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Defining the Effectiveness of Factors in Process of Drying Industrial Bakers Yeast by Using Taguchi Method And Regression Analysis, and Comparing the Results

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Abstract: *Taguchi Method and Regression Analysis have wide spread applications in statistical researches. It can be said that Taguchi Method is one of the most frequently used method especially in optimization problems. But applications of this method are not common in food industry .*
In this study, optimal operating parameters were determined for industrial size fluidized bed dryer by using Taguchi method. Then the effects of operating parameters on activity value (the quality chracteristic of this problem) were calculated by regression analysis. Finally, results of two methods were compared.To summarise, average activity value was found to be 660 for the 400 kg loading and average drying time 26 minutes by using the factors and levels taken from application of Taguchi Method. Whereas, in normal conditions (with 600 kg loading) average activity value was found to be 630 and drying time 28 minutes. Taguchi Method application caused 15 % rise in activity value.
Keywords: *Taguchi method, regression analysis, ortogonal array, fluidized bed dryers, baker's yeast*

1. INTRODUCTION

Drying processes are widely used in industrial applications and basis in drying of chemical, food and pharmaceutical products. Drying processes are based on removal of water from product by means of evaporation (Mujumdar, 1995; Strumillo and Kudra, 1986). Anotherdirection of drying process is its effect on product quality. In spite of a lot of research have been done in this area, there are also a lot of points waiting for solving. *Bremner and Poslethwaite (1998)* developed control algorithm using fuzzy logic. Another study about changing the particule size and shape was prepaired by *Kerkoff (1994)* and critical granule size concept was suggested. *Watano et al(1997)* handled same subject by using artificial neural networks. Yüzgeç et al. (2006) have developed a nonlinear predictive control technique to determine the optimal drying profile for a drying process. In order to minimize the difference between the model predictions and the desired trajectory throughout finite horizon, an objective function is described and the optimization problem is solved using a genetic algorithm.

2. TAGUCHI'S EXPERIMENTAL DESIGN METHOD

In order to develop a robust process design or production system, unanticipated events and system stability must be effectively controlled. By means of parameter design that is offered by Taguchi, product quality and system robustness can be improved and experimental cost is reduced *(Shang et. al., 2004)*. Parameter design is one of the important phase for the improved product quality and can be regarded as the robust design studies. The control factors can be divided as controllable and noncontrollable. In order to determine the effect of these factors, the most effective way is experimental designsuggested by Taguchi.

Experimental design methods were originally developed by *Fisher (1925)*. However, classical experimental design methods are too complex and are not easy to use. Furthermore, a large number of experiments has to be carried out as the number of process parameters increases. The Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with only a small number of experiments *(Tarng et. al,2000)*. Experimental design phase can be implemented easily by using orthogonal arrays.

2.1.Orthogonal arrays ın the taguchı method

An optimal experimental design should provide maximum amount of information by means of minimum experimental trials. Taguchi has developed orthogonal array triangular tables to reduce the experimental trials and to increase the accuracy. The L18 orthogonal array has six column corresponding to the factors and 18 rows for the possible combination of factor levels as shown in Table 2. Taguchi's experimental design offers 18 experiments instead of 36 (=729) trials needed for a six factor, three level factorial design. It is assumed that there is no interaction between our controllable factors.

3. PROCESS DESCRIPTION OF THE FLUIDIZED BED DRYING BAKER'S YEAST

Drying of microbiological products is not only heat and mass transport process, at the same time it is a technological process, which has effective role on the product quality. A well optimised drying process can improve to the product quality and preserve viability of microorganizms. Baker's yeast, *Saccharomyces cerevisiae*, is sensitive biological product to the heat. Fluidized bed driers are used for drying this matter. In industrial conditions, after the fermentation, baker's yeast contains approximately %35 moisture, and it is dried in fluidised bed drying batch process, by means of feeding unsaturated air after the rawmaterials are loaded to dryer. Schematic representation of an industrial type fluidised bed dryer is given in Fig.1. By feeding hot and unsaturated air to the dryer, the humidity contents of yeast is removed. In practice, the drying period is divided to in two phase, first phase (fast drying) and second phase (slow drying). When the dry matter of yeast reaches to a critical value, the drying process is stopped and yeast is taken away from dryer. The most important quality chracteristic of baker's yeast is activity (gasing power) and the aim of this study is to maximize baking activity. The activity value of baker's yeast is measured by offline laboratory analysis.

