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PLANNING AND CONDUCTING EXPERIMENTS OF THE DRYING PROCESS USING HEAT PIPES

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Abstract:
Evaluation of the effectiveness of the main factors, such as temperature, time and thickness of the slicing layer for drying sliced onions, was carried out using the method of a full factorial experiment. For this, the variables were coded, a planning matrix was compiled, regression equations were calculated, the equation was checked for adequacy, and a posteriori analysis was performed. The main factors influencing the drying of sliced onions in drying installations using heat pipes have been determined.

Keywords: Drying, factor, experiment, model, regression, interaction, coding, adequacy, criterion, variance

1.INTRODUCTION

Drying is not only the most complex non-stationary process of heat and mass transfer, but also a technological process. The dried product, especially food, must have high quality indicators that are attached to the work [1; c.10-14., 2; c.7-8., 3; c.33-43., 4; 5; 6;, 22;.].

The drying process should, if possible, be preceded by mechanical removal of free moisture. Bound moisture is removed only by applying heat. During thermal drying, moisture is converted into a vapor state, and the resulting vapor is removed from the material into the environment. Drying methods differ in the way that heat is transferred to the material.

In drying technology, both traditional methods of drying are used - solar, convective, conductive, and non-traditional - by thermal radiation, high and ultrahigh frequency currents, etc. [7; c.13-25., 8; c.19-28.].

Drying of agricultural products is one of the energy-intensive processes in agriculture. The main energy sources for drying are liquid fuels, gas and electricity. The use of intensive farming methods leads to the need to harvest crops with a high moisture content, which necessitates artificial drying, and this process is studied in the following works [9; c.22-44., 10; c.18-30., 11; c.17-28., 12; c. 21-61., 13; c.11-24., 14; c.13-35., 21; c.80.,22; c.202.,23; c.348.,24;ps.151-166.,25;,26;.].

2. THE PURPOSE OF THE STUDY.

The drying process we propose is the use of heat pipes, which takes energy from the energy stream of the saline. Proceeding from this on this process it is necessary to study the influence of some factors, such as drying temperature, drying time, thickness of the studied product, etc. It is possible to study these factors theoretically on the basis of mathematical models.

3. METHODS AND MATERIALS.

As a rule, simulation is carried out to find the optimal parameters of the system. At the same time, after some experimental studies, regression equations are obtained on their basis. If the factors influencing the investigated value lie in the interval between some upper and lower levels, a full factorial experiment is applied (FFE) [17; c.36., 20; p. 273-286.].

When drying, chopped onions with a moisture content of 89% were selected and it is influenced by the following main factors such as drying temperature, drying time and layer thickness of the chopped onions.

The investigated quantity is the moisture content of onions. During the experiments, the main intervals of variation of the factors were established so that for drying at 12% moisture, onions will be at the optimal level.

On the moisture content of the onion influencing factors 3 experiments were carried out according to the plan of a FFE 2^3 [15; c.62–94., 16; c.50. 17; c.36., 18; c.117-121., 21; c.66-100.].

To search for mathematical models, a polynomial algorithm of the type

$$y=b_0+b_1x_1+b_2x_2+ b_3x_3+ b_{12}x_1x_2+ b_{13}x_1x_3+ b_{23}x_2x_3+ b_{123}x_1x_2x_3 \quad (1)$$

Within the framework of a FFE for processing the results of the results presented and further determining the coefficients of the regression equation, the factors lead to the same scale. This is achieved by encoding the variables. Following the theory of a FFE, we perform the following:

Z_1 – drying temperature (C^0), $Z_1^- = 55$, $Z_1^+ = 65$;

Z_2 – onion drying time (minutes), $Z_2^- = 210$, $Z_2^+ = 450$;

Z_3 – layer thickness of sliced onions (mm), $Z_3^- = 2$, $Z_3^+ = 6$;

It is required to construct a regression equation, taking into account all interactions of factors, to check the obtained model for adequacy and to make its interpretation.
Initial planning matrix for a FFE 2^3

Table 1.

