KAPITEL 4 / *CHAPTER 4* [4]

STUDY OF THE COLOR AND AROMA OF PLANT RAW MATERIALS OBTAINED BY DRYING WITH MIXED HEAT SUPPLY

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Introduction.

Vegetables are high-tech crops and a necessary component of the human diet. Practice and statistical data indicate a high volume of cultivation, consumption and use in food technology of white cabbage, zucchini and carrot. Such crops are disease-resistant, high-yielding and widely distributed in Ukraine.

When storing and processing vegetable raw materials and creating competitive food products, various methods of drying raw materials are promising: cold spray drying, convective drying, sublimation drying with the use of cryodestruction, etc. Modern methods of drying make it possible to preserve nutrients contained in native vegetable raw materials and reduce their loss during storage. The volume of dried vegetables is 3..5 times smaller than that of fresh ones.

For the formation of the color and aroma of plant raw materials drying with mixed heat supply (MHS-drying) should be considered the most energy efficient of all the currently known methods. In addition to energy efficiency, this method is a certain approximation to freeze-drying, and, from the point of view of heat or thermal action on food raw materials, is the most economical.

The color and aroma of dried raw materials are determining factors in the quality level since, during the evaporation of moisture from the raw material, it carries away volatile components, resulting in a partial loss of taste, aroma and color [1–3]. The formation of aroma involves a large number of chemical compounds formed during the growth of vegetables and their drying: heterocyclic and carbonyl compounds, hydrocarbons, sulfur-containing compounds, esters and others. The aroma of dried vegetable raw materials is formed by 5 to 30 harmonized individual components [4–6].

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For the investigation of the quality of vegetable plant raw material obtained by MHS-drying at temperatures of 50 °C and 70 °C, as well as convective drying, their aroma intensity and color were studied.

Materials and methods.

The aroma intensity of the investigated samples was determined using a technique based on the interaction of essential oils with a chromic mixture, where their oxidation occurs due to the oxygen released by potassium dichromate $K_2Cr_2O_7$:

$$Cr_2(SO_4)_3+K_2SO_4+4H_2O+3O_2 \rightarrow K_2Cr_2O_7+4H_2SO_4 \quad (1).$$

Upon adding a solution of KI, a reaction occurs between the remaining $K_2Cr_2O_7$, after the oxidation of all the essential oils extracted from the weighed product and KI. As a result of the redox reaction, free iodine is released, which is titrated with a solution of sodium thiosulfate ($Na_2S_2O_3$) in the presence of starch. The blue color of the solution, caused by the reaction of starch with iodine, changes to blue due to Cr^{3+} ions. The difference (in mL) of $Na_2S_2O_3$ used for titration of the control and the test sample is referred to as the aroma intensity (AI):

$$AI = \frac{(L-B)\cdot Y\cdot 100}{10} \quad (2)$$

where L represents the consumption of $Na_2S_2O_3$ for the control sample, B is the consumption of $Na_2S_2O_3$ for the test sample, and Y is the correction factor for the titration of $Na_2S_2O_3$.

To measure the color of dried plant raw materials, the computer colorimetric method was employed. For this purpose, samples with a thickness of 1.5 to 3 mm were scanned, and the quantity of three separate colors in the reference sample and the test sample was measured. The analysis was conducted on an identical area of approximately ~288 mm² in each sample. The obtained digital images were evaluated using the RGB and CIElab systems [4, 5].

Based on statistical data, two-factor quadratic regression models were determined and their coefficients were found using the method of least squares.

Results and their discussion.

Changes in the quantity of phases and thermodynamic potentials of dried plant raw materials should lead to changes in equilibrium for certain chemical compounds, including those determining the so-called aroma intensity. Therefore, research on this indicator was conducted in samples of plant raw materials obtained by mixed-heat supply drying compared to convective drying, which is traditionally used for raw material preservation.

The results of aroma intensity determination are presented in the figure. It is evident that the dried raw material from cabbage using MHS-drying contains more aroma-forming substances and undergoes insignificant changes at different drying temperatures, compared to samples from convective drying. During the restoration of cell structure in water, the cabbage samples from MHS-drying exhibit slightly higher aroma intensity compared to the convective drying sample. Aroma intensity of vegetable raw material ostend at the fig. 1.

