Effect of cream-plant mixtures on properties of multicomponent albumin-based products

Olena Grek[1], Alla Tymchuk[1], Artem Bogachuk[2], Nikita Soloviov[1], Oleksii Shumylo[1]

1 – National University of Food Technologies, Kyiv, Ukraine
2 – St. Lawrence College, Kingston, Canada

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Corresponding author:

Alla Tymchuk
E-mail: 589112@ukr.net

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Abstract

Introduction. The aim of the research is to determine the effect of adding cream-plant mixtures on the properties of multicomponent albumin-based products.

Materials and methods. The research utilized albumin mass, bird cherry flour, and cocoa fiber. Solubility was determined using the Shoha method. The fat- and moisture-holding capacities were measured by centrifugation. Thermogravimetric analysis was performed using a derivatograph. The moisture-holding capacity was assessed by the modified gravimetric method.

Results and discussion. The solubility of cocoa fiber and bird cherry flour in water is higher compared to their solubility in whey by 1.6±0.1% and 1.5±0.1%, respectively; in cream with 10% fat content, solubility increases by 4.9±0.1% and 4.5±0.1%; and in cream with 20% fat content, by 6.5±0.1% and 5.3±0.1%, respectively. This increase is attributed to the high content of water-soluble carbohydrates and certain dietary fibers present in the plant-based ingredients. The optimal amounts of plant ingredients were found to be 3.0–5.0% for bird cherry flour and 2.0–3.0% for cocoa fiber. The addition of bird cherry flour had a slight impact on the active acidity (pH) of the test samples, while also contributing to a reduction in moisture content. To investigate the forms of moisture binding in the albumin product containing bird cherry flour, a thermogravimetric analysis was conducted. It was established that incorporating this plant ingredient into the albumin product increases its hydrophilicity and raises the specific heat required for product dehydration. Adding bird cherry flour directly to the albumin mass with 77±2% moisture content enables binding of free moisture, which is then normalized by the subsequent addition of cream. This approach ensures stable quality indicators of the product, enrichment with flavonoids, phytoncides, and essential amino acids (leucine, valine, and phenylalanine). A potential extension of shelf life is possible due to the presence of antioxidants in bird cherry flour. Cocoa fiber binds and retains moisture due to its hydrophilic properties, moisture-retaining, and primarily fat-retaining capacities.

Conclusions. The use of cocoa fiber and bird cherry flour in the composition of cream-plant mixtures helps to normalize multicomponent albumin products.

Introduction

Albumin-based snack and dessert products have a wide assortment range (Bintsis and Papademas, 2023; Kindar, 2022). Whey cheeses are currently produced worldwide under various local names. In Italy, they are known as ricotta, ricotta salata, ricottone, and ricotta fresca; in Greece – anthotyros, myzithra, manouri, xynomyzithra, and urda; in Turkey – lor; in Cyprus – anari; in Croatia and Serbia – skuta; in Norway – gjetost and brunost; in Sweden – mesost and messmör; in Iceland – mysuostur; in Denmark – myseost; in Portugal – requeijão; and in Spain and Mexico – requesón (Bintsis and Papademas, 2023).

One of the well-established technologies for ricotta cheese production involves the incorporation of dietary fibers at varying concentrations—1%, 3%, and 5% of the raw material mass. The sample with the addition of 3% citrus dietary fiber demonstrated the most harmonious sensory characteristics (Zinina et al., 2021). Other studies explore the addition of various herbs and/or plant extracts to diversify the range of whey cheeses and extend their shelf life (Akpinar et al., 2022). Specifically, black cumin, thyme, and rosemary are frequently used as additives that enhance sensory characteristics and impart antioxidant properties to the cheese (Ramírez-Rivas et al., 2022). Another direction in the improvement of such technologies involves the use of quality prediction methods for albumin-based products during storage. The possibility of predicting the quality indicators of albumin paste using potato fiber "Potex" as a moisture regulator during storage has been substantiated (Grek et al., 2017)

In modern albumin product technologies, functional additives are widely used (Grek et al., 2023). The technology for Ricotta cheese enriched with spirulina powder at levels of 0.25, 0.5, 0.75, and 1.0 g/100 g of cheese is known. Enrichment with spirulina powder led to an increase in the content of proteins, fats, ash, fiber, carbohydrates, and minerals, phenolic compounds, β-carotene compared to the control (Ismail et al., 2023). Furthermore, Kaminarides et al. (2019) determined the effect of fat content in whey on the technological and consumer properties of whey cheeses. Four cheese variants were studied. It was found that increasing the fat content in rennet whey contributes to a higher yield of the final product and improves its sensory and textural characteristics. There is a limited amount of studies concerning the enrichment of albumin-based products standardized for fat. For the effective use of plant ingredients in such multicomponent albumin products, selection criteria have been developed, including functional and technological properties, regional availability, and industrial processing methods. It is advisable to give preference to plant raw materials that have undergone special thermal treatment, exhibit stable characteristics, and are microbiologically safe.

The increasing use of plant-based ingredients in food formulations is a notable trend in the food industry (Stabnikova et al., 2021). Fruits of bird cherry (*Prunus padus* L.) are rich in bioactive compounds possessing antioxidant activity, while bird cherry flour could serve as a useful ingredient in the preparation of functional foods (Stabnikova et al., 2024). Bird cherry flour is a raw material obtained from bird cherry fruits by drying and grinding using specialized equipment. The flour has a brown color and an almond-like flavor, which can impart original sensory properties to the final product (Telichowska et al., 2020). Bird cherry flour is used in the production of bakery and confectionery products, including gluten-free items, as well as a component in reduced-calorie sauces (Dziundzia and Zvaholska, 2021; Niemirich, 2018).

