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Process Improvement and an Application with Taguchi Method in Food Industry

Taguchi Yöntemiyle Süreç İyileştirme ve Gıda Sektöründe Bir Uygulama

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Abstract: Taguchi method was used to optimize the the dragee coating process and to minimize the processing time in a nut factory . Within the framework of the application, the factors affecting the dragee coating process time were determined, the experiments were carried out and analyzed twice , using the Taguchi method according to the L9 experiment plan. In accordance with the data obtained, optimum parameter values for the dragee coating process were chosen as 50Rh air humidity, 18 °C air temperature, 38 °C syrup temperature and 600 ml amount of syrup. In order to determine the percentage effects of the factors on the processing time, variance analysis was performed and it was seen that the most effective factor on the processing time with a value of 77.56% was the humidity of the air. As a result of the study, 40% improvement was achieved in the processing time by using the optimum process parameter values obtained by the Taguchi method. Thus, resources will be used more effectively and this will reflect to the business in the long term in terms of time and money.

Keywords: Taguchi Method, Experimental Design, Food Industry

JEL Classification: C10, C16, C61

Öz: Bu makalede bir kuruyemiş fabrikası için draje kaplama sürecinde işlem süresinin en küçüklenmesi için Taguchi yöntemi kullanılmıştır. Öncelikle draje kaplama işlem süresine etki eden faktörler belirlenmiş, daha sonra ise Taguchi metodu ile L9 deney planına göre deneyler 2 kez tekrarlı olarak gerçekleştirilmiş ve analiz edilmiştir. Elde edilen veriler doğrultusunda draje kaplama süreci için optimum parametre değerleri havanın nemi 50Rh, havanın sıcaklığı 18 °C, şurubun sıcaklığı 38 °C ve şurubun miktarı 600Ml olarak seçilmiştir. Faktörlerin işlem süresi üzerindeki yüzdesel etkilerinin belirlenmesi için varyans analizi yapılmış ve %77,56 değeri ile işlem süresi üzerindeki en etkili faktörün havanın nemi olduğu görülmüştür. Çalışma sonucunda Taguchi metodu ile elde edilen optimum proses parametre değerleri kullanılarak işlem süresinde %40 iyileşme sağlanmıştır. Böylece kaynaklar daha etkin kullanılacak olup, bu da zaman ve para olarak işletmeye uzun dönemde yansıyacaktır.

Anahtar Sözcükler: Taguchi Metodu, Deney Tasarımı, Gıda Sektörü

JEL Sınıflandırması: C10, C16, C61

1. Introduction

Food sector is an essential sector in terms of human food supply chain. Meeting the quality standards is inevitable since both health and customer satisfaction is a core parameter in this industry. Furthermore, today's technology and the rapid increase in the world population

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trigger the need for food, forcing businesses to produce production capacity at world standards, making this sector a locomotive sector in the economy of countries (Akın 2012,45).

In the simplest definition of food terminology, dried fruits are called nuts. Most of the dried nuts are fruits or vegetables obtained by heat treatment or drying (Garipoğlu 2006, 24). The nuts sector is included in the fruit and vegetable processing sector, which is a sub-sector of the food industry (Yılmaz 2018, 36).

According to the report titled “Analysis of the Current Situation in the Dried Nuts Industry” prepared by All Nuts Industrialists and Businessmen Association (Tüksiad) in 2014; Due to its climate and geographical location, Turkey produces chickpeas, seeds, hazelnuts, grapes, apricots, etc., which are the raw materials of the nut industry. Although it is a lucky country for the production of agricultural products such as nuts, it ranks first in exports in the world in terms of nuts. The consumption of the mentioned products in the country is also quite high. Therefore, the dried nuts sector has an important place in Turkish trade. Considering the quantity, quality and price, as a result of the development of the dried nuts sector with a sustainable and planned production, many sectors, especially the food industry, will be beneficial (TÜKSİAD 2021).

Although the food sector is of such importance in terms of economy, many businesses still produce with traditional methods today, and when improvement and efficiency studies are carried out on the processes, positive changes can occur. Experimental design is a statistical analysis method that increases the efficiency and quality of production by determining the most appropriate levels of production parameters and is used by many businesses. The Taguchi method, on the other hand, is an effective experimental design method that can achieve this with the least number of experiments at the lowest cost.

In this study, Taguchi method was used to optimize the operating parameters of the dragee coating process and to minimize the processing time in a nut factory . Initially, we reviewed the the papers implementing the Taguchi method in the literature.Then, the experimental design methodology, especially Taguchi method is explained in general terms. As a case study, a dried nuts company data is provided and the problem is modeled with the Taguchi method. In the fourth section, the experiments are carried out, and the data obtained from the experiments are analyzed. Finally, the results are explained in the light of the data obtained from the study and suggestions are given for businesses and researchers who are interested in the subject.

2. Literature Review

Taguchi method is an experimental design method that tries to eliminate or minimize the variability of parameters that make changes in products or processes (Mercan 2019, 32). Experimental design methods allow to obtain effective results in less time and less cost in the industry.

Studies on experimental design can be examined in two main parts as product development and process improvement. Looking at the literature, Kayı's (Kayi 2006, 39) study, which explains the effect of injection plastic coated parts on shrinkage with process parameters, Binal's (Binal 2007, 42) model of floor tile, which is one of the ceramic production, in which process parameters affecting its properties are formed by experimental design, The study of Makadia (Makadia 2013, 1524) in which the optimization of the process parameters in the turning process with the surface response method, Peşsen (Peşsen 2018, 49), the traffic accident data that occurred in Çorum and the data obtained from the geographic information system were modeled as an experimental design in Minitab , one of the package programs, Akaslan's (Akaslan 2019, 61) using the experimental design method to produce the desired quality cement, optimization study for many factors affecting the quality of cement can be given as an example of process improvement.

In addition to the above studies, studies in the food sector are classified in Table 1 in terms of subject and method.

Table 1. Literature Review

Author	*Subject*	*Method*
Tasirin et al . (2007)	Drying Parameters of Eyelet Pepper in a Fluid Bed Dryer with Taguchi Method	Taguchi Method
Hasgul (2011)	Developing the Weight Feature of the "Urfa Kebab" Product by Experimental Design	Factorial Design
Kumar et al .(2014)	Taro (Colocasia Optimization of Esculenta) as a Potential Alternative to Wheat Flour in Cake with Taguchi Method	Taguchi Method
Baynal and Gencel(2015)	Taguchi Good Optimization of Seven Quality Characteristics That Determine the Quality of Alcoholic Beverages	Taguchi Method
Dooyum et al .(2016)	Japonica with the Taguchi Method to Determine Optimum Boiling Conditions for Grinding	Taguchi Method
Morakinyo and Bamgboye (2016)	Optimum Operating Parameters of a Newly Developed Sterilizer of Oil Palm Processing Plant by Taguchi Method	Taguchi Method
Cevik et al . (2017)	Optimization of Extraction Yield and Quality Parameters of Olive Oil by Response Surface Method	Response Surface Method