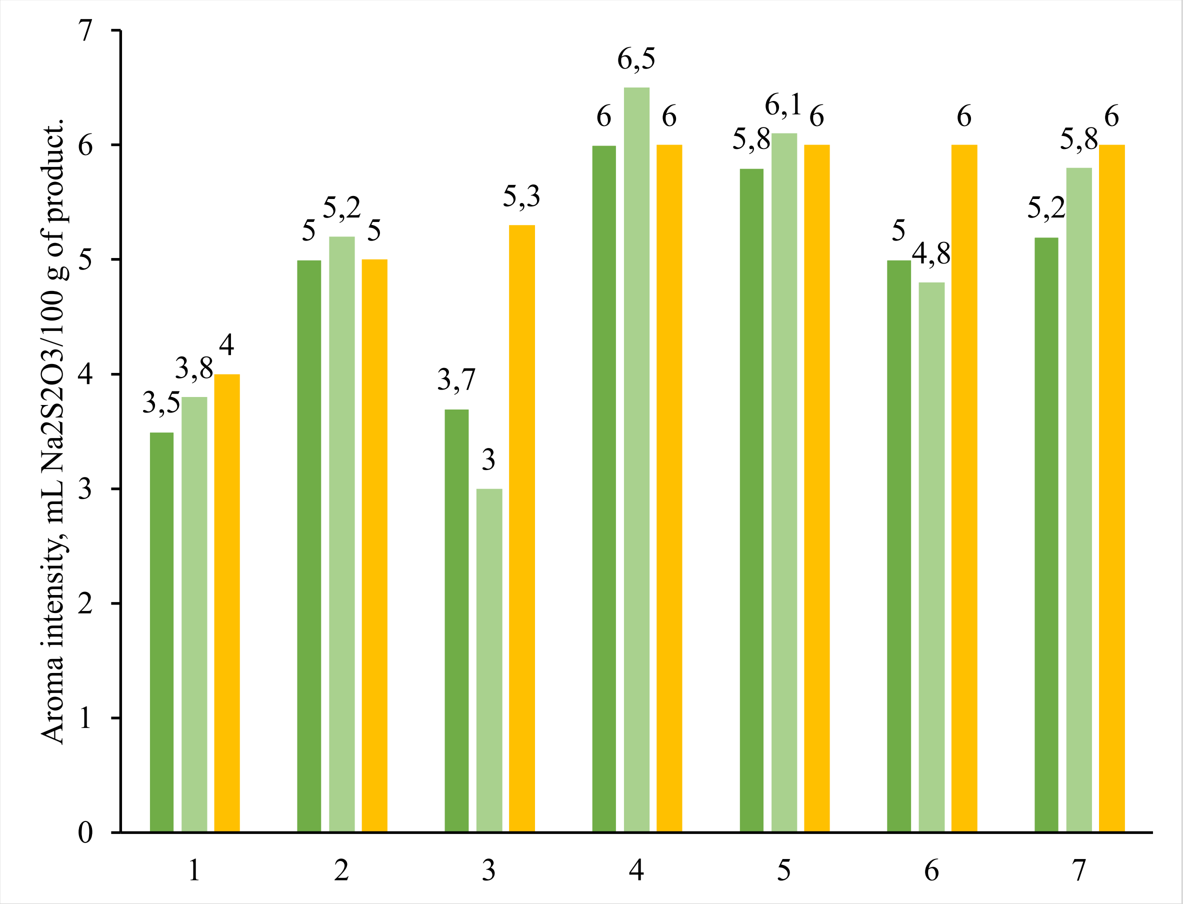


Figure 1 – Aroma intensity of vegetable raw material:

🟩 – cabbage; 🟩 – zucchini; 🟨 – carrot;

1 – fresh; 2 – convective drying; 3 – convective drying, rehydrated in water; 4 – MHS-drying at 50 °C; 5 – MHS-drying at 70 °C; 6 – MHS-drying at 50 °C, rehydrated in water; 7 – MHS-drying at 70 °C, rehydrated in water.

