Application of the design of experiments for product knowledge attainment: the case of nourishing ovens for roasting of chickens

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Abstract: This work presents the Design of Experiments (DOE) application in the enhancement of a nourishing oven produced by a medium size company. The objective is to evidence the relevance of DOE in the generation of knowledge on the product, testing common senses resultant of pragmatism and experiences without statistical severity. The obtained results had allowed to improve the performance of the oven in the cookery of chickens, as well as reduced significantly the customers claims, since the performance of the optimized product had an improvement of the loss of weight from 45 to 33%, the firing time reduced from 50 to 44 minutes and the appearance of the ready chicken was classified with note 4. The efforts of the product development process (PDP) had been directed for the optimization of the performance of the fan. It is evident that the difficulties of applying DOE in medium size companies due to the unfamiliarity of the technique, however, it is rewarding to perceive the changes of the presuppositions existing through the generation of new knowledge concerning the product and its posterior incorporation in the PDP.

Keywords: *DOE, products development, DFSS.*

1. Context of the research

New approaches such as Simultaneous Engineering, Funnel and Stage Gates were developed between the end of the decade of 1980 and the end of the decade of 1990 resulting in the nominated Integrated Product Development. Currently new approaches for the development of products have been developed, such as the Lean Development and the Design for Six Sigma (DFSS), searching innovative solutions and a systematic process for the evaluation of the technology and the optimization of the product (ROZENFELD et al., 2006). The DFSS supports that only one superior design can create products or services with high value for the customer, low project vulnerability and high-quality (YANG, 2005). Kalamdani (2006), cites some types of models with different focuses on development of technology in general or commercialization of project such as: Invention, Innovation, Development, Optimization and Validation (I2DOV); Conception, Design, Optimization and Validation (CDOV); Identification, Definition, Development, Optimization and Validation (IDDOV); Definition, Measurement, Analysis, Design and Validation (DMADV). The application of the DFSS bases in the use of statistical techniques, highlighting the planning and analysis of experiments (DOE - Design of Experiments).

The DOE has as purpose the determination and to analysis, through tests, the changes that occur in the output variables or in the answers of a product, when deliberate changes are produced in the input variables of the process (MONTGOMERY, 1991). Antony et al. (1998) and Coleman and Montgomery (1993), suggest that the solution of the problems could be easier reached when the experiments are planned and the answers analyzed with methods or statistical techniques (Analysis of Variance - ANOVA). Thus this article describes the case of application of DOE in a medium size firing ovens manufacturing company.

2. Planning and analysis of experiments (DOE - design of experiments)

When accomplishing experiments, a common problem might appear: the necessity of simultaneously study the effect of the factors with different levels of regulations. As a consequence the tests number required for the experimentation tends to rise similarly to the increasing of the amount of factors. As a result, this turns impracticable the experiments because the costs and the execution time are raised. For Steinberg and Hunter (1984) and Montgomery (1991), the techniques of planning and analysis of experiments (Design of Experiment - DOE and Taguchi's Methods) can solve these problems. The planning of experiments is attributed to Ronald. A. Fisher, that during some years was responsible for the statistics and data analysis in the experimental agricultural station in London. Furthermore, Fisher developed and used for the first time the technique of the variance as the primary tool for statistical analysis of the experimental project. Although he was a pioneer author, there are many others who had produced additional contributions (MONTGOMERY, 1991). According to Galdámez and Carpinetti (2001), the terminologies used in experimentation are:

- Output Variables: they are the variables that suffer any effect in the experiment, when changes intentionally forced are produced in the factors that regulate or adjust the machines in the manufacturing process. During the tests, there could be one or more output variables that are important to evaluate;
- Control Factors: they are the factors modified deliberately in the experiment, with the purpose to evaluate the effect produced in the output variable and, to be able to determine the main factors of the process;
- Noise Factors: they are the factors, known or not, which influence in the output variable of the experiment. Some can be controlled, others not. In this case, there are some cares, which must be taken during the tests. This process prevents that the effect produced by the control factors, which are being evaluated in the experiment, are mixed or hidden with the effect of the noise factors;
- Factor Levels: they are the operation conditions of the control factors either of the process or the system. Throughout the experiments there is necessity to determine the optimum levels of the control factor or the value next to the ones defined by the designers;
- Treatments: they are the specific combinations of the levels of the control factors in the experiment. In other words, each trial of the experiment will represent a treatment;
- Main effect: it is the change of the output variable produced through the change in the level of the control factor;
- Randomization: it is the process to define the order of the treatments in the experiment. It could happen throughout a drawing or specific limitations of the experiment;
- Repetition: it is the process to repeat each one of the treatments in the experiment. According to Montgomery (1991), this concept allows to find an estimation of the experimental error, which transforms itself into a basic unit that determines if the differences observed between the data are statistically significant; and
- Blocks: it is the used technique to eliminate the effect of one or more factors in the results of the experiments. According to this technique, it creates a more homogeneous experiment and increases the precision of the output variables that are analyzed.