Kırmacı et al .(2017)	Optimization of Freeze Drying Process with Taguchi Method	Taguchi Method
Kuvat (2018)	Multi-Response Optimization with Taguchi Parameter Design in a Package Food Manufacturing Plant	Multiple Response Optimization - Taguchi Method
Saydam et al .(2018)	-Behnken Experimental Design for Maximum Reducing Water Content by Ultrasound Assisted Osmotic Dehydration (US-OD) of Apple Cubes	- Behnken Design
Kilic et al .(2018)	Response Surface Method Approach to Determine Factors Affecting the Amount of Phytic Acid in Cornbread	Factorial Experiment Design
Chakraborty and Shrivastava (2018)	Optimizing Baking Conditions for Chickpea Flour-Based Wheat Bread	Response Surface Method
Hayit and Rose (2018)	Optimization of Gluten-Free Biscuit Flour Formulation Using Response Surface Method	Response Surface Method
Yildiz and Gokayaz (2019)	Optimization of Drying Conditions of Apple Slices Dried in Solar Dryer with RSM	Response Surface Method
Turkan and Etemoglu (2019)	Optimization of Parameters Affecting Food Drying Using Taguchi Method	Taguchi Method
Singh and Kumar(2019)	Selection of Storage-Specific Packaging Material for Gluten-Free Biscuits by Taguchi Method	Taguchi Method
Mayasti et al .(2019)	Optimization of Gluten-Free Spaghetti Production Process with Taguchi Method	Taguchi Method
Durmaz and Özel(2019)	Taguchi Method	Taguchi Method
Sadr et al .(2019)	Determination of Fertilizer Spray at Optimal Levels with the Taguchi Method	Taguchi Method
Chung et al .(2020)	Taguchi and Gray Relational Analysis Approach to Investigate Processing Parameters in Quality of Sourdough Bread	Taguchi And Gray Relational Analysis
Türker and Doğan, 2021	Effects of ultrasound homogenization on the structural and sensorial attributes of ice cream: optimization with Taguchi and data envelopment analysis	Taguchi and Data Envelopment Analysis

In the recent studies, Dooyum et al . (Dooyum 2016, 766) adopted Taguchi L9 (34) orthogonal array optimization method to determine the optimum boiling conditions for milling of Japonica , a widely grown rice variety in Korea . Afolabi and Bamgboye (Afolabi 2016, 43) investigated the optimum operating parameters of a newly developed sterilizer of a medium-sized oil palm processing plant in terms of maximum oil yield. Çevik et al . (Çevik 2017, 341), in their study, aimed to optimize the kneading process in production with the response surface method, which is one of the experimental design methods in terms of oil yield and quality parameters. Kuvat (Kuvat 2018, 221) used the experimental design method with Taguchi in his studies to improve the quality of chicken Adana Kebabs in a food business. Saydam et al . (Saydam 2019, 329) conducted experiments within the framework of the experimental design designed by Box- Behnken to reduce the water content at the maximum level with ultrasound-assisted osmotic dehydration (US-OD) of apple cubes . Chakraborty and Shrivastava (Chakraborty 2019, 47) optimized the baking conditions (relative humidity, baking time and temperature) for fermented chickpea flour-based wheat bread by considering multiple responses: (crumb firmness, specific loaf volume, crust and crumb color change). Hayıt and Gül (Hayıt 2019, 188) tried to create a recipe for the production of gluten-free biscuit flour by using corn and rice as flour and corn and potato starch as starches . Singh and Kumar (Singh 2019, 68) evaluated optimal processing parameters for storage-specific packaging material selection for gluten-free biscuits. Yıldız and Gökayaz (Yıldız 2019, 104) dried apples in multi-rack solar dryers and optimized the parameters of the drying process together with the response surface method. Türkan and Etemoğlu (Türkan 2020, 660) demonstrated the application of optimization of parameters affecting the drying of cucumbers in a convective dryer with the Taguchi method in experimental design methods . The levels of the parameters affecting the drying process were determined as 0.5-0.8 and 1 m/ s for the air velocity, 40-50 and 60°C for the drying temperature and 0.5-1 and 1.5 cm for the cucumber slice thickness.

Chung et al . (Chung 2020, 24) have shown in their study that a combination of Taguchi and gray associative analysis, namely the Taguchi -GRA approach, can be used to investigate the processing parameters in the quality of sourdough bread and to determine the optimal settings for producing new bakery products with multiple characteristics.

As an example of the studies made for dragee coating, Eyyuboglu et al (Eyyüboğlu 2019, 125), examined the process conditions of confectionery products with the response surface method.

A hybrid method of Data Envelopment Analysis and Taguchi is combined and used to optimize the sensorial attributes of ice cream (Turker and Dogan 2021, 4889). They initially investigated the preferences of consumers by DEA and then optimized these parameters by using Taguchi method.

As we reviewed the literature, as far as our knowledge, this will be the first study that optimizes the process by using Taguchi in dragee coating systems.

3. Method

3.1. Experiment Design

The main purpose of experimental design studies is to create a mathematical model about the effects of the inputs on the outputs in the examined process and to conduct as few experiments as possible while creating this model (Özden 2020, 70). It is divided into two groups as classical experimental design and statistical experimental design (Taphasanoğlu 2020, 26).

In classical experimental design applications made with traditional methodology, only the effect of controllable factors on the output is investigated and the effect of uncontrollable factors is ignored (Ercan 2019, 19). The basic principle here is to obtain results by examining the effect on the output by changing one of the parameters and keeping the others constant.

Today's competitive environment where R& D studies are extremely important, businesses that want to achieve the highest quality with the lowest cost have turned to statistical experimental design methods instead of classical experimental design (Taphasanoğlu 2020, 28). Contrary to classical experimental design, it is possible to achieve more effective results with less cost and number of experiments with statistical experimental design methods. The most commonly used statistical experimental design methods; Response Surface Method, Taguchi Method and Factorial Design Method.

In Response Surface Method the effects of the variables on the result can be learned individually and interactively. Factorial Design Method which is one of the most common methods used to examine the effect of two or more parameters on the output. With this method, experiments are made for the combinations of all parameters that have an effect on the output according to the model and their effects on the output are investigated. (Demir 2004, 38).

Taguchi method, which gives the optimum factor combination for systems consisting of more than one factor and factor level, can keep the number of experiments to be done at a minimum level thanks to the orthogonal arrays it uses (Mercan 2019, 29). This method, which we used in our study, is explained in more detail in 3.2.

3.2. Taguchi Method

According to the Taguchi philosophy, the main goal is to ensure quality, starting from the design of all phases related to the product. In this way, rework, process development, etc. that may occur in the product and process will be avoided. This method is an experimental design method that gives better results with a small number of experiments by calculating the loss function.

This function determines the poor quality of the product and the severity of consumer dissatisfaction (Çelik 1993, 56). Taguchi's loss function is shown in the graph in Figure 1.