No. experiment	Studied factors			Experimental results		
	z_1	z_2	z_3	y_1	y_2	y_3
1	+	+	+	11,8	13,1	12,3
2	−	+	+	15,9	16,4	16,1
3	+	−	+	42,7	42,2	40,7
4	−	−	+	44,5	46,1	45,7
5	+	+	−	5,5	4,8	6,1
6	−	+	−	5,7	6,4	5,5
7	+	−	−	7,1	7,8	7,4
8	−	−	−	12,7	12,5	13,3

We carry out the work in the following order:

1) we encode the variables;

2) we complete the scheduling matrix in coded variables taking into account pair interactions and supplement it with a column of average response values;

3) calculate the coefficients of the regression equation;

4) we check the calculated coefficients for significance, having previously determined the reproducibility variance, and we obtain the regression equation in coded variables;

5) check the resulting equation for adequacy;

6) we carry out the interpretation of the resulting model;

7) write out the regression equation in natural variables.

1. For each factor, we find the center, the variation interval and the dependence of the coded variable x_i on the natural z_i.

Based on the equations of the influencing factors on the moisture content of the onion, which were obtained during the experiments, we draw up the following factor coding table. We present the results in table 2.

Table 2.

Factors	Upper level +i	Lower level -i	Centre Z_i^0	Variation interval λ_i	Dependence of the encoded variable on the natural
z_1	65	55	60	5	$X_1 = \dfrac{Z_1 - 60}{5};$
z_2	450	210	330	120	$X_2 = \dfrac{Z_2 - 330}{120};$
z_3	6	2	4	2	$X_3 = \dfrac{Z_3 - 4}{2};$

2. We calculate the average of the sample results for each experiment:

$$\bar{y}_{\text{i}} = \frac{(y_{1\text{i}} + y_{2\text{i}} + y_{3\text{i}})}{3} \quad (2)$$

Where i- the number of the experiment.

We build a planning matrix taking into account all interactions and average response values in coded units. Here we present auxiliary graphs necessary for calculating the regression coefficients b_{ij} and b_{ijk}.

Planning Matrix for Results Management

Table 3.

No. experiment	Factors			Interactions				Experimental results			Average results
	x_1	x_2	x_3	x_1x_2	x_1x_3	x_2x_3	$x_1x_2x_3$	y_1	y_2	y_3	$\bar{y}_{\text{j}}$
1	+	+	+	+	+	+	+	11,8	13,1	12,3	12,4
2	−	+	+	−	−	+	−	15,9	16,4	16,1	16,133
3	+	−	+	−	+	−	−	42,7	42,2	40,7	41,867
4	−	−	+	+	−	−	+	44,5	46,1	45,7	45,433
5	+	+	−	+	−	−	−	5,5	4,8	6,1	5,467
6	−	+	−	−	+	−	+	5,7	6,4	5,5	5,867
7	+	−	−	−	−	+	+	7,1	7,8	7,4	7,433
8	−	−	−	+	+	+	−	12,7	12,5	13,3	12,833

3. The coefficients of the regression equation are determined by the following formulas.

$$b_0 = \frac{1}{n}\sum_{j=1}^{n} \bar{y}_{\text{j}} \quad (3)$$

$$b_{\text{i}} = \frac{1}{n}\sum_{j=1}^{n} x_{ji}\bar{y}_{\text{j}}, \quad \text{i}=\overline{1,k} \quad (4)$$

$$b_{\text{i}} = \frac{1}{n}\sum_{j=1}^{n} x_{jr}x_{ip}\bar{y}_{\text{j}}, \ \text{r<P, r=}\overline{i,k}, \ \text{P=}\ \overline{1,k} \quad (5)$$

$$b_{1,2,3} = \frac{1}{n}\sum_{j=1}^{n} x_{j1}x_{j2}x_{j3}\bar{y}_{\text{j}} \quad (6)$$

Using the values of Table 3 and the formula, we find the coefficients of the regression equation (1)

Table 4.

b_0	b_1	b_2	b_3	$b_{1,2}$	$b_{1,3}$	$b_{2,3}$	$b_{1,2,3}$
18,4292	-1,6375	-8,4625	10,5292	0,6042	-0,1875	-6,2292	-0,6458

