Наведені результати визначення забарвлення рослинних порошків з овочів та фруктів з використанням сучасної цифрової техніки. Визначені величини колірних координат порошків у сухому та відновленому станах, а також в готових стравах. Обґрунтовано перспективу використання методики визначення забарвлення сировини, напівфабрикатів і готових виробів для контролю якості виробництва

Ключові слова: колірні координати, комп'ютерна колориметрія, індекс жовтизни, рослинні порошки, цифрове зображення, колір

Приведены результаты определения цвета растительных порошков из овощей и фруктов с использованием современной цифровой техники. Определены величины цветовых координат порошков в сухом и восстановленном видах, а также в готовых блюдах. Обоснованы перспективы использования методики определения цветности сырья, полуфабрикатов и готовых изделий для контроля качества производства

Ключевые слова: цветовые координаты, компьютерная цветометрия, индекс желтизны, растительные порошки, цифровое изображения, цвет

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EXPLORING THE COLOR OF PLANT POWDERS USING COMPUTER COLORIMETRY

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1. Introduction

The level of development of infrastructure of the agrarian market of Ukraine is determined by the state of food safety and socio-economic development of the country, since the agrarian sector, formed on the basis of wide application of contemporary innovative and information technologies, can become one of the profitable directions in the development of economy.

Drying is characterized by technological effectiveness, efficiency and eco-friendliness of the production [1]. Dry production has high food nutritious value and possesses many advantages: mass and volume of the products decreases considerably with the storage and preliminary preparation, as well as the need for boxes, warehouses and separate production premises, which makes transportation easier and cheaper.

Therefore, expansion of assortment of the processed fruit and vegetable production due to increasing the share and variety of the assortment of dry fruits and vegetables nowadays is expedient and promising.

In future, due to an increase in the consumption of production by the enterprises of food industry, as well as development of culture of consumption of dry vegetables, fruits and nuts by the population of the country, a further increase and development of market both in the quantitative and in the qualitative indicators is expected. Powders are one of the promising forms of dry plant products [2, 3]. Fruit and vegetable powders, having rich chemical composition, in particular, can be used in the technologies of whipped sweet dishes for the purpose of their enrichment, assortment expansion, intensification of processes, forming high sensory properties. In recent years, it has been established by many studies that the risk of diseases, caused by negative environmental effect, is substantially reduced with the use of food ration, enriched by the complex of biologically active materials, in particular, vitamins, bioflavonoids, microelements, pectic substances of the fruit and vegetable raw material [4].

Color is the key index of quality and consumer properties of foodstuffs with the use of plant powders. Sweet whipped dishes, in particular, sambuc, form a special group of culinary products, the composition of which implies creation of slightly acidic medium. In connection with this, a relevant direction of studies is exploring biotransformation of pigments of vegetable and fruit powders in the given multi-component food systems in the course of technological process of making dishes and culinary products.

2. Literature review and problem statement

Sweet whipped dishes are heterogeneous systems, which are obtained by whipping a foaming agent with the subsequent introduction of flavour, aromatic and coloring substances into the mixture [5].

Varieties of the assortment of sambuc, their flavour qualities and the content of substances useful for organism are created by introduction of additional ingredients, which make changes in the colour of these dishes [6]. The use of vegetable and fruit powders in the technological process of their preparation makes it possible to simplify the operations on mechanical culinary processing of vegetables and fruits, to reduce duration of the technological process of making culinary products, to widen the assortment, to decrease the areas of warehouses and manufacturing premises and to avoid seasonality of using vegetables and fruits [7].

The majority of plant powders can be used for creating new products. Nevertheless, depending on the final use, the pigment composition of the powders must be considered [8].

For controlling the used raw material, sensory assessment of products is frequently used [9]. This method is not accurate enough because of possible subjectivity of the views of a taster [10].

The progressive development of digital technology gave rise to formation of the new direction – the method of computer colorimetry, the essence of which lies in the description of the color of objects in the system of color coordinates according to the results of processing digital images of the tested sample [11]. Thus, the results obtained by the researchers [12] showed that the measurement of color coordinates by the method of processing the image of the sample may be used for controlling the tendency of change in the chromaticity of food products.

This method was used for controlling the process of drying fish [13], assessment of quality of tomatoes [14] and ham [15], etc.

