IRSTI 65.63.33 https://doi.org/10.58805/kazutb.v.4.25-630

OPTIMIZATION OF THE FORMULATION OF VEGETABLE MILK WITH THE ADDITION OF LEGUMES ON THE EXAMPLE OF MUNG BEAN

[1]N. Alzhaxina✉, [1]I. Aubakirova

[1]Astana branch «Kazakh research institute of processing and food industry» LTD, Astana, Kazakhstan
✉Corresponding-author: alzhaxina@inbox.ru

One of the key positions of food security is ”improving the health of the population” as the most complete satisfaction of human needs for basic nutrients - proteins, fats, carbohydrates, vitamins, minerals. A balanced diet has a huge impact on all aspects of the human body’ s vital activity. Continuously occurring life processes are impossible without the introduction of nutrients from the outside. Nowadays, human nutrition is of particular importance precisely during illness. This study is aimed at developing a functional drink based on vegetable ”milk” using different ratios of mung bean, water and stabilizer. The results obtained made it possible to select the formulation of vegetable milk from mung bean by applying the developed mathematical model. One of the most important indicators of milk quality is acidity, which characterizes the freshness of milk, its suitability for further processing and pasteurization. The article describes the results of fitting various models to the acidity data of vegetable milk. An increase in acidity leads to the fact that proteins become less resistant to heat. A model in three-dimensional space is also presented, characterizing the dependence of acidity on the components of vegetable milk.

Keywords: formulation, optimization, vegetable milk, legume culture, mung bean, acidity, functional purpose.

МАШ ДАҚЫЛЫ МЫСАЛЫНДА БҰРШАҚ ДАҚЫЛДАРЫН ҚОСУ АРҚЫЛЫ ӨСІМДІК СҮТІНІҢ РЕЦЕПТУРАСЫН ОҢТАЙЛАНДЫРУ

[1]Н.Е. Альжаксина✉, [1]И.Е. Аубакирова

[1]Астана филиалы ЖШС «Қазақ қайта өңдеу және тағам өнеркәсіптері ғылыми-зерттеу институты,
Астана, Қазақстан,
e-mail: alzhaxina@inbox.ru

Азық - түлік қауіпсіздігінің негізгі ұстанымдарының бірі адамның негізгі тағамдық заттарға-ақуыздарға, майларға, көмірсуларға, дәрумендерге, минералдарға деген қажеттілігін барынша толық қанағаттандыру «халықты сауықтыру» болып табылады. Теңдестірілген тамақтану адам ағзасының барлық аспектілеріне үлкен әсер етеді. Үздіксіз жүретін өмірлік процестер қоректік заттарды сырттан енгізбестен мүмкін емес. Қазіргі уақытта адамның тамақтануы ауру кезінде ерекше маңызға ие. Бұл зерттеу әртүрлі арақатынаста маш, су және тұрақтандырғышты қолдана отырып, өсімдік негізіндегі «сүт» негізінде функционалды сусын жасауға бағытталған. Алынған нәтижелер әзірленген математикалық модельді қолдану арқылы маштан өсімдік сүтінің рецептурасын таңдауға мүмкіндік берді. Сүт сапасының маңызды көрсеткіштерінің бірі-сүттің балғындығын, оны әрі қарай өңдеуге және пастерлеуге жарамдылығын сипаттайтын қышқылдық. Мақалада өсімдік сүтінің қышқылдық деректеріне әртүрлі модельдерді сәйкестендіру нәтижелері сипатталған. Қышқылдықтың артуы ақуыздардың ыстыққа төзімділігінің төмендеуіне әкеледі. Сондай-ақ, қышқылдықтың өсімдік сүтінің компоненттеріне тәуелділігін сипаттайтын үш өлшемді кеңістіктегі модель ұсынылған.

Түйін сөздер: рецептура, оңтайландыру, өсімдік сүті, бұршақ дақылдары, маш, қышқылдық, функционалдық мақсаты.

