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Use of expert estimate extrapolation method for selecting sourdough starter technological parameters

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Abstract. The quality of rye bread and bread made of the mixture of rye and wheat flour is largely determined by biotechnological processes occurring during the ripening of the sourdough starter. The factors that allow regulation of this process are the parameters of the nutrient mixture and the starter technology. Among the latter, there is the dosage of malt in the nutrient mixture, the ratio of fermented sourdough and the nutrient mixture, its humidity. The use of the specific decision depends on the experience and professionalism of the technologist. At the same time, given the complexity and multifactorial nature of the problem to be solved, decision making is not always unequivocal and guarantees the stability of the quality characteristics of the starters. Under these conditions, the use of extrapolation methods for unclear expert estimates has been proposed. The essence of this method consists in extrapolating the decision, made based on limited sample by the decision maker (DM) as a result of pairwise comparison, to the entire set of alternatives, identifying the DM's preferences and constructing a selection mechanism based on the information received. Testing the methods based on the results of the undertaken research allows us to conclude that the proposed methods are effective in solving the problem of choosing the optimal technological parameters for preparing liquid rye sourdough starter.

1. Introduction

One of the most complex biotechnological processes in food technology is the ripening of liquid sourdough starters in the technology of rye bread and bread made of mixture of rye and wheat flour. The process of making liquid rye sourdough starter is characterized by the complexity and relative instability. With the undoubted directionality of the process of acid and gas formation, the starters can differ not only by the qualitative characteristic of these indicators, but also by the ratio between them, which largely determines the quality of the finished products. Such specificity is associated with the fact that the process of reproduction of yeast cells and lactobacilli occurs simultaneously, but each of these groups of microorganisms responds to external conditions in its own way. The content of digestible carbohydrates and proteins fluctuates both due to the different initial characteristics of the flour, and as a result of deviations in the cooking parameters of the malt, the nutritional mixture, and the starter itself. There are various ways of adjusting the nutrient media of starter cultures by introducing unconventional raw ingredients or modifying traditional technologies [1-5]. However, from the point of view of modern production, options for controlling the parameters of the starter culture prepared according to the classical technology are of more interest.

Under these conditions, it is advisable to study the effect of the parameters of the process on the final properties of the starter.



2. Materials and methods

In this paper we took the basis of the liquid rye starter with flour brewing prepared in accordance with unified instruction using pure cultures of lactobacilli *L. brevis*-1, *L. casei*-26, *L. plantarum*-30, *L. fermenti*-34 and yeast *S. cerevisiae* JI-1 in the solution cycle.

Reference starter was prepared with humidity of 82 % within entering 33% of malt with flour and water proportion of 1:3. The final acidity of the starter was 10 numbers, dough fermentation property 25 minutes, dough fermentation time 4 hours.

In the model experiments we measured the dosage of the malt in the nutritional mixture (10 % of the reference) – model system I; the dosage of the malt in the nutritional mixture compared to the fermented starter (20 % of the reference) - model system II; the nutritional mixture humidity (5 %) - model system III [6].

The final parameters were set to be acidification dynamics and fermentation property as well as accumulation of yeast and lactobacillum cells and the speed of their growth.

3. Results and discussion

Acidity accumulation is inversely related to the malt dosage, i.e. the amount of digestible sugars. This indicator is mainly determined by the life of the inversely related to the welding dosage, i.e. the amount of digestible sugars. This indicator is mainly determined by the life of the ICD. The values of their growth rate confirm the results. The values of their growth rate confirm the obtained results (table 1). This may be due to the suppression of cells with an excess amount of substrate, as well as changes in other physico-chemical parameters of the medium, such as viscosity and redox potential. A different relationship is observed in the analysis of the dough fermentation property. The starter with minimum of malt shows low rates. At the same time, for the starter with the addition of 43% of malt the lift remains high in the last fermentation period. этом для закваски с внесением 43 % заварки the dough fermentation property remains high even during the last period of fermentation. There is no typical for this period deterioration in this indicator. On the one hand, this may be due to the total acidity, which is optimal for yeast - within 10 numbers [7, 8], on the other hand - with higher sugar consumption rate and, accordingly, faster metabolic processes in yeast cells compared to lactobacilli. This is confirmed by previous studies: the consumption of reducing substances by yeast is 1.1% with an initial cell number of 1.5 million/G, while for lactobacilli it is 0.6% with a cell number of 3 million/G.

