MULTICRITERIA OPTIMIZATION OF TECHNOLOGICAL PROCESSES FOR DOUGH PREPARATION IN BREAD PRODUCTION

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Abstract. *The article is devoted to the study of the automated intellectual subsystem of the decision making support at bread production on the basis of the product quality optimization with the use of vector optimization of the main technological processes of bread production: the sponge and dough preparation. The intellectual system for bread production processes management based on the principles of multicriteria optimization has been developed with the use of the knowledge acquired.*
Keywords: *bread production, multicriteria optimization, dough preparation, mathematical model.*

Depending on the type of the object and the management tasks, the optimization goals to finally achieve an automatic control have been determined. In the bread production, such goals are: increased productivity, reduced costs, and improved product quality. The goals set are generally heterogeneous and contradictory.

In general, the bread production processes management is a multi-step decision-making process [1]. Each step in the decision selection procedure is associated with a certain target function of the technological process management and is a set of control actions. The general target function is an additive one, which consists of the sum of the target functions of each separate bread production process management, however, optimal control of a separate technological process for a significant increase in the efficiency of the control object operation is carried out on a multi-criteria basis. Determination of a multi-criteria solution by its nature is compromise and based on subjective information [2].

The process of finding a solution consists of two stages. The pattern recognition of the situation is performed at the first stage. At the next stage - with the help of the built-in scenarios [3] - the development of optimal control in accordance with the set criteria of the technological process management is carried out. Management scenarios are presented in the form of Petri nets with colored chips, which are determined by the unclear values of technological factors in situationally significant zones.

When solving optimal management tasks, the following sets of criteria have been identified (1).

Aggregate criteria set:

$$F = \left\{ \begin{matrix} I_i \\ \tau_i \\ Bmp_i \end{matrix} \right\}_i^s \quad \begin{matrix} \text{– quality;} \\ \text{- productivity;} \\ \text{- loss.} \end{matrix} \tag{1}$$

The bread production process consists of many technological processes, the article deals with the two of them:

- the sponge stage;
- the dough stage.

The optimization criteria for the sponge stage are:

- **Quality** - intensity of the sponge fermentation, *$mlCO_2/kg*min$*

$$I_{sp.fr.} = f\,(t_{sp.fr.},\, W_{sp.fr},\, t_{sp.fr.}) \tag{2}$$

- **Productivity** - sponge fermentation time, hours

$$t_{sp.fr.} = f\,(t_{sp.},\, W_{sp.}) \tag{3}$$

- **Loss**, %

$$Lss = f\,(t_{sp.fr.},\, W_{sp.fr},\, t_{sp.fr.}) \tag{4}$$

where t_{sp} - the sponge temperature, °C;
$W_{sp.}$ – the sponge wetness, %.
The optimization criteria for the dough stage are:
- **Quality** - oxidation-reducing potential, mB;

$$Eh = f\,(t_d,\ A_{sp.d.},\ t_{d.f,}\ pH_{sp.},\ I_{sp.\ fr}) \tag{5}$$

- **Productivity** - fermentation time, hours;

$$t_{d.f,} = f\,(t_d,\ A_{sp.d.}) \tag{6}$$

- **Loss**,%;

$$Lss = f\,(t_d,\ A_{sp.d.},\ t_{d.f,}\ pH_{sp.},\ I_{sp.\ fr}) \tag{7}$$

where t_d – dough temperature, °C;
$A_{sp.d.}$ - specific work, J/kg;
$pH_{sp.}$ - sponge acidity, pH units.

Due to the fact that the optimization criteria contradict each other, and the nature of their interaction is quite complex, there is a criterion conflict. For the best analysis and evaluation of the criteria impact on each other, there is a need for a graphical construction of the relationship between criteria and influential technological factors.

The criteria are presented in accordance with the analyzed experimental data, the fragments of which samples are given in tables 1, 2.

The identification of the mathematical models in situationally significant zones has been performed with the use of the least squares method [4]. Yield surfaces of the models obtained are shown in Fig. 1-6.