ОПТИМИЗАЦИЯ РЕЦЕПТУРЫ РАСТИТЕЛЬНОГО МОЛОКА С ДОБАВЛЕНИЕМ БОБОВЫХ КУЛЬТУР НА ПРИМЕРЕ МАША

[1]Н.Е. Альжаксина, [1]И.Е. Аубакирова

[1]Астанинский филиал ТОО «Казахский научно-исследовательский институт перерабатывающей и пищевой промышленности», Астана, Казахстан,
e-mail: alzhaxina@inbox.ru

Одним из ключевых позиций продовольственной безопасности относится «оздоровление населения» как наиболее полное удовлетворение потребности человека в основных пищевых веществах - белках, жирах, углеводах, витаминах, минеральных веществах. Сбалансированное питание оказывает огромное влияние на все стороны жизнедеятельности организма человека. Непрерывно происходящие жизненные процессы невозможны без введения извне питательных веществ. В наше время особое значение приобретает питание человека именно во время болезни. Данное исследование направлено на разработку напитка функционального назначения на основе растительного «молока» с использованием в разных соотношениях маша, воды и стабилизатора. Полученные результаты позволили подобрать рецептуру растительного молока из маша путем применения разработанной математической модели. Один из важнейших показателей качества молока - кислотность, характеризующая свежесть молока, его пригодность к дальнейшей переработке и пастеризации. В статье описаны результаты подгонки различных моделей к данным кислотности растительного молока. Повышение кислотности приводит к тому, что белки становятся менее устойчивыми к нагреванию. Также представлена модель в трехмерном пространстве, характеризующая зависимость кислотности от компонентов растительного молока.

Ключевые слова: рецептура, оптимизация, растительное молоко, бобовая культура, маш, кислотность, функциональное назначение.

Introduction. The main task of the food industry is to develop recipes that incorporate plant raw materials to achieve balance and expand the range of products. From the perspective of enhancing the biological value of the product, the recipe composition is determined by enriching it with polyunsaturated fatty acids and their derivatives from plant raw materials. One of the promising types of plant raw materials is leguminous crops, specifically mung beans. Mung beans contain approximately 24% protein. Sprouted mung beans are particularly popular among vegetarians and health enthusiasts. Mung bean sprouts, which can be eaten raw and added to salads, are a low-calorie food rich in fiber and vitamins [1-3].

When recalculated to 100 g of the product in its natural values, the recipe for plant-based milk is as follows:

- Mung bean powder - 19.7 g;
- Water - 77.1 ml;
- Stabilizer - 3.2 g.

The goal of the research is to optimize the recipe for plant-based milk based on leguminous crops (mung beans).

Materials and methods. The objects of the study were plant-based milk made from mung beans, mung bean powder, water, and stabilizer. Experimental research was conducted at the base of the Astana branch KazNII of Processing and Food Industry LTD in 2024. The optimization of the recipe was carried out using the Statgraphics Centurion 19 software package. Experiments were conducted according to a simplex-lattice design (Sheffe' s plan) of the third order (Simplex-Lattice). During the experiment, a recipe for plant-based milk from mung beans was developed, where the main components were mung bean powder, water, and stabilizer.

The variable factors in composing the recipe were the mass fractions of mung bean powder (x1), water (x2), and stabilizer (x3) in the recipe composition. These factors were varied according to Sheffe' s third-order plan [4-6]. Other conditions of the experiments remained unchanged. The results of the experiments characterized the change in one of the parameters - the acidity of the plant-based milk.

The determination of acidity was conducted in accordance with GOST 3624-92 [7-9].

Discussion of the results. The components of the plant-based milk that form the planning matrix and the results of the experiments are presented in table 1.

