Determination of technological parameters for the production of enriched flour mixtures in a drum mixer

I Yu Reznichenko, D M Borodulin, A M Chistyakov, N Yu Ruban and S S Komarov
Kemerovo state university, Kemerovo, Krasnaya St., 6

E-mail: yul48888048@yandex.ru

Abstract. The lack of micronutrients in the diet of the population affects the growth of alimentary-dependent diseases, affects the preservation of health and active longevity. One of the most effective methods of preventing micronutrient insufficiency is the enrichment of mass-consumption food products with vitamin and mineral premixes. Additionally, it is recommended to enrich the missing micronutrients to the level corresponding to the physiological needs of the body with mass-use products, which can include flour confectionery products, in particular cookies. The main factors shaping the quality of finished enriched products are raw materials and production technology. A special role in the application of premixes for flour products is assigned to the mixing process, because when mixing the premix with flour, its uniform distribution must occur throughout the entire volume of the mixture to obtain high-quality finished products with a guaranteed content of vitamins and minerals declared in the premix. Development of recipes and selection of technological parameters of mixing are relevant for the practical implementation of results in industrial production. For this purpose, studies have been conducted to obtain a homogeneous flour mixture consisting of wheat flour and vitamin-mineral premix on a drum mixer. The obtained data allowed us to determine the rational parameters of mixing the initial ingredients, which produce an enriched flour mixture with the specified quality indicators. The numerical values of quality indicators were processed using multiple regression methods, on the basis of which a regression model was obtained describing the quality of a flour-enriched mixture (with a high degree of accuracy) depending on the technological parameters of mixing a drum mixer.

1. Introduction

Studies of the health status of the population of the Russian Federation, the structure of the ration, security of the human body of nutrients, conducted by the Institute of nutrition of RAMN, established a deficiency of vitamins and mineral substances [1, 2]. As the world and domestic experience shows, the most effective and appropriate method of preventing micronutrient insufficiency is the development and introduction of fortified food products into production. At the moment formulated science-based enrichment principles, carried out the production of vitamin-mineral premixes, designed a wide range of enriched products, conducted clinical testing of enriched products and proven effectiveness of their use in the diet. As a rule, they enrich products of mass consumption. Positive results are known and the profitability of salt fortification with trace elements, in particular iron and iodine, is noted especially in low-and middle-income countries [3, 4]. In Russia, iodized salt is a product available to every consumer, and since 2003, the Ministry of health of the Russian Federation has issued an order “on providing educational institutions with iodized salt and food enriched with micronutrients”. Vitamin a deficiency
is eliminated by fortification of vegetable oils and sugar [5, 6]. Due to the enrichment of bread and flour confectionery products, they make up for the lack of vitamins, iron, calcium and other minerals [7–11]. Iron deficiency is also compensated by fortification of food products of different homogeneous groups [12–16].

Correction of vitamin and mineral values due to the traditional diet is practically impossible, so fortification of food products with missing nutrients in quantities corresponding to the physiological need remains an important research area [2]. Both individual vitamins or minerals and complex mixtures of vitamins and minerals are used as fortifiers. Known multivitamin and vitamin-mineral mixtures of the company “Valetek” for food fortification, developed by specialists Of the Institute of nutrition of the Russian Academy of medical Sciences, have passed clinical trials and have a wide practical approbation. Enriching mixtures are developed taking into account food shortages and the needs of the Russian population. Among the advantages of using ready-made mixes (premixes) in production, we can highlight: the elimination of errors and unacceptable combinations of vitamins and mineral elements in the preparation of enriching recipes; simplification of the technology of enrichment to a single operation for adding a ready-made vitamin and mineral mixture to the food mass; simplification of calculations when composing the product recipe (the manufacturer gives recommendations on the quantitative introduction of premix); control of the finished product for one or two components of the premix.

Premixes are homogeneous loose, powdery, homogeneous mixtures of vitamins, antioxidants, and minerals in a set and quantities corresponding to the norms of human physiological needs. Based on the purpose of using the premix in a food product, the food carrier can be wheat flour (for flour confectionery and bakery products), sucrose (for sugary confectionery products, food concentrates, beverages) and other inert food substances (glucose, lactose, dodextrin). Along with the advantages of using ready-made premixes, there is a significant problem in the technology of flour products. Food enterprises operate on the established technological line and although the use of premix does not require additional technological equipment and changes in the technological parameters of production, however, the limitation of the use of premixes in production is the lack of mechanical homogeneous mixing of premix with flour. The premix is made at the rate of 500 g per 100 kg of flour, and it must be evenly distributed over the surface of the flour in the bowl or kneading capacity of the kneading machine before kneading the dough.