Bird cherry flour has the following chemical composition: protein – 7.6%; carbohydrates – 21.8%; dietary fiber – 4.7%; ash – 2.7%; iron – 0.2 mg; potassium – 13.4 mg; calcium – 2.2 mg; manganese – 0.9 mg; zinc – 0.3 mg. It also contains vitamins B_1 (0.39 mg), B_2 (0.07 mg), E (1.7 mg), PP (0.9 mg), ascorbic acid (0.45%), malic acid (0.63%), and citric acid (0.28 mg) (Dziundzia and Zvaholska, 2021; Niemirich et al., 2018). Bird cherry flour contains tannins (6–

8%) and flavonoids (1.5–2.0%), including hyperoside, quercetin 3-galactoglucoside, and astragalin. It also contains anthocyanins (5.4–16.5% of total flavonoids), primarily cyanidin 3-rutinoside (9.13%) and cyanidin 3-glucoside (7.35%). Additional bioactive components include carotene; cyanogenic glycosides such as amygdalin, prunasin, and amygdonitril glycoside; carbohydrates including fructose (4.42–6.44%), glucose (5.33–6.35%), sucrose (0.6–6.2%); pectin substances (1.1%); and benzaldehyde with essential oils (0.26%). The flour also contains trace elements such as Mg, Cr, Al, Se, Ni, Sr, Pb, B, I, Cu, and Co (Telichowska et al., 2020).

Cocoa fiber is a modern functional ingredient derived from the husk and kernel of cocoa beans, ground during the production of cocoa butter or cocoa powder. It is non-alkalized and contains no flavorings, preservatives, or added sugars. Cocoa fiber contains higher levels of antioxidants and magnesium than any other plant product and has a low fat content. It can be considered a carbohydrate-protein complex with valuable technological functionalities (Anoraga et al., 2024).

Cocoa fiber was used for enrichment (Certificate NC-3413, COID: POL-1-9445-658511) with the following composition, %, per 100 g of product: protein – 17.0, fat – 2.5, carbohydrates – 0.7, fiber – 72.0% (including insoluble – 61.0, soluble – 11.0), salt – 0.1. The energy value of the product is 249 kcal per 100 g. According to sensory indicators, the fiber is a brown powder with a uniform texture, a pronounced chocolate aroma and taste, and no foreign flavours (Rojo-Poveda et al., 2020). In addition to its functional properties, dietary fiber possesses specific technological capabilities that enable the development of products with a moderately viscous consistency (Anoraga et al., 2024).

In the production of multicomponent dessert products based on dairy protein concentrates, including high-albumin content mass, normalization is achieved by adding cream (Gawande et al., 2023). Similarly, in the production of sour milk cheese using the separated method, it is essential to normalize the protein base with cream of varying fat contents. This cream was heat-treated at (78±2) °C for 15–20 seconds, and then cooled to (8±2) °C before mixing.

For albumin products with a fat content of up to 3.0%, it is relevant to normalize with cream of various fat contents up to 20% (Freitas et al., 2024). When enriching albumin products with normalization, it is necessary to determine the most effective methods for incorporating bird cherry flour and cocoa fiber, considering their functional and technological properties.

It is advisable to determine the effect of cream-plant mixtures on the characteristics of multicomponent albumin products.

Materials and methods

Materials

The basis for the production of experimental samples of multicomponent albumin products was albumin mass obtained from rennet whey by the thermo-acid coagulation method, which had a moisture content of 77±2 %, titratable acidity of (60±3) °T, protein content at the level of 18.0±1.0%, and lactose content of 1.7±0.1%.

The whey had the following physicochemical characteristics: titratable acidity – 15±1 °T, fat content – (0.2±0.1) %, and dry matter – (6.30±0.02) %.

Plant components – bird cherry flour and cocoa fiber were used for enrichment of multicomponent albumin products (Figure 1).

a b

Figure 1. Bird cherry fruits and bird cherry flour (a); cocoa pods and cocoa fiber (b) used for enrichment of multicomponent albumin products

Preparation of cream-plant mixtures for normalization of multicomponent albumin products

Cream-plant mixtures for the normalization of multicomponent albumin products consisted of dairy cream, cocoa fiber or bird cherry flour, and sugar. Before being added to the albumin mass, the plant ingredients were soaked in pasteurized dairy cream at a temperature of 60-65 °C with a holding time of 10-15 minutes, followed by cooling to a temperature of 4±2 °C. Sugar was added for 15%.

The cream had the following physicochemical characteristics: fat content – 10% or 20%, protein – 2.8-2.9%, carbohydrates – 3.7-4.3%, titratable acidity – 17±1 °T, density – 1005 kg/m³. The cream had a liquid, homogeneous consistency without fat lumps or protein flakes; a sweetish, clean flavor and odor, with no foreign or uncharacteristic notes for fresh cream.

Production of model samples of multicomponent albumin products

For the research, model samples were produced, normalized with cream and supplemented with cocoa fiber or bird cherry flour in amounts ranging from 2.0% to 6.0% of the final product mass.

To prepare the multicomponent products, albumin mass at a temperature of 10–15 °C, the cream-plant mixture, and sugar were mixed, and then sent for packaging and further cooling to a temperature not exceeding 8 °C.

The control was an albumin product (including fat-standardized) obtained using the aforementioned technology without the addition of plant ingredients.

At the first stage, the functional and technological properties of cocoa fiber and bird cherry flour were determined for their use as components of multicomponent albumin products, including the identification of optimal environments and methods of incorporation (cream or directly into the albumin mass). The parameters studied included solubility, water- and fat-binding capacities, which are associated with the carbohydrate and protein composition of the ingredients.

The solubility of dry plant ingredients in an aqueous medium is determined by the presence of soluble compounds – certain proteins and carbohydrates, including some pectic substances and starch; insoluble compounds include fiber, and lignin.

