THE TAGUCHI METHOD USED IN IMPROVING THE QUALITY COSTS IN BAKERY INDUSTRY

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Among the quality instruments we dispose of at present, the experience plans are the most powerful to define the optimum levels of factors tested in order to reduce the dispersion of characteristics regarding the functioning of a product or manufacturing process, and then its adjustment to the desired target values. The Taguchi method carried out by dr. Genichi Taguchi makes appeal to the techniques of quality engineering which also includes control statistical methods together with quality management ones. Most attention of Taguchi method focuses on the statistical elements of the procedure. The experimental planning has been a major concern of his research activities. Taguchi experience plans have brought significant contribution to the success of Japanese industry, especially in the field of quality, thus becoming for more than 20 years the world leader in terms of quality and competitive costs as well.The method consists in identifying the combinations of parameters which reduce the factors' effects, without the latter ones being directly attacked. Taguchi uses the word „noise" for any cause of variation in the process functioning, other than that established by the user. The use of experience plans allows a great decrease of the experience number to be achieved in order to identify coefficients of a model. Genichi Taguchi settled an original method which allows, starting from a few standard tables, to solve easily the most part of the industrial problems in terms of experience plans. The paper focuses on optimization of white bread manufacturing process; the parameter in view is the core moisture after baking. After having established the factors influencing the process, we have calculated for each factor its effect upon the system response (the core moisture) and the response value as interaction between factors. The graphic representation analysis of medium effects of factors and interactions between them provides us with the answer regarding the method to be used in the baking process optimization.

Key words: *experience plans, factors' effects, optimization*

The period we are going through, consumers become more and more aware of the qualitative aspects of their life and alimentation and that is why it became compulsory that the producers of aliments should respect both the technological and the qualitative requirements [2].

The TAGUCHI METHOD is based on the conception of the Japanese specialist having the same name regarding the improvement of the quality. The

Taguchi's major contribution consists in combining the engineering techniques and the statistic ones in order to achieve the rapid improvement of the quality costs, looking for the optimization of the product design and of the fabrication processes. The Taguchi's experience plans contributed to the Japanese's success in the quality field, which permitted them to become, for more than 20 years, the world leaders of quality [1].

The strategy adopted by Taguchi is rather opposite: instead of trying to eliminate these parasite factors (also named the noise factors), he tried to minimize their impact. Concretely, the method consists in identifying the combinations of parameters that decrease the causes' effects, without attacking them directly.

Searching the good values to be attributed to the controlled factors is done in an experimental way, in order to optimize the product or the process, so that [1]:

- it respects the desired functional performances;
- to be solid, meaning insensitive to the parasite factors.

The Taguchi method supposes that, varying a certain number of factors, greater the number of factors tried, greater the optimization chances, assuming that these ones are pertinent relative to the optimized criteria.

The Taguchi experience plans use simultaneously the average and the variability of the measured features values. They use as performance indexes, the *Signal/Noise* ratio, which take into account, simultaneously, of: the desired value (The signal) to achieve and the undesired variable of this value (The noise) to be fought against.

How can we determine the components to be optimized?

Beside a logical deductive reasoning cause-effect that any specialist used spontaneously, one can also resort to the following instruments, separately or successively:

- searching of the incriminated components;
- pair comparisons ;

These are meant to isolate, from an important number of possible causes, a small group that contains "the guilty ones".

PREPARING THE EXPERIMENT

The success of an experiment essentially depends on its preparation. This task is for the reflection group constituted for this purpose. The Taguchi method is efficient as it permits the rapid achievement of 70-90% of the desired optimization with minimum expenses. The missing 10-30% can be reached using one or two complementary experiments, limited to 2-4 parameters considered to be the most influent. This pragmatic approach, in successive steps, resorts to knowing the phenomena and to the experience acquired during the years by the interested engineers and technicians [1]. Trusting the department staff, it is possible to establish the more pertinent factors to be checked. In addition to that, this experience will be enriched during the performance of the experiments and it will permit the increase of the efficiency. It derives from here that persons with the best theoretical, technological and practical training referring to the subject to be solved must take part from the reflection group.

