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A Study on the Food Taste Consistency by using DOE in Foodservice

Chulwon Kim

Woosong University

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실험계획법을 이용한 메뉴 맛의 일관성에 관한 연구

김 철 원

우송대학교

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국문요약

본 연구는 외식산업을 대상으로 6시그마에서 사용하는 프로세스 개선의 접근방식과 그 통계적 기법을 활용하여, 고객만족의 핵심요인 중의 하나인 음식 맛의 일관성을 구현하는 방안을 제시하고자 하였다. 연구방법으로는, 프로세스 개선을 위한 6시그마 로드맵 DMAIC(Define, Measure, Analyze, Improve, Control) 방식을 사용하였고, 연구대상은 단체급식에서 사용하는 특정 메뉴를 중심으로 하였고, 관련 데이터는 해당 기업에서 실험한 자료와 전문가 집단을 대상으로 한 Brainstorming, Matrix 분석기법, 그리고 상관분석과 t-test 등을 통해 특정메뉴(돈육고추장볶음)의 조리작업에 필요한 구성요소 -식재료 및 조리방법-를 제시하고 이들 중에서 가장 적합한 맛을 만들기 위한 최적의 조합을 도출한 결과, 해당메뉴의 양념을 구성하는 마늘, 고춧가루, 참기름의 구성비가 제시되었다. 이 외에도 조리방식과 비용 측면에서도 최적의 조건을 도출함으로써 음식 맛의 개선과 품질관리의 일관성 방안이 제시되었다.

Key Words : 실험계획법, 일관성, 6시그마, 메뉴, 맛

I. INTRODUCTION

In today's competitive environment, our customers, no matter who they are, will judge our progress to determine service quality. We believe such mind-set and approach offers true competitive advantage.[1] One of the greatest benefits of Six Sigma aside from improving product-to-market times is how it engages employees and customers in greater dialogue in a way that both energizes and unites the company. Rocks are turned over, problems are analyzed, and solutions are implemented not only between the business and its employees but also between the business and its customers.[2]

In terms of technical approach to solve or improve the effectiveness, notable by Kivela, Inbakaran, and Reece[3] and Kivela and Chu[4], suggests that quality service research is important it is directly linked to customer satisfaction and return behaviour. However, the literature also reveals that there is little theoretical understanding of quality systems and applications in the foodservice environment and how these effect the formation of customer satisfaction.[5]

As Lowenstein[6] suggested, it is one thing to attract the customers, but quite another to keep them returning. If we are to accept the postulation in the service quality and satisfaction literature, that return or repurchase is a consequence of satisfaction, and that satisfaction is a consequence of a high quality organization, then the decision to return to the foodservice operation indicates whether or not the foodservice operator's performance exceeded

교신저자: Chulwon Kim, Department of International Hospitality Management, Woosong University, 17-2 Jayang-dong Dong-gu, Daejeon 300-718, Korea
Tel : 82-42-630-9252 Fax : 82-42-630-9251 E-mail : cwkim@wsu.ac.kr

customer