Table 1. Effect of the malt dosage in the nutritional mixture on the microorganism growth in the liquid rye starter

Starter fermentation time, h	Microorganism growth rate, h ⁻¹ , depending on malt dosage, %					
	yeast			lactobacilli		
	23	33	43	23	33	43
1	0.11	0.13	0.15	0.13	0.13	0.09
2	0.21	0.24	0.24	0.24	0.23	0.14
3	0.15	0.23	0.28	0.28	0.26	0.20
4	0.04	0.09	0.11	0.12	0.08	0.06

The growth rate of yeast is in direct proportion to the concentration of digestible carbohydrates (Table 1). For starter culture with minimum content of malt, which means digestible sugars corresponds to the smallest value of the growth rate of yeast. Probably, the deficiency of fermented sugars by the end of the process takes its effect. At the same time, for lactobacilli such pronounced pattern is not observed. Probably, they are less dependent on the concentration of carbohydrates, or the intervals we studied at any point completely provide the lactobacilli with assimilable sugars.

Thus, a real channel has been found for regulating the ratio of the number of microorganisms and metabolic products of lactobacilli and yeast in liquid rye starter which is the change in the malt dosage within 10% of the traditional limits [6].

The effect of the dosage of the nutritional mixture (20% of the traditional composition) on the characteristics of the processes in liquid rye starter has been detected. Under the higher initial total acidity in the case of (-20%) acidity accumulation is inferior to the reference sample and the variant (+20%), although in the first period the process with the ratio of the nutrient mixture and the malt of 1:2 does not have a characteristic slowdown and its rate exceeds all other options. With the lower dosage of the nutrient mixture, there is no adaptation period in the first hour of fermentation. The rate of acidity accumulation, as well as lactobacilli growth, is higher than in other variants. But later it decreases slightly, especially after three hours. This is a natural phenomenon, since this option is closer to the non-replaceable medium - cells to this period are transferred to the stationary phase. As for the starter with large amount of nutritional mixture (70%), despite the short lag-period of acidity accumulation, it is more intense, and respectively, the growth rate of lactobacilli is faster.

Similar results are obtained for dough fermentation property. The starter with the introduction of the nutritional mixture in a 2:1 ratio after the upgrade has an incomparably greater (worse) fermentation property, but after 3-4 hours it evens out and even exceeds all other options. The initial deterioration of the starter indicators during the 2:1 update is due to the dilution of the cell titer. But the high level of nutrient concentrations allows us to intensify gas and acid formation within the technological cycle.

Analysis of the microorganism growth rate (Table 2) showed that under the same regularities: the minimum growth rate during the first hour due to partial changes in the conditions of cultivation, and maximum rate closer to the completion of the process - when renewing the nutritional mixture in relation to the starter by 2:1, has an initial amount of microorganisms. Even under favorable external conditions (maximum nutrients), four hours is not enough to achieve an acidity index similar to that of the reference starter. Therefore, the constant renewing of the liquid ferment of 2/3 of the nutrient mixture can lead to the dilution of its titer and the deterioration of technological parameters. In general, a series of experiments (model system II) shows that it is impossible to interpret unequivocally both the method of intensifying biochemical and microbiological processes in liquid rye starter by renewing 2:1, and the method of preservation - 1:2 (starter culture: nutritional mixture). The choice will be determined by the final goal: if it is necessary to improve the fermentation property and acidity of the starter in the first 2 hours of the process, it is better to add 30% of the nutrient mixture, if in the last hour of fermentation - 70%.

Table 2. Effect of the fermented starter and nutritional medium during its reproduction on the microorganism growth rate

Starter fermentation time, h	Microorganism growth rate, h ⁻¹ , under renewing the malt with nutritional mixture, %					
	yeast			lactobacilli		
	50	70	30	50	70	30
2	0.24	0.16	0.26	0.23	0.15	0.30
3	0.23	1.20	0.18	0.26	0.84	0.18
4	0.09	1.10	0.017	0.08	0.84	0.027

The change in the parameters of the liquid rye starter in model system III is presented in Table 3. Increase in humidity leads to decrease in acidity, which is consistent with known information on this issue [2] and is associated with an increased oxygen content in more liquid media, which changes the conditions for lactobacilli for the worse.

As for the fermentation property, its noticeable deterioration by the third hour of fermentation can definitely be attributed to the shortage of fermentable sugars. This information is confirmed also by the yeast growth rate (table 3). With the sufficiently high initial indicator, due to the high saturation of the

environment with oxygen, in the first period of fermentation, by the end of the process there is a noticeable decrease. So, an increase in the starter moisture content up to 87% is unacceptable.