4. Some of the coefficients in the regression equation written on the basis of table 4. may turn out to be negligible and insignificant. To establish whether the coefficient is significant or not, let's do the following: calculate the reproducibility estimate $S^2_{\{y\}}$.(7)

$$S^2_{\{y\}} = \frac{1}{n(m-1)}\sum_{j=1}^{n}\sum_{i=1}^{m}(y_{ji} - \bar{y}_j)^2 = \frac{1}{n}\sum_{j=1}^{n}\left(\frac{1}{m-1}\sum_{i=1}^{m}(y_{ji} - \bar{y}_j)^2\right) = \frac{1}{n}\sum_{j=1}^{n} S_j^2$$

Where n- the number of experiments (the number of rows in the matrix of the FFE);

m- the number of experiments in each experiment;

y_{ji}- the result of a separate i-th observation in the j-th experiment.

$\overline{y}_i$ - sample values of observations for the j-th experiment.

For convenience, we draw up the calculations in the form of table 5.

Table 5.

j	y_1	y_2	y_3	$\overline{y}_j$	$(y_{j1}-\overline{y}_j)^2$	$(y_{j2}-\overline{y}_j)^2$	$(y_{j3}-\overline{y}_j)^2$	S_j^2
1	11,8	13,1	12,3	12,4	0,3600	0,4900	0,0100	0,4300
2	15,9	16,4	16,1	16,133	0,0544	0,0711	0,0011	0,0633
3	42,7	42,2	40,7	41,867	0,6944	0,1111	1,3611	1,0833
4	44,5	46,1	45,7	45,433	0,8711	0,4444	0,0711	0,6933
5	5,5	4,8	6,1	5,467	0,0011	0,4444	0,4011	0,4233
6	5,7	6,4	5,5	5,867	0,0278	0,2844	0,1344	0,2233
7	7,1	7,8	7,4	7,433	0,1111	0,1344	0,0011	0,1233
8	12,7	12,5	13,3	12,833	0,0178	0,1111	0,2178	0,1733

Summing up the elements of the last column of Table 5, we get:

$$\sum_{j=1}^{n} S_j^2 = 3{,}2133$$

From formula (7) we obtain the reproducibility variance:

$$S_{\{y\}}^2 = \frac{1}{8}\sum_{j=1}^{8} S_j^2 = 0{,}4017$$

Determine the standard deviation of the coefficients:

$$S_{КОЭФ} = \sqrt{\frac{S_{\{y\}}^2}{n \cdot m}} = 0{,}1294 \qquad (8)$$

From the tables of the Student's distribution by the number of degrees of freedom $n(m-1)=8\cdot 2=16$ at significance level α = 0,05 find $t_{кр.}$= 2,12. Consequently,

$t_{кр.} \cdot S_{коэф} \cdot$ 2,12 · 0,1294= 0,27425 · 0 ,274.

Comparing the obtained value of $t_{кр.} \cdot S_{коэф}$ ·0,274 with the coefficients of the regression equation presented in Table 4, we see that all except $b_{1,3}$ coefficients are larger in absolute value 0,274. Therefore, except for $b_{1,3}$, all coefficients are significant. Assuming $b_{1,3}$= 0 , we obtain the regression equation in coded variables:

$$y=18{,}43-1{,}64x_1-8{,}46x_2+10{,}53x_3+0{,}6x_1x_2-6{,}23x_2x_3-0{,}65x_1x_2x_3 \qquad (9)$$

5. Let us check the obtained equation (9) for adequacy according to the Fisher criterion. Since the reproducibility variance was found in the previous paragraph, to determine the calculated value of the $F_{расч}$ criterion, it is necessary to calculate the residual variance $S^2_{ост}$.

