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STUDY OF THERMODESTRUCTIVE CHANGES IN MILK POWDER DEPENDING ON THERMAL EXPOSURE

Khasan Sagdiyev [1], Mokhira Zokirkhujaeva [2], Mirolim Aripov [2], Ulugbek Kadirov [2], Sherzod Mamatov [3]

[1] Department of Biotechnology, Tashkent State Technical University;

[2] Department of Food Technology, Tashkent chemical-technological Institute;

[3]Webster University in Tashkent

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Abstract

In this work, we looked at the weight loss of a dry milk sample depending on time with increasing temperature in the range of 80–120 °C. Experimental data on the kinetics of the thermal decomposition process of whole milk powder for conditions of isothermal conditioning of the sample are also presented. The degree of decomposition was determined by the relative loss of mass depending on the time of exposure at constant temperatures, ranging from 80 to 120 °C.

Keywords: *dry milk, whole milk powder for conditions of isothermal conditioning, thermal decomposition*

Introduction

Drying is the most ancient method of preserving milk. During the development of the dairy and canning industry, extensive research was carried out to improve the drying technology, as well as to create agglomerated and rapidly soluble dry dairy products. The composition, properties and structure of dried dairy products, which determine their ability to recover and the nutritional value of recovered dairy products, have been and are being comprehensively studied.

The number of food additives used in the food industry has increased dramatically. The adverse effects of some of them can be diverse both in nature and intensity. Many substances, when ingested for a longer or shorter period of time, especially in combination with other similar substances, even in relatively low concentrations may be far from safe for the body. This adverse effect of food additives can manifest itself in the form of acute or chronic poisoning, mutagenic, carcinogenic or other effects. It is impossible to exclude the possible allergenic effect of foreign food substances, as there is sufficient clinical and scientific data.

Food products of the XXI century are positioned primarily as healthy, so the question

arises about the production of milk powder without food additives, by selecting dairy raw materials, changing the composition of the product and regulating technological processes.

In fresh spray-dried milk powder, all the constituent components are fairly evenly distributed in the particle mass. In this case, the continuous phase is lactose, in which fat globules, protein particles and other components are dispersed. More recent studies have established that the continuous phase in the particles can be a protein, which is a porous system of interconnected protein micelles (Ming, J. L. K., Anuar, M. S., How, M. S., Noor, S. B. M., Abdullah, Z., & Taip, F. S., 2021; Saha, D., Nanda, S. K., & Yadav, D. N., 2019). A significant proportion of milk powder particles mainly has a spherical shape and is in a free state. The bulk of the particles has a size of up to 50 microns. A small part of the powder forms agglomerates by combining individual particles with each other. The surface of the particles under the microscope at low magnification appears smooth, glossy and slightly melted. There are crater-like depressions on the surface of individual particles.

During the drying process, the components of milk powder undergo a number of changes, which affects the quality of the product. Changes in milk fat under the influence of temperature concern both its physical condition and chemical composition.

The fat in powdered milk is mostly fairly evenly distributed inside its particles. Electron microscopic studies show that the size of fat globules in the particles of powdered milk obtained from a homogenized product is 0.04–1 microns, and from non-homogenized milk – 5 microns (Babu, K. S., & Amamcharla, J. K., 2022).

Depending on the drying temperature, the size of the fat balls varies. It was also found that when drying milk on the company's direct-flow spray system, the diameter of the fat balls is linearly dependent on the temperature of the air entering the dryer.

The temperature conditions of the drying process also affect the stability of the fat phase of milk. Also, when the temperature of the air entering the direct-flow spray dryer increases from 160 °C to 190 °C, the free fat content increases by 2–3%. Free fat can be found on the surface of the particles in the form of tiny balls and irregularly shaped clusters. Electron microscopic studies show that fat can also be located in the folds of the surface and at the points of contact of particles. The nature of the distribution of free fat on the particle surface is influenced by the presence of micropores, which are channels connecting the particle surfaces with its internal regions, through which part of the free fat can reach the surface (Vincenzetti, S., Cecchi, T., Perinelli, D. R., Pucciarelli, S., Polzonetti, V., Bonacucina, G., Ariani, A., Parrocchia, L., Spera, D. M., Ferretti, E., Vallesi, P., & Polidori, P., 2018).

In our work, we studied the thermodestructive changes in milk powder depending on temperature and duration of thermal exposure.

Objects and Methods

The objects of research at various stages of the work were: – selected whole pasteurized milk with a mass fraction of 3.4–6.0% fat.