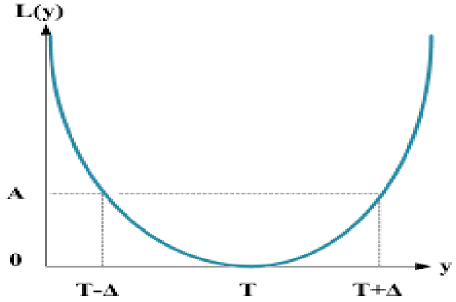

Figure 1. Taguchi Loss Function

Taguchi the loss function should be a continuous function as in equation (1) (Şanyilmaz 2006, 46)

$$L(Y) = k(Y - \mathrm{T})^2 \qquad (1)$$

L(Y) is the monetary value of the losses given to any consumer by a product with a performance characteristic Y and it is called the loss function of Y (Şanyilmaz 2006, 46). Y is the value of the performance characteristic and m is the target value. Here, k indicates the unit cost of the measures to be taken by the manufacturer in order to bring a unit product deviating from the target back to its target value (Şanyilmaz 2006, 54).

By changing a factor in the experimental design, the change in product quality is tried to be observed. If this factor has created the desired effect here, it is called signal. In addition, there are external factors that affect the test result in the experimental design . The effect of these external factors on product quality is defined as noise (Topçu 2018, 34). The ratio of signal to noise, referred to as S/N, is one of the statistical terms used together with the standard deviation and mean value to determine the effect of the Taguchi method on the output of changeable or controllable parameters and uncontrollable parameters (Kandemir 2018, 29).

If a high Signal/Noise is found in the experimental design results, it can be concluded with this study that the deviation is low and the parameters are significant. While evaluating the results, 3 different S/N ratios can be used according to the desired result for the study. The high result value for all types of S/N ratio reveals that the test result is significant.

1) Smallest-Best:

As a performance indicator, it is the case where the “Target value is the smallest” (noise, harmful substances, contamination, machine overheating, etc.). In such problems, the target value of the performance characteristic y is zero. In the smallest best case, the Signal/Noise ratio can be defined as given in equation (2) (Şanyilmaz 2006, 57).

$$\frac{S}{N} = -10\log(\frac{1}{10}\sum_{i=1}^{n} y_i^2) \tag{2}$$

2) Highest- Best:

“The target value is the largest”; (strength, strength, etc.). In this case, the target value of y is infinite and the Signal/Noise ratio is defined as in equation (3) (Şanyilmaz 2006, 58).

$$\frac{S}{N} = -10\log(\frac{1}{n}\sum_{i=1}^{n} \frac{1}{y_i^2}) \tag{3}$$

3) Nominal Value-Best:

“Target Value Best” (product dimensions, electrical voltage, etc.). In such problems, a certain target value is given for y (Şanyilmaz 2006, 60).

Equation (4) shows the mean value of μ and the expression σ shows the standard deviation.

$$\frac{\mathrm{S}}{\mathrm{N}} = 10\log(\frac{\mu^2}{\sigma^2}) \tag{4}$$

4. Application

4.1. General Information About the Business

The company, which is the subject of the study, was established in the Serinhisar district of Denizli in 1979 and is one of the leading dried nut factories in the city. In 2000, the company boosted its capacity by moving to new plant in order to meet the increased demand of roasted chickpeas and to produce other types of nuts fresh and bring them to the end consumer. Later, company started its retail service in 2004 and today it serves with one factory and four retail stores.

Most of the products produced in the enterprise are based on roasted chickpeas. Chickpeas are a type of nut obtained by soaking and heating chickpeas. By looking at the production in the process, the type of process and other spices, sauces, chocolate, cocolin , sugar, poppy, etc. used in the production. It can be sold at different prices depending on the size of the chickpeas and the sales quantities. In addition to roasted chickpeas, they use hazelnuts, peanuts, almonds, sunflower seeds, pumpkin seeds, corn, orange peel, etc. Various nuts are produced by going through different production processes.

4.2. Dragee Coating Processes in the company

For any type of nut such as almond , hazelnut , pistachio, orange peel, raisins, roasted chickpeas, coffee beans, etc., production is carried out on the coating of dried nuts such as chocolate or cocolin . Then they are polished if needed according to the product type, or coloring and flavoring with sugar syrup .

Hard candy coating, that is, dragee coating, is carried out on the dried nuts selected as raw material or on the products previously coated with cocolin or chocolate. Dragging process, in a more understandable expression, is the process of coating the filling material with colored and hot syrup, 75% of which is sugar. With the dragee process, the product is covered with a colored layer of sugar; different flavors are obtained by combining various raw materials, flavors and dyestuffs. During the process, the aim is to remove the water in the syrup and cover the outside of the product with a colored sugar layer.

The basis of dragee production is the coating of the product with colored syrup in a constantly rotating pan. Dragee coating process is done in the coating pan. Coating pans are made of copper or stainless steel (Çelik 1998). Dragee coating pans are placed at an angle to the section in the horizontal plane . Depending on the product to be processed, the rotation speed of the dragee pan varies between 15-45 rpm.

In the dragee coating process, the raw material or semi-finished product selected as the raw material to be coated is taken into the coating pan. The cold air air handling unit is adjusted for the coating process. The coating pan starts to be rotated. The colored syrup prepared for the dragee process is sprayed or poured into the rotating coating pan, as in chocolate coating. The syrup, which is the liquid coating material, is homogeneously dispersed by the rotation or rolling motion. In the process, the process is continued until the desired coating thickness is reached. Unlike chocolate coating, the water in the syrup is tried to be removed during the dragee process.

After the water is removed, the product is covered with the remaining sugar layer. For this reason , the humidity of the air supplied into the coating pan is the most important factor in terms of the efficiency of the coating process . The faster the moisture transfer takes place, the sooner the process is completed. Since coating syrup is given with the coffee pot many times during the coating process, each coffee pot syrup must dry very well. Otherwise, cracks occur in the later coated products. Or, in the “polishing” stage after the dragee process, the product cannot be polished or it loses its shine and fades after it is done.

The process in which the cycle time is the longest in the company where the application is made is the "dragee coating" process. For this reason, the unit costs of the products coming out of this section increase and the deadlines given to the customers cannot be met. Bids given above the sales price and order deadline of the competitors cause the company not to receive orders and the process to be empty in some periods. In addition, as a result of the wrong planning of the working parameters of the process due to the adoption of traditional methods, unplanned downtimes and malfunctions occur in the process. A large number of failure costs and the cost of products that cannot be produced due to the failure of the department are incurred.

4.3. Taguchi Method Application

4.3.1. Identifying the Problem

The process parameters of the enterprise were examined for problem determination, which is the first step of the Taguchi Method , which is one of the experimental design methods . The demand for dragee coated products has a large share in the enterprise market. For this reason, quality problems caused by the lack of dragee coating process, rework costs are of great importance.

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There are 24 dragee coating boilers in the production section, which is handled to improve the process. There are air ducts inside each boiler. During the coating, air is given to the product through these channels. In this way, it is ensured that the colored sugar layer is homogeneously coated on the product by evaporating the water from the colored syrup given on the coated product. In this section, approximately 120 kg of product is filled into each coating pan for dragée . For the product in each coating pan, 60 kg of colored syrup is added throughout the process. Since approximately 75% of 60 kg syrup is sugar, the temperature of the syrup does not fall below 35 degrees. Dragee coating unit is shown in Figure 2.