Coleman and Montgomery (1993), Montgomery (1991), Werkema and Aguiar (1996), Taguchi (1993) and Antony et al. (1998), suggest a systematic procedure to DOE, which it consists of:

- Define the objectives of the experiment: the problems of the products are defined, the objectives of the experiment and, mainly, the team responsible for the experimental process activities is selected. Werkema and Aguiar (1996) detaches that the involved people should be awarded of the importance to analyze scientifically the factors that influence in the product or manufacturing process. Colemam and Montgomery (1993) recommends the accomplishment of a brainstorming with people from several areas (quality, manufactures, production, suppliers, engineering and even clients) or anyone that could contribute with pertinent information of the experiments. In the brainstorming, all the ideas or information collected are critically examined by the responsible team. According to Antony et al. (1998), it is natural that people describe some problems in the products or manufacturing processes, and, in this case other tools such as Pareto Diagrams and the Cause-effect Diagrams can be used to identify the main problems;
- Obtain technical information of the experiment: the technical information gathering of the product or manufacturing process occurs, in which, the group list all the control factors, noise factors, the regulation levels and the output variables. Montgomery (1991) detaches that the technical information techniques can result from a combination between the practical knowledge (experience) and the theoretical understanding of the study object;
- Select the factors of control, the regulation levels and the output variables: the team selects the control factors (independent variables), the variation range of the regulation levels of these factors and the outputs of the experiment (dependent variables). Not only the method of measurement of the control factors is defined but also the numerical scale used to evaluate the defined outputs of the experiment in the previous phases. The parameters of the process are classified into categories (degree of influence in the reply, capacity of controlling or capacity of measuring - precision), presented in the Table 1 (COLEMAM and MONTGOMERY, 1993);
- Select the experimental matrix: for Montgomery (1991), if the three previous stages had been fol-

Table 1. Variables of the design of experiment.

Variables		Level 1	Level 2	Level 3
TC	Temperature of the chamber (°C)	160	180	200
VT	Speed of the fan (rpm)	1680	840	-
TS	Temperature of vapor exit	AQ (no vapor)	80	150
Ti	Initial temperature (°C)	Noises		
CT	Total load (g)			
Pi3	Weight of the chicken with temperature device			
ΔC	Loss of weight (%)	Outputs		
T	Final time (minutes)			
Ap	Appearance			

lowed correctly, the fourth stage is relatively simple to accomplish. When selecting or constructing the experimental matrix, the number of control factors, the levels number and factors that are not controllable in the process must be considered. Montgomery (1991) and Taguchi (1993) describe some of the techniques of planning of experiments that can be used in this phase: Factorials, Factionary factorials, 2 k-p Factionary Factorial, Taguchi Method. Still in this phase, the sequences of the tryouts are defined (randomly), the number of replications, the restrictions of the experiments and the possible interactions that could occur between the evaluated factors;