The method of identification of the products of the thermal degradation reaction was carried out by the method of absorption spectroscopy.

Absorption spectroscopy is one of the methods of qualitative analysis. The identification of a pure compound is based on a comparison of the spectral characteristics (maxima, minima, inflection points) of an unknown substance and pure compounds; the close similarity of the spectra serves as a good proof of chemical identity, especially if the spectrum of the substance being determined contains a large number of clear, easily identifiable maxima. Spectral studies in the ultraviolet region of the spectrum provide information about the presence or absence of certain functional groups.

There are catalogues of the spectral characteristics of organic compounds in the ultraviolet and visible regions of the spectrum. They are used in the qualitative analysis of organic compounds. The reliability of identification by the absorption method is determined by the number of matching spectral characteristics in the spectra of the compound being determined and the standard.

The identity of the substance to be determined and the standard is confirmed by comparing their spectra obtained at different pH values or after further chemical treatment.

The absorption of functional groups is identified using this method.

The spectra were taken on a spectrophotometer SF-26, in the wavelength range 220–320 nm. The cuvette is 0.3 cm. 100 times diluted raw milk was used as a comparison solution. The object of the study was milk recovered from milk powder samples subjected to thermal exposure in the temperature range of 60–160 °C.

The composition of gases released during decomposition was determined by gas adsorption chromatography on an LHM- ZMD chromatograph with a thermal conductivity detector using aluminum oxide as a sorbent (AlYammahi, J., Rambabu, K., Thanigaivelan, A., Hasan, S. W., Taher, H., Show, P. L., & Banat, F., 2023).

Investigation of the microstructure of milk powder particles. The microstructure of milk powder particles obtained at different temperatures was studied by scanning scanning microscopy using a JEOL JSM – 6390 electron microscope.

Results and Discussion

A series of experiments was conducted to determine the weight loss of a milk powder sample depending on time with an increase in temperature in the range of 80–120 °C. Properly prepared powdered milk retains almost all the beneficial properties and taste qualities of the dairy product. At the same time, the dry concentrate has an extended shelf life and greater compactness during transportation, depending on the main quality indicators of the finished product.

The kinetics of the thermal decomposition of whole milk powder for the conditions of isothermal holding of the sample is shown in Figure 1.

The degree of decomposition was determined by the relative loss of mass depending on the holding time at constant temperatures ranging from 80 to 160 °C. Curves for temperatures of 80, 90 °C characterize a slight loss of mass. At temperatures of 100.110 °C, the process is activated and the mass loss is 15%.

For higher temperatures of 120 °C, the process is characterized by intensive decomposition during the first 60–90 minutes and does not exclude changes in the future. The percentage of mass loss is 27%. The experimental data obtained are shown in (table 1).

Table 1. *Weight loss of whole milk powder samples depending on temperature and holding time*

Variants	Thermostat temperature, °C	Weight loss.%					
		30	60	90	120	150	180
		Exposure time. min.					
experience 1	60	1.0 0.2	1.4 ± 0.2	2.0± 0.2	2.0± 0.2	2.7± 0.2	3.7± 0.2
experience 2	80	2.4±0.2	2.4 ± 0.2	2.4 ± 0.2	3.3 ± 0.2	3.4 ± 0.2	4.3± 0.2
experience 3	100	3.4 ± 0.2	3.9 ± 0.2	4.0 ± 0.2	4.0 ± 0.2	4.1 ± 0.2	4.6± 0.2
experience 4	110	2.8 ± 0.2	3.4 ± 0.2	3.4 ± 0.2	3.7 ± 0.2	4.0 ± 0.2	5.1± 0.2
experience 5	120	2.4 ± 0.2	3.3 ± 0.2	5.4 ± 0.2	6.0 ± 0.2	9.3 ± 0.2	13.2± 0.2
experience 6	130	5.7 ± 0.2	6.3 ± 0.2	9.4 ± 0.2	11.3± 0.2	12.9± 0.2	14.8± 0.2
experience 7	140	7.5 ± 0.2	8.1 ± 0.2	12 ± 0.2	18.6± 0.2	24.1± 0.2	24.7± 0.2
experience 8	150	14.4± 0.2	20.8± 0.2	22.8 ± 0.2	23.7± 0.2	25.5± 0.2	27.2± 0.2
experience 9	160	8.2 ± 0.2	17.5 ± 0.2	23.2 ± 0.2	25.5± 0.2	25.5± 0.2	27.7± 0.2

Based on thermogravimetric analysis and existing concepts, it has been established that the decomposition of whole milk powder begins with the fat-free part of the product. Upon visual observation, whole milk powder after thermal exposure with time exposure thickens, and the color changes from light cream to dark brown already at 110–120 °C.