Table 3. Effect of the nutritional mixture moisture on the microorganism growth rate in the liquid rye starter

Starter fermentation time, h	Microorganism growth rate, h^{-1} , under renewing the malt with nutritional mixture, %					
	yeast			lactobacilli		
	82	87	77	82	87	77
1	0.13	0.17	0.13	0.13	0.10	0.17
2	0.24	0.21	0.20	0.23	0.18	0.25
3	0.23	0.15	0.28	0.26	0.24	0.29
4	0.09	0.07	0.12	0.08	0.02	0.12

Thus, the studies of biochemical processes in liquid rye starter demonstrated the following: there is not always a correlation between the processes of acidity accumulation and gas formation, which is associated with different reactions of yeast and lactobacilli to changes in external conditions.

In practice, the decision concerning the selection of parameters for the starter preparation, normally is based on the production experience of the company's employees and the historically developed variant of the technology. The starter quality control is to make the decision about the need to perform a distribution cycle while maintaining the previously adopted parameters of the production cycle. Under conditions of mass production, it is not possible to carry out an experimental change in the previously developed parameters. In this connection, the simulation of the situation on the basis of a limited block of laboratory studies with the subsequent decision-making, remains the task of considerable practical interest.

To solve this problem, methods of extrapolation of expert estimates were tested in this research, the essence of which is as follows: at the beginning, in a limited sample (observable for the decision maker (DM)) of technological solutions, pairwise comparisons reveal preferences of DM; then, based on the information obtained, a selection mechanism is constructed $M = \langle s, p \rangle$, which is extrapolated to the whole set of alternatives (Figure 1).

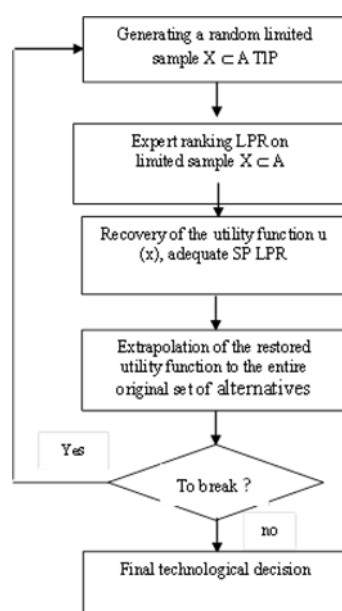


Figure 1. The iterative process of choosing the optimal solution.

The effectiveness of the proposed methods of extrapolation of expert evaluations for selection of the method of starter preparation was studied on a previously experimentally obtained block of starter quality indicators (acidity and fermentation property) depending on the moisture of the nutrient mixture, malt dosage, autolytic activity of the used batch of flour, process duration in the production cycle (Tables 1-3).

In order to perform an expert survey, six variants of technological solutions were randomly generated (Table 4).

Table 4. Random variant selection

13	1.000	0.588	1.000	0.500	0.719	1.000
14	1.000	0.588	1.000	0.750	0.875	0.930
19	0.417	0.168	0.083	1.000	0.758	0.860
26	0.417	0.168	0.083	0.500	0.648	0.614
39	1.000	0.588	1.000	0.500	0.688	0.842
40	1.000	0.588	1.000	0.750	0.828	0.807

Further, the expert was asked to make three pair comparisons. Moreover, if an expert on any presentation indicated the superiority of one alternative over the other, he was also asked to indicate the linguistic assessment of the strength of this superiority, using the linguistic scale with five gradations: slight superiority, small superiority, medium superiority, large superiority, very great superiority.

The following expert assessments were obtained:

(x_{14} , x_{40}) – slight superiority;

(x_{13} , x_{39}) – small superiority;

(x_{19} , x_{26}) – considerable superiority.

The corresponding polyhedron of preferences, adequate to the examination, looks as follows:

$$\left\{ \begin{array}{l} -0.167\alpha_1 - 0.42\alpha_2 - 0.917\alpha_3 + 0.16\alpha_5 + 0.158\alpha_6 \geq \zeta_I \\ -0.167\alpha_1 - 0.42\alpha_2 - 0.917\alpha_3 + 0.16\alpha_5 + 0.158\alpha_6 \leq 0.4\zeta_S + 0.6\alpha_I \\ 0.25\alpha_4 + 0.039\alpha_5 + 0.052\alpha_6 \geq \zeta_I \\ 0.25\alpha_4 + 0.039\alpha_5 + 0.052\alpha_6 \leq 0.4\zeta_S + 0.6\zeta_I \\ 0.832\alpha_1 + 0.58\alpha_2 + \alpha_3 + 0.25\alpha_4 + 0.531\alpha_5 + 0.158\alpha_6 > \zeta_S \\ \alpha_1 + \alpha_2 + \alpha_3 + \alpha_4 + \alpha_5 + \alpha_6 = 1 \end{array} \right. \quad (1)$$