To do this, we find the values of the studied parameter according to the obtained regression equation $\tilde{y}_j$ (j = 1, ..., 8), substituting +1 or -1 instead of x_i in accordance with the number j of the experiment from Table 4:

The residual variance $S_{ост}^2$ is calculated by the formula (10):

$$S_{ост}^2 = \frac{3}{8-7}\sum_{j=1}^{8}(\tilde{y}_j - \overline{y}_j)^2 = 0{,}84375 \qquad (10)$$

The calculated value of the Fisher criterion $F_{расч}$. is determined by the formula (11):

$$F_{расч} = \frac{S^2_{ост}}{S^2_{\{y\}}} = \frac{0,84375}{0,4017} = 2,1 \quad (11)$$

Table value of the criterion $F_{табл.}$ we find from tables the critical points of the Fisher distribution at a significance level α =0,05 for the corresponding degrees of freedom $k_1 = n – r =8–7=1$ and $k_2 = n(m-1) = 8·2 = 16$:

$F_{табл.}$ =4,49

Since $F_{расч}$=2,1<$F_{табл.}$= 4,49, the regression equation (9) is adequate.

4.RESULTS AND DISCUSSION

Let us interpret the resulting model (9)

$$y=18,43-1,64x_1-8,46x_2+10,53x_3+0,6x_1x_2-6,23x_2x_3-0,65x_1x_2x_3$$

The equation shows that the factor x_3 and x_2- the thickness of the onion layer and the drying time - have the strongest effect, since it has the largest coefficient in absolute value.

The coefficients for the factors x_1 and x_2 are negative. This means that raising the temperature and lengthening the drying time will reduce the moisture content of the onions. Moreover, the drying time has a stronger influence.

The coefficient at the factor x_3 is positive. This means that moisture loss is prevented by increasing the thickness of the sliced onions. Moreover, it has a strong influence than other factors. If we evaluate the effects quantitatively, then the free term b_0 = 18,43 characterizes the average rate of moisture loss when all factors are at average levels.

After x_1, x_2, x_3 in terms of the strength of influence on the response, there are: double interaction of factors x_2x_3 (drying time and thickness of the onion layer); factor x_1- chamber drying temperature; after it, triple interaction factors $x_1x_2x_3$ (drying temperature, drying time and onion layer thickness) affect, then double interaction x_1x_2 (drying chamber temperature, drying time);

Thus, the use of a full factorial experiment for modeling the drying of products makes it possible to determine the degree of influence of factors on the output parameters of the system. The use of this approach in the development of drying plants makes it possible to develop flexible management strategies and a comprehensive assessment of situations that are implemented in the agricultural sector.

REFERENCES

1. Касьянов Г.И., Мякинникова Е.И., Сязин И.Е., Карикурубу Ж.Ф.. Установка для сушки сельскохозяйственного сырья. /Техника и технология пищевых производств.2014.№2, с.10-14.
2. Джураев Х.Ф. Сушка плодов сельскохозяйственных культур:моделирование, оптимизация, разработка высокоэффективных аппаратов. //Автореф.дис.докт.техн.наук в форме научного доклада.ТашХТИ, Ташкент, 2005, с.7-8.
3. Абдиева Г.М. Обоснование параметров и режимов работы сушильной установки для дыни. //дис.док.филос.(PhD) ТХТИ, Ташкент 2019, с.33-43, с. 127.
4. Патент № 2194228 Российская Федерация, F26B 3/347, A23B 7/02. Способ сушки и обеззараживания фруктов и ягод / Чекрыгина И.М., Букреев В.Г., Еремин А.Д. - № 2000123044/13; заявл. 04.09.2000; опубл. 10.12.2002.
5. Патент № 2195824 Российская Федерация, A23B 7/00. Способ сушки плодов и овощей / Иванов В.А., Сапунов Г.С. - № 2000116678/13; заявл. 23.06.2000; опубл. 10.01.2003.
6. Патент №26684 Республика Казахтан. Гелиосушилка для фруктов и овощей. Атыханов Е.А., Касымбаев Б.М.и дрг. // Алматы, F26B 3/28 опубликовано. 15.02.2013.
7. Хазимов К.М. Интенсификация процесса сушки продуктов растительного происхождения с использованием солнечной энергии. //дис.док.филос.(PhD) КНАУ, Республика Казахстан Алматы 2015, с.13-25. с.150.
8. Машарипова З.А. Ўсимлик махсулотларини самарали қуритиш технологик жараёнини моделлаштириш ва қуритиш қурилмасини такомиллаштириш. //дис.док.филос.(PhD). ТКТИ, Тошкент 2018, с.19-28. с.137.
9. Желтухова Е.Ю. Научное обеспечение процесса комбинированной радиационно-конвективной сушки фруктов и овощных чипсов при импульсном энергоподводе. //дис.техн.наук ВГУИТ, Воронеж, 2013, с.22-44.
10. Лягина Л.А. Повышение эффективности сушки продуктов растителного происхождения за счет инфракрасного-конвективного воздействия. //дис.техн.наук СГАУ имени Н.И.Вавилова, Саратов 2010, с.18-30.