The decomposition process of whole milk powder was also investigated using a differential analysis method.

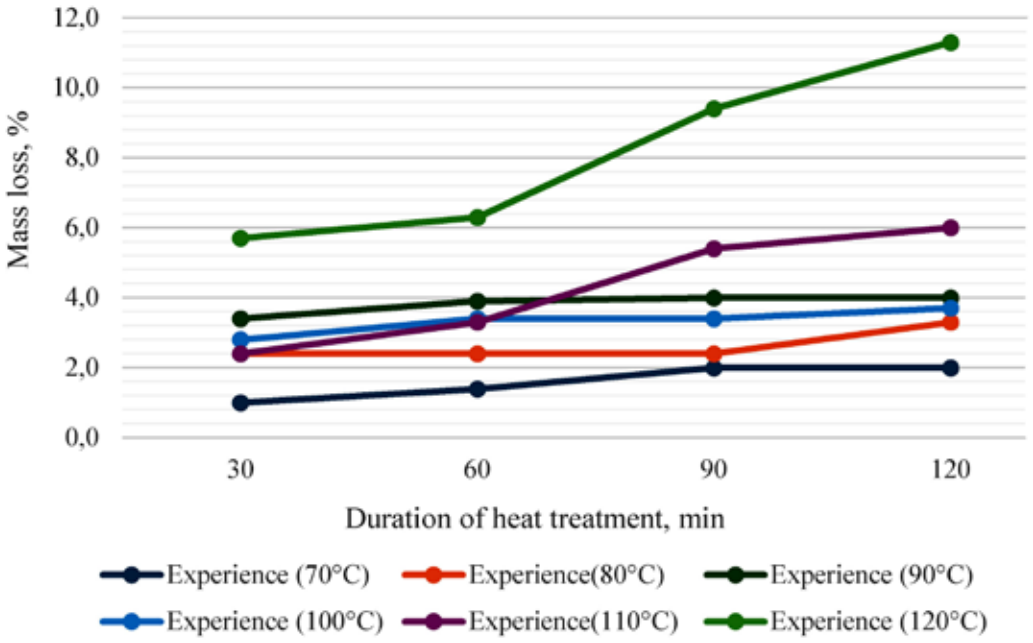
Analyzing the obtained curves, the following can be noted:

When heated to 110 °C, the mass loss is 9.3%. Heating the product in this zone contributes to the release of water vapor, carbon dioxide, and hydrogen. The maximum rate

of mass loss at a temperature of 110 °C. The ongoing processes are endothermic in nature (the curve – DTA goes down from the main position).

When heated from 110 to 146 °C to activate the process of thermal destruction. The maximum decomposition rate is 41.2%. There is a decomposition process, accompanied by the release of heat.

Figure 1. *Mass change depending on the holding time in the isothermal mode*



The temperature range is 146–184 °C. Weight loss is 8.4%. The process is exothermic – the DTA curve rises and reaches a peak at 170 °C.

A noticeable change in mass begins at a temperature of 90 °C. The rise of the DTA curve characterizes the gradual heating of the suspension followed by self-heating, and therefore the development of exothermic reactions. The nature of the TG curve characterizes the activation of the decomposition process, which accelerates to a temperature of 136 °C. Thus, the temperature of 136 °C is characteristic. The maximum decomposition rate characterizes a significant loss of mass. The sharp upward rise of the dTA curve characterizes the predominance of exothermic reactions.

Conclusion

It can be seen from the curves of the differential decomposition rate that the process of thermal decomposition proceeds in stages with clearly defined maxima. The curves shift to the high temperature region.

The processing of the results of the derivatographic analysis consisted in determining the characteristic temperatures according to the DTG and DTA curves, calculating the weight loss of the suspension in characteristic temperature ranges. Temperature extremes on the DTA curve are also quite characteristic. Thus, based on the results of the derivatographic analysis, the following conclusions can be drawn:

– the data obtained by gravimetry and derivatography are quite comparable, although the latter method more accurately and consistently shows the process of thermal decomposition of the product;

– the depth of thermal decomposition depends on the time to reach the temperature and the holding time at this temperature.

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Contact: sherzod_mamatov@mail.ru