Methods

Research procedure. Standardized and validated methods for analysing techno-functional properties and quality indicators were applied during the research process, ensuring the reliability of the obtained results and achievement of the stated objective.

Functional and technological properties of bird cherry flour and cocoa fiber

The solubility of plant ingredients of various origins was determined using the Shoha method (Onopriichuk et al., 2022). This method is based on the ability of carbohydrates to swell and dissolve in water depending on the strength of their structure.

T*he fat-binding capacity* of cocoa fiber or bird cherry flour mixed with cream with fat contents of 10% and 20% was determined by the centrifugation method (Delgado-Ospina et al., 2021).

The method for determining the water-holding capacity of plant ingredients is similar to that of fat-binding capacity but is conducted in water (control) and whey. The result is expressed in grams of absorbed moisture per gram of plant ingredient sample (Grek et al., 2020).

Physicochemical and sensory indicators of multicomponent albumin products

The water-holding capacity (WHC) of multicomponent albumin products was determined by the gravimetric method of Grau-Hamm as modified by A.A. Alekseev (Grek et al., 2023).

The sensory indicators of multicomponent albumin products were assessed according to ISO standard 22935-3:2009 and individual sensory attributes (Elsamani, 2016).

Thermogravimetric parameters of multicomponent albumin products

Derivatography allows determination of the stages and temperature intervals of decomposition, type of thermal effects, and depth of structural-chemical transformations (Lammerskiten et al., 2019).

Thermogravimetric studies were conducted using a modernized Q–1000 derivatograph produced by MOM.

Information on changes in T, TG, DTG, and DTA is transmitted to an analog-to-digital converter and then via interface converter to a personal computer, where it is stored and processed.

Conditions for thermal analysis:

- Sample heating rate 3.6 K/min;
- Temperature interval from 20±2 °C to 250 °C;
- Weight scale 100 mg.

Samples (control and albumin product with bird cherry flour) were placed in an open conical platinum crucible from the derivatograph set. The atmosphere was static air. Aluminium oxide was used as the inert substance in the comparison crucible. The DTA scale of the derivatograph was calibrated using stearic acid (ΔH_{ref} = 198.9 J/g), a reference substance used for calibration of DTA and DSC instruments. The temperature deviation did not exceed ±0.5 K (Ovsiienko et al., 2021).

Determination of the rheological characteristics of cream-plant mixtures

The dynamic viscosity of cream-plant mixtures with varying amounts of cocoa fiber was determined using a Hepler viscometer equipped with a set of balls of different diameters and a cylindrical gauge. Absolute (dynamic) viscosity (η) of cream-plant mixtures with cocoa fiber was calculated using the formula, Pa·s × 10^{-3}:

$$\eta = \tau \cdot (d - d_1) \cdot k, \quad (1)$$

where τ is a time of ball descent, s; d is a density of the material from which the ball is made at 20 °C, kg/m³; d_1 is a density of cream-plant mixtures with cocoa fiber at 20 °C, kg/m³; k is a ball constant. The density of the ball material and the constant are specified in the certificate supplied with the device (Sapiga et al., 2019).

Statistical analysis

All experiments were conducted in triplicate or more, and the results were expressed as mean ± standard deviation. Data were analysed using one-way ANOVA and Tukey's HSD tests by the SPSS statistical package. Significant difference was defined at $p \leq 0.05$.

Results and discussion

Functional and technological properties of bird cherry flour and cocoa fiber

The results of determining the solubility of plant ingredients in water, whey, and cream with fat content of 10 % and 20% are presented in Figure 2. The process was conducted at a temperature of 20±2 °C.

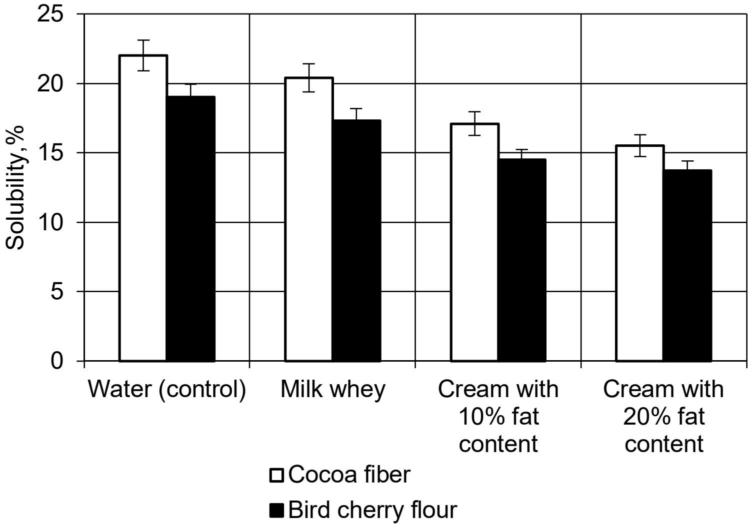

Figure 2. Solubility of cocoa fiber and bird cherry flour in different media

The solubility of cocoa fiber in water is higher by 1.6±0.1%, 4.9±0.1%, and 6.5±0.1% than in whey and cream with fat content of 10 % and 20 %, respectively, while for bird cherry flour these values are higher by 1.47±0.1%, 4.5±0.1%, and 5.3±0.1% respectively. This is explained by the presence of surface-active substances in the dispersive media (whey and cream), which adsorb onto the surface of plant ingredients, form a protective layer, and hinder fluid access. These indicators are due to the content of nearly 11.0 % soluble fiber, proteins, and other substances in cocoa fiber that ensure high solubility (Chico, 2022; Younes et al., 2023), as well as the ability to increase mixture viscosity, and its high dispersibility (99 % < 40 µm) (Soares et al., 2022). Bird cherry flour contains a large amount of water-insoluble carbohydrates and dietary fibers (21.8 % and 4.7 %) (Dziundzya et al., 2021), which reduce the solubility level of this plant ingredient to 19.0±0.2 % (in water). Thus, it has been found that for normalization of cream-plant mixtures, it is appropriate to use cocoa fiber, while bird cherry flour should be added directly into the albumin mass, which contains 77±2 % moisture (whey), followed by cream-based normalization. This technological technique is effective.