- Accomplish the experiment: it is important that the process is followed by the team or a responsible person, to make sure that all the procedures are executed in agreement with the plan. According to Hoppen et al. (1996) any change at the moment where the experiments are carried through must be registered (dates, additional rehearsals, alteration in the sequence of the trials, etc.) and it employs elaboration of reports, therefore the information can enrich the results obtained for the data analysis and to verify if the experiments had been correctly executed by the responsible person. Another important aspect that must be considered during the accomplishment of the experiments is the balance of the available resources of experimentation. Montgomery (1991) considers the experimental research as an iterative process, that is, the congregated information of the first test trial are used as inputs of the second round and therefore, attention must be paid to not deplete all the resources in the first tryout of the experiment;
- Analyze the data: normally there are used softwares (MINITAB or EXCEL) to accomplish the linear analysis of variance, charts and the normal probability charts. The statistical concepts are applied in the results of an experiment, with the objectives to describe the behavior of the control variable, the relation between them and esteem the effect produced in the observed answers. Still, the statistical analysis allows deciding how much to accept or to reject the hypotheses formulated in the first stage of the experiments (REY, 1993). In the analysis of the results, linear graphs can be used to represent and to analyze the main effect and the interactions of the factors. However, Montgomery (1991) affirms that to analyze the results, statistical techniques must be used. In special, the Variance Analysis (ANOVA), that allows evaluating, with statistical confidence, whether or not the effects are significantly different from zero and provided that to conclude which of the factors that in fact, when modified, intervene in the output;
- Interpret the results: the team in charge of the activities plan must extract the practical conclusions of the results and recommend the continuous improvement actions of the manufacturing process. In this phase, the data must be described through charts, especially when the results are presented to the external people of the project; and
- Elaborate reports: the work accomplished must be described identifying the practical and theoretical limitations found, the obtained recommendations for future experiments and conclusions (WERKEMA and AGUIAR, 1996). It can be demonstrated that the developed study is a continuous process of learning (MONTGOMERY, 1991).

3. Application of DOE

The work consists in the accomplishment of an action research in a Brazilian medium size company located in the South of Minas Gerais State. Nowadays, the main focus of the company is the bakery industries and food services where it develops, manufactures and commercializes equipment of food preparation. The company has an area of 27.986,17 ft² and 85 collaborators. It was starting from customers claims, especially the Pão de Açúcar Group, that the necessity to determine the best parameters of the oven to optimize the cooking of ready chickens was determined together with the professionals of the company, which were the variables desired by the customers: the time of preparation, the loss of weight and the roast appearance. It was decided to accomplish an experimental project to evaluate significance of the parameters and to direct the redesign of the product. The existing knowledge in the company in relation to the product, are strongly associated to the pragmatism and tests without planning and statistical analysis. The weight loss, the time of roasting and the homogeneity of the visual aspect of the chickens are influenced by the speed of the turbine (the higher the better), temperature of the chamber and vapor temperature. For all these parameters, the higher it is obtained the better will be their value.

Figure 1. Combined gas oven model ECG6.

3.1. Define the objectives of the experiment

- Reduce the weight loss of the roasted chicken to 35%. The chicken acquired by the supermarket is congealed and its price is defined by the weight, after the roasting of the chicken, it looses part of its weight due to evaporation of the water. This loss currently is about 45%;
- Reduce the preparation time to the maximum of 45 minutes. The chickens are flavored through a high-pressure pistol that injects the flavoring into the chicken. As the supermarkets add value to the chicken selling it hot and for ready for the consumption (roasted), the minor the roasting time the higher the number of chickens sold. Currently the average time for roasting chickens is 50 minutes;
- The appearance of the chicken is also a result to be considered; therefore it is preponderant for the decision of purchase of the customer. Being defined a visual standard for the appearance (the 1 – the lighter appearance is considered the worse and 4 – the darker appearance is considered the better), the established goal is that all the chickens should achieve at least note 3. The lot of production of chickens of the oven needs to assure the uniformity in the roasting of the chickens, once different visual aspects of the chickens should lead the customer to abandon the purchase; and
- The flavor of the chicken was not considered due to the fact that it was a dependent result of the operation responsible for the chicken flavoring, being a responsibility of the customer to define the formularization and the method to be used.

3.2. Technical information gathering of the experiment

The product selected for the accomplishment of the project was the combined gas oven ECG6 presented in Figure 1.

The roasting oven functions through the heating of the cooking chamber. For the best distribution of the temperature in the chamber (uniformity) an axial fan exists that incites the circulation of air in the chamber. This fan possesses constant speed and a reversion system, permitting the air flow in the chamber what contributes for the temperature uniformity. To contribute to the softness of chicken meat it is used vapor injection in the chamber. The ending of the process of chickens roasting occurs through a temperature measurement device that is placed in one of the chickens. The temperature of this gadget is regulated to 180 °C, when the internal temperature of this chicken reaches 180 °C the oven is off and blinking and sonorous signals are started informing that the roasting process is finished. They had been considered as variables of noise: the initial temperature of the chickens that are placed in the oven (the chickens normally are placed frozen), the total load of the oven (once the weight of the chickens can vary as well as not necessarily the oven is loaded with its total capacity); and the weight of the chosen chicken to be placed the temperature device.