Figure 2. Dragee Coating Unit

Since the most important basis affecting the cycle time in dragee coating is the evaporation of the water in the syrup, the absence of moisture in the environment will accelerate the process. Therefore, the humidity and temperature of the air supplied to the coating vessel during the process, the temperature of the syrup, the feeding amount of the syrup and the temperature of the coating room are the parameters that affect the cycle time. With the optimization of the parameters, the process will be accelerated when the humidity in the environment is reduced.

In the light of the information obtained from the experience in the enterprise until this time, the values were adjusted randomly with traditional methods and dragee coating was performed depending on the initiative of the operator. The humidity and temperature values of the air supplied to the department and coming from the department to the cooling plant can be adjusted and monitored from the computer environment as shown in Figure 3.

Figure 3. Dragee Process Parameter Control Screen

The aim here will be to minimize the cycle time of the process by finding the optimum values of the parameters affecting the dragee coating process with the experimental design model to be proposed.

4.3.2. Determination of Factors and Levels

The parameters affecting the cycle time of the dragee coating process examined in the study were evaluated with the other staff working in this department, and the factors to be taken as variables during the experiments and the factors to be fixed were decided by using the fishbone diagram in Figure 4.

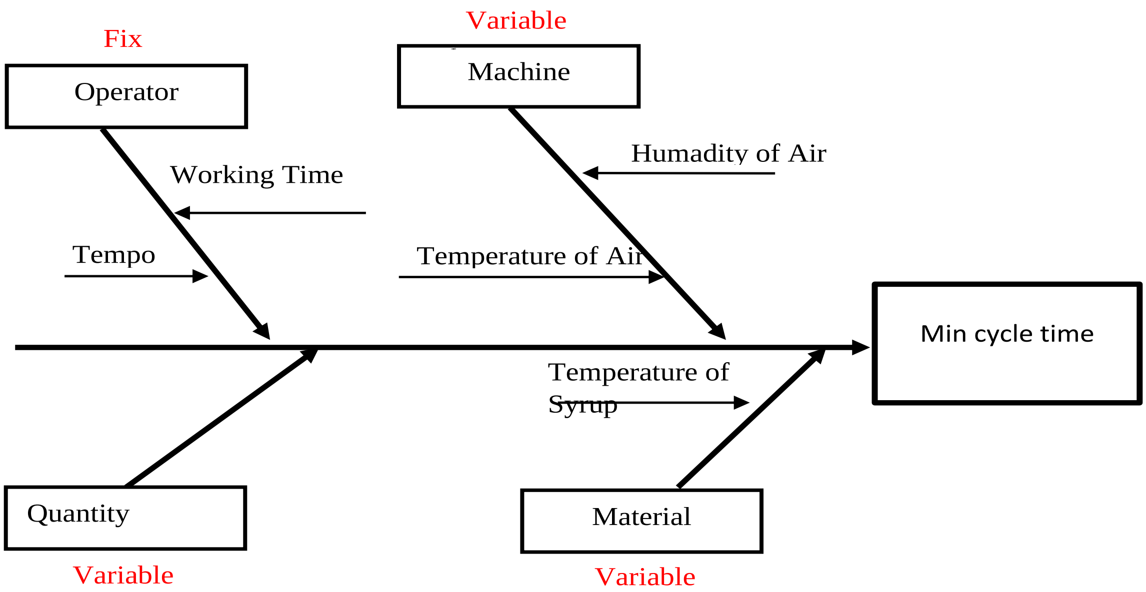

Figure 4. The Fishbone Diagram For Process.

In the analysis, the operator was accepted as a constant variable; The humidity and temperature of the air supplied to the boilers from the machine connected to the machine, the temperature of the syrup depending on the material and the feeding amount of the syrup were determined as variables.

For the parameters selected as different factors was determined in three stages as the highest, the lowest and the middle value, based on previous experiences.

Table 2 shows the factors and levels of the experiments.

Table 2. Experimental Factors and Levels

Factors	*Level 1*	*Level 2*	*Level 3*
Humidity of the Air (Rh)	40	50	60
Air Temperature(°C)	16	18	20

Syrup Temperature(°C)	36	38	40
Syrup Feeding Amount (ml)	600	800	1000

4.3.3. Orthogonal Arrays and Their Selections

Orthogonal arrays selected in accordance with the type of problem are determined by the sum of the degrees of freedom of the parameters. In this case, the total degrees of freedom is eight, as in Table 3.

Table 3. Total Degrees of Freedom

Factor	*Symbol*	*degrees of freedom*
Humidity of the Air (Rh)	A	3-1=2
Air Temperature(°C)	B	3-1=2
Syrup Temperature(°C)	C	3-1=2
Syrup Feeding Amount (ml)	D	3-1=2
Total Degrees of Freedom		2+2+2+2=8

The humidity of the air, the temperature of the air, the syrup temperature and the syrup supply amount each consist of three levels and each has two degrees of freedom. The total degrees of freedom in this case is eight.

The total degree of freedom will be one less than the number of attempts of the maximum orthogonal sequence to be selected. In this case, the smallest orthogonal index L9(3^4) will be selected.

4.3.4. Assigning Factors to Columns

The L9 experiment plan, which has nine experiments, is one of the designs suitable for the degree of freedom of the problem.

Table 4 shows the Taguchi L9 experiment plan for the parameters.

Table 4. L9 Taguchi Orthogonal Array Combination

Experiment	of the air humidity	of the air temperature	of syrup temperature	of syrup Feed amount
One	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2

8	3	2	1	3
9	3	3	2	1

After assigning the factors shown in Table 5 to the columns and creating a new table with the actual levels of the factors, the experiments were started after the experimental conditions were created. Nine experimental conditions to be applied in accordance with the determined experimental plan were repeated twice, taking into account Taguchi's repetition principle. Thus, the analysis was made according to the results of 18 observations.

Table 5. Dragee Process L9 Orthogonal Array Test Conditions

Experiment	of the air humidity	of the air temperature	of syrup temperature	of syrup Feed amount
One	40	16	36	600
2	40	18	38	800
3	40	20	40	1000
4	50	16	38	1000
5	50	18	40	600
6	50	20	36	800
7	60	16	40	800
8	60	18	36	1000
9	60	20	38	600

4.3.5. Performing Experiments and Collecting Data

L9 Taguchi orthogonal array was used for four factors and three levels of each factor in the experiment. Observation results were noted by the chronometer method. The measurements made in the results of the experiment are as important as the experiment. Because an incorrectly measured experiment can cause all the effort to go to waste and make the work meaningless. Cycle times measured according to the experimental plan are presented in Table 6.

Table 6. Experiments and Results According to L9 Orthogonal Sequence

Experiment	Observation Results-1	Observation Results-2
1	713	728
2	718	684
3	783	800
4	663	682
5	615	633
6	706	700

7	804	815
8	815	800
9	790	835

4.3.6. Analysis of Data

In the study, the data obtained as a result of the experiment were modeled using the Taguchi method in the Minitab 19 package program, and the control factors that gave the optimum cycle time were determined based on the signal/noise (S/N) ratio and the average effect values.

