Water-sorption ability of fruit and vegetable stabilizers

Dilafruz Kalanova, and *Nasillo* Kuliev*

Bukhara Engineering-Technological Institute, Bukhara, Uzbekistan

Abstract. The article presents the relevance of the development of new technologies and formulations of food products with a foamy structure. The kinetics of moisture sorption of fruits and vegetables subjected to hydrothermal and mechanical processing at various partial vapor pressures in the environment has been studied. Calculations of hygroscopic characteristics of fruit and vegetable stabilizers have been made. Such parameters of the monolayer as the concentration of substances in a continuous monomolecular layer, specific surface and relative air humidity at which the moisture monolayer is adsorbed, and the pore volume of the stabilizers were determined.

1 Introduction

One of the ways to change the consistency and structure of food products in order to satisfy tastes and evaluate consumers is to introduce dispersed air into food raw materials. For many food products, the foam structure has a decisive influence on its distinctive properties. Foamy products have an original, airy texture, they are distinguished by a more pronounced taste and smell compared to the original semi-finished products. Due to the increase in volume, such products are visually larger and have a reduced number of calories per unit volume [1].

Foamy products can eliminate the deficiency of incoming oxygen in the body. With the help of these products, you can cope with chronic fatigue syndrome. The study of the mechanism of the occurrence of fatigue (or overwork) showed that it is accompanied by a symptom complex of oxygen deficiency, so the use of whipped foods can serve as a prophylaxis to prevent pre-pathological and pathological conditions.

In food technology, herbal additives perform the functions of enrichers, stabilizers, foaming agents, emulsifiers, thickeners, dyes, flavors, substitutes, and a number of others, often combining several functions at the same time. The use of herbal additives in food production makes it possible to partially replace sugar and reduce the consumption of stabilizers, to exclude food colors and flavors from the recipe [2-4].

Meeting the growing needs of the population in foamy products is associated with the involvement in its production of cheap stabilizers, in terms of raw materials, with high nutritional values and effective in influencing the quality of the product. Currently used stabilizers do not always meet these requirements, some of them are produced in limited quantities, expensive and have a low stabilizing ability. Fruit and vegetable purees or pastes

* Corresponding author: n.kuliyev1962@mail.ru

© The Authors, published by EDP Sciences. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (https://creativecommons.org/licenses/by/4.0/).

fully comply with these requirements, the use of which in food establishments in the production of products with a foamy structure and having specified rheological parameters is constantly increasing.

2 Material and methods

The viscosity properties of the ingredients of the product, including stabilizers, which affect the formation and stability of the structure of the finished product, largely depend on the moisture-binding capacity of the systems, so its study is of considerable interest in the development of technology for the production of food products with a foam structure.

The kinetics of moisture sorption by apple, carrot and pumpkin subjected to hydrothermal and mechanical treatment at various partial vapor pressures in the environment was studied. In addition to apple, carrot and pumpkin puree, apple pectin was used as a control.

3 Results and discussion

Isotherms of water vapor sorption by apple, carrot, pumpkin puree and apple pectin have the form of S-shaped curves, typical for capillary-porous colloidal bodies (Figure 1).

There are three characteristic areas on the isotherms:

- In this section, in the area of water vapor activity up to 0.1, moisture absorption increases significantly with increasing vapor pressure. The adsorbate-adsorbent interaction predominates;
- In the range of water vapor activities from 0.1 to 0.6, there is a relatively weak and almost linear change in the moisture content with increasing vapor pressure, mainly mono-polymolecular and microcapillary adsorption of moisture occurs.

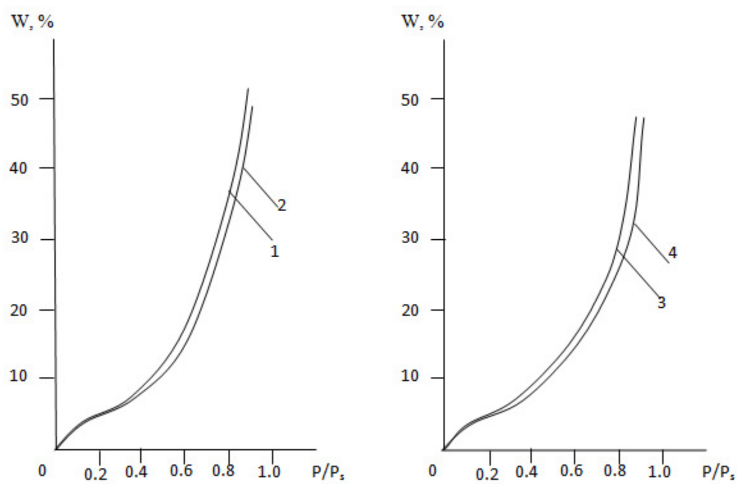

Figure 1. Isotherms of water vapor sorption by apple pectin (1), apple (2), carrot (3), pumpkin (4) puree.