3.3. Select the control factors, the regulation levels and the output variables

Figure 2 presents the diagram of process firing of the chickens roasting and Table 1 presents the used description of the output variables and values.

The levels chosen for the experimental arrangement had been defined based on the experience of professionals of the company. The initial temperature of the chickens, the total weight and the weight of the chicken with the temperature gadget, although being known variables, could not be controlled and, consequently, had been considered as noises.

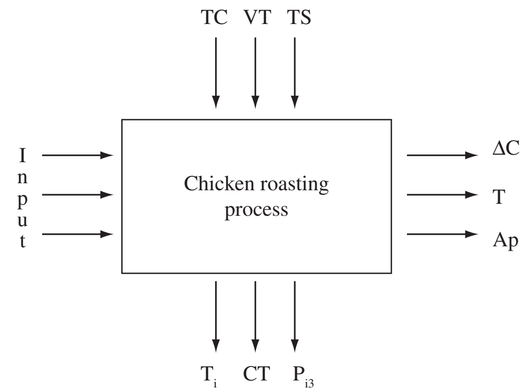

Figure 2. Diagram of the chickens roasting process.

3.4. Selection of the experimental matrix

It was planned 20 experiments, considering 2 replications and 4 central points.

3.5. Accomplish the experiment

Table 2 presents the results of the accomplished experiments. The test procedure consisted of preheating the oven to the temperature determined for each experiment and after that to place the chickens to bake after weighing up. The end of the experiment was definitive when the temperature of the temperature device lodged in one of the chickens reached 88 °C. The chickens were then, photographed and weighed. The output variables time and weight loss could, therefore to be directly verified. Yet, the variables appearance was determined later. The photos had been commanded according to the coloration of the separate roasted chickens in 4 categories being attributed to each group a note from 1 to 4 (1 – lightly roasted up to 4 - darkly roasted).

3.6. Data analysis

3.6.1. Time analysis

The temperature of the chamber (TC), as it was presumed, affects the total preparation time of the process. However, it did not have significant difference between of 180 and 200 °C, as it can be observed in Figure 3 and Table 3. The speed of the fan (VT) influences clearly in the preparation time of the process, being the current speed (~1680 rpm) the one that provides inferior preparation times. The temperature of vapor exit (TS) did not present significant influence in the time of the process. However, Figure 3 points a average of inferior time with regarding the high vapor level. It is important to consider that the load (total weight of the chickens) also influences the roasting time. Bigger loads will demand greater time in the process.

3.6.2. Analysis of the weight loss

Although some differences in Figure 4 can be observed, the only variable that has significant influence in the weight loss is the speed of the fan (Table 4 and Figure 4). The current speed (~1680 rpm) presented average of loss of inferior weight. It was evidenced that the initial temperature of the chicken is correlated with the weight loss (higher initial temperature takes the minor loss of weight).

3.6.3. Analysis of the appearance

The temperature of the chamber has significant influence on the appearance of the chicken (Table 5 and Figure 5). Optimum result gotten was 200 °C. The speed of the fan also presented significant influence, being the current speed (~1680 rpm) the best.

3.7. Interpret the results

The accomplished tests point the best configuration regarding the temperature of the chamber and the speed of the fan. The temperature of vapor exit did not have significant influence in accomplished tests. The initial temperature had influence in the weight loss. The results indicate that a bigger initial temperature would take the loss of minor weight. One notices that the speed of the fan is determinative in the results, mainly for the loss of weight, being interesting to explore other possibilities of speed and a different type of fan. As a consequence, new tests with the addition of a diffuser (cylindrical part placed in the protection bottom area of the oven) in the fan of the oven had been done to verify the influence of this conception in the roasting process. The common sense is that the diffuser significantly contributes in the increase of the performance of the oven when directing the air flow. The experiment consisted of the analysis of three factors with two levels each:

- Temperature of the chamber (TC): 200 and 230 °C;
- Speed of the fan (VT): 1680 (without the diffuser) and 1680+ (with the diffuser); and
- Temperature of vapor exit (TS): AQ (hot air) and 150 (vapor about 150 °C).

The data gotten with the experiments are summarized in Table 6.