As seen from the fig. 1, the rehydrated sample of shredded cabbage from convective drying has an aroma intensity 1.7 times lower compared to the rehydrated shredded cabbage from MHS-drying obtained at temperatures of 50 and 70 °C. However, the MHS-drying at 50 °C allows obtaining a rehydrated product with a better aroma. A similar trend is observed for dried zucchini raw material. The values of the indicator are almost identical for zucchinis rehydrated by MHS-drying at temperatures of 50 and 70 °C, confirming the rational temperature of MHS- drying at 70 °C. It should be noted that in the rehydrated state, the aroma intensity of shredded zucchinis from MHS-drying is 1.1 to 1.2 times lower and from convective drying is 1.4 times lower than that of fresh zucchinis, which is an important technological aspect of their application. Moreover, shredded zucchinis rehydrated from convective drying have an aroma intensity 1.2 and 1.4 times lower compared to shredded zucchinis rehydrated from MHS-drying at temperatures of 50 and 70 °C, respectively. The regularity of aroma formation in dried carrot raw material using MHS-drying is also maintained.

The next stage of the research involved determining the influence of MHS-drying on the characteristics of vegetable raw material in its dried and rehydrated state using the color models RGB, CIELab, and XYZ (Table 1). From the obtained values, it is evident that the rehydrated vegetable raw material has high color saturation values – C_{ab} unit. The dried vegetable raw material exhibits a variety of pigments determining the color, but their concentration approaches the color intensity during rehydration. This is clearly observed in the color coordinates in the RGB system, which tend toward maximum values. It should be noted that the vegetable raw material obtained by MHS-drying has a saturated color, as indicated by the coordinates, which are lower compared to the raw material obtained by convective drying.

Also, for vegetable raw material from cabbage, there is a more significant decrease in the coordinate values of the rehydrated powder compared to the sample from convective drying, due to its higher hydration properties; this fact is also confirmed by the increase in the yellowing index.

Table 1 - Characteristics of vegetable raw material in dried and rehydrated state in color models RGB, CIELab, and XYZ

Dried food products	State	Color coordinates, unit									Saturation, C_{ab} unit	Yellowing index, Y, unit
		RGB systems			CIELab systems			XYZ systems				
		R	G	B	L	a	B	X	Y	Z		
from cabbage using convective drying	native	215	209	173	84	–2	19	60	64	49	365	38,84
	rehydrated	166	153	107	64	0	27	31	33	19	729	59,21
from cabbage MHS-drying	native	189	161	118	68	6	27	38	38	22	765	66,63
	rehydrated	126	96	53	43	9	30	14	13	5	981	97,08
from zucchinis using convective drying	native	209	162	81	70	11	49	42	41	13	2522	97,51
	rehydrated	171	120	32	55	15	53	25	23	5	3034	116,09
from zucchinis MHS-drying	native	201	178	139	74	4	24	46	47	31	592	55,36
	rehydrated	156	126	73	55	7	34	23	23	9	1205	86,52
from carrots using convective drying	native	255	103	15	64	57	71	49	33	4	8290	177,21
	rehydrated	181	66	0	45	46	57	22	15	2	5365	173,60
from carrots MHS-drying	native	235	212	61	65	40	54	45	34	9	4516	141,35

Thus, based on the obtained data, it is demonstrated that vegetable raw material obtained by MHS-drying has higher technological properties compared to convective drying.

Individual complex indicators of the quality of dried food products were optimized according to functional and technological properties depending on the temperature of MHS-drying and dispersion during grinding; taking into account the weighting factor, the technological purpose of dried food products for various dispersed systems is substantiated, which has scientific and practical significance.

Table 2 – Conceptual model of the functional and technological properties of dried food products from cabbage