Multicriteria identification of the technological process of the sponge stage for the case t_{sp} - average, W_{sp} - norm

Table 1. Experimental data (fragment)

T_{sp}, ^0C	W_{sp}, %	I_f, $mlCO_2/kg{*}min$	T_f, hours	Lss, %
31.5	71.5	26.5	3.80	3.22
29.4	69.7	25.4	3.85	3.24
30.5	69.0	26.9	3.85	3.23
30.9	70.3	26.0	3.55	3.24
30.3	70.4	26.9	3.70	3.28
29.8	71.4	25.8	3.70	3.40
30.5	71.3	26.2	3.70	3.36
30.8	69.5	26.3	3.90	3.34
29.8	70.3	26.0	3.80	3.28

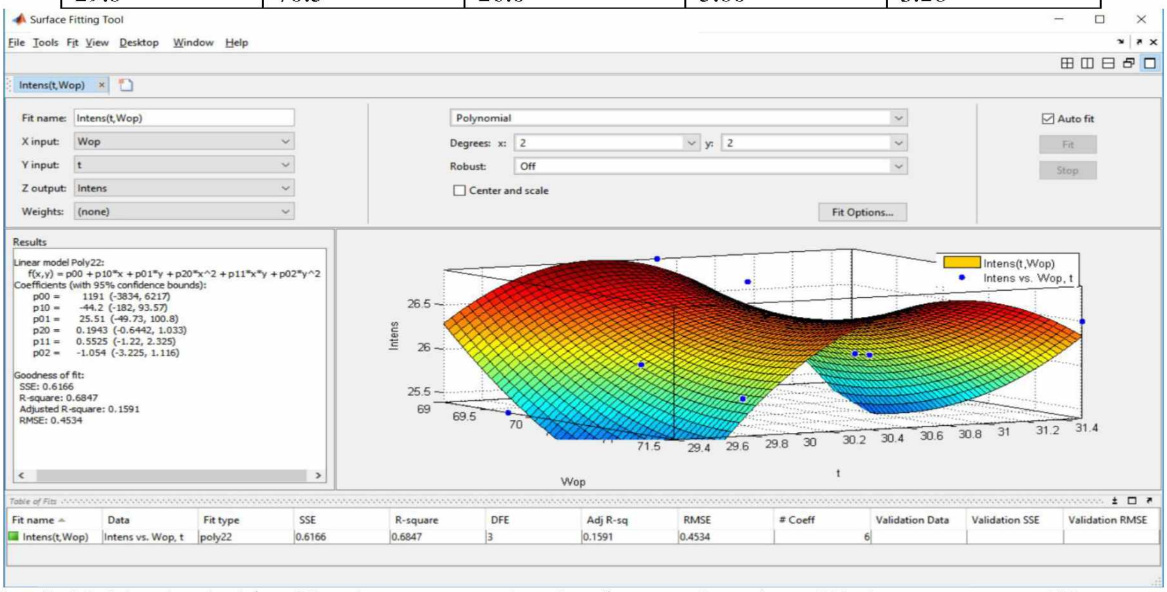

Fig. 1. Multi-criteria identification presentation for the case $I_{sp.fr.}$ ($t_{sp.}$; $W_{sp.}$), t_{sp} - average, W_{sp} – norm