3.8. Analysis

Regarding the roasting time it can be seen in Table 7 that the only significant factor is the temperature of the chamber (P-value < 0,05). This performance was expected, once that in the highest temperatures the roasting time tends to be lesser. Figure 6 shows the averages of time in function of the levels of the factors.

Table 2. Result of the experiments.

	Factors			Noises			Outputs		
	TC (°C)	VT (rpm)	TS	Pi3 (g)	Ti (°C)	CT (g)	T (minutes)	Ap. (1-4)	ΔC (%)
Replication 1	160	840	AQ	1750	6	9500	63	2	32,26
	160	840	80	1770	8	10860	57	1	31,91
	160	840	150	1670	3	9370	48	1	28,01
	160	1680	AQ	1665	5	9695	45	2	30,27
	160	1680	80	1870	7	10235	53	2	31,36
	160	1680	150	1670	4,9	10180	48	1	27,75
	180	840	AQ	1735	2	9550	53	2	32,57
	180	840	80	1710	5	11355	56	1	31,00
	180	840	150	1715	5	10085	56	2	32,42
	180	1680	AQ	1405	6	10165	38	4	26,32
	180	1680	80	1550	7	10835	40	4	30,69
	180	1680	150	1540	7	10215	37	2	26,97
	200	840	AQ	1720	5	10665	63	3	36,19
	200	840	80	1705	9	10395	51	3	33,67
	200	840	150	1755	2,5	10080	55	3	36,01
	200	1680	AQ	1815	10	10350	46	3	30,48
	200	1680	80	1705	9,5	10460	44,5	4	33,60
	200	1680	150	1930	5	11550	41	4	31,13
Replication 2	160	840	AQ	1750	7	10705	63	1	33,30
	160	840	80	1715	6	10340	66	1	35,01
	160	840	150	1740	6	10000	54	1	28,40
	160	1680	AQ	1760	3,5	12000	50,25	3	27,13
	160	1680	80	2225	5	11910	61	3	33,17
	160	1680	150	1780	12	10375	57	3	37,88
	180	840	AQ	1715	7,5	11045	63	1	35,36
	180	840	80	1720	6,5	10825	53	1	31,59
	180	840	150	1790	7	9905	52	2	33,92
	180	1680	AQ	2230	9	12435	53,5	4	30,92
	180	1680	80	1750	8	10030	42	4	27,77
	180	1680	150	1985	9	10645	46	4	33,26
	200	840	AQ	1720	9	9855	57	2	36,68
	200	840	80	1730	12	10735	48	3	35,17
	200	840	150	1620	7	9875	48	2	33,27
	200	1680	AQ	1630	7	9665	44,5	4	33,32
	200	1680	80	2195	4	12795	50,5	4	32,59
	200	1680	150	1930	5	11955	45	3	28,36

Regarding the weight loss, it does not have statistical significant factors as can be noticed in the Table 8 (P-value > 0,05). However, if it is considered 10% of significance the addition of the diffuser could be interpreted with a factor that leads to the increase of the weight loss (Figure 7).

The main objective of the described experiments in this report was to evaluate the influence of the addition of the diffuser in the bottom protection area of the oven (represented in the design process for level VT = 1680+) on the roasting time and the weight loss. In fact, the diffuser did not exert any influence on the output time. However the loss of weight seems to be influenced by the addition of the diffuser that increased the loss amount. However, as it is desirable to minimize the loss of weight the diffuser is an alternative to be discarded for the attainment of better performance of the oven to roast chickens. The speed of the fan is identified as main factor, being the lesser loss of weight registered with 1680 rpm. The speed of the fan is of difficult alteration; therefore the company possesses a supply contract of engine with Weg, which uses an engine with constant speed. The speed of the fan is directly related

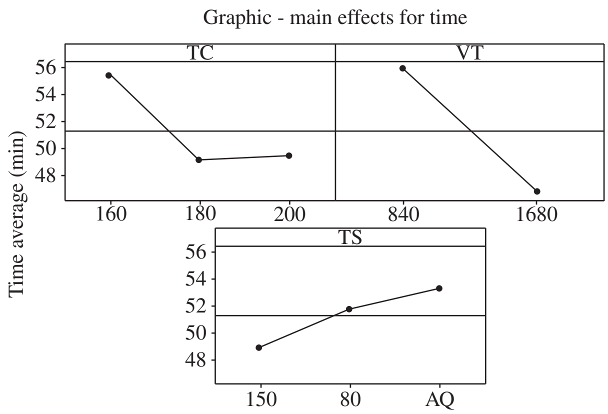

Figure 3. Chart of main effect for the output time. Results for the parameters of lesser time are: TC: 180 or 200 °C; VT: 1680 rpm (current); and TS: independent.