Therefore, the organization of production of food products enriched with premixes faces the problem of their uniform distribution over the entire mass.

In this regard, only about 2% of bakery products and confectionery products are enriched. At the same time, the Russian Federation has developed the necessary regulatory framework that regulates the forms of vitamins and minerals, as well as the levels of introduction of premixes in products [8].

In connection with the above, the purpose of this research is to determine the rational technological parameters of mixing flour and premix in the production of oatmeal cookies enriched with vitamin and mineral premix.

2. Objects and methods of research

The object of research was a drum mixer for fortification of flour with premix.

The subject of the study was the establishment of regularities describing the operation of the drum mixer at rational operating parameters that affect the quality of the obtained flour-enriched mixtures.

We used wheat flour, premix “Valetek-8”, developed according to TU 9281-019-17028327-09, of sanitary and epidemiological conclusion № 77.99.57.928. D. 007876. 07. 09 from 06.07.09. Cookies were prepared according to the developed recipe [10, 11].

To assess the quality of the flour-enriched mixture, a coefficient of heterogeneity Vc was used [17, 22] showing the ratio of the standard deviation of the concentration of the key component in the samples to its average concentration in the entire volume of the mixture.

The vitamin value was determined by conventional methods [11].

Setting up an experiment
To analyze the influence of technological parameters on the quality of the resulting flour mixture, a full-factor experiment was performed, during which the following parameters were varied:
- speed of rotation of the mixer drum \( (n = 30, 45, 60 \text{ rpm}) \);
- mixing time of flour mixture components \( (t = 1, 3, 5 \text{ min}) \);

The base (zero) points and the range of variation are shown in Table 1.

**Table 1. The levels and intervals of variation.**

| Factor and its designation | Top level | Lower level | The centre of the plan | The range of variations |
|---------------------------|-----------|-------------|------------------------|------------------------|
| Rotation speed of the mixer drum, rpm, \( X_1 \) | 60        | 30          | 45                     | 15                     |
| Mixing time, min, \( X_2 \) | 5         | 1           | 3                      | 2                      |

The research was carried out on a drum mixer [18] in the engineering center “Food Engineering” of the Department "Technological design of food production" of Kemerovo state University.

The ingredients of the flour mixture (wheat flour and premix “Valetek-8”) were fed into the mixer drum using volumetric dispensers. Then the necessary drum rotation speed and mixing time were set on the mixer control panel, after which the mixing process was performed.

At the end of the mixing process, 30 samples weighing 60 g were taken from the finished mixture, then the concentration of the key component (vitamin \( B_2 \)) was determined in each of them. Further, the inhomogeneity coefficient (characterizing the quality of the resulting mixture) \( (V_c, \%) \) was determined for each combination of technological modes based on the found concentrations. It is known that the lower the value \( (V_c, \%) \), the higher the quality of the resulting mixture [17, 22].

Regression analysis of the results was performed in the Statistica program. using the “General regression models” module.

3. Results and discussion

Premix “Valetek-8” is recommended for the enrichment of flour confectionery products for the prevention of vitamin-iron deficiency anemia, prevention of rickets in children and osteoporosis in the elderly. The carrier of the premix is wheat flour.

The recipe and technology of oatmeal cookies enriched with vitamin and mineral premix “Valetek-8” have been developed, the recipe composition of which includes the following vitamins and minerals, g / kg: \( B_1 \)-0.9; \( B_2 \)-0.55; PP-11.5; \( B_6 \)-1.33; \( B_9 \)-85; iron-5.5; calcium-192.

Production technology includes the main stages: preparation of raw materials for production, dough kneading, molding, baking, cooling of finished products, packaging, storage [19]. The main technological stage that forms the quality of enriched cookies is the process of mixing wheat flour and premix. Then the resulting mixture is used for kneading the dough. Obtaining a mixture with a uniform distribution of premix in flour is a complex technological task, which is given special attention.

Data on the conduct of a full-factor experiment and the obtained numerical values of the quality indicators of the resulting mixture are presented in Table 2.

**Table 2. Changes in quality indicators depending on technological parameters.**

| №  | \( n, \text{rpm} \) | \( t, \text{min} \) | \( V_c, \% \) |
|----|-------------------|-------------------|--------------|
| 1  | 30                | 1                 | 13.88        |
| 2  | 30                | 3                 | 12.47        |
| 3  | 30                | 5                 | 11.26        |
| 4  | 45                | 1                 | 11.49        |
| 5  | 45                | 3                 | 8.24         |
When processing the results obtained, the Statistica program analyzed the dependence of the inhomogeneity coefficient on independent variables (n and t).