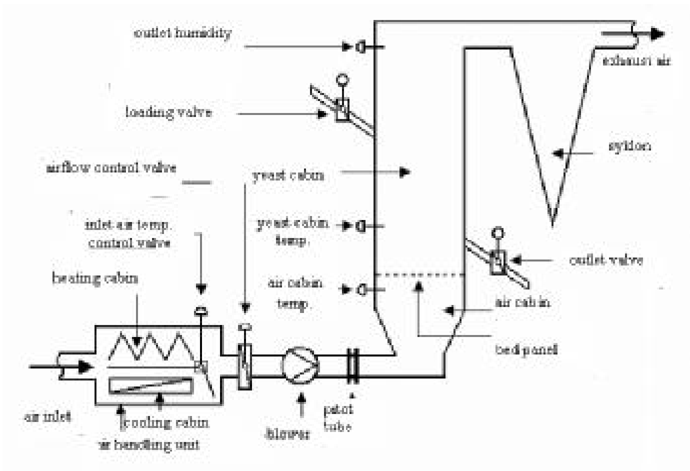

Figure 1. Structure of ANP

4. IMPLEMENTATION

By inspecting practical observations, the most important factors and their levels that have effect on the activity of yeast are given Table 1.

			Levels		
factor number	Symbol	Factors	Level 1	Level 2	Level 3
1	B	1^{st} phase inlet air flow rate	80	90	100
2	C	2^{nd} phase inlet air flow rate	60	70	80
3	D	1^{st} phase inlet air heat	69	77	85
4	E	2^{nd} phase inlet air heat	35	38	42
5	F	Loading quantity	400	500	600
6	G	dry matter of transition from 1^{st} phase to 2^{nd} phase	80	85	90

Table 1. The controllable factors and levels real process values are normalized because of commercial purposes.

4.1. Factors and levels

The number of controllable factors (M) is six and each factor has three level (K). On the other hand, there are uncontrollable factors like yeast strain, fermentation type and other additives. For the present work these uncontrollable factor are fixed (not considered).

4.2. Selectıng of orthogonal array

For fluidised bed drying process, $\boldsymbol{L}_{18}$ orthogonal array is chosen by considering the degree of freedom. Total degree of freedom (V_{TOT}) is equal to the sum of each factor's degree of freedom and this value is twelve. The array's degree of freedom (V_{LN}) is given by Eq. 1.

$V_{LN} = N – 1 = 18 – 1 = 17.$
(1)

$V_{TOT} = M*(K – 1) = 6 *(3-1) = 12.$
(2)

Because of V_{LN} is higher than V_{TOT}, L_{18} orthogonal array is suitable for this application. The developed orthogonal array is given in Table 2.

4.3 Sıgnal to noıse ratıo

Taguchi divides the factors into two categories; controllable factors and noise factors. Controllable factors are created by manufacturers and cannot be changed by customers directly. Noise factors can not be controlled by manufacturers directly and differentiate by customers environment and usage. Activity value, which is defined as quality characteristic, is established as the maximum is the best and calculated as the formula 1.

$$S/N_1 = -10\log \frac{1}{n_i}\sum_{k=1}^{n_i}\frac{1}{yi^2}$$
(3)

$$S/N_2 = k_1 \ \frac{1}{n_1}\sum_{k=1}^{n_i} y_{ijk}^2$$, for the smallest is the best,
(4)

$$S/N_3 = k_3\left(\frac{s_{ij}}{\overline{y}_{ij}}\right)^2$$, for the nominal is the best (5)

According to Taguchi experimental design, first column must contain 2 leveled controllable factor so in this application first column is left empty and because of there are six factor, eigth column of this orthogonal array is left empty.

4.4 Defınıng of effectıve factors and levels

All the experiments are held two times and their average are used in later calculations. The obtained results are compared with proof experiments

Factors									Activity Values				
	A	B	C	D	E	F	G	H					
trial number	1	2	3	4	5	6	7	8	Y1	Y2	average	s	s/n
1	*	80	60	69	35	400	80	*	640	660	650	14,142	56,255
2	*	80	70	77	38	500	85	*	620	650	635	21,213	56,048
3	*	80	80	85	42	600	90	*	650	670	660	14,142	56,388
4	*	90	60	69	38	500	90	*	630	670	650	28,284	56,246
5	*	90	70	77	42	600	80	*	630	660	645	21,213	56,184
6	*	90	80	85	35	400	85	*	640	640	640	0	56,124
7	*	100	60	77	35	600	85	*	660	670	665	7,0711	56,456
8	*	100	70	85	38	400	90	*	670	680	675	7,0711	56,585
9	*	100	80	69	42	500	80	*	590	620	605	21,213	55,627
10	*	80	60	85	42	500	85	*	660	640	650	14,142	56,255
11	*	80	70	69	35	600	90	*	660	670	665	7,0711	56,456
12	*	80	80	77	38	400	80	*	670	660	665	7,0711	56,456
13	*	90	60	77	42	400	90	*	670	670	670	0	56,521
14	*	90	70	85	35	500	80	*	630	680	655	35,355	56,306
15	*	90	80	69	38	600	85	*	660	630	645	21,213	56,184
16	*	100	60	85	38	600	80	*	660	630	645	21,213	56,184
17	*	100	70	69	42	400	85	*	650	620	635	21,213	56,048
18	*	100	80	77	35	500	90	*	660	640	650	14,142	56,255

Table 2. The orthogonal array for fluidized bed drying process. [real process values are normalized because of commercial purposes.]