Table 3. Results of the experiment for the variable time.

Term	Seq SS	Adj SS	Adj MS	F	P
Pi3	134,13	47,71	47,71	3,96	0,065
Ti	10,07	4,87	4,87	0,40	0,535
CT	56,83	32,58	32,58	2,70	0,121
TC	233,22	304,10	152,05	12,61	0,001
VT	985,74	943,25	943,25	78,21	0,000
TS	125,82	117,59	58,79	4,87	0,023
TC*VT	46,03	41,96	20,98	1,74	0,209
TC*TS	66,40	73,71	18,43	1,53	0,244
VT*TS	77,11	71,87	35,93	2,98	0,081
TC*VT*TS	93,12	93,12	23,28	1,93	0,158

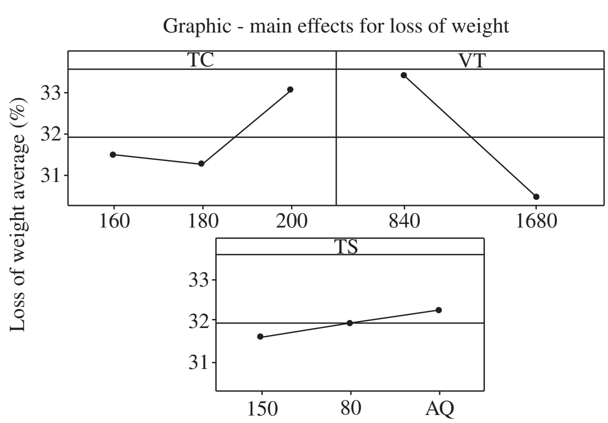

Figure 4. Chart of main effect for the reply loss of weight. Parameters for minor loss of weight are: TC: independent; VT: 1680 rpm (current); and TS: independent.

to the speed and pressure of air in the interior of the chamber. Thus it was opted to modifying the configuration of the fan. The best condition for the roasted is: TC 2: Temperature

Table 4. Results of the experiment for the variables weight loss.

Term	Seq SS	Adj SS	Adj MS	F	P
Pi3	8,565	12,101	12,101	2,40	0,142
Ti	34,735	21,826	21,826	4,33	0,055
CT	16,282	1,242	1,242	0,25	0,627
TC	29,007	22,803	11,402	2,26	0,138
VT	66,110	62,799	62,799	12,47	0,003
TS	2,962	2,390	1,195	0,24	0,792
TC*VT	25,069	24,892	12,446	2,47	0,118
TC*TS	6,279	6,035	1,509	0,30	0,874
VT*TS	17,321	15,389	7,694	1,53	0,249
TC*VT*TS	26,330	26,330	6,583	1,31	0,312

Table 5. Results of the experiment for the variables appearance.

Term	Seq SS	Adj SS	Adj MS	F	P
Pi3	3,3909	0,9401	0,9401	2,04	0,174
Ti	2,1264	0,0710	0,0710	0,15	0,700
CT	1,5862	0,1770	0,1770	0,38	0,545
TC	9,6514	11,8303	5,9151	12,83	0,001
VT	14,9867	14,1205	14,1205	30,62	0,000
TS	0,5710	0,6479	0,3239	0,70	0,511
TC*VT	2,7963	2,7639	1,3819	3,00	0,080
TC*TS	0,9208	0,8412	0,2103	0,46	0,767
VT*TS	0,6170	0,4626	0,2313	0,50	0,615
TC*VT*TS	1,4351	1,4351	0,3588	0,78	0,557