Using regression analysis, the regression model "response surface Regression" is obtained, the coefficients of which are shown in table 3.

Table 3. Coefficients of the regression model.

| Free term | Vc, % | Vc, % | Vc, % | Vc, % |
|-----------|-------|-------|-------|-------|
| Vc, %     |       |       |       |       |
| Param.    |       |       |       |       |
| n         | -0.689| -2.08 | 0.128 | -5.9  |
| n²        | 0.0064| 1.782 | 0.172 | 4.98  |
| t         | -2.665| -1.763| 0.176 | -3.04 |
| t²        | 0.262 | 1.29  | 0.287 | 1.82  |
| nt        | 0.0173| 0.432 | 0.432 | 1.02  |

According to the parameters presented in table 3, we obtained a regression equation showing the dependence of the inhomogeneity coefficient on the mixing process parameters:

\[ V_c = 30.817 - n \cdot 0.689 + n^2 \cdot 0.0064 - t \cdot 2.665 + t^2 \cdot 0.262 + nt \cdot 0.0173 \]

Equation (1) shows that the mixing time has the greatest influence on the quality of the resulting flour mixture, and the numerical value of this parameter has a negative value. This means that the longer the mixing time of the initial components of the resulting mixture, the lower the value of the inhomogeneity coefficient, and therefore the higher the quality of the resulting mixture. The speed of rotation of the drum has a lesser impact on the quality of mixing in these conditions, but its numerical value has a significant weight, in order to leave this parameter for further analysis.

The qualitative indicators of the resulting model are shown in table 4.

Table 4. Quality parameters of the regression model.

| Indicator                  | Values |
|----------------------------|--------|
| Multiple correlation coefficient R | 0.88   |
| Multiple coefficient of determination R² | 0.78   |
| Adjusted correlation coefficient R² | 0.42   |
| F- criterion                | 12.56  |
| p- criterion                 | 0.0001 |
the mixer drum \( n \), rpm. and from the mixing time \( t \), min. bulk components of the flour mixture, shown in figure 1.

Figure 1. Response Surface describing the dependence of the inhomogeneity coefficient \( V_c \), % depending on the rotation speed of the mixer drum \( n \), rpm. and from the mixing time \( t \), min.

Figure 1 shows that the minimum values (\( V_c \), %) are in the zone of dark green color at the average values of the studied technological parameters for mixing the bulk components of the flour mixture. Based on this, the rational mixing parameters will be: rotor speed \( n \) equal to 45 rpm; mixing time of bulk components \( t \) equal to 3 minutes. At these values, the coefficient of heterogeneity \( V_c \) will be equal to 8.5 %.

The obtained experimental values of the inhomogeneity coefficient were compared with the predicted values using a regression mathematical model (1) (table 5). For each experimental and model (predicted) value, the relative error was calculated using formula (2).

\[
\delta = \left| \frac{V_c^{\text{exp}} - V_c^{\text{pr}}}{V_c^{\text{exp}}} \right| \times 100 \% ,
\]

\( \delta \) – relative error, %;
\( V_c^{\text{exp}} \) – experimentally obtained optical density value;
\( V_c^{\text{pr}} \) – the optical density value predicted using a mathematical model.

Table 5. Comparison of experimental and predicted values of the inhomogeneity coefficient.

| №  | The coefficient of heterogeneity \( V_c \), % | Relative error, % |
|----|------------------------------------------|------------------|
|    | Experimental value | Predicted value  |
| 1  | 13.88          | 14.031          | 1.07619        |
| 2  | 12.47          | 11.83           | 5.409975       |
The average value of the relative error is about 5.5%. Therefore, this model is considered adequate, and can be applied with a sufficient degree of accuracy to determine the quality of the resulting flour mixtures, in a given range of variable technological parameters.

4. Conclusion
The use of a batch drum mixer allowed to obtain a homogeneous mixture of wheat flour and premix, to solve the problem of uniform distribution of these ingredients. The obtained materials allow us to conclude about the effective parameters of mixing wheat flour and premix before kneading the dough. A high degree of uniformity of the resulting flour mixture can be obtained at the speed of the mixer drum 45 rpm for 3 minutes. The technological process of producing enriched cookies in compliance with the established parameters allows you to get a finished product with the specified properties.