Table 1 - Sheffe' s Plan and Experimental Results

Experiment numbers	Mass fraction of components						Acidity, °T
	Encoded values			Natural values			
	x1	*x2*	*x3*	М, г	В, мл	С, г	*y*
1	1	0	0	100	0	0	25
2	2/3	1/3	0	66,6	33,3	0	21,6
3	2/3	0	1/3	66,6	0	33,3	21
4	1/3	2/3	0	33,3	66,6667	0	18
5	1/3	1/3	1/3	33,3	33,3	33,3	19,9
6	1/3	0	2/3	33,3	0	66,6	19,5
7	0	1	0	0	100	0	17,5
8	0	2/3	1/3	0	66,6	33,3	19,5
9	0	1/3	2/3	0	33,3	66,6	21,5
10	0	0	1	0	0	100	25

The average model consists only of a constant. The linear model includes first-order terms for each component. The quadratic model adds cross-products between pairs of components. The special cubic model includes terms that involve products of three components. The cubic model adds additional third-order terms [10].

The estimated effects of the full model for acidity are presented in table 2.

Table 2 - Estimated Effects of the Full Model for Specific Volume

Values	Sum of squares	Difference	The middle square	F-ratio	P value
Average	4347,23	1	4347,23	-	-
Linear	32,4013	2	16,2007	4,21	0,0631
Quadratic	24,8284	3	8,27615	15,65	0,0112
Special cubic	0,524991	1	0,524991	0,99	0,393
Cubic	1,59023	3	0,530078	-	-
Mistake	-7,02188*10-13	0	0	-	-
Total	4406,57	10	-	-	-

As seen in table 2, each model is presented with a P-value that tests whether the model is statistically significant compared to the mean square for the term provided below. Typically, the most complex model with a P-value of less than 0.05 is chosen, assuming that the work is conducted at a significance level of 95.0%. Unfortunately, there are no degrees of freedom for error, so the statistical significance of the cubic model cannot be tested. Adding additional runs to the design would help alleviate this issue.

The currently selected model is the quadratic model, and the analysis of variance is presented in table 3.

Table 3 presents the analysis of variance for the currently selected quadratic model. Since the P-value for this model is less than 0.05, there is a statistically significant relationship between acidity and the components at a 95.0% confidence level.

Table 3 - Analysis of Variance (ANOVA) for the Acidity of Plant-Based Milk from Mung Beans

Values	Sum of squares	Difference	The middle square	F-ratio	The value of P
The quadratic model	57,2297	5	11,4459	21,64	0,0054
The final error	2,11526	4	0,528814	-	-
Total (corr)	59,345	9	-	-	-

The lack-of-fit test is designed to determine whether the chosen model adequately describes the observed data or if a more complex model should be used. This test is performed by comparing the variability of the residuals of the current model with the variability between observations at repeated settings of the components. Unfortunately, in this case, the test cannot be conducted as there are no repeated observations.

The coefficient of determination indicates that the fitted model explains 96.4357% of the variability in acidity based on the components of the plant-based milk. The adjusted coefficient of determination, which is more suitable for comparing models with different numbers of independent variables, is 91.9802%. The standard error of the estimate shows that the standard deviation of the residuals is 0.727196. The mean absolute error (MAE) of 0.410477 represents the average of the residuals. The Durbin-Watson (DW) statistic checks the residuals to determine if there is any significant correlation based on the order in which they appear in the data. Since the P-value is greater than 5.0%, there is no indication of serial autocorrelation in the residuals at a 5.0% significance level.

The results of fitting the quadratic model for acidity and the regression coefficients are presented in table 4.

Thus, the dependence of acidity on the components of plant-based milk from mung beans can be represented in terms of the mass fraction of the ingredients individually, and the regression equation can be written in the following form (formula 1):

$$y = 25,2714x_1 + 17,3143x_2 + 24,6143x_3 - 6,04284x_1x_2 - 20,4428x_1x_3 - 1,41427x2x_3 \quad (1)$$

Based on the obtained regression equation, a model was constructed in three-dimensional space, representing a plane that characterizes the dependence of acidity on the components of plant-based milk.

Figures 1-4 present graphical representations of the dependency plots. The analysis of the behavior of the obtained response surface showed that the optimal zone for the acidity of plant-based milk is achieved when the mass fraction of mung bean powder is 19.7%, the mass fraction of water is 77.1%, and the mass fraction of stabilizer is 3.2%. The analysis of the distribution of errors in predicting acidity values yielded satisfactory results: a significant portion of the points did not deviate noticeably from the line, indicating the adequacy of the obtained model.