However, literary sources do not reveal the possibility of applying the method of computer colorimetry of finished dishes and culinary products while using the plant raw material, which predetermines the relevance of the chosen direction of the study.

3. The aim and the tasks of the study

The aim of the work was to prove experimentally a possibility of using the method of computer colorimetry for the quality control of plant powders.

To achieve the set goal, it is necessary to solve the following tasks:

– to explore color of plant powders in the dry and restored state with the use of computer colorimetry;

– to examine influence of the pigments of plant powders on the color of finished dishes by the method of computer colorimetry;

– to propose the sequence of assessment of the quality, namely, color of the finished products by the method of computer colorimetry.

4. Materials and methods of determining chromaticity of plant powders by the method of computer colorimetry

The powders from cabbage, obtained by new prospective method of drying with the mixed heat supply (TUU 10.3-01566330-279:2012) were selected as tested materials. The sample for the comparison in this case was the powder from cabbage of traditional convective method. The powders from spinach and apples of low-temperature drying (LTD), peaches and strawberries of cold spray drying (CSD) of the Swiss company «OBIPEKTIN AG», CH-9220 BISCHOFSZELL were also analyzed. The studies evaluated the powders from fruits of sea buckthorn of convective drying (TU 9164-089-38826547-2014), which are the concentrate of biologically active substances, structuring agents, color-forming and aromatic natural additives in the technology of sweet whipped products – sambuca and cream.

Detailed description of the procedure of computer colorimetry, which was used for evaluating the color of plant powder, is represented in [18, 19]. The assessment of color of the image of the tested powders was conducted in two models of color: RGB (Fig. 1, *a*) and in CIELab (Fig. 1, *b*) [18].

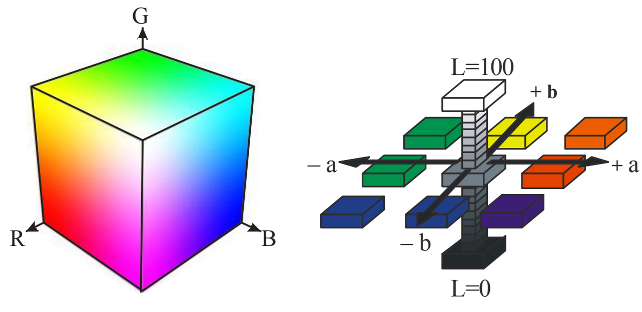


Fig. 1. Color space of color systems: *a* – RGB; *b* – CIELab

5. Results of studies of color of plant powders and meals made with their use by the method of computer colorimetry and discussion of these results

The obtained digital images of powders in the native state and in the state, restored in water, were assessed for the value of coordinate magnitudes in the RGB and CIELab systems (Fig. 2).

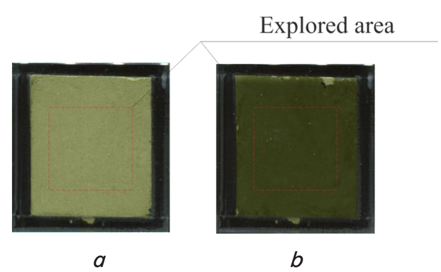


Fig. 2. Digital images of the tested samples of powder of spinach: *a* – in native state; *b* – in restored state

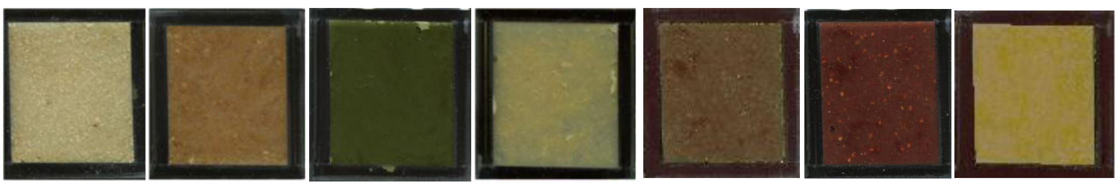
In each tested sample, an equal area of ~288 mm^2, which corresponds to the square of 235×235 pixels, was analyzed. General view of digital images of the restored powders is shown in Fig. 3. The average value of color coordinates of the analyzed areas (Fig. 3) is represented in Table 1.

