2. Scheme of ultrasonic wave formation and cavitation in MAH.](image)

The minimum loading volume is 20 ... 25 liters; productivity is from 100 to 5000 kg / hour (depending on the type of product).

Chemical composition of raw materials. Paste-like semi-finished products should have, among other characteristics, fluidity, sedimentation stability and homogeneous consistency. The fluidity of a semi-finished product depends on the content of the liquid phase, which can be not only water, but also fat. With an increase in the content of the liquid phase, the fluidity of the semi-finished product will increase. Different types of plant materials differ in their ability to bind moisture, which depends both on the chemical composition and on the surface area, which in turn depends on the degree of grinding. Moisture first accumulates on the surface of the particles, and then is distributed throughout the volume by diffusion. Therefore, the water-binding capacity of plant raw materials is determined by the size of its particles.

Plant raw materials include hydrophilic and hydrophobic compounds. High molecular weight compounds (HMW) that form a hydrogen bond with water are called hydrophilic.

Hydrophilic compounds include proteins, carbohydrates, and dietary fiber, while hydrophobic ones are fat. The amount of moisture that a chemical compound, raw material or finished product can bind is called water-binding capacity.

Water can be bound to hydrophilic compounds through chemical interactions, capillary forces, or be physically enclosed within the structure of high molecular weight compounds. Bound moisture is
located at the interface and, under the influence of surface forces, has physicochemical properties that differ from those of free water.

Hydrophilic compounds bind water by ionic and molecular absorption. During ion absorption, ionized (charged) groupings of side chains: \(-\text{NH}_3\) (proteins) and \(\text{COO}^-\) (proteins, carbohydrates, dietary fibers) of polar groups of molecules interact with water dipoles. During molecular absorption, non-ionized (uncharged) groups of side chains interact with water: \(-\text{OH}, \ -\text{SH}, \ -\text{NH} \) corresponding amino acids and peptide groups of the main chains: \(-\text{CO} - \text{NH} -\) [2].

Figure 3 shows the chemical composition of various plant raw materials (figure 3a) and pasty semi-finished products obtained from it by hydromechanical dispersion (figure 3b).

All semi-finished products had a homogeneous sedimentation-stable consistency. Pea groats contain only 1.6% fat and 81.8% hydrophilic substances, therefore the fluidity of semi-finished peas is mainly determined by the water content, which was 82.8%.

Amaranth seeds contain 14.4% fat and 75% hydrophilic substances, in the semi-finished product the water content was 84.4%. Flax seeds contain a large amount of fat 42.2% and 47.1% hydrophilic substances.

Flax seed shells contain mucus that binds water. In the pasty semi-finished product from flax seeds, the water content was, as in the semi-finished product from amaranth seeds, 84.4%. Thus, the qualitative composition of hydrophilic substances also affects the amount of bound water.

**Figure 3.** Chemical composition of plant raw materials (a) and semi-finished products (b).
The kernel of a pine nut contains a large amount of fat, so 34.5% of water was enough to obtain a pasty semi-finished product. However, a comparison of the mass fractions of protein, carbohydrates and dietary fiber in the studied pasty semi-finished products indicates that the water-binding potential of the pasty semi-finished product from pine nuts is not fully realized. The amount of hydrophilic substances in the semi-finished product from pine nuts is 27.8%, and in pea, amaranth and flax, respectively, 16.3, 11.6 and 8.2, which ensures the content of the mass fraction of moisture in these semi-finished products at the level of 83-84%. That is, with technological necessity, it is possible to obtain a more fluid pasty semi-finished product with a sedimentation-stable consistency.

Hydromodule for hydromechanical dispersion. The mass fraction of moisture in the finished product largely depends on the selected hydromodule. The values of the hydromodule parameter are closely related to the chemical composition of the raw material.