Finally, the obtained results are run in two different methods to make the decision for best experimental setup.

These methods are

- § variance analysis (ANOVA)
- § alculation table.

Founded factor effect values and levels are given below in Table 3:

Factor	Level	Effect	Arrangement
B	1	8,33	G3
C	1	10,83	F1
D	2	13,33	D2
E	1	10,00	C1
F	1	15,00	E1
G	3	17,50	B1

Table 3. Factors, levels and effects

According to Table 3, the factor levels which cause maximum activity for baker's yeast are; for factor B (1st phase inlet air flow rate) first level, for C (2nd phase inlet air flow rate) first level, for D (1st phase inlet air heat) second level, for E (2nd phase inlet air heat) first level, for F (Loading quantity) first level, for G (dry matter of transition from 1st phase to 2nd phase) third level. Arrangement of factors from most effective to the least effective is like this: **G3 , F1 , D2 , C1 , E1 , B1 .**

4.5 Confırmatıon test

After these calculations, in % 90 confidence level confirmation test interval is calculated as 624,415≤ μ confirmation test ≤ 676,140. Under **B1 C1 D2 E1 F1 G3** conditions, four confirmation tests are done and 660, 630,670,670 results are found. All these values are placed between confidency interval. This means factors and levels which have been thougt have effect on yeast activity are selected truly.

5. REGRESSION ANALYSIS

Results of Categoric Regression Analysis which was applied for determining effects of factors that effective on identified quality chracteristic are shown in Table 4 and 5.

Multiple R	R Square	Adjusted R Square
,891	,794	,500

Table 4. Model Summary

Factors	Standardized Coefficients		df	F	Sig.
	Beta	Std. Error			
B	-,071	,171	1	,173	,690
C	-,365	.	1	.	.
D	,404	.	3	.	.
E	-,277	.	1	.	.
F	-,417	,171	1	5,902	,045
G	,492	,171	3	8,225	,011

Table 5. Coefficients

It can be seen that R square value is 0,79. That means the model can explain approximately % 80 of varience in quality chracteristic. And remained % 20 part was resulted from other factors which were not taken place in the model. Beta values of factors represent effects of factors on quality characteristic. Accordingly ordering from the most effective to the least like this: **GFDCEB**. And This result is fully compatible with the results of Taguchi Method. According to categoric regression results only G and F factors could pass from F test. And this shows the most effective factors are G and F, and other choosen factors are not adequate for explaining the variance in quality characetristic.

6. CONCLUSIONS

It was definitely taken care that any of the yeasts were not classified as scrap but packaged as final product. All the factors and their degrees were selected in these restrictions.By the factors under these limitations, it was tried to maximize the value of activity which is the basic quality characteristic.

The factor string which had been defined comparatively with analysis of variance and calculation table method was assumed to maximize the value of activity. The average value of activity reached by correction tests due to this factor string is in the confidence interval calculated. Then the results confirmed with categorical regression analysis. Same results were obtained from Taguchi Method and Categorical Regression Analysis.

When the working conditions in Taguchi Technique and the real situation are compared, it has been clearly seen that the value of activity is maximized by Taguchi Technique. But, on the other hand, it has been seen that there will be enormous drying capacity loss while maximizing the activity. While it had been discussed with the drying plant people, they explained that it was the expected result and could be used for all products which are higher than the lowest packaging limit (600 is the sub-limit for the packaging). It was also defined that to get the higher usage capacity for the drying plant, they chose different working conditions. So, to do this, it was accepted to loose a little bit activity unless being under the critical value.

As a result, the optimum factors and their degrees at the start stage of a drying plant were chosen from the experience and the studies of trials. But at that stage, if the trails and factor degrees were chosen due to the Taguchi Technique, it was thought to define the optimum factor string in shorter time and to get the production with less scrap.

Briefly, by using the factors and levels which are taken from Taguchi technique application (with 400 kg loading) average activity value is found 660 and average drying time is found 26 minutes. However in normal conditions (with 600 kg loading) average activity value was found 630 and drying time was found 28 minutes. As a result Taguchi Technique application caused 15 % raise in activity value.

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