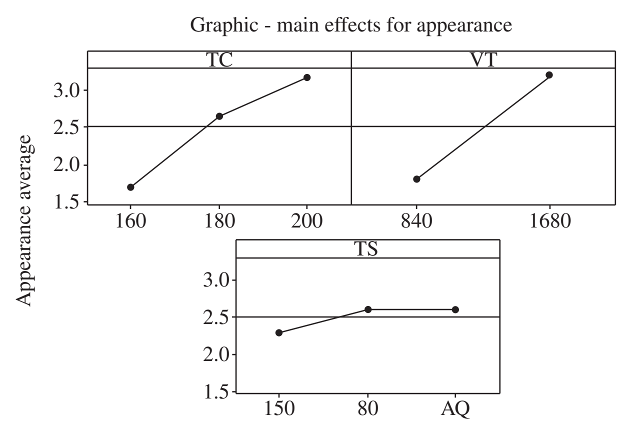

Figure 5. Chart of main effect for the reply appearance. Parameters for better appearance are: TC: 200 °C; VT: 1680 rpm (current); and TS: independent.

of the Chamber 180 °C; TS 3: Temperature of Vapor 150 °C; e VT 2:1680 rpm. (Table 9 - Results gotten with the optimization).

Table 6. Experimental data of test with roasted chicken.

StdOrder	RunOrder	TC (°C)	VT	TS	Time (minutes)	Perda (%)
1	1	200	1680	AQ	45,25	31,90
2	7	230	1680	AQ	38,00	30,65
3	3	200	1680+	AQ	45,00	33,11
4	4	230	1680+	AQ	42,00	33,03
5	2	200	1680	150	43,00	29,74
6	8	230	1680	150	40,00	31,04
7	5	200	1680+	150	45,00	35,85
8	6	230	1680+	150	41,00	31,88

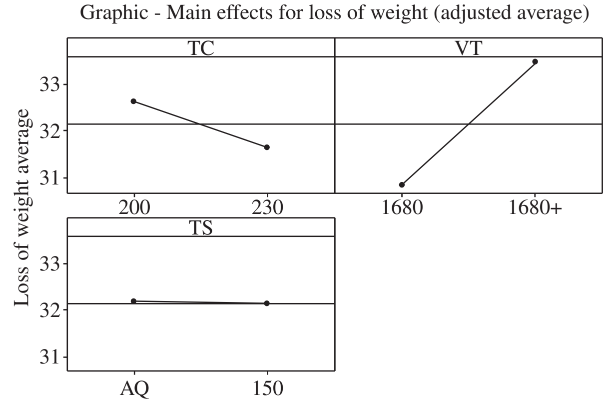

Figure 7. Graph of the effect on the weight loss.

Table 7. Analysis of the experiment for the variables time.

Term	Effect	Coef	SE Coef	T	P-value
Constant		42,406	0,4386	96,68	0,000
TC	-4,313	-2,156	0,4386	-4,92	0,008
VT	1,687	0,844	0,4386	1,92	0,127
TS	-0,313	-0,156	0,4386	-0,36	0,740

Table 9. Results gotten with the optimization.

Results	Previous	Optimized
Weight loss	45%	35%
Preparation time (minutes)	50	40
Visual aspect	Not identified	4

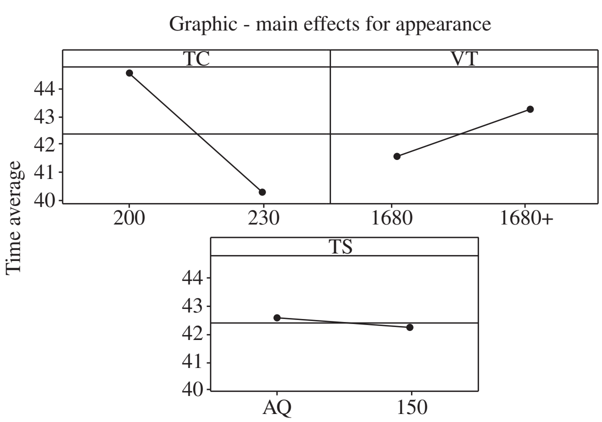

Figure 6. Chart of the effect of the factors on the time.