Depending on the problem, the data were modeled in the Minitab 19 package program. First of all, as seen in Figure 5 on the main screen of the Minitab 19 program , the experimental model was started to be created with the Stat-DOE-Taguchi-Create Taguchi Design buttons, respectively.The step by step illustration of the entering data in Minitab spreadsheet program is given below in Figures 6,7,8 respectively.

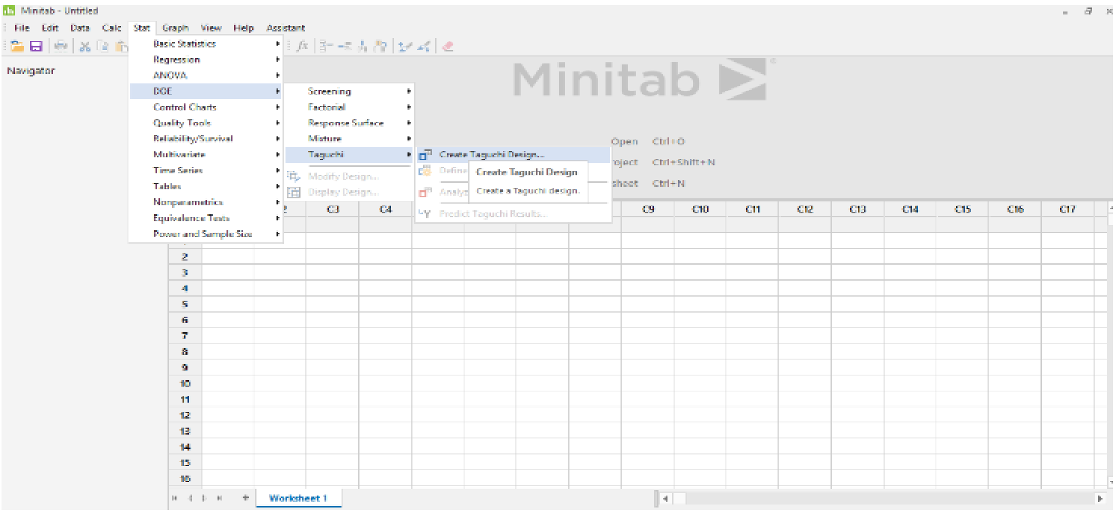

Figure 5. Experiment Modeling in Minitab

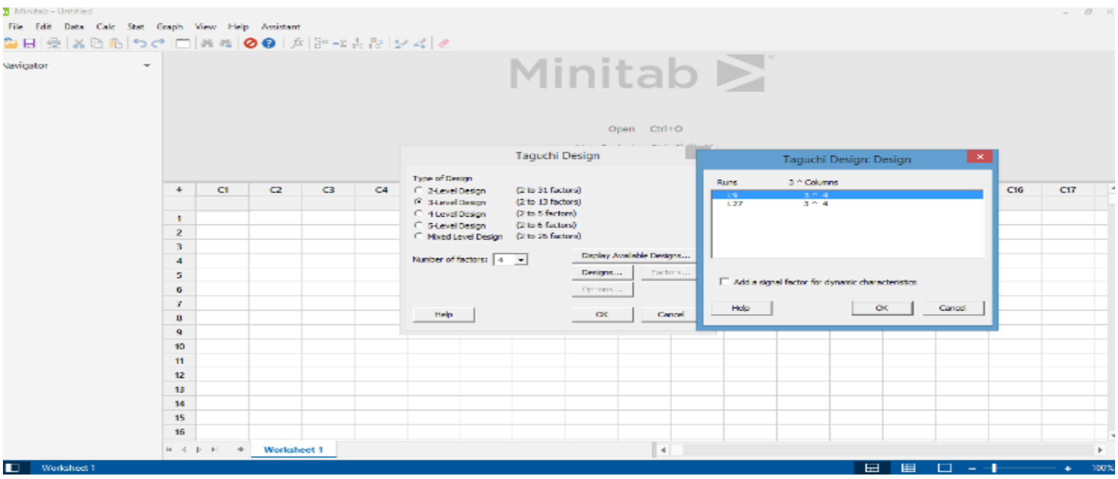

Figure 6. Selection of Experimental Factor Level and Orthogonal Sequence

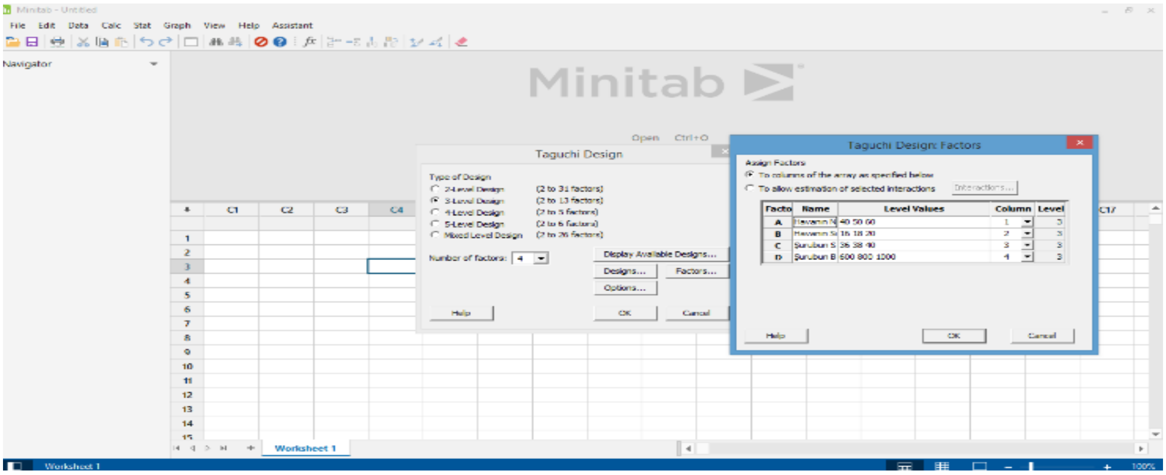

Figure 7. Entering Factors Names and Levels

While determining the optimum levels of the factors, since the problem is to reduce the cycle time of the process in order to increase the efficiency of the process, the aim is to get the minimum value of the performance characteristic. For this reason , the “ Smaller is better ” option is selected from the “ options ” section, as seen in Figure 8 and the experiment is run to obtain the signal noise ratio which is illustrated in Figure 9 and 10 respectively.