Table 4 - Results of Fitting the Quadratic Model for Acidity

Components	Coefficients	Mistake
A: Mung bean powder	25,2714	0,684381
B: Water	17,3143	0,684381
C: Stabilizer	24,6143	0,684381

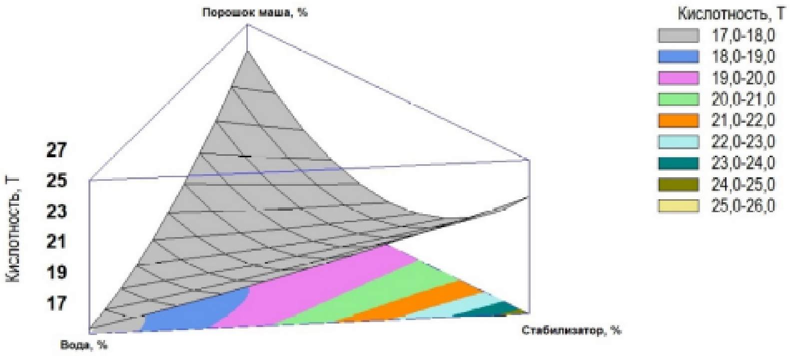

Figure 1 - Response Surface of the Output Parameter: Dependence of Acidity on the Mass Fraction of Components

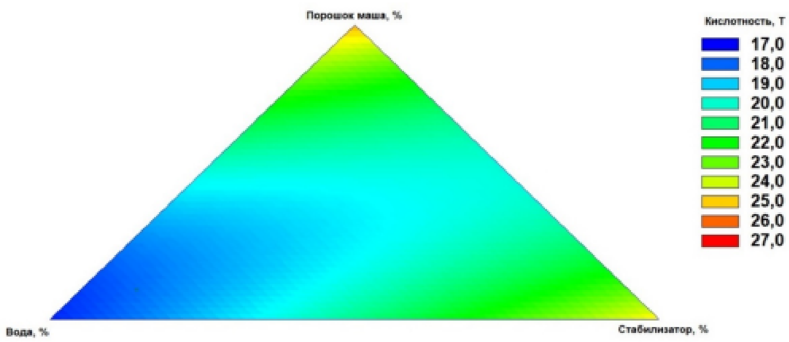

Figure 2 - Projections of the Response Surface Sections Characterizing the Dependence of Acidity on the Mass Fraction of Components

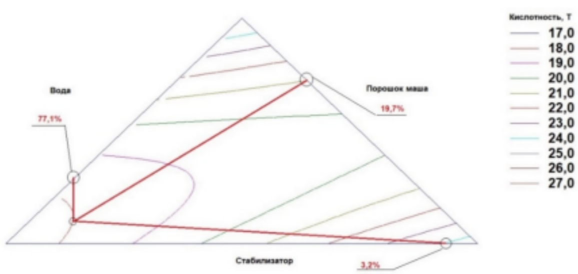

Figure 3 - Projections of the Response Surface Sections Characterizing the Dependence of Acidity on the Mass Fraction of Components with Optimal Points

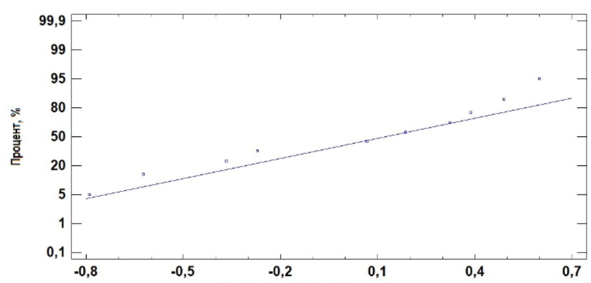

Figure 4 - Diagnostic Plot of the Deviation of Predicted Acidity Values from Normal Distribution

Conclusion. Mung beans are a widely recognized plant-based source of protein and a means of maintaining health due to their high nutrient content. Currently, people' s demands for quality of life are continuously improving, while simultaneously, the prevalence of unhealthy populations is steadily rising. The "generation of people who eat medicines" is gradually being perceived by consumers as a whole.