Weight coefficient of functional and technological properties of dried food products (relative units)					Assortment of food products	Y^{max}, relative units	x_1, °C / x_2 × 10^{-6}, m	Mathematical model of the complex indicator of the functional and technological property dried food products
Water Absorption Coefficient	Water Retention Capacity	Fat Retention Capacity	Emulsifying Capacity	Aroma intensity				
0,2	0,2	0,2	0,2	0,2	All types of dispersed systems	0,89	50 / (10…30)	$Y = 0{,}773679 + 0{,}006787x_1 - 0{,}000485x_2 - 0{,}000081x_1^2 - 0{,}000002x_2^2 - 0{,}00004x_1x_2$
0,1	0,3	0,2	0,2	0,2		0,89	50 / (10…30)	$Y = 0{,}821006 + 0{,}005607x_1 + 0{,}000756x_2 - 0{,}000075x_1^2 - 0{,}000001x_2^2 - 0{,}000001x_1x_2$
0,3	0,1	0,2	0,2	0,2	All types of dispersed systems	0,89	50 / (10…30)	$Y = 0{,}726352 + 0{,}007967x_1 - 0{,}000213x_2 + 0{,}000087x_1^2 - 0{,}000003x_2^2 - 0{,}000008x_1x_2$
0,1	0,2	0,2	0,2	0,3		0,88	50 / (10…30)	$Y = 0{,}792325 + 0{,}005533x_1 - 0{,}000069x_2 - 0{,}000074\, x_1^2 - 0{,}000002x_2^2 - 0{,}000004x_1x_2$
0,1	0,1	0,4	0,1	0,3	With predominantly emulsion phas	0,88	46 / (10…30)	$Y = 0{,}642999 + 0{,}009509x_1 - 0{,}001159x_2 - 0{,}000098\, x_1^2 - 0{,}000008x_2^2 - 0{,}000014x_1x_2$
0,1	0,2	0,2	0,3	0,2		0,88	50 / (10…30)	$Y = 0{,}808056 + 0{,}005738x_1 + 0{,}000995x_2 - 0{,}000075x_1^2 - 0{,}000001x_2^2 - 0{,}000003x_1x_2$

As seen from Table 2, the optimal temperature of the drying agent and dispersion for obtaining dried plant raw material from cabbage with the highest values of the complex indicator of functional and technological properties is 50°C and (10…30) × 10^{-6} m.

With a weight coefficient of the Fat Retention Capacity indicator being 0.4, the drying temperature of 46°C is reasonable. This allows the formation of a capillary-porous structure, which, due to simultaneous phenomena of wetting by a polar liquid and impregnation with fat, contributes to the stabilization of the emulsion structure.

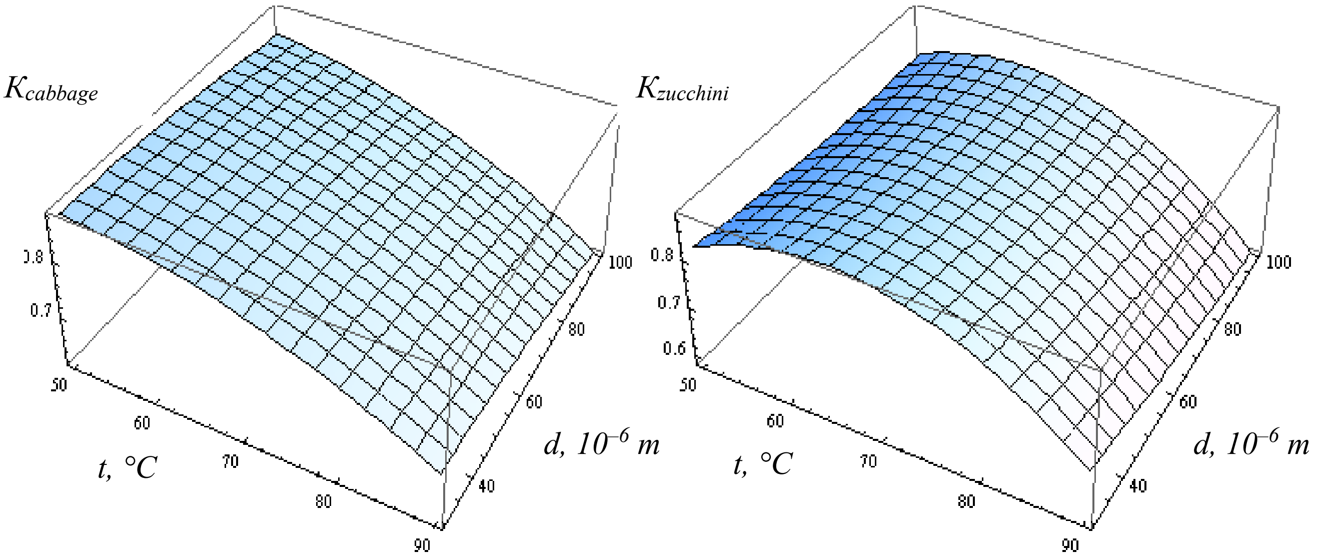
Table 3 - Conceptual model of the functional and technological properties of dried plant raw materials from zucchinis