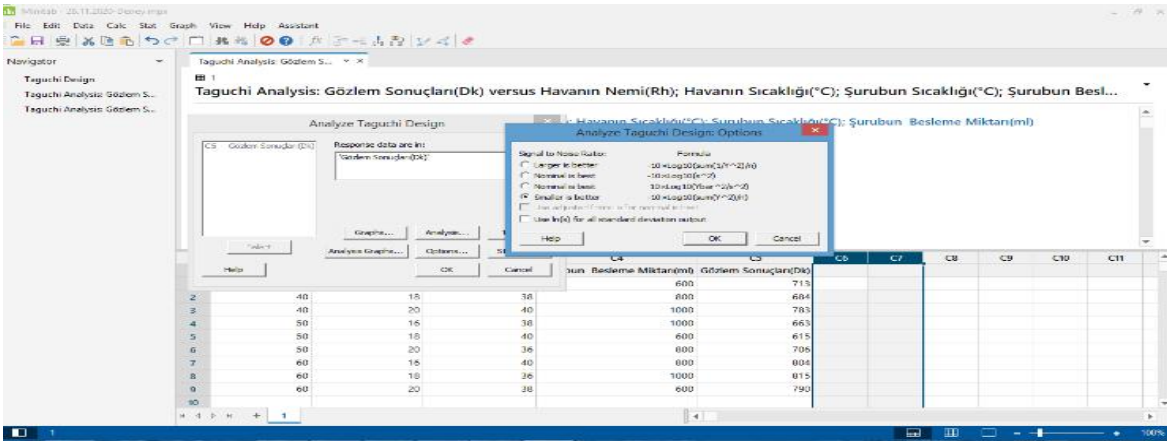

Figure 8. Selecting “ Smaller Is Better ” Module in Minitab Is Selected

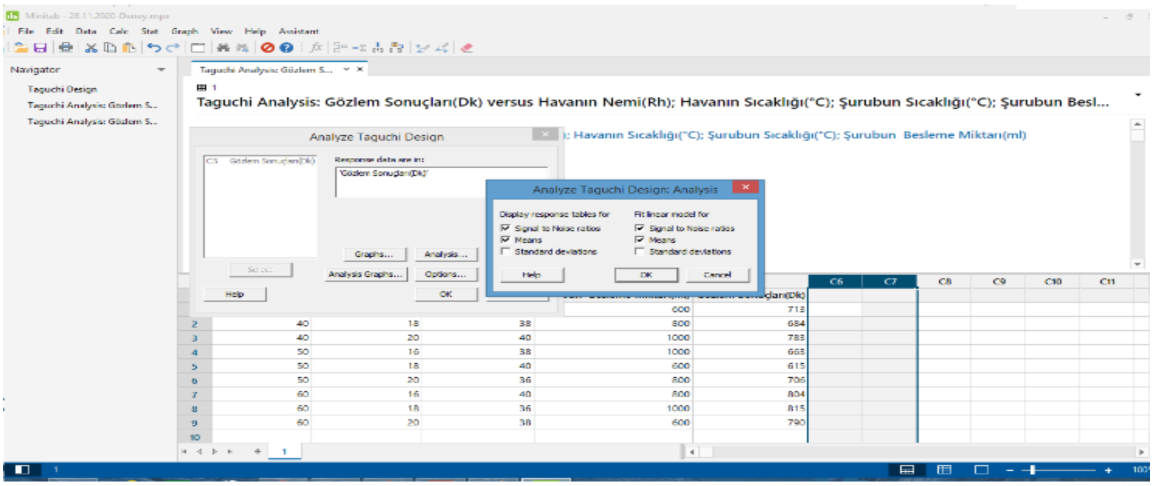

Figure 9. Signal ” From The Analysis Section to Noise Ratio And Means ” Selection

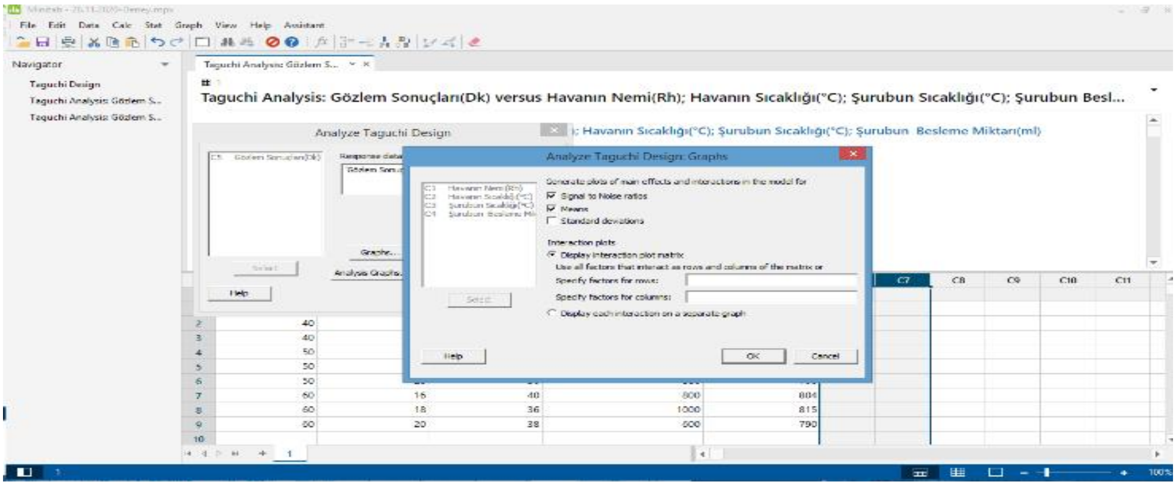

Figure 10. Signal ” From Graphs Section To Noise Ratio And Means ” Selection

The results of experiment is summurized in Table 7 below:

Table 7. S/N Values Of Experiments

Experiment	S/N ratio (dB)
1	-57,1532
2	-56,9169
3	-57,9695
4	-56.5547
5	-55,9046
6	-56.9392
7	-58,1645
8	-58,1432
9	-58,1998

Taguchi analysis for the cycle time are given in Figure 11 and Figure 12. In Figure 11, the S/N (Signal / Noise) ratios of the factors on the cycle time, and in Figure 12, the average effects (main effects) of the factors on the cycle time are given.

Mean effects graph in figure 12 are also summarized in tabular form. Table 8 shows the change in the S/N ratio, and Table 9 shows the values showing the change in the mean according to the factors.