Funding: *This research was funded by the Ministry of Agriculture of the Republic of Kazakhstan (BR22886613).*

References

1. Merenkova S.P., Androsova N.V. Aktual' nye aspekty proizvodstva napitkov na rastitel' nom syr' e // Vestnik YUUrGU. Seriya «Pishchevye i biotekhnologii». - 2018. - T.6. - № 3. - S. 57-67. DOI: 10.14529/food180307. [In Russian]

2. Egorova S.V., Ahmatziaeva M.M., Rostegaev R.S. Rastitel' naya pishcha budushchego // V sbornike: Advanced science: sbornik statej III Mezhdunarodnoj nauchno-prakticheskoj konferencii: v 2 ch. - 2018. - S.134-137. [In Russian]

3. Kazakov I.O., Kiseleva T.F., Eremina I.A., Mikova D.S. Issledovaniya vliyaniya ul' trazvukovoj obrabotki na stojkost' napitkov na osnove zernovogo syr' ya // Food Processing: Techniques and Technology. - № 1. - 2015. - S. 30-34. [In Russian]

4. Mayuri Chavan, Yogesh Gat, Mugdha Harmalkar, Roji Waghmare. Development of nondairy

fermented probiotic drink based on germinated and ungerminated cereals and legume // LWT -Food Science and Technology. - 2018. - Vol. 91. - P. 339-344. DOI: 10.1016/j.lwt.2018.01.070

5. Mridula D. Monika Sharma. Development of non-dairy probiotic drink utilizing sprouted cereals, legume and soymilk // LWT – Food Science and Technology. - 2015. - vol. 62. - P. 482-487. DOI: 10.1016/j.lwt.2014.07.011

6. Pasquale Russo, Maria Lucia, Valeria de Chiara et al. Lactobacillus plantarum strains for multifunctional oat-based foods // LWT – Food Science and Technology. - 2015. - vol. 68. - P. 288 -294. DOI: 10.1016/j.lwt.2015.12.040

7. Mradula Gupta, Somesh Sharma. Probiotics in limelight // Journal of Innovative Biology. - 2016. - vol. 3. - P. 276-280.

8. Loh W. The epidemiology of food allergy in the global context Int. // J. Environ. Res. Public Health. – 2018. – 15. – 2043. DOI:10.3390/ijerph15092043

9. Muhammad Iqbal, Nadiah Zafar, Hatem Fessi, Abdelhamid Elaissari Double emulsion solvent evaporation techniques used for drug encapsulation // International Journal of Pharmaceutics. – 2015. - Volume 496. - P. 173-190. DOI:10.1016/j.ijpharm.2015.10.057

10. Rajan A. Production of soya milk containing low flatulence-causing oligosaccharides in a packed bed reactor using immobilised α-galactosidase: Immobilised α-galactosidase // International Journal of Food Science & Technology. - 2010. - V. 45. - № 10. - P. 2023-2031. DOI:10.1111/j.1365- 2621.2010.02354.x.

Information about the authors

N.Alzhaxina - PhD, Director of the Astana branch of «Kazakh Research Institute of Processing and Food Industry», Astana, Kazakhstan, e-mail: alzhaxina@inbox.ru;

I.Aubakirova - Master' s student, Junior researcher, Astana branch of «Kazakh Research Institute of Processing and Food Industry», Astana, Kazakhstan, e-mail: aubakirova.inkar@bk.ru.

Информация об авторах

Альжаксина Н.Е. - PhD, и.о. директора Астанинского филиала ТОО «Казахский научно-исследовательский институт перерабатывающей и пищевой промышленности», Астана, Казахстан, e-mail: alzhaxina@inbox.ru;

Аубакирова И.Е. - магистрант, младший научный сотрудник Астанинского филиала ТОО «Казахский научно-исследовательский институт перерабатывающей и пищевой промышленности», Астана, Казахстан, e-mail: aubakirova.inkar@bk.ru.