Weight coefficient of functional and technological properties of dried food products (relative units).					Assortment of food products	Y^{max}, relative units	x_1, °C / $x_2 \times 10^{-6}$, m	Mathematical model of the complex indicator of the functional and technological property dried food products
Water Absorptin Coefficient	Water Retention Capacity	Fat Retention Capacity	Emulsifying Capacity	Aroma intensity				
0,2	0,2	0,2	0,2	0,2	All types of dispersed systems	0,87	65 / (10…30	$Y = -0,395181 + 0,040035\ x_1 - 0,000254\ x_2 - 0,000304\ (x_1)^2 + 0,000008\ (x_2)^2 - 0,000026\ x_1x_2$
0,1	0,1	0,2	0,1	0,5		0,85	59 / (30...45)	$Y = -0,047248 + 0,028527\ x_1 + 0,002529\ x_2 - 0,000229\ (x_1)^2 - 0,000004\ (x_2)^2 - 0,000037\ x_1x_2$
0,1	0,1	0,1	0,2	0,5		0,83	58 / (30…46)	$Y = -0,015676 + 0,026932\ x_1 + 0,002622\ x_2 - 0,000216\ (x_1)^2 - 0,000005\ (x_2)^2 - 0,000037\ x_1x_2$
0,1	0,1	0,1	0,1	0,6		0,84	52 / (50…81)	$Y = 0,073230 + 0,024331\ x_1 + 0,003268\ x_2 - 0,000200\ (x_1)^2 - 0,000007\ (x_2)^2 - 0,000042\ x_1x_2$
0,2	0,2	0,3	0,1	0,2	With predominantly emulsion phas	0,89	64 / (10…30)	$Y = -0,426753 + 0,041629\ x_1 - 0,000348\ x_2 - 0,000317\ (x_1)^2 + 0,000010\ (x_2)^2 - 0,000026\ x_1x_2$

From Table 3, it follows that for obtaining dried plant raw material from zucchinis with high organoleptic properties of food systems, particularly their aroma corresponding to the weight coefficient of the aroma intensity indicator of 0.6, it is necessary to perform MHS-drying at an agent temperature of 52°C and further disperse the dried plant raw material to a fraction of medium size – (50…80) × 10^{-6} m.

The response surfaces illustrating the influence of the drying agent temperature in MHS-drying and the particle size of dried plant raw materials from cabbage and zucchinis for the highest values of their complex indicators of functional and technological properties *($K_{cabbage}$) ma ($K_{zucchini}$)* respectively in fig. 1.

Similarly, models were developed for dried plant raw materials from carrot.



$Y_5 = 0{,}642999 + 0{,}009509\,x_1 + 0{,}001159\,x_2 - 0{,}000098\,(x_1)^2 - 0{,}000008\,(x_2)^2 - 0{,}000014\,x_1x_2$

$Y_{cabbage}^{(complex)\,(max)} = 0{,}88$,

$x_1^{(max)} = 46$, $x_2^{(max)} = 10…33$

a

$Y = -\,0{,}426753 + 0{,}041629\,x_1 - 0{,}000348\,x_2 - 0{,}000317\,(x_1)^2 + 0{,}000010\,(x_2)^2 - 0{,}000026\,x_1x_2$

$Y_{zucchini}^{(complex)\,(max)} = 0{,}89$,

$x_1^{(max)} = 64$, $x_2^{(max)} = 10…30$

b

Figure 1 - Response surface depicting the influence of the drying agent temperature in MHS-drying and particle size on the values of the complex indicator of functional and technological properties of dried plant raw materials from cabbage *($K_{cabbage}$)* (a) and zucchinis *($K_{zucchini}$)* (b) , respectively.

As evident from fig. 1, for zucchini the predominant drying temperature in MHS-drying is 64°C when dispersing the product to a particle size fraction of (10…30) × 10^{-6} m to achieve high complex indicators, close to 1 relative unit on the Harrington scale.

This correlates with previous studies on the rehydration and emulsifying capacity of dried plant raw materials.

Conclusions

As evident, the samples of plant raw materials from MHS-drying, regardless of the process temperature, are characterized by a higher content of aroma-forming substances, while the dried samples from the convective drying method have a lower content. This is associated with the reduced thermal and thermic impact during MHS-drying, which slows down chemical transformations and the removal of aroma-forming substances.