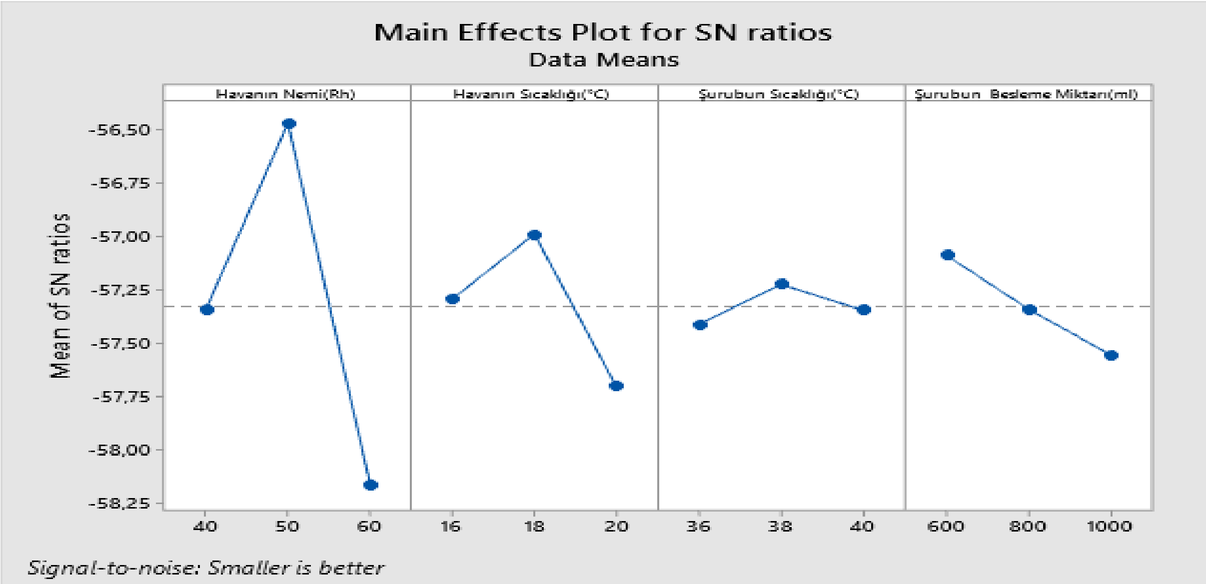

Figure 11. Taguchi Method Noise/Intensity Values

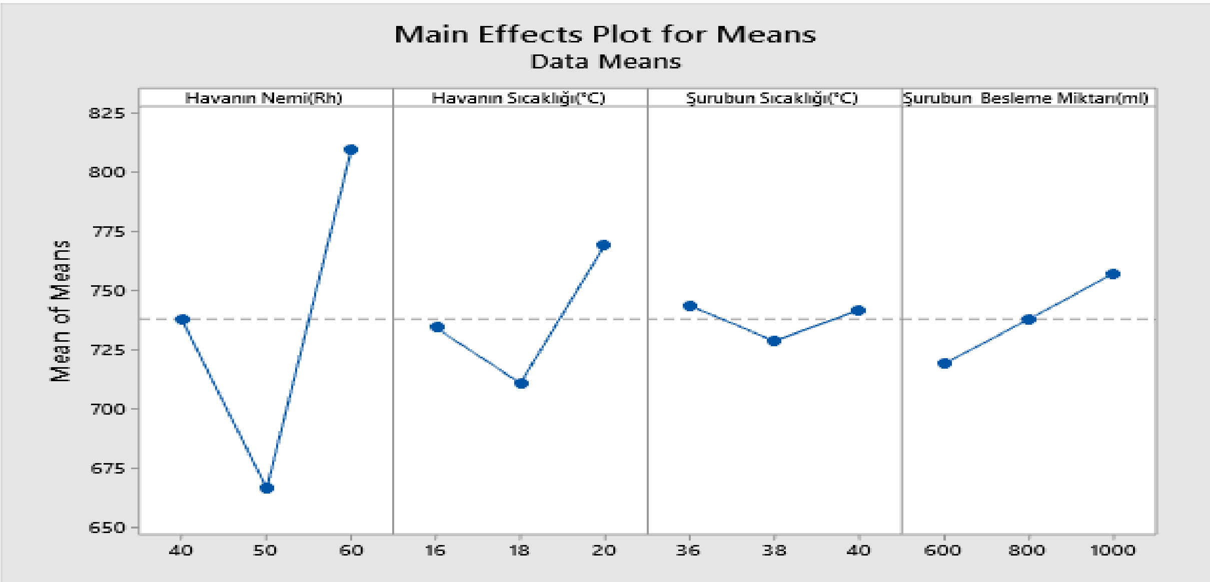

Figure 12. Taguchi Method Mean Effect Values

Table 8. S/N Ratios for Factors (Least Best)

Level	Air Humidity (Rh)	Air Temperature (°C)	Temperature of Syrup (°C)	Feeding Amount of Syrup (ml)
One	-57.35	-57.29	-57.41	-57.09
2	-56.47	-56.99	-57.22	-57.34
3	-58.17	-57.70	-57.35	-57.56
Delta	1.70	0.71	0.19	0.47
Rank	1	2	4	3

Table 9. Averages for Factors

Level	Air Humidity (Rh)	Air Temperature (°C)	Temperature of Syrup (°C)	Feeding Amount of Syrup(ml)
One	737.7	734.2	743.7	719.0
2	666.5	710.8	728.7	737.8
3	809.8	769.0	741.7	757.2
Delta	143.3	58.2	15.0	38.2
Rank	1	2	4	3

Figure 12 shows the effect of the dragee coating process parameters on the cycle time. The value with the highest S/N ratio calculated for each factor shows the best test result, that is, the test result with the smallest cycle time. From the slopes of the process parameters, it can be analyzed which parameter is effective on the cycle time. If we look at the maximum and minimum value differences of the S/N ratios for each factor, namely the delta values, from Table 8, it can be seen that the most important variable that has an effect on the cycle time is the “humidity of the air” parameter with a rank value of 1 and a delta of 1.7. It has been determined that the "Humidity of the Air" parameter has a significant effect on the performance characteristic in this case. It is seen that the order of importance according to their effects on the performance characteristic is "Temperature of Air", "Feeding Amount of Syrup" and "Temperature of Syrup" with the lowest delta.

Signal / Noise) ratios on the cycle time of the factors in Figure 12, under conditions where the S/N value is maximum for the parameters, that is, Air Humidity=50Rh, Air Temperature=38° C, Temperature of Syrup = Minimum cycle time will be achieved with the combination of 38°C and Syrup Feed Amount=600ml.

Regardless of the "maximum best" or "minimum best" problem types in Taguchi designs, the maximum point is always taken to determine the factor levels in order to optimize the problem in the noise/intensity graph. Another solution for determining factor levels is to look at the average effect graph. If the problem is in the form of "minimum best", the minimum value is taken on the average effect graph.

In Figure 13, in the graph of average cycle times for the factors, the highest change is seen in the parameter “Air humidity”. This is followed by the "Temperature of the Air" factor, the "Feeding Amount of the Syrup" and the "Temperature of the Syrup" factor. In addition, when the rank and delta values given in Table 9 are examined, it supports the above order by giving results in parallel with the change in the cycle time averages graph for the factors in Figure 13.

As in Table 8, the values given in Table 9 also reveal the effect of change on the cycle time of each level (Level) of the factors (Air Moisture, Air Temperature, Syrup Temperature and Syrup Feed Amount) on the observation values. In Table 8 and Table 9, the biggest change, namely the delta value, occurred with the 2nd (level 2) level of the “humidity of the air” factor. Level 2 of the “Humidity of the Air” factor in Table 8 = -56.47 and Level 2 of the “Humidity of the Air” factor in Table 9 = 666.5.

As a result, when the results are evaluated according to the Taguchi method average effect values and S/N ratios, the same levels of factors are reached in order to reach the optimum cycle time. In addition, in both cases, it is seen that the order of importance according to their effects on the performance characteristics is "Air Moisture", "Air Temperature", " Feeding Amount of Syrup" and "Temperature of Syrup" with the lowest delta.

that the most effective factors and levels in reducing the cycle time are: Air humidity (2), Air Temperature (2), Syrup Temperature (2) and Syrup Feed Amount (1).