At the next stage, the water- and fat-binding capacities of cocoa fiber and bird cherry flour in water, whey, and cream with fat content of 10 and 20% were studied. The process was conducted at a temperature of 20±2 °C. The research results are presented in Figure 3.

According to Figure 3, the highest fat-binding capacity was recorded for cocoa fiber: in cream with 10% and 20% fat content, the indicator was 3.3±0.1 g/g and 2.7±0.1 g/g respectively. At the same time, this dietary fiber shows high water-binding capacity: in water – 4.6±0.1 g/g and in whey – 4.01±0.1 g/g. This effect in cocoa fiber results from its chemical composition and is similar to the values reported by other authors in similar systems (Delgado-Ospina et al., 2021). The fat- and water-binding capacity values of bird cherry flour are lower than those of cocoa fiber by 1.1±0.1 g/g and 0.9±0.1 g/g in cream with 10 % and 20 % fat content, respectively, and by 1.3±0.1 g/g in whey and 1.11±0.1 g/g in water.

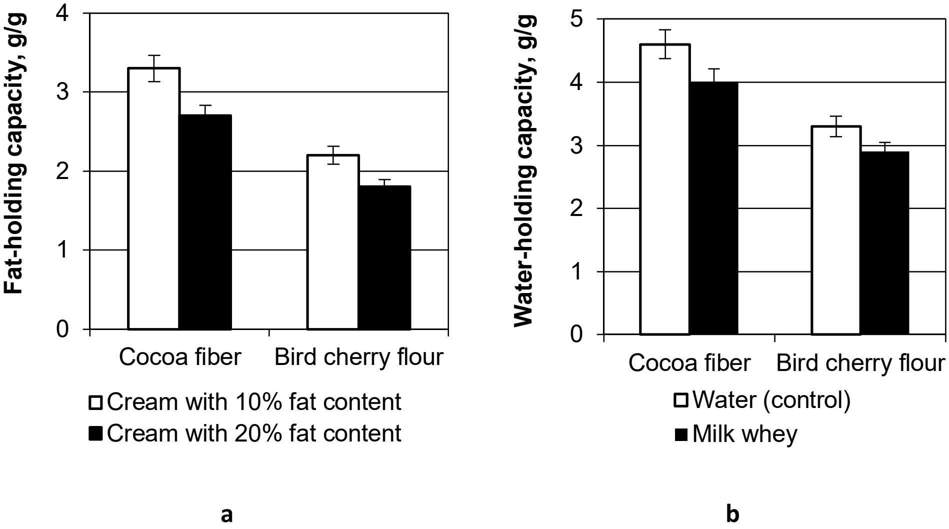

Figure 3. Fat- (a) and water-holding (b) capacities of cocoa fiber and bird cherry flour in different media

Considering the results of the solubility, fat- and water-binding capacity studies of cocoa fiber and bird cherry flour; it is advisable to use 10% fat cream for normalization by fat content in albumin products.

Physicochemical and sensory characteristics of multicomponent albumin-based products

The selection of the optimal level of plant ingredient incorporation was based on maintaining the standard sensory properties characteristic of albumin-based products. Table 1 presents the results of the sensory evaluation of multicomponent albumin-based products with varying levels of bird cherry flour addition.

Appropriate taste properties and consistency of the multicomponent albumin product were achieved with the addition of 3.0–5.0% bird cherry flour. The samples had stable quality indicators, increased content of biologically active components, original sensory characteristics, and a brown color evenly distributed throughout the mass with inclusions of the plant ingredient.

Adding more than 5% bird cherry flour results in excessive changes in the sensory properties of the multicomponent albumin product – an intensely pronounced almond aroma and dark brown color with significant inclusions of bird cherry flour appear. Adding less than 3% of the plant ingredient has no noticeable positive effect on sensory properties and minimizes the enrichment of the albumin product with biologically active nutrients. The almond aroma of the multicomponent albumin product is due to the content of glucosides (amygdalin, prulaurasin, and prunasin) in bird cherry flour (Telichowska et al., 2020).

An albumin product containing 3.0–5.0% bird cherry flour can be used as a base for dairy-protein products with a plastic structure (creams, desserts, sauces).

Table 1

Sensory characteristics of multicomponent albumin products with varying amounts of bird cherry flour added

Parameters	Amount of bird cherry flour added,%				
	2	3	4	5	6
Consistency and appearance	Homogeneous, with inclusions of bird cherry flour	Homogeneous, moderately dense, does not change during storage			Homogeneous, moderately dense
Taste and aroma	Clean, creamy, with a slight almond aroma	Clean, creamy, with an almond aroma			Clean, creamy, with a strongly pronounced almond aroma
Color	Light brown, uneven throughout the mass with occasional inclusions of bird cherry flour	Brown, even throughout the mass with inclusions of bird cherry flour			Dark brown, even throughout the mass with significant inclusions of bird cherry flour

At the next stage, the main physicochemical indicators of normalized albumin products with 3.0–5.0% bird cherry flour content were studied. The respective values are presented in Table 2.