It is clear from the obtained data (Table 1) that the restored powders from cabbage have higher values of the color saturation index – C_{ab} units. The powder from cabbage has varieties of pigments, which determine color; however, their concentration brings the color of the powder close to white color. This is clearly seen by the color coordinates in the RGB system, which, correspondingly, tend to maximum value. It should be noted that the powder from cabbage, obtained by drying with the mixed heat supply, has saturated color, which is observed by the values of the coordinates, which are decreased in comparison with the powder from cabbage, obtained by convective drying.

Table 1

Color characteristics of native vegetable and fruit powders and of those restored in water

Powder	State	Color coordinates, units						Saturation, C_{ab}	Yellowness index
		Systems RGB			Systems CIELab				
		R	G	B	L	a	B		
From cabbage of convective drying	native	215	209	173	82	1	17	290,00	68,67
	restored	166	153	107	64	0	27	765,00	77,93
From cabbage of drying with mixed heat supply	native	189	161	118	68	6	27	765,00	82,66
	restored	126	96	53	43	9	30	981,00	106,34
From spinach LTD	native	135	142	91	58	–9	27	810,00	–
	restored	54	60	25	24	–7	21	490,00	–
From apples LTD	native	209	190	138	78	1	30	901,00	77,03
	restored	146	136	86	57	–2	29	845,00	81,26
From peaches CSD	native	131	120	92	68	1	26	879,00	70,03
	restored	92	84	55	42	–2	24	825,00	80,05
From strawberries CSD	native	123	76	61	38	19	18	685,00	–
	restored	80	38	28	21	19	16	617,00	–
From sea buckthorn of convective drying	native	194	151	63	65	9	50	2581,00	110,06
	restored	163	132	96	57	8	23	593,00	85,36



a *b* *c* *d* *e* *f* *g*

Fig. 3. Digital images of the restored samples of plant powders: *a* — from cabbage of convective drying; *b* — from cabbage of drying with mixed heat supply; *c* — from spinach; *d* — from apples; *e* — from peaches; *f* — from strawberries; *g* — from sea buckthorn

The restored powders from spinach, apples, strawberries and sea buckthorns have somewhat other properties, since in the dry state their index of color saturation is higher than in the native state. This may be caused by the composition of pigments of the raw material. Thus, the powder from spinach is characterized by the saturated green color (Fig. 2), caused by content of chlorophyll, which is evident from the higher value of the green component – G ~142 un., in comparison with the blue component – B ~92 un. However, the red component – R has somewhat lower value in comparison with the green one; however, its value is determined by the presence of the pigment carotene.

The powder from strawberries contains the pigments anthocyans and flavonoids. The color of anthocyans ranges from bright red to violet, and the color of flavonoids ranges from yellow to orange. The red component does not reflect the presence of such pigments. However, examining the values of coordinate systems of CIELab, it is clear (Table 1) that the color of the native and restored powder from strawberries lies in the plane of red-orange shades. This regularity proves the presence of anthocyans and flavonoids. The size of the component of the coordinates of color "+a" (the plane of red color Fig. 1, *b*) remains constant for both samples of powder from strawberries.

Apples, as well as powders from them, are characterized by a wide range of content of natural pigments: riboflavin, chlorophyll, carotene, anthocyan and tannin. Their concentration in the pulp of apples does not give them bright color, and is mainly characterized by the yellowish-white shade (prior to the beginning of oxidation processes).

Yellow color in the RGB system has the values of coordinates R=255, G=255 and B=0, white color – R=255, G=255 and B=255, respectively (Fig. 1, *a*). By the results of obtained values of coordinates, it is seen that the color of powder from apples tends to yellow-white color.

The shift of color to yellow is proved by the value of magnitudes of CIELab, and, namely, «+b» (Table 1 and Fig. 1, *b*). The values of smaller magnitudes of coordinates remain the same for the restored powder. This is explained by the better capability for hydration. The values of the yellowness index increase as well.

It should be noted that all plant powders in the restored state have a smaller value of lightness – L in comparison with the dry powder (Fig. 4). The linear dependency of this change, depending on a plant powder, has a different slope angle.

The most significant difference of lightness is observed for the powder from spinach – magnitude L decreases by ~59 % (Fig. 1, *b*) and for the powder from strawberries it decreases by ~44 %. For other plant powders, the lightness decreases on average by 21 %. This decrease is explained by the fact that during the restoration of powders, the pigments fully demonstrate their properties of coloring.

Color is one of the indices, which will make it possible to estimate the content of additives of the plant powder to a culinary product. In further studies, the color of foam structures, sambuc and creams made from sour cream with added plant powders, was determined (Table 2).