4.3.7. Anova Table

According to the S/N and mean values obtained by the Taguchi method, the effects of the factors in reducing the cycle time were investigated. ANOVA analysis is performed to calculate and determine the effect ratios of the dragee coating parameters on the cycle time statistically. In this analysis, the humidity of the air, the temperature of the syrup, the temperature of the syrup and the feeding amount of the syrup were analyzed. The test results were evaluated at a confidence level of 95%.

ANOVA table was prepared in Minitab 19.0 package program. Nine experiments were conducted in the study and since each experiment was repeated twice, a total of 18 experiments were observed. Total degrees of freedom: Since N-1, the total degrees of freedom of the problem were found to be 17.

The hypotheses for the ANOVA analysis within the scope of the study are defined as follows:

H0: Factors have no effect on the cycle time → μ1= μ2= μ3= μ4

H1: Factors have an effect on the cycle time →At least two of the means are not equal: μi ≠ μj ,

The p value obtained as a result of the ANOVA analysis represents the smallest level of significance for rejecting the H0 hypothesis. The H0 hypothesis argues that the factors have no effect on the cycle time. ANOVA analysis results are given in Table 10.

Table 10. ANOVA Table for Cycle Time (Analysis of Variance for Cycle Time)

Parameter	freedom Degree (DF)	squares Sum (SS)	Mean Square(MS)	F-Value	P-Value	Factor Effect (%)
Humidity of the Air (Rh)	2	61634.3	30817.2	116.49	0,000	77.56
Air Temperature(°C)	2	10282.3	5141.2	19.43	0.001	12.94
Temperature of Syrup (°C)	2	796.0	398.0	1.5	0.273	1.00
Feeding Amount of Syrup (ml)	2	4370.3	2185.2	8.26	0.009	5.50
Error (Error)	9	2381.0	264.6			3.00
Total (Total)	17	79464.0				100.00
R- Sq = 97.00%	R - Sq (adj) = 94.34%					

As a result of the ANOVA analysis, it is seen that the humidity of the air, the temperature of the air and the feeding amount of the syrup factors are statistically significant for the cycle time ($p<0.05$), while the temperature of the syrup factor is not statistically significant ($p>0.05$). .

When the effect of the factors on the cycle time is examined, the humidity parameter shows the highest effect and the effect is calculated as 77.56%. As can be seen from these values, the most important factor on the cycle time is the humidity of the air. Changing the humidity from 40 to 50 will affect the cycle time change by 77.56%. In addition, the effect of the temperature factor of the air is 12.94%; 5.5% of the effect of the feeding amount factor of the syrup; It is seen that the effect of the temperature of the syrup is 1% and the effect of the error term is 3.0%.

4.3.8. Performing the Validation Experiment

As a result of the evaluations made according to the average obtained from the Taguchi method and the S/N ratio, the parameter combination that will minimize the cycle time is the humidity of the air (2), the temperature of the air (2), the temperature of the syrup (2) and the feeding amount of the syrup (1). These values are summarized in Table 11.

Table 11. Optimum Process Conditions of the Validation Experiment

Parameters	Humidity of Air (RH)	Air Temperature(°C)	Temperature of Syrup (°C)	Amount of Syrup (ml)
Levels	50	18	38	600

Confirmation experiments should be performed according to the combination in Table 11 and the accuracy of the optimization process should be tested. The results obtained by re-observing three times and the data obtained by the Taguchi method were evaluated.

Table 12. Validation Experiment Results

Experiment	of the air humidity	of the air temperat ure	Syrup temperat ure	Syrup amount	Feed	Observation Results
1	50	18	38	600		609
2	50	18	38	600		619
3	50	18	38	600		612

The average value of the results of the three observations in Table 12 is 613 minutes. The levels of the factors planned for the optimum observation value were selected by selecting the "Levels" section from the Stat-DOE-Taguchi-Predict Taguchi Design section in the program , and the predicted values shown in Table 13 were obtained.

Table 13. Taguchi Prediction Values

S/N Ratio	Mean
-55,7822	611

The Mean value obtained from Table 13 was calculated according to the mean values and 611 minutes were obtained. S/N Ratio value is calculated according to logarithmic transformations. Since the smallest best result was accepted to find the true value , the estimated cycle time was found to be 615.33 minutes according to the S/N value using the formula $10^{-SN/20}$ ($10^{55.7822/20}$).

The values obtained by the Taguchi method and the current working conditions were compared. What is meant by the current working conditions is the traditional production conditions that have been used in the enterprise until today. In the initial conditions, the humidity of the air is 60-95RH, the temperature of the air is between 18-22°C, the temperature of the syrup is between 38-40°C and the feeding amount of the syrup used is 1000ml. In Table 14, the comparison chart presenting the process values in the current and proposed system is given**.**

Table 14. Comparison Chart

	Current Status	Recommended Status
of the air Humidity (Rh)	60-95	50
of the air Temperature (°C)	18-22	18
of syrup Temperature (°C)	38-40	38
of syrup Feed Quantity (Ml)	1000	600
Process Duration (Minutes)	1020	613

In the current situation, the cycle time is around 1020 minutes as a result of the parameters adjusted with traditional methods, while the value obtained as a result of the application of the optimum parameter condition determined by the Taguchi method is around 613 minutes. In this way, an improvement of 40% was achieved in the process. In order to reach the minimum cycle time, the observation value calculated as a result of the model under optimum experimental conditions and the observation values obtained as a result of the verification experiments are quite close. It is seen that the results of the validation experiments (613 Minutes) and the Taguchi analysis results (S/N=615,Mean=611) are compatible.

5. Conclusion

Taguchi method , which is widely used in product and process development studies, was applied to optimize the processing time of the dragee coating process of a nut factory in this study. The experiment plan was prepared using the L9(3^4) orthogonal array, and considering the repetition principle of the experimental design, the experiment plan was repeated 2 times and a total of 18 experiments were carried out. The reason for choosing this figure is that as a result of operating the production line once, approximately 4000 kg of product is dragged . Each experiment performed creates an extra cost for the enterprise. In addition, production is disrupted due to the operations carried out in the unit reserved for the experiment. Since the dragee coating process costs one full working day, it has been tried to reach the solution with the least number of experiments.

In order to minimize the processing time, the optimum values of the relevant parameters are calculated as a result of the calculations in the Minitab 19 program ; It has been determined that the 1st level of the parameter is 600Ml. As a result of the Anova analysis, in the model in which four parameters were examined together, the humidity of the air, the temperature of the air and the feeding amount of the syrup factors were statistically significant for the cycle time ($p<0.05$), while the temperature of the syrup factor was not statistically significant ($p>0.05$). is seen. When the effect of the parameters on the processing time was examined, it was seen that the most effective parameter with 77.56% was the humidity of the air.

In the current situation, the cycle time is around 1020 minutes with traditional methods, however after the implementation of Taguchi method, the obtained cycle time is around 613 minutes. This is an improvement of 40% in the process. With the new parameters, the company is observed for four months. Systemic breakdowns and unplanned stoppages were reduced in the production with new values, and the production planning department was able to reach the deadlines with the shortening of the processing time. Positive results were presented to business managers and experimental design studies were suggested for other units in the department to improve their processes.

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