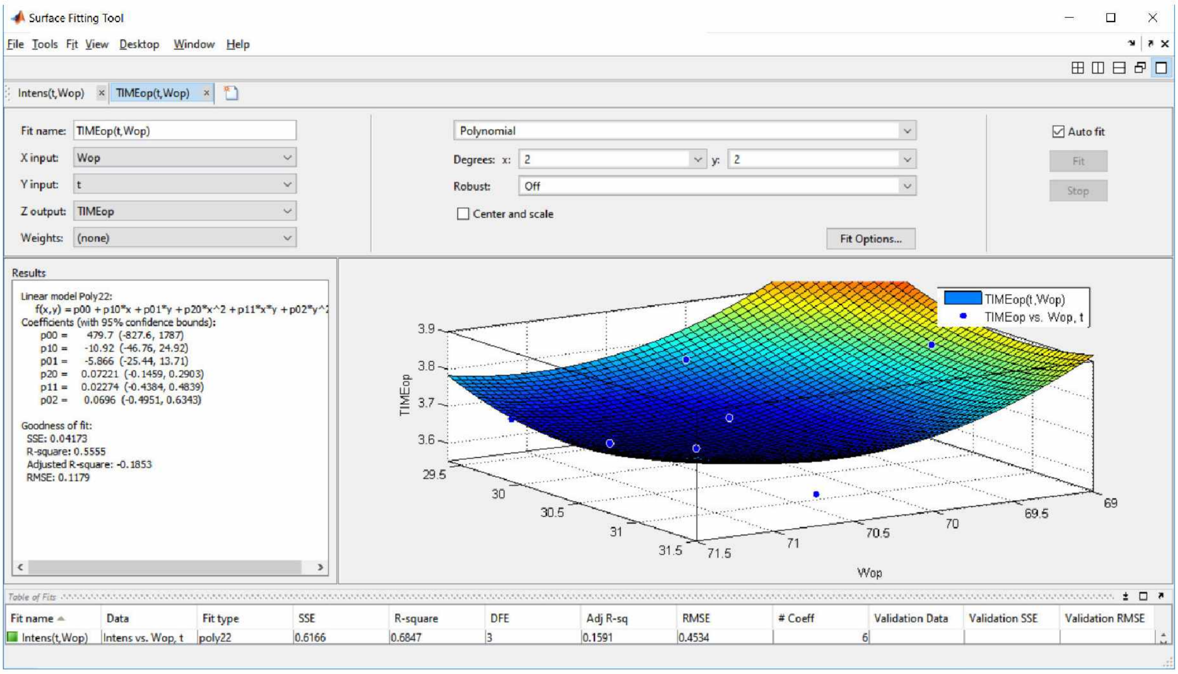

Fig. 2. Multi-criteria identification presentation for the case τ_f $(t_{sp}\ ;\ W_{sp})$, t_{sp} *- average,* W_{sp} *- norm*

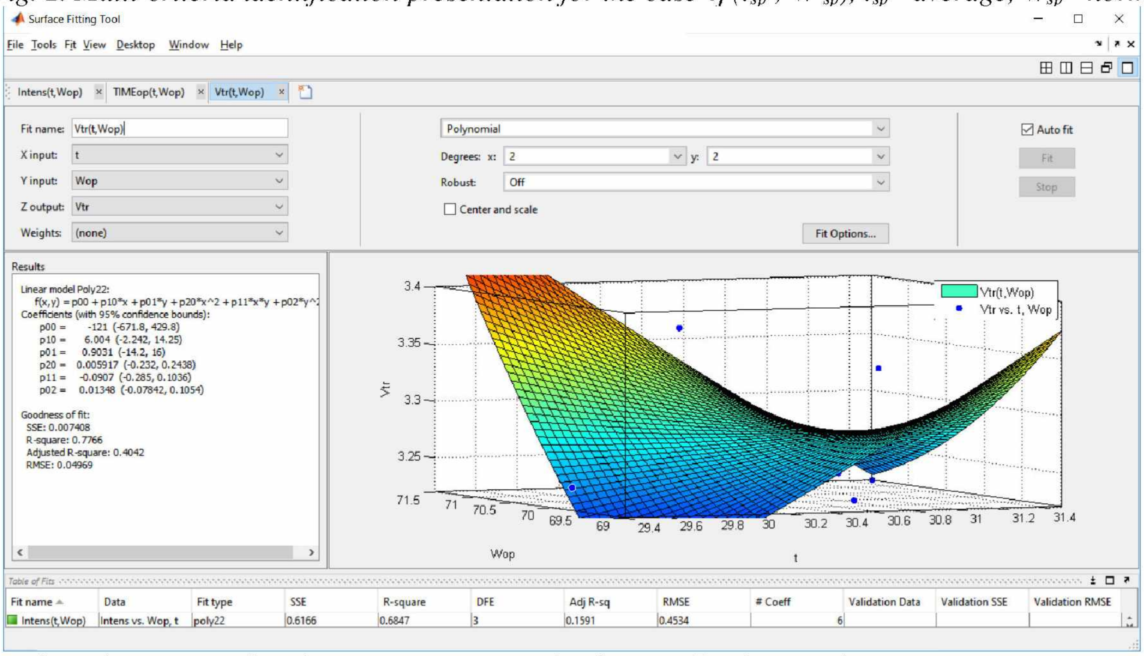

Fig. 3. Multi-criteria identification presentation for the case **Lss** $(t_{sp}\ ;\ W_{sp})$, t_{sp} *- average,* W_{sp} *- norm*

Multicriteria identification of the technological process of the dough stage for the case t_d - norm, A_{sp} – norm

Table 2. Experimental data (fragment)

T_d, ^0C	A_{sp}, J/kg	E_h, mB	T_f, hours	Lss, %
32.3	16.3	-74.4	0.79	0.38
33.3	15.2	-81.8	0.80	0.21
32.0	15.0	-62.7	0.81	0.40
32.6	13.6	-82.8	0.95	0.29
31.8	15.4	-70.0	0.96	0.27
30.9	12.8	-78.0	0.81	0.40