Table 2

Color coordinates of sambuc and cream made of sour cream depending on the type of added powder

Sambuc or cream made of sour cream with powder	Amount of powder, % to the mass of formulation composition	Color coordinates						Saturation, C_{ab} units
		Systems RGB			Systems CIELab			
		R	G	B	L	a	B	
Control – foam system	–	152	152	118	52	–4	18	340,00
From cabbage	25	156	154	119	54	–3	21	351,00
	50	162	167	129	64	–2	26	371,00
From spinach	25	149	156	115	63	–8	21	505,00
	50	144	152	109	62	–9	22	565,00
From strawberries	25	128	110	80	47	4	20	416,00
	50	131	112	81	49	4	21	457,00
From peaches	25	135	131	95	55	–3	21	450,00
	50	113	110	78	46	–3	19	370,00
From apples	25	130	128	91	54	–3	21	445,00
	50	110	107	69	40	–3	19	368,00
From sea buckthorn	10	252	238	192	94	–1	23	530,00
	15	247	217	118	87	1	51	2602,00

It is necessary to note the decrease in the magnitude of color saturation of sambuc in comparison with the restored powders (Fig. 5), which is caused, first of all, by decrease in the concentration of powders and, correspondingly, the pigments (which form the color of product).

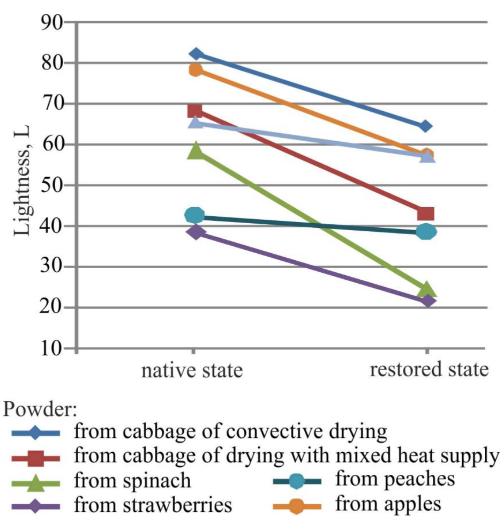


Fig. 4. Magnitudes of lightness of plant powders in native and restored state

It is clear from Fig. 5 that in the foam systems with addition of 25 % of powder from peach, the color of product becomes lighter, i. e., the magnitudes of color coordinates of RGB increase (Fig. 1, *a*). With the increase in the amount of added plant powder and, respectively, of the pigment, the value of coordinates shift in the direction of restored powder. This situation is characteristic for all plant powders and, consequently, for the products made with their use.

Adding the powder from strawberries 25 % and 50 % shifts the magnitude of coordinates from the plane of red color to the plane of orange color, with the corresponding change in the value of the coordinate "+a" from 19 to 4, and that of the coordinate «+b» from 20 to 18 (with the addition of 25 %) (Table 2 and Fig. 1, *a*). An increase in the quantity of added powder from strawberries to sambuc somewhat changes the magnitude of the red component of color coordinates in the RGB system by 4 units, but in the CIELab system, the red component "+a" remains constant with a decrease in brightness.

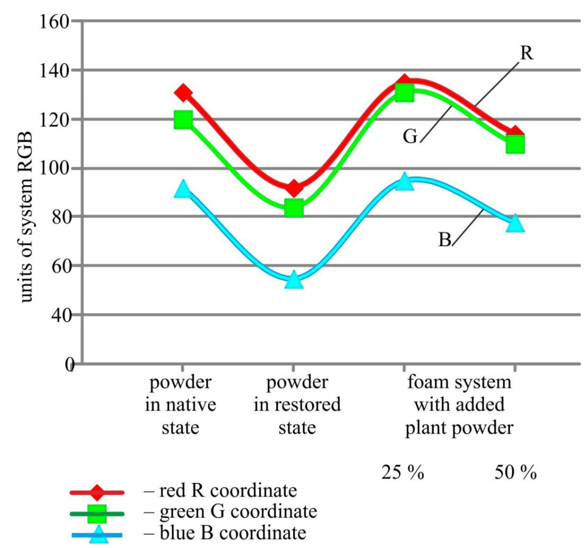


Fig. 5. Change in magnitudes of color coordinates of powder from peach in native and restored state as well as in foam system

The powder from sea buckthorn in the cream made of sour cream demonstrates less intensive color against the background of the white component of the sour cream components, which is proved by an increase in the values of the RGB coordinates. If we examine the obtained values of coordinates in the CIELab system, it should be noted that the magnitude of green and yellow component «–a» and «–b» remained the same.