Table 2

Physicochemical indicators of normalized albumin products with different bird cherry flour content

Amount of bird cherry flour added,%	Physicochemical indicators of the albumin products			
	Content,%		Moisture retention capacity,%	Active acidity, pH units
	Dry matter	Moisture		
Control	23.0 ± 0.3^{a}	77.0 ± 2.0^{a}	47.5 ± 0.2^{a}	5.00 ± 0.02^{a}
3	25.8 ± 0.2^{b}	74.2 ± 1.0^{ab}	51.2 ± 0.1^{b}	4.89 ± 0.03^{ab}
4	26.7 ± 0.3^{bc}	73.3 ± 0.5^{b}	53.4 ± 0.3^{bc}	4.85 ± 0.01^{b}
5	27.8 ± 0.3^{c}	72.2 ± 1.0^{b}	55.3 ± 0.2^{c}	4.83 ± 0.01^{b}

Note: Values are the means ± standard deviation. Means within the same column with different superscripts are significantly different at $p \leq 0.05$.

With the addition of 3% to 5% bird cherry flour, the active acidity of the experimental samples changes slightly. For the control, this indicator is 5.00±0.02 pH units, while for the sample with the maximum amount of bird cherry flour it is 4.83±0.01 pH units. The moisture content decreased as the amount of bird cherry flour added increased. The change in moisture content and moisture retention capacity of albumin products with plant ingredients can be explained by the chemical composition of bird cherry flour – a complex of linear and branched biopolymers with hydroxyl (cellulose, hemicellulose), phenolic (lignin), and carboxyl (hemicellulose, pectic substances) groups, which over time strengthen hydrogen bonds and the ability to sorb water and other polar molecules and ions, thereby increasing moisture retention capacity.

Effect of bird cherry flour addition on thermogravimetric parameters of multicomponent albumin products

The quality of food products, appearance, taste, and stability during storage directly depend on the moisture content. One of the methods for determining the moisture content of food products is thermogravimetric analysis. When setting research objectives in this area, the analysis of the kinetics of mass loss under differences in the internal heat content of the system during exothermic and endothermic transformations is important; as well as comparing the thermal stability of food systems under specific values of mass loss.

Qualitative and quantitative assessment of the processes occurring during sample heating is carried out using curves of temperature change (T), sample mass (TG), rate of mass change (DTG), which is the derivative of the TG curve, and DTA. The DTA curve represents the temperature difference between the sample and an inert material in the form of the difference in thermoelectromotive forces of thermocouples. DTA allows the identification of thermal processes occurring in the sample during heating. Due to the thermal resistance of the sample material, the temperature peaks of thermal effects (DTA) are higher than the corresponding maxima in the rate of mass change (DTG).

Figures 4 and 5 show the derivatograms of the multicomponent albumin product with bird cherry flour (experimental sample) and the albumin product (control sample).