11. Демьянов В.Д. Научное обоснование и разработка способов СВЧ-конвективной сушки фруктов. //дис.техн.наук ВГУИТ, Воронеж 2015, с.137.
12. Бочаров В.А. Совершенствование элементов технологии сушки овощей. //дис.сель.наук МГАУ, Мичуринск-наукоград РФ 2010, с. 21-61.
13. Мамонтов М.В. Разработка и исследование сушки тонко измельченной моркови при комплексной ее переработке. //дис.техн.наук ВГТА, Воронеж 2009, с. 11-24.
14. Королев А.А. Разработка технологии производства плодоовощных чипсов. //дис.техн.наук ВНИИКОП, Москва 2013, с. 13-35.
15. Грачев Ю.П., Плаксин Ю.М. Математические методы планирования эксперимента. - М .: ДеЛи принт, 2005. –296 с.
16. Хамханов К.М. Основные планирования эксперимента.//Методическое пособие. Улан-Удэ, 2001, с. 50
17. Соколовская И.Ю. Полный факторный эксперимент // Методические указания. Новосибирск. НГАВТ, 2010, с. 36.
18. Семенов А. Д., Артамонов Д. В., Брюхачев А. В. Идентификация объектов управления: Учебн. пособие. - Пенза: Изд-во Пенз. гос. ун-та, 2003, с. 117-121.
19. Закгейм А.Ю. Введение в моделирование химико- технологических процессов.-2-е изд., перераб. И доп.-М.: Химия, 1982, с.66-100.
20. Djuraev Kh.F, Gafurov K.Kh., Jumayev J., Mukhmadiev B.T., Mirzaeva Sh.U. The Influence Of Technological Parameters On The Process Of Co2-Extraction Of Biologically Active Substances From Licorice Root//The American Journal of Applied Sciences (ISSN – 2689-0992)Published: September 30, 2020 | Pages: 273-286 Doi: https://doi.org/10.37547/tajas/Volume02Issue09-38
21. Холиков А.А., Мирзаева Ш.У.Расчет конденсирующей части высокоэффективного теплопередающего устройства.Международная научно- практическая конференция "Интеграция современных научных исследований в развитие общества" 28-29 декабря Россия, г.Кемерево-2016г. Том1, 80 стр.
22. Холиков А.А., Гафуров К.Х. Исследование теплопроводности тепловых труб. «Инновации в индустрии питания и сервисе» электронный сборник материалов III Международной научно-практической конференции, посвященной 100-летию ФГБОУ ВО «Кубанский государственный технологический университет» Краснодар, 25 октября 2018 г. 202 стр.
23. Холиков А.А.,Мирзаева Ш.У., Фатуллаев Ш. Подсистемы аккумилирования тепла. "Новые решения в области упрочняющих технологии: взгляд молодых специалистов" сборник научных статей международной научно- практической конференции 22 - 23 декабря Курск-2016 г. Том 2,348 стр.
24. Kholikov A.A., Quldosheva F.S. Testing And Determining The Temperature Characteristics Of Heat Pipes (HP). The American Journal of Applied Sciences, 2020. 2(11), Ps.151-166.
25. http://mehanik-ua.ru/sbornik-statej/1034-mirovoj-opyt-sushki-selskokhozyajstvennoj-produktsii.html
26. http://proiz-teh.ru/sushka.html

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