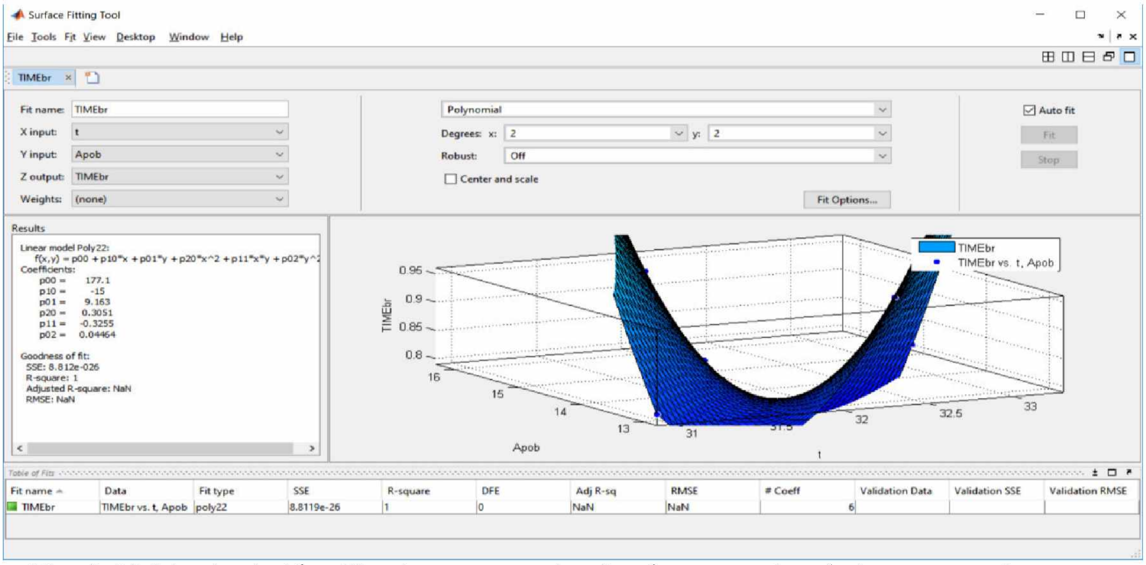

Fig. 4. Multi-criteria identification presentation for the case τ_f (t_d , A_{sp}), t_d - norm, A_{sp} - norm

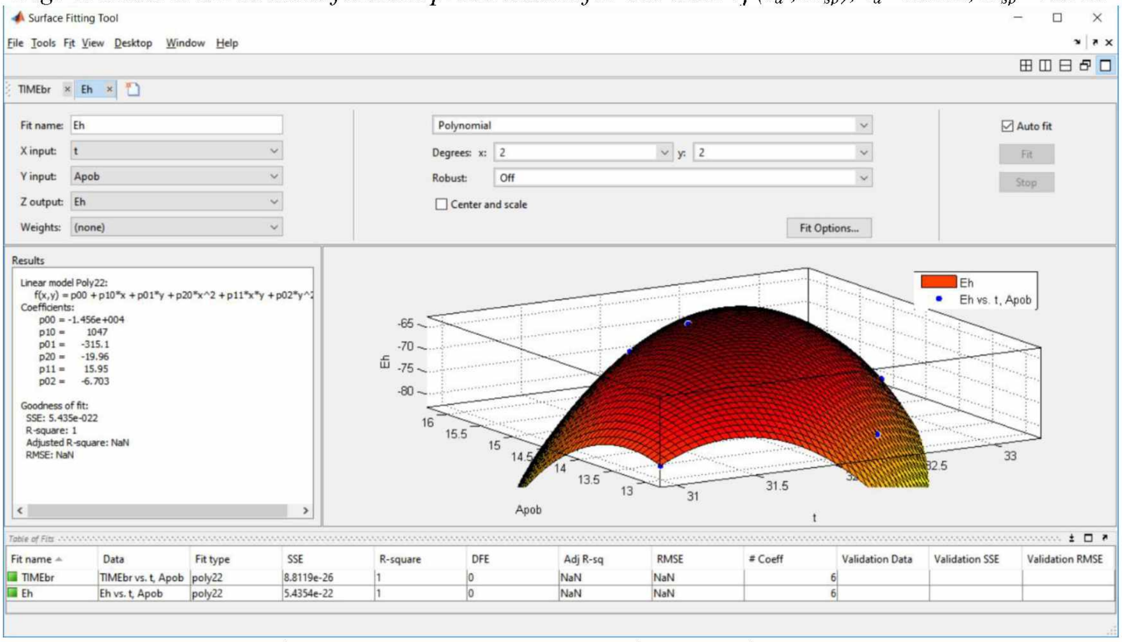

Fig. 5. Multi-criteria identification presentation for the case Eh (t_d, A_{sp}), t_d - norm, A_{sp} – norm

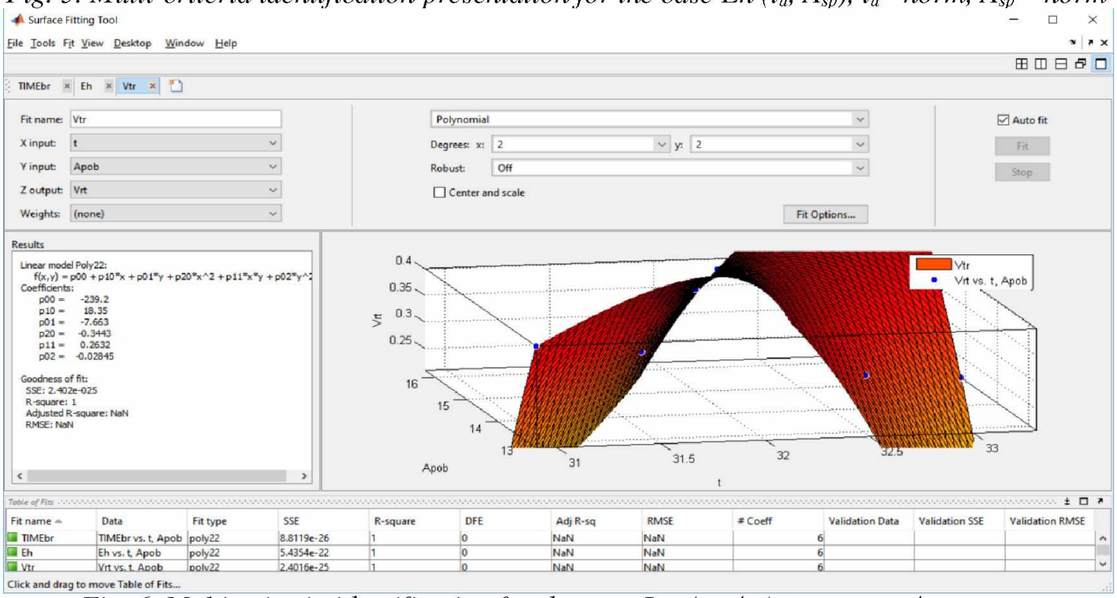

Fig. 6. Multi-criteria identification for the case Lss (t_d, A_{sp}), t_d - norm, A_{sp} – norm

Let's consider the models of some of the main controlled variable processes of sponge and dough stages in bread production.

The model of the sponge stage quality indicator.

The given model corresponds to the area of the unclear value parameter change, the "high" fermentation intensity of the sponge. Namely, the temperature of the sponge is "low", the wetness of the sponge is "normal", the fermentation time is "short".

$$Y = 1.1749\, t_{sp}^{\ 2} + 0.0244\, W_{sp}^{\ 2} - 0.4306\, t_{sp} W_{sp} - 37.7031\, t_{sp} + 9.1866\, W_{sp} + 241.7074$$

Quadratic average = 4.1530

The model of the sponge stage performance indicator.

The given model corresponds to the area of the unclear value parameter change of the "short" sponge fermentation time. Namely, the temperature of the sponge is "low", the wetness of the content is "normal".

$$Y = -0.0121 t_{sp}^{\ 2} + 0.0352\, W_{sp}^{\ 2} - 0.2845\, t_{sp} W_{sp} + 20.7471\, t_{sp} + 3.3791\, W_{sp} - 419.3326$$

Quadratic average = 0.1238

Attrition model of the dough stage.

The given model corresponds to the area of the unclear value parameter change of the "average" loss. Namely, the dough temperature is "norm", the specific work is "norm", the dough fermentation intensity is "low", the dough fermentation time is "short".

$$Y = 0.1184\, t_d^{\ 2} + 0.0634\, A_{sp}^{\ 2} - 0.6098\, t_d^{\ 2} A_{sp} + 3.2415\, t_d + 16.3967\, A_{sp} - 189.5246$$

Quadratic average = 9.1328e-04

Through the Matlab software environment, the relationship between management criteria has been studied and it has been shown that in the multicriteria space (quality, productivity, loss) there are areas in which the optimal solution can be found, and vice versa, it is clear that an improvement in one of the criteria leads to a sharp deterioration of the other (Fig. 2). Thus, at the sponge fermentation stage, with the fermentation time increase, sp. f. and decrease in the sponge fermentation intensity Isp.f – the dry matter loss Lssp.f. increases. The best solutions were in the compromise zone according by the Pareto method of approximate goals [5] in the Matlab environment.

Conclusion.

An effective management of such a complex object as the technological processes of bread production is possible by achieving many goals that determine the quality of products, the productivity of the technological line and the dry matter loss. To achieve these goals, it is necessary to apply the most modern management methods, which include the multicriteria optimization studied in this article.

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