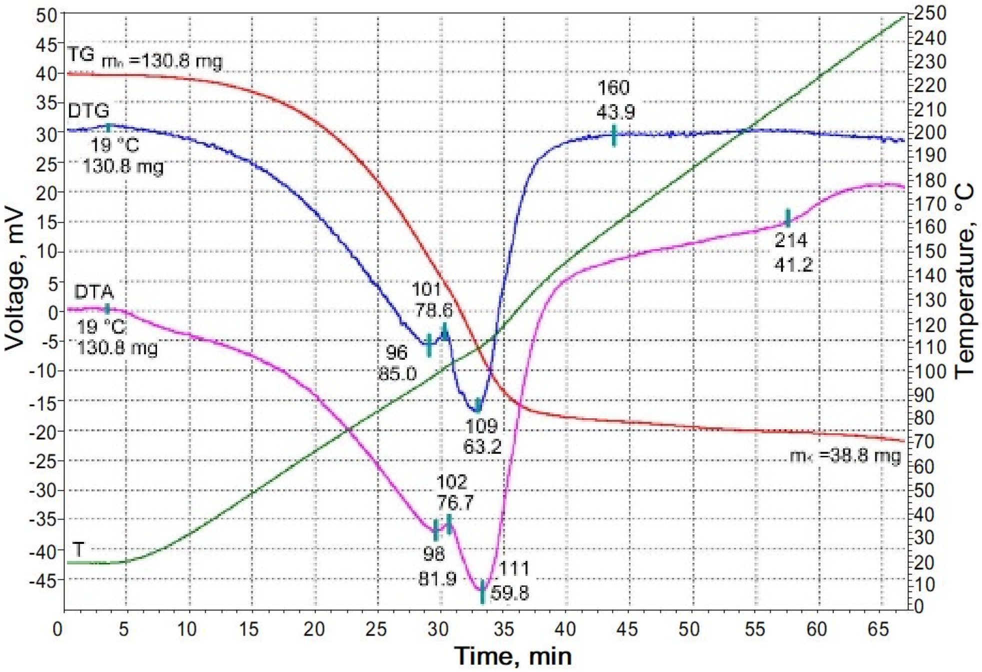

Figure 4. Derivatograms of multicomponent albumin product with bird cherry flour

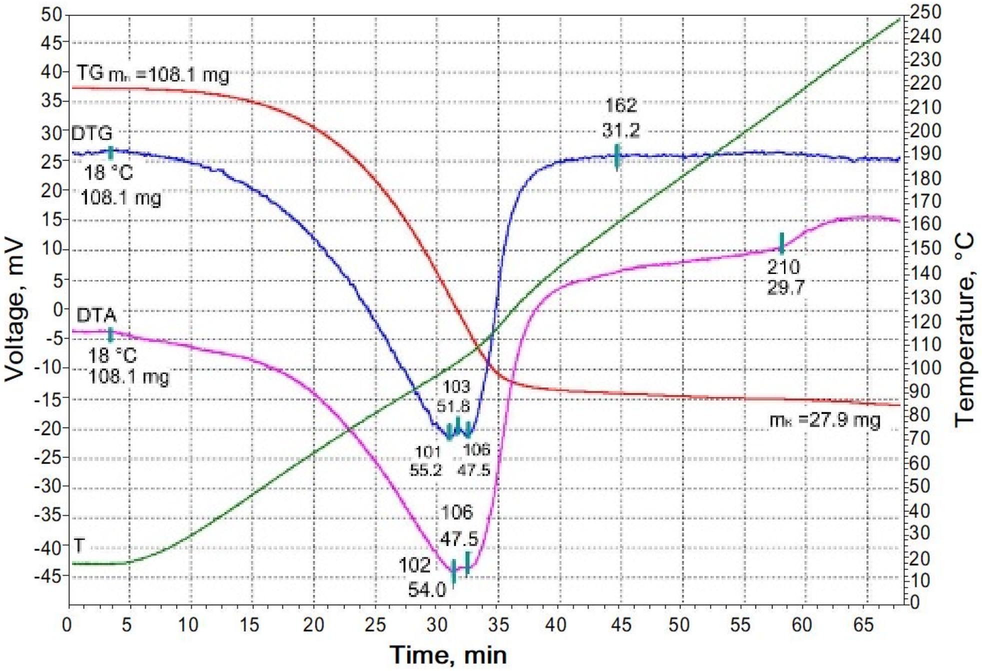

Figure 5. Derivatograms of the albumin product

The nature of both derivatograms is similar and shows the feature that dehydration occurs in two stages. Mass loss of the multicomponent albumin product samples with and without bird cherry flour (TG curves) begins at 18 and 19 °C (for control and experimental samples respectively) and is accompanied by heat absorption, as the DTA curves deviate downward. As the temperature increases, the dehydration rate (DTG curves) rises, reaching a maximum during the first stage of dehydration for the experimental sample of the multicomponent albumin product with bird cherry flour at 109 °C (Figure 4), and for the control sample of the albumin product at 106 °C (Figure 5).

A slight increase in dehydration rate is recorded for both the control and experimental samples, with maxima at 101 °C and 96 °C, respectively. During the first stage of dehydration, 77.79% and 78.80% of water is removed from the multicomponent albumin products with and without bird cherry flour, with an average rate of 1.57% and 1.72%, respectively.

The temperature ranges of dehydration, average rate, and share of removed water relative to the total water mass are presented in Table 3.

According to the method (Ovsiienko et al., 2021), based on DTA curves, the integral heat used for dehydration of the multicomponent albumin product samples with and without bird cherry flour during heating was determined and the specific heat of dehydration was calculated (Table 4).

Table 3

Amount of water removed during dehydration and loss of dry matter during thermal decomposition

Material	Dehydration							
	Firs stage			Second stage			Total	
	τ, °C	RW, %	AR, %/min	τ, °C	RW, %	AR, %/min	τ, °C	AR, %/min
Albumin product	18–106	78.80	1.72	106–162	21.20	1.23	18–162	1.59
Multicomponent albumin product with bird cherry flour	19–109	77.79	1.57	109–160	22.21	1.36	19–160	1.53

Note: τ is temperature; RW – removed water; AR – average rate.

Table 4

Mass and moisture of samples, temperature range and specific heat of dehydration, interval and dry matter loss during thermal decomposition

Material	Moisture content, %	Dehydration				Thermal decomposition	
		τ, °C	RW, mg	IH, J	SH, kJ/kg	τ, °C	DML,%
Albumin product	71.14	18–162	76.9	208.062	2706	162–250	3.05
Multicomponent albumin product with bird cherry flour	66.44	19–160	86.9	238.521	2745	160–250	3.90

Note: RW – removed water; IH – integral heat; SH – specific heat; DML – dry matter loss.

The second stage of dehydration of the multicomponent albumin product with bird cherry flour begins at 109 °C, while that of the control sample starts at 106 °C, and differs from the first stage by a significant increase in the dehydration rate, which reaches a maximum at 117.7 °C and 114.4 °C, respectively, for the experimental and control samples. At the final stage of dehydration, slight increases in the rate are recorded, with maximum values at 162 °C for the experimental sample and 160 °C for the control.

The amount of water removed during the second stage of dehydration of the multicomponent albumin product with bird cherry flour (experimental sample) is 22.21% of the sample's mass at an average dehydration rate of 1.36%/min. The control sample loses 21.20% of water with an average rate of 1.23%/min. The higher dehydration rate of the control albumin product sample compared to the experimental one is associated with its higher moisture content. Dehydration of the multicomponent albumin product samples is completed at practically identical temperatures (160.0–162.0 °C) and at the same temperature, the thermal decomposition process begins.

After complete dehydration of the samples, mass loss is observed on the TG and DTG curves along with heat generation, which is reflected in the rise of the DTA curves (Figures 5 and 6). Such process behavior results from the onset of thermal decomposition, which occurs in the intervals of 162–250 °C and 160–250 °C. Before reaching 250 °C, the samples lose different portions of dry matter. The experimental sample loses 3.9% of dry matter, while the control loses 3.05%. These results are likely due to differences in the initial content of dry matter in the products under the same decomposition conditions.

According to the method described by (Mykhailyk et al., 2015), the integral heat consumed for dehydration of the samples of multicomponent albumin products with and without bird cherry flour during heating was determined from the DTA curves, and the specific heat of dehydration was calculated. The DTA scale of the derivatograph was calibrated using stearic acid (ΔH_{ref} = 198.9 J/g) – a reference substance used for calibrating DTA and DSC instruments (Lammerskiten et al., 2019).

According to the method described by Ovsiienko et al. (2021), the integral heat consumed for sample dehydration during heating was determined from the DTA curves, and the specific heat of dehydration was calculated (Table 4).