It was found that adding powders to the formulation composition of sambuc gives it attractive color in all added concentrations in comparison with the control.

Thus, the color of meals was defined with the use of computer colorimetry to prove that plant powders retain the ability to give attractive color to products and to improve their sensory properties.

In accordance with this method, digital images of sambuc and cream made of sour cream were obtained with subsequent determining the chromaticity coordinates and calculation of the corresponding indices, which are represented in Table 2.

A study of color of plant powders in different states and in the composition of multi-component food system, using the method of computer colorimetry, makes it possible to estimate transformation of coloring substances in the course of technological process of making whipped sweet meals. However, for detailed estimation of color of prepared meals, it is necessary to consider and preliminarily study color-forming peculiarities of main ingredients of the formulation, which requires additional measures to control innovative products.

The accessibility of the method makes it possible to use it for evaluating quality, controlling technological process of preparing meals and culinary products with the use of traditional and innovative ingredients, including vegetable and fruit-and-berry powders. Conducting corresponding studies might be rather expedient since it would make it possible to widen the concept of coloring pigments during their transportation and storage, which allows predicting the shelf life of food products.

6. Conclusions

1. By the method of computer colorimetry, color of plant powders was studied, as a result, it was established that the color of restored powders from cabbage and from apples is more intensive than that of native powders. However, powders from spinach, strawberries and peach have such color properties that are more expressed in the dry state than after the restoration, which is caused by pigment composition of the raw material.

2. By using the method of computer colorimetry, the effects of pigments of plant powders on the color of prepared meals was explored, which, in turn, makes it possible to control finished products by the color index of the ingredient that is added to the product. In this case, the limits of variation of each component in the RGB system must not exceed ±10 units and for the CIELab system, ±6 units.

3. The sequence of assessing the color of prepared meals and culinary products implies measuring the color of the main ingredients of the formulation with subsequent consideration of the influence of each of them on the final result of this indicator.

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THE EFFECT OF CRYOMECHANODESTRUCTION ON ACTIVATION OF HETEROPOLYSACCARIDE-PROTEIN NANOCOMPLEXES WHEN DEVELOPING NANOTECHNOLOGIES OF PLANT SUPPLEMENTS

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Вивчено вплив процесів глибокої переробки рослинної сировини, яка включає кріогенне «шокове» заморожування та дрібнодисперсне подрібнення, на активацію важкорозчинних та важкозасвоюваних гетерополісахарид-білкових нанокомплексів в розчинну форму. Установлено, що відбувається руйнування і трансформація їх значної частини в наноформу (на 45...55 %) при розробці нанотехнологій пюре з топінамбуру. Розкрито механізми процесів

Ключові слова: глибока переробка сировини, кріомеханодеструкція, дрібнодисперсне подрібнення, топінамбур, нанокомплекси, інулін, нанопюре

Изучено влияние процессов глубокой переработки растительного сырья, которая включает криогенное «шоковое» замораживание и мелкодисперсное измельчение, на активацію труднорастворимых и трудноусвояемых гетерополисахарид-белковых нанокомплексов в растворимую форму. Установлено, что происходит разрушение и трансформация их значительной части в наноформу (на 45...55 %) при разработке нанотехнологий пюре из топинамбура. Раскрыт механизм процессов

Ключевые слова: глубокая переработка сырья, криомеханодеструкция, мелкодисперсное измельчение, топинамбур, нанокомплексы, инулин, нанопюре

1. Introduction

Deep processing of raw materials using the processes of cryomechanodestruction opens up a possibility of the more complete use of biological potential of plant raw materials (higher by 45–55 % than when using existing methods) and manufacturing a new generation of natural nanoproducts for healthy nutrition.

The relevance of development of nanotechnologies, based on applying the processes of cryomechanochemistry and cryomechanodestruction that make it possible to maximally preserve and extract biologically active substances (BAS) of the original raw materials, is caused by the need to address a global problem that is currently observed in many countries of the world. The problem is the imbalances and deficiency (by 50 %) in the food rations of population of vitamins, high-