- C. In the region of relative vapor pressures greater than 0.6, a significant increase in the sorption capacity is observed. In this area, the liquid wets the walls of microcapillaries well and its meniscus is concave. In this case, the saturation vapor pressure will be lower than over a flat surface. As a result, steam that has not yet reached saturation pressure with respect to a flat surface can be saturated with respect to the liquid phase in the capillaries and condense in them, gradually filling them.With a further increase in the amount of absorbed water, some crystalline substances are dissolved, and moisture is sorbed osmotically.

For a comparative assessment of the hygroscopic properties of the studied stabilizers, their sorption characteristics were determined using the BET equation in linear form [5]:

$$\frac{\frac{P}{Ps}}{A\left(1-\frac{P}{Ps}\right)} = \frac{1}{A\infty\ C} + \frac{C-1}{A\infty\ C} \cdot \frac{P}{Ps};$$

where

A -is the concentration of the sorbed substance, mmol/g;

A∞ -is the concentration of substances in a continuous monomolecular layer, mmol/g;

C - constant;

P is the equilibrium vapor pressure of the adsorbate over the adsorbent;

Ps is the saturation vapor pressure of the adsorbate at the same temperature.

According to the BET equation, the plot of P/Ps/A(l - P/Ps) versus P/Ps is expressed by a straight line that cuts segment B on the ordinate axis and is inclined to the abscissa axis at an angle whose tangent is equal to K (Figure 2).

It can be seen from the figure that the experimental data, presented in the linear form of the BET equation, really fit on a straight line in the range of water vapor activities from 0.1 to 0.3. This makes it possible to state that, in section A of the sorption isotherm in the studied systems, predominantly localized sorption of water molecules occurs on the polar centers of the adsorbent.

Knowing the tangent of the slope angle and the segment cut off by a straight line on the y-axis, it is possible to calculate the amount of moisture in the monomolecular layer and the constant C [6]:

$$A\infty = \frac{1}{K+B}; \qquad C = \frac{K+B}{B}; \qquad \frac{P/P_S}{A(1-\frac{P}{P_S})} \cdot 10^2 \ \text{mmol/g}$$

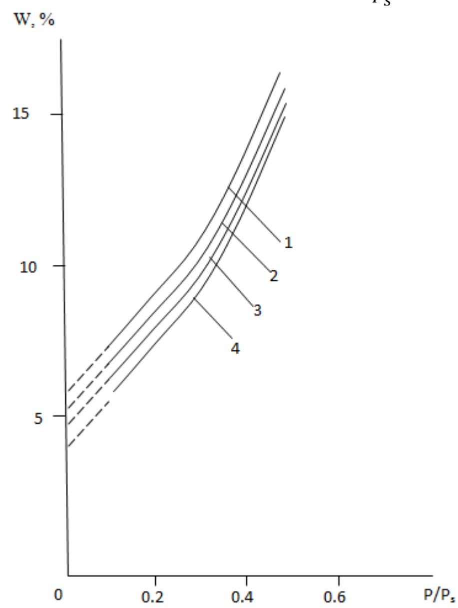

Figure 2. Anamorphosis of isotherms of water vapor sorption by stabilizers in the coordinates of the BET equation. 1 - apple pectin; 2 - applesauce; 3 - carrot puree; 4 - pumpkin puree.

The values of A and C, found from the experimental isotherms, make it possible to determine such parameters of the monolayer as the specific surface area (S_{sp}) and relative air humidity (φ_m), at which the moisture monolayer is adsorbed [7]:

$$S_{sp} = \frac{A_\infty N_A S_B}{M};$$

where NA is Avogadro's number;

SB is the surface area of water molecules;

M is the molecular weight of water.

$$\varphi_m = \frac{(\sqrt{C}-1)}{(c-1)}$$

The calculation results are shown in Table 1.

As the relative vapor pressure increases, the curve of the BET equation goes up from a linear dependence, which can be interpreted as a result of the influence of absorbed water on the structure of stabilizers. Water absorption creates new sorption centers. They are formed as a result of the separation of the surfaces of macromolecules that are initially in contact. In other words, water absorption acts like temperature: under the influence of moisture, segmental mobility of macromolecules appears, the structural organization of samples becomes more complicated, and their sorption capacity increases. The complication of the structure is accompanied by an increase in the porosity of the adsorbent.