The obtained values of the specific heat of dehydration of the multicomponent albumin products with and without bird cherry flour exceed the average specific heat of evaporation of pure water from a free surface, which is approximately 2360 kJ/kg, in the studied temperature ranges, characterizing the studied objects – multicomponent albumin products – as systems with a high degree of hydration.

A comparison of the specific heat values during dehydration of the studied samples showed that the multicomponent albumin product containing bird cherry flour exhibited a 1.5% higher specific heat compared to the control albumin sample. The addition of bird cherry flour to the composition of the albumin product increased the content of hydrophilic centers in the composition and thus increased the amount of bound water, which caused an increase in the specific heat of dehydration.

Effect of cocoa fiber addition on the quality characteristics of multicomponent albumin products

The profile chart of sensory evaluation of the multicomponent albumin product with varying amounts of cocoa fiber is presented in Figure 6.

When 2.0–3.0% cocoa fiber is added, the multicomponent albumin product exhibits the best taste and texture. A smaller amount (less than 2.0%) has an insufficient effect on the properties of the final product, whereas an excess (more than 3.0%) makes the structure heterogeneous, dense, with an intensely pronounced color and aroma of cocoa fiber. The influence of the optimal amount of cocoa fiber addition on the change in dynamic viscosity of the cream-plant mixture was determined, as well as the change of this indicator depending on the temperature of the mixtures.

To determine the effect of the studied dietary fibers on the change in dynamic viscosity of cream-plant mixtures at different temperatures, mixtures with the addition of 2% and 3% cocoa fiber were prepared under the parameters identified in previous studies – the profile chart of sensory evaluation of the multicomponent albumin product. The heating temperature of the mixtures ranged from 20 °C to 80 °C. This temperature range was chosen due to the further development of technologies for multicomponent albumin products and for the purpose of destroying unwanted microflora. As the temperature rises, denaturation of the cream proteins occurs, leading to a decrease in the biological value of the cream-plant mixtures.

The change in dynamic viscosity of cream-plant mixtures with different amounts of cocoa fiber at temperatures from 20 °C to 80 °C is graphically presented in Figure 7.

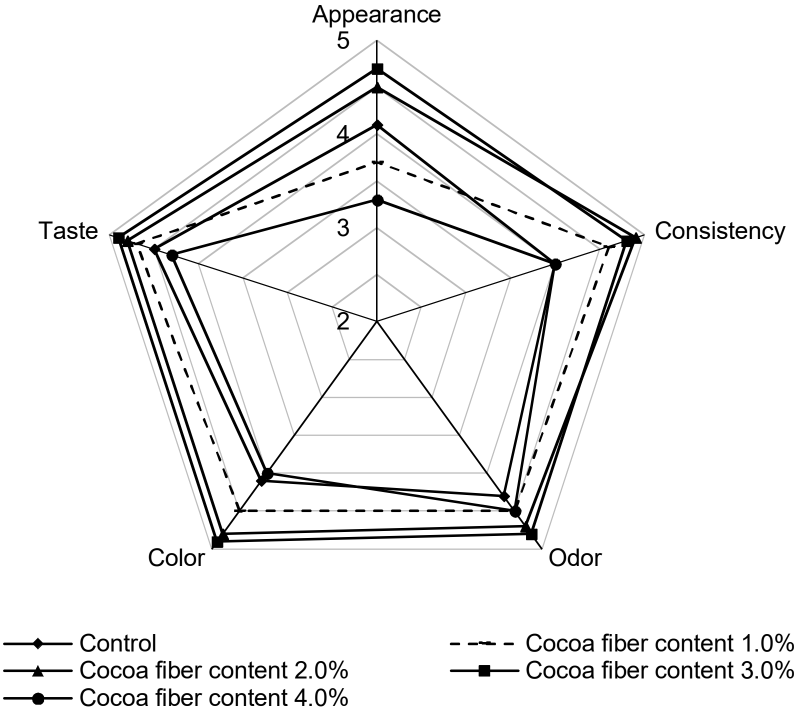

Figure 6. Sensory evaluation profile diagram of multi-component albumin products with different cocoa fiber contents

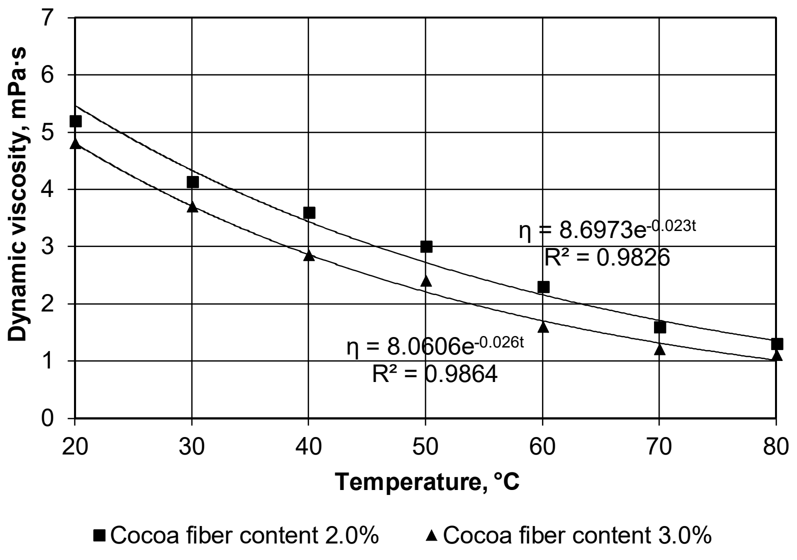

Figure 7. Change in dynamic viscosity of cream-plant mixtures with different contents of cocoa fiber at temperatures from 20 to 80 °C