When extrapolating from the vector adequate to the obtained unclear preferences of the decision maker, a single-extremization selection mechanism $M = \langle \sigma, \pi \rangle$ was synthesized, in which the σ structure is a point estimate of the coefficients of the utility function of the considered variants of technological parameter values.

$$U(x) = \sum \alpha p, \quad (2)$$

As an estimate in the proposed extrapolation method, based on the stability of the obtained expert estimates, the gravity center of the obtained polyhedron of unclear preferences (1) is taken. The search for the gravity center was carried out by the random search method, while the implementation of a random variable inside the polyhedron was uniform. As a result, the following α coefficient values were obtained: $\alpha_1 = 0.0872$; $\alpha_2 = 0.0294$; $\alpha_3 = 0.0239$; $\alpha_4 = 0.1602$; $\alpha_5 = 0.01857$; $\alpha_6 = 0.5136$.

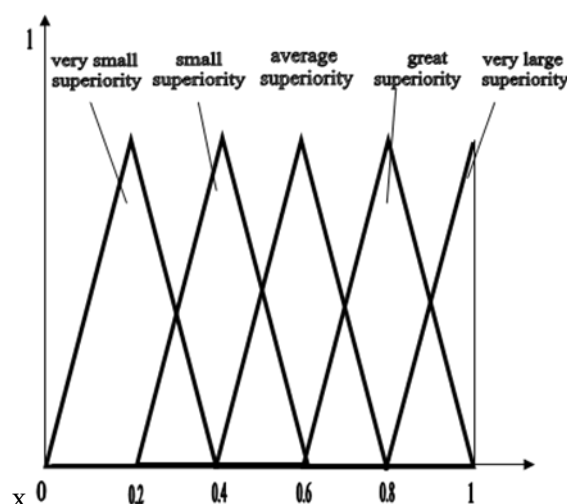


Figure 2. The functions of the linguistic variable SUPERIORITY STRENGTH terms implementation.

When extrapolating the first seven best solutions to all the considered set of options for technological parameters, they were arranged in this order: x_{10} ; x_{15} ; x_{14} ; x_{13} ; x_9 ; x_{41} ; x_{40} . Thus, among the analyzed options for the starter preparation, the basic two were selected: with moisture of 75%, made of flour with autolytic activity of 58%, without using malt; and with increasing moisture up to 77%, made of flour with autolytic activity of 42.2% and adding 23% of malt to nutritional mixtures. This confirms the following regularities in the choice of parameters for preparing the liquid starter: when the humidity increases above 75% and the flour with normal autolytic activity is used, it is necessary to add the malt to the composition of the nutrient mixture, which required amount is 20-23% at 80% of humidity. Reducing humidity (below 75%) provides the possibility of obtaining the starter with good quality indicators and without the use of malt, especially if flour with increased autolytic activity is used.

The use of the extrapolation method for the cone of preferences, adequate to the expertise, involves the synthesis of a multi-extremization selection mechanism, in which the structure of σ is the binary relation R defined by the formula (3):

$$(x, y) \in R \Leftrightarrow \forall \alpha_0 \in \Lambda : u(x) - u(y) \geq 0; \exists \alpha_0 \in \Lambda : u(x) - u(y) > 0. \quad (3)$$

Restoring this binary relation requires a multiple estimate of the coefficients of the utility function, for which a fundamental set of solutions Λ of the unclear preferences polyhedron was found. As a result of applying the synthesized multi-extremization mechanism of choice on the entire set of solutions, a subset was obtained consisting of six options: x_{45} ; x_{28} ; x_{15} ; x_{14} ; x_{13} ; x_{10} .

The selection, obtained after dropping out of the binary relation (3), contains four best options regarding extrapolation by vector: x_{10} ; x_{15} ; x_{14} ; x_{13} .

4. Conclusion

The analysis of the undertaken research allows one to conclude about the effectiveness of using the proposed methods of extrapolating unclear expert estimates when solving the problem of choosing the optimal technological parameters for preparing the liquid rye starter under specific production conditions (with the existing instrumentation and using a batch of flour with certain characteristics).

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