The developed enriched cookies were tested in the conditions of industrial production at the LLC “Confectioner” enterprise in Kiselevsk.

References
[1] Spirichev V B 2017 On the 30th anniversary of the state program of food fortification (Food industry) 8–12
[2] Tutelyan V A, Spirichev V B and Shatnyuk L V 2017 Correction of micronutrient deficiency is the most important aspect of the concept of healthy nutrition of the Russian population (Nutrition issues) Vol. 1 p 3
[3] Malochleb M 2019 Fortifying salt with micronutrients; Plant-based protein demand on the rise (Food technology magazine) Vol. 73 (11)
[4] Maria J, Larson L, Mannar V and Martorell R 2018 Impact of Double-Fortified Salt with Iron and Iodine on Hemoglobin, Anemia, and Iron Deficiency Anemia: A Systematic Review and Meta-Analysis (Advances in Nutrition) Vol. 9 3 207–218
[5] Tanumihardjo S, Gannon B and Kaliwile C 2016 Controversy Regarding Widespread Vitamin A Fortification in Africa and Asia (Advances in Nutrition) Vol. 7 1 p 5
[6] Debelo H, Novotny J and Ferruzzi M 2017 Vitamin A (Advances in Nutrition) Vol. 8 6 992–994
[7] Belyavskaya I, Vrzhesinskaya O, Kodentsov V and Shatnyuk L 2020 Nutritional value of spelt flour bakery products enriched with vitamins, iron and calcium (Bread products) Vol. 2 54-57
[8] Kostyuchenko M, Kodentsov V and Shatnyuk L 2019 Micronutrient enrichment of bakery products: international experience and new trends (Bread products) Vol. 7 36–41
[9] Yudina A, Shatnyuk L, Savenkova T, Kodentsov V, Pereverzeva O and Vorob’eva V 2014 Enrichment of long-term storage biscuits with vitamins and minerals (Nutrition issues) Vol. 3 p 207
[10] Reznichenko I, Chistyakov A, Ustinova Y and Ruban N 2019 Justification for the development of enriched flour confectionery products (Food industry) Vol. 5 56–59
[11] Reznichenko I, Chistyakov A, Renzaeva T and Ramzaev A 2019 Development of recipes of flour confectionery products of functional purpose (Bread products) Vol. 6 40–43
[12] Harding K and Neufeld L 2012 Iron deficiency and anemia control for infants and young children
in malaria-endemic areas: a call to action and consensus among the research community (Advances in Nutrition) Vol. 3 4 551–554

[13] Fernandez P, Branca F, Miyagishima K, Peña-Rosas J, Rogers L, Mingard ÖT et al 2018 Guideline: fortification of rice with vitamins and minerals as a public health strategy (World Health Organization) p 62

[14] Reznichenko I 2008 Theoretical and practical aspects of developing and evaluating the quality of confectionery and functional food concentrates (GOU VPO “Kemerovo technological Institute of food industry”) p 496

[15] Spirichev V, Trichina V and Poznyakovsky V 2012 Fortification of food products with micronutrients is a reliable way to optimize their consumption (Polzunovskii Herald) Vol. 2 9–11

[16] Weaver C and Peacock M 2019 Calcium (Advances in Nutrition) Vol. 10 3 546–548

[17] Borodulin D 2013 Development and mathematical modeling of a continuously operating mixing aggregates of centrifugal type for the processing of bulk materials. generalized theory and analysis (cybernetic approach) (Ministry of education and science of the Russian Federation, Kemerovo technological Institute of food industry) p 200

[18] Ivanets V, Borodulin D, Shushpannikov A and Sukhorukov D 2015 Intensification of bulk material mixing in new designs of drum, vibratory and centrifugal mixers (Foods and Raw Materials) Vol. 1 62–69

[19] Reznichenko I, Chistyakov A and Surkov I 2018 Method for enriching flour confectionery products with vitamin and mineral premix (Patent 2665618 of the Russian Federation)

[20] Ivanets V, Trichina V and Spirichev V 2017 Technology for the production of dry specialty drinks and using a high-performance mixer (Bulletin Of SUSU. A series of "Food biotechnology") Vol. 2 31–37

[21] Tarasenko N, Novozhenova A and Mikhailenko M 2014 Improving the production line for the production of functional gingerbread (News of higher educational institutions. Food technology) Vol. 4 (340) 107–110

[22] Borodulin D, Shushannikov A and Vojcikova L 2012 Investigation of the functioning of a continuous centrifugal mixer by multiple regression analysis (Equipment and technology of food production) Vol. 1 (24) 98–103