The influence of the hydromodule extends largely to such properties of the product as "mass fraction of moisture", "fluidity", and "homogeneity" and is interrelated with such a property of raw materials as "water-binding capacity". If the water content in the semi-finished product is insufficient to realize the water-binding potential, then the consistency fluidity will be low. As noted above, the water-binding capacity depends on the chemical composition of the raw material. In addition, the ability to bind moisture is influenced by the acidity and structure of organic substances. Therefore, the indicators "mass fraction of moisture" and "water-binding capacity" cannot be described by one general relationship and must for each type of raw material (legumes, nuts, etc.) be determined by the ratio and structure of the components of the chemical composition.

Figure 4 shows the dependences of the mass fraction of moisture in mixtures of plant raw materials with water at different values of the hydromodule.

The dependences shown in the figure were obtained by modeling the chemical composition of mixtures of plant raw materials with water at the corresponding hydromodule. The dependences show the possible content of the mass fraction of moisture in the vegetable semi-finished product. When processing pine nut kernels, a hydromodule of 0.5 is sufficient to obtain a sufficiently fluid consistency of a semi-finished product. When processing pea groats, amaranth grains or flax seeds, such a hydromodule will be insufficient due to the high water-binding capacity of starch, which is part of pea groats and amaranth grains, or surface mucus that is part of flax seeds.

The dependencies described do not take into account water losses (for example, evaporation losses), but thanks to them, preliminary data on the moisture content of the product can be obtained.
If Figure 4 is compared with Figure 3, then the differences in the mass fraction of moisture of the presented mixtures can be explained by the water content in the raw material. The figure shows that the mass fraction of moisture with the same hydromodule in a mixture of pine raw materials with water is always less than in other mixtures, in mixtures with water, seeds of amaranth and flax are approximately the same, and in a mixture of peas with water, it is more than in others. Figure 3 shows that the mass fraction of moisture is least in pine raw materials, approximately the same in flaxseed and amaranth, and most of all in peas. Thus, a direct correlation is noticeable between the mass fraction of moisture in the raw material and in the mixture of this raw material with water. The figure also shows that with an increase in the hydromodule, the initial water content in the raw material has a lesser effect on the mass fraction of moisture in the mixtures. Therefore, the difference in the mass fraction of moisture with a hydromodule of 0.5 is 8% for a nut and pea mixture, and with a hydromodule of 7 it is already only 1.6%, which is due to an increase in the ratio between the added water and the initial mass fraction of moisture.

Temperature and duration of treatment with hydromechanical dispersion. Factors «processing temperature» and «duration of processing» also have a significant impact on the characteristics of dispersed systems obtained by dispersing plant raw materials in RPA.

As an example, figure 5 shows the results of the temperature effect and treatment duration at a constant temperature on the consistency scoring of a semi-finished product from amaranth seeds.

Figure 5. Scoring the consistency of a semi-finished product from amaranth seeds.

The data in the figure indicate that an increase in both temperature and processing time has a positive effect on the scoring of semi-finished products. The homogeneity of the consistency of semi-finished products depends, among other things, on the presence or absence of starch gelatinization. Starch granules can increase in volume during hydration and create a graininess of the consistency of a semi-finished product. The gelatinization of amaranth starch begins at 65 °C and ends at 85 °C [3], therefore, the maximum points for consistency were obtained precisely within these temperatures.

Dietary fibers, when exposed to a temperature of about 60 °C, soften and loosen, gaps appear between the fibers. Upon further heating to temperatures of the order of 80 °C, loose bundles of dietary fibers begin to combine, forming a framework in the product that retains drops of fat, water
and other low molecular weight substances inside. Hydrophilic areas of dietary fiber also retain moisture, forming hydration membranes and preventing the release of water on the surface of the semi-finished product [4,5,6].

Thus, the transformations occurring with starch and dietary fiber directly affect the consistency of pasty semi-finished products obtained using starch-containing raw materials.

In this way, to obtain pasty vegetable semi-finished products with a homogeneous flowing consistency, it is necessary to install a hydromodule, which will realize the maximum water-binding capacity of the raw material, depending on its chemical composition (the ratio between water and dry matter, mass fraction of fat, quantity and quality of hydrophilic substances). The temperature and duration of processing should ensure the gelatinization of starch (if it is present in the raw material) and the required degree of grinding of the raw material particles.

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