Table 1. Hygroscopic characteristics of stabilizers.

Name of stabilizers	Monolayer parameters				
	A_∞, g/g	C	φ_m, %	S_{sp}, м^2/g	W_0, sm^3/g
apple puree	0.074	5.5	29	259	0.098
carrot puree	0.070	3.9	32	245	0.090
pumpkin puree	0.072	3.7	33	252	0.082
apple pektin	0.075	5.6	30	261	0.099

To characterize the porosity of the material, the pore volume (Wo) of the adsorbent was calculated using the equation of Dubinin, Zaverina, Radushkevich [6]:

$$lg_a = \lg\left(\frac{W_o}{V}\right) - 0.43\, b\, (lg\frac{P_s}{P})^2 \quad (1)$$

where a is the amount of adsorbate, mmol/g;

V - is the volume of millimoles of adsorbate, sm^3/g;

b - is a constant.

According to (1), the graph of lg_a versus $(lg\frac{P_s}{P})^2$ is a straight line that cuts off segment C on the y-axis, which determines the pore volume according to the formula:

$W_o = V10^c$;

Figure 3 shows that the experimental data of all samples of stabilizers well satisfy equation (1).

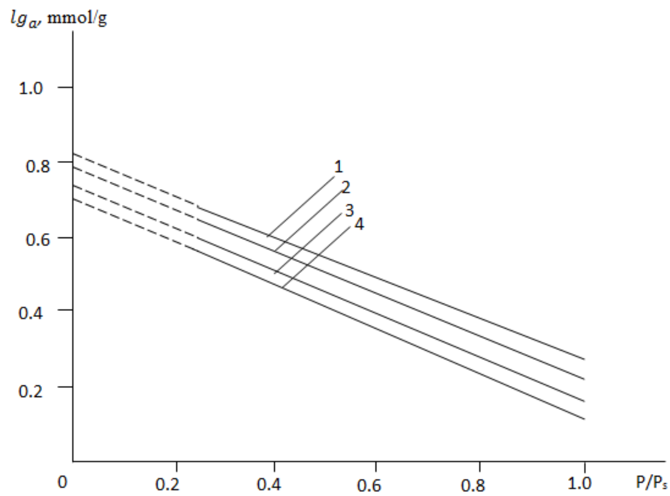

Figure 3. Anamorphosis of the Initial Segment of Water Vapor Sorption Isotherms by Stabilizers in the coordinates of the Dubinin, Zaverina, Radushkevich equations. 1 - Apple pectin; 2 - Applesauce; 3 - Carrot puree; 4 - Pumpkin puree.

The pore volume values of the stabilizers are given in Table 1. It follows from the data in the table that, according to the hygroscopic characteristics, the used apple, carrot and pumpkin purees are close to the properties of apple pectin.

4 Conclusion

A comparable analysis of the moisture absorption capacity of crushed apples, carrots and pumpkins, as well as apple pectin, allows us to conclude that the studied fruit and vegetable stabilizers are close to the properties of apple pectin in terms of sorption characteristics. This confirms the expediency of their use as stabilizers in the production of food products with a foamy structure.

The technologies being developed for foamy food products with fruit and vegetable stabilizers, in addition to expanding the range, will help improve the quality of products, enrich them with vitamins, dietary fiber, minerals and other substances that are often found in diets in insufficient quantities.

References

1. Nasullo Kuliev, IOP Conf. Ser.: Earth Environ. Sci. **981** 022080 (2022)
2. K. S. Rakhmonov, T. I. Atamuratova, N. R. Djuraeva, I. B. Isabaev, L. N. Haydar-Zade, Journal of Critical Reviews **7(5)**, 850-860 (2020)
3. K. S. Rakhmonov, T. I. Atamuratova., M. E. Mukhamedova., N. K. Madjidova., I. Sh. Sadikov, Journal of Critical Reviews **7(12)**, 934-941 (2020)
4. Khayot Bakhronov et al, AIP Conference Proceedings **2432**, 050050 (2022)
5. Yu. G. Frolov, *Course of colloid chemistry* (Chemistry, M., 2009)
6. A. A. Tager, *Physicochemistry of polymers* (Chemistry, M., 1978)
7. A. S. Ginzburg, I. V. Savina, *Mass-moisture exchange characteristics of food products* (Light industry, M., 1982)