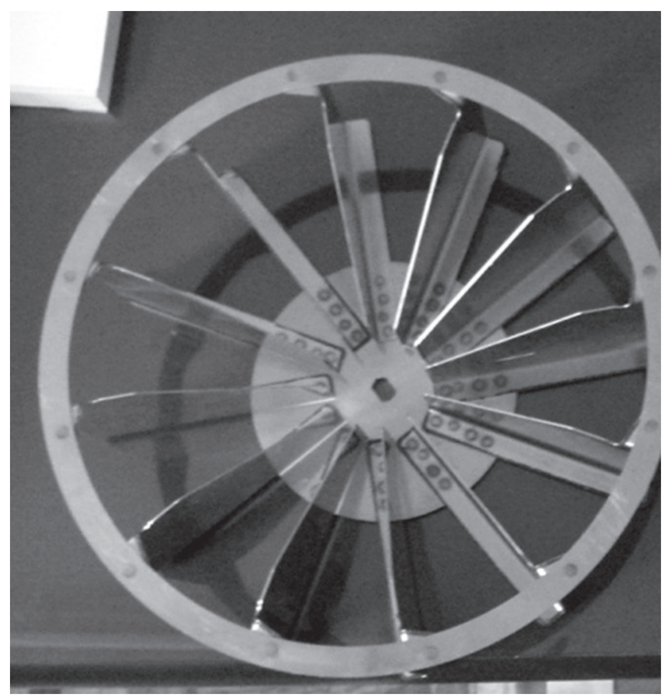

Figure 8. Current conception of the fan.

Table 8. Analysis of the experiment for the variables weight loss.

Term	Effect	Coef	SE Coef	T	P-value
Constant		32,1506	0,5275	60,94	0,000
TC	-1,0013	-0,5006	0,5275	-0,95	0,396
VT	2,6338	1,3169	0,5275	2,50	0,067
TS	-0,0437	-0,0219	0,5275	-0,04	0,969

The existing knowledge in the company in relation to the product had been questioned and were demonstrated that the weight loss, the time of roasting and the homogeneity of the visual aspect of the chickens are strongly influenced by the speed of the turbine (the higher the better), being irrelevant: the temperature of the chamber and temperature of the vapor, previously considered excellent parameters. The engineering of the company considered a new conception for the fan (Figure 8 and 9).

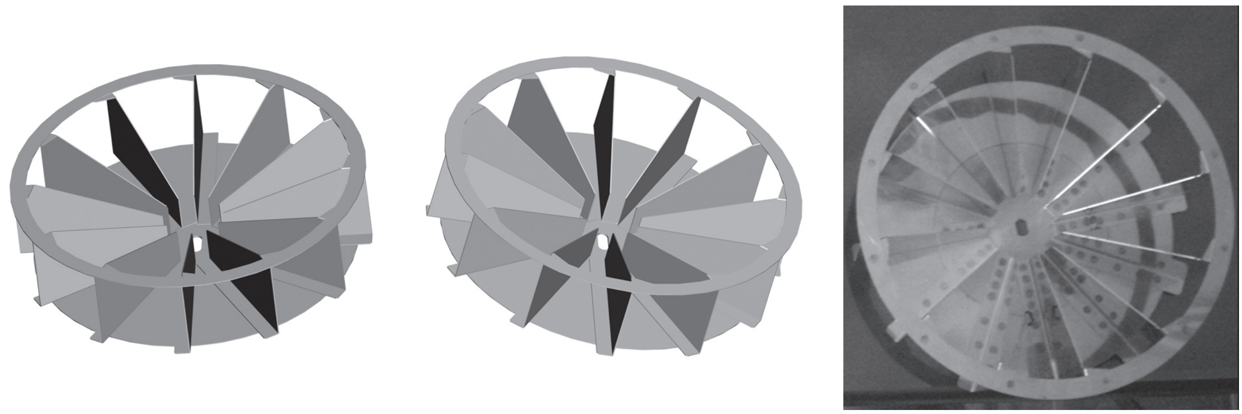

Figure 9. Conception proposal for fan (CAD 3D and archetype).

4. Conclusions

This work presents resultes from the application of DOE in a medium size company. The process of development of products of the company, empirical in a large extent, resulted from the probabilistic approch the generation of knowledge on the product that later can be incorporated in the products development. Existing common senses in the company regarding the products had been tested, such as the relevance of the diffuser for performance improvement of the oven, the influence of the temperature of the chamber and the vapor. From the obtained results the focus of the development that previously was the increase of temperature and speed of the fan, better was defined having been the given emphasis the conception of the fan of the oven. DOE allowed to define the factor of higher impact in the requirements of the customers. There are considered as future works the application of others statistical techniques and modeling that allow the increase of the thermal efficiency of the oven, with consequent economy of energy. It can also be applied techniques such as the Design for Manufacture for reduction in the amount of parts and consequence reduction of costs.

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