As seen from Figure 8, the highest dynamic viscosity – 5.20±0.01 mPa·s at a temperature of 20 °C – was recorded for the cream-plant mixture with 3.0% cocoa fiber. With the addition of 2.0% fiber, this indicator at the aforementioned temperature was 4.80±0.01 mPa·s. Creams with a fat content of 10–20% approach Newtonian fluids, but when the fat content exceeds 30%, they become significantly structured and acquire non-Newtonian fluid properties (Kyazze et al., 2004; Šestan et al., 2016). As the temperature of cream-plant mixtures with cocoa fiber increases, dynamic viscosity decreases by 3.7-3.9 mPa·s, respectively, due to the increased Brownian motion of solution molecules and the weakening of interaction forces between them. The viscosity of the studied cream-plant mixtures significantly depends on the content of milk fat and proteins, particularly whey proteins, which correlates with the data of Biglarian et al. (2022). With further influence of high temperature on milk proteins due to the increase in the size of casein particles and complex formation between whey protein fractions and casein (Sutariya et al., 2017), the viscosity of cream-plant mixtures decreases. The decrease in viscosity of cream-plant mixtures during prolonged heat treatment can also result from partial destabilization of the milk fat emulsion. This pattern is observed in all samples of mixtures with plant-based ingredients. The presence of carbohydrates, including soluble (pectins) and insoluble fiber, as well as mineral compounds in the cocoa fiber composition, additionally binds free water and improves the structuring of cream-plant mixtures.

The effect of varying amounts of cream-plant mixtures with cocoa fiber on the physicochemical indicators of multicomponent albumin products was also studied. The corresponding values are presented in Table 5.

Table 5

Main physicochemical indicators of multicomponent albumin products with cocoa fiber

Amount of added cream-plant mixture,%	Mass fraction,%		Moisture retention capacity,%	Active acidity, pH units
	Dry matter	Moisture		
10	25.6±0.2[a]	74.4±0.2[a]	50.11±0.10[a]	5.16±0.01[a]
15	26.5±0.1[ab]	73.5±0.3[ab]	49.20±0.15[ab]	5.24±0.02[ab]
20	27.4±0.1[b]	72.7±0.2[b]	48.60±0.13[b]	5.32±0.01[b]

Note: Values are the means ± standard deviation. Means within the same column with different superscripts are significantly different at $p \leq 0.05$.

It was found that with an increase in the content of cream-plant mixtures, the active acidity of the multicomponent albumin products slightly increased – from 5.00±0.02 pH units to 5.32±0.01 pH units.

From the obtained values of water-holding capacity (Table 5), it can be seen that with an increase in the content of cream-plant mixtures, this indicator changes for all multicomponent albumin products, with the growth dynamics varying. This is due to the amount of added soluble fiber, protein, and other substances that ensure high solubility (Chico, 2022; Younes et al., 2023) and indicates the ability to increase the viscosity of cream-plant mixtures, as well as having high dispersibility (99% <40 μm) (Soares et al., 2022). When cream-plant mixtures were added at levels between 15% and 20%, the difference in water-holding capacity among the experimental samples was less pronounced, amounting to just 0.6%. The highest WHC values were observed in samples with the addition of 10% cream-plant mixtures. In addition, these multicomponent albumin product samples were characterized by a dense consistency.

Conclusions

The possibility of effective use of cocoa fiber and bird cherry flour in the composition of cream-plant mixtures for normalization in the technology of multicomponent albumin products has been proven.

The solubility, water- and fat-holding capacities of cocoa fiber and bird cherry flour were determined. The solubility in water, whey, and cream of different fat content was recorded for cocoa fiber at the level of: in water – 22.0±0.3%, in whey – 20.4±0.2%, in cream with 10% fat – 17.1±0.2%, and in cream with 20% fat – 15.5±0.1%. For bird cherry flour, the corresponding values were: in water – 19±0.1%, in whey – 17.3±0.1%, in cream with 10% fat – 14.5±0.1%, and in cream with 20% fat – 13.7±0.1%, respectively. The highest fat-holding capacity was shown by cocoa fiber in cream with 10% fat content (3.3 g/g) compared to cream with 20% fat. For bird cherry flour, the mentioned indicators were recorded at the level of 2.8±0.1 g/g and 1.8±0.1 g/g in cream with 10% and 20% fat content, respectively, and the water-holding capacity was sufficiently high – 3.2±0.1 g/g in milk whey.

The physicochemical and sensory parameters of multicomponent albumin products depending on the amount of cocoa fiber or bird cherry flour added were studied. The appropriate sensory indicators were observed in products with the addition of 3.0-5.0% bird cherry flour and 2.0-3.0% cocoa fiber. The samples had stable quality indicators, an increased content of biologically active components, and original sensory properties.

By means of thermogravimetry and differential thermal analysis, it was determined that the dehydration of multicomponent albumin product samples with bird cherry flour and albumin product samples occurs in two stages due to the composite composition and structural changes. These stages differ in temperature intervals, the proportion of removed water, and the rate of removal. Due to the sufficiently high content of bound water in the materials of both multicomponent albumin product samples, the specific heat of their dehydration significantly exceeds the average heat of water evaporation from a free surface. The addition of bird cherry flour to the composition of the albumin product increases the product's hydrophilicity, which leads to an increase in the specific heat of dehydration.

The physicochemical parameters of multicomponent albumin products depending on the amount of cream-plant mixtures with cocoa fiber were studied. It was established that with an increase of the amount of cream-plant mixtures from 10% to 20% in multicomponent albumin products, the content of dry substances increases from 23.0±0.3% (for control) to 27.4±0.1% and the active acidity up to 5.32±0.01%. At the same time, the moisture content and water-holding capacity decrease to 72.7±0.2% and 48.60±0.13%, respectively.

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