PRINCIPLES TO BE RESPECTED FOR CHOOSING THE FACTORS THAT MUST BE CHECKED

When we speak about choosing the controlled factors, we refer to their nature, their number, their independence and the levels they should be checked in.

a. The number of factors that must be checked: in an experiment, the more factors we test, the better the chance to identify the influence factors, and more over, it ensures the reproducibility of the results.

b. The qualitative choice of the factors to be checked: while preparing an experiment, choosing the factors is done taking into account the people's experience within the organization, choosing a greater number, subsequently, by the calculus of the importance in the final result, eliminating a certain number.

c. Choosing the factors really independent one from another: the purpose of this step is to determine the points/operations/stages corresponding to the technological process in which the control can and must be applied in order to prevent, to eliminate or to reduce the risk of appearing dangers.

d. Choosing the values of the factors levels to be checked: choosing the factors levels to be tested has a decisive role for the success of an experiment, but if they are too close one from another there is the risk that the factors differs in a small proportion and believes that this actor has little influence [4].

MATERIAL AND METHOD

Before starting an experiment, one must establish the field he will work in, meaning the limits within which each studied factor will be valued. Starting from the limits in which the factors can evolve, we chose the possible experimental field, taking into account the theoretical, experimental and technical conditions.

PLANNING THE EXPERIMENT.

Researches done in a bakery unit, which aimed the production of a superior quality bread with parameters within the standard values, brought to the identification of some factors that influence the final quality. We have chosen three corrective elements from the multitude of the parameters that influence this quality:

- *The dough humidity* – u – measured in [%];
- *The baking temperature* - T – measured in [°C];
- *The baking time* - t – measured in [min.]

According to the existing standard, the optimum humidity of the crumb is 44%.

In *table 1* there are presented the factors and the levels to work with.

Table 1

The factors and their validity field

Factors	Minimum	Maximum
A: The dough humidity [%]	70	90
B: The baking temperature [°C]	200	270
C: The baking time [min.]	20	50

The study of a complete plan consists in studying all the possible combinations of the factors considered during the experiment. A complete plan is noted with X^K, notation that indicated the influence of k factors on X levels [3]. The factorial plans with factors on 2 levels are the simplest, but they are very often used in the industrial applications. For instance, for 3 factors of 2 levels each, the complete plan determine 2^3=8 experiments.

In order to represent the experiments in a simple manner, a coded variable will be used, a symbol for each of the factor levels, named the *Yates notation*, after the name of its author [3].

Thus we symbolize by:

1 (-) – the inferior level of a factor

2 (+) – the superior level of a factor.

According to those notations, the obtained plan of experiments is presented in *table 2.*

Table 2

The complete matrix of the experiments

Number of the experiment	Dough humidity u [%]	Temperature T [°C]	baking time t [min.]	ResponseCrumb humidity U [%]
1	70	200	20	52
2	70	200	50	45
3	70	270	20	47
4	70	270	50	39
5	90	200	20	57
6	90	200	50	53
7	90	270	20	50
8	90	270	50	48

RESULTS AND DISCUSSIONS

Calculus of the average of the responses. The general average of the results Y_i is calculated according to the formula (1)

$$M = \frac{1}{8}\sum_{i=1}^{8} Y_i \qquad \boxed{M = 48.87} \qquad (1)$$

The calculus of the average effects of the factors for each level:

$$E_{A1} = \frac{Y1+Y2+Y3+Y4}{4} - M \qquad E_{A1} = -3.12$$

$$E_{A2} = \frac{Y5+Y6+Y7+Y8}{4} - M \qquad E_{A2} = 3.12$$

$$E_{B1} = \frac{Y1+Y2+Y5+Y6}{4} - M \qquad E_{B1} = 2.88$$

$$E_{B2} = \frac{Y3+Y4+Y7+Y8}{4} - M \qquad E_{B2} = -2.88$$

$$E_{C1} = \frac{Y1+Y3+Y5+Y7}{4} - M \qquad E_{C1} = 2.63$$

$$E_{C2} = \frac{Y2+Y4+Y6+Y8}{4} - M \qquad E_{C2} = -2.62$$

The calculus of the interaction between the factors

$$I_{A1B1} = \frac{Y1+Y2}{2} - M - E_{A1} - E_{B} \qquad I_{A1B1} = -0.13$$

$$I_{A1B2} = \frac{Y3+Y4}{2} - M - E_{A1} - E_{B2} \qquad I_{A1B2} = 0.12$$

$$I_{A2B1}=\frac{Y5+Y6}{2}-M-E_{A2}-E_{B1} \qquad I_{A2B1}=0.12$$

$$I_{A2B2}=\frac{Y7+Y8}{2}-M-E_{A2}-E_{B2} \qquad I_{A2B2}=-0.13$$

$$I_{A1C1}=\frac{Y1+Y3}{2}-M-E_{A1}-E_{C1} \qquad I_{A1C1}=1.12$$

$$I_{A1C2}=\frac{Y2+Y4}{2}-M-E_{A1}-E_{C2} \qquad I_{A1C2}=-1.13$$

$$I_{A2C1}=\frac{Y5+Y7}{2}-M-E_{A2}-E_{C1} \qquad I_{A2C1}=-1.13$$

$$I_{A2C2}=\frac{Y6+Y8}{2}-M-E_{A2}-E_{C2} \qquad I_{A2C2}=1.12$$

$$I_{B1C1}=\frac{Y1+Y5}{2}-M-E_{B1}-E_{C1} \qquad I_{B1C1}=0.12$$

$$I_{B1C2}=\frac{Y2+Y6}{2}-M-E_{B1}-E_{C2} \qquad I_{B1C2}=-0.13$$

$$I_{B2C1}=\frac{Y3+Y7}{2}-M-E_{B2}-E_{C1} \qquad I_{B2C1}=-0.13$$

$$I_{B2C2}=\frac{Y4+Y8}{2}-M-E_{B2}-E_{C2} \qquad I_{B2C2}=0.12$$

$$I_{A1B1C1}=Y1-M-E_{A1}-E_{B1}-E_{C1} \qquad I_{A1B1C1}=0.74$$

$$I_{A1B1C2}=Y2-M-E_{A1}-E_{B1}-E_{C2} \qquad I_{A1B1C2}=-1.01$$

$$I_{A1B1C2}=Y2-M-E_{A1}-E_{B1}-E_{C2} \qquad I_{A1B1C2}=1.49$$

$$I_{A1B2C2}=Y4-M-E_{A1}-E_{B2}-E_{C2} \qquad I_{A1B2C2}=-1.26$$

$$I_{A2B1C1}=Y5-M-E_{A2}-E_{B1}-E_{C1} \qquad I_{A2B1C1}=-0.51$$

$$I_{A2B1C2}=Y6-M-E_{A2}-E_{B1}-E_{C2} \qquad I_{A2B1C2}=0.74$$

$$I_{A2B2C1}=Y7-M-E_{A2}-E_{B2}-E_{C1} \qquad I_{A2B2C1}=-1.76$$

$$I_{A2B2C2}=Y8-M-E_{A2}-E_{B2}-E_{C2} \qquad I_{A2B2C2}=1.49$$

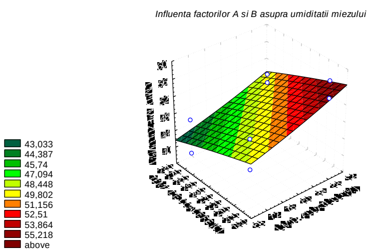

Figure 1 **Variation of the crumb humidity according to the dough humidity and to the baking temperature**

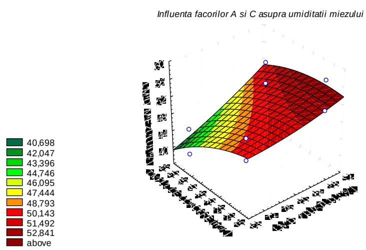

Figure 2 **Variation of the crumb humidity according to the dough humidity and to the baking time**

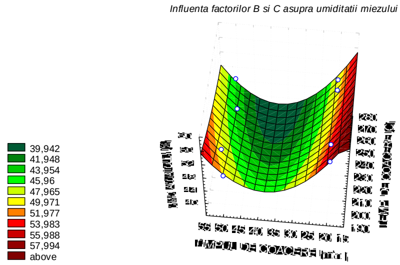

Figure 3 **Variation of the crumb humidity according to the baking temperature and to the baking time**

CONCLUSIONS

The success of an experiment depends in an essential way on its preparation. This pragmatic approach, in successive steps, resorts to knowing the phenomena and to the experience acquired during the years by the interested engineers and technicians.

Analyzing the charts we can notice the following things:

1. *fig.1* - when we consider only the A and B factors effect there can be noticed that the optimum working condition is between 260-270°C and a humidity of 68-76%;
2. *fig.2* - when we consider only the A and C factors effect, there can be noticed that the optimum working conditions is between 45-50 min. and a humidity of 72-84%;
3. *fig.3* - when we consider only the B and C factors effects, there can be noticed that the optimum working conditions is between 30-45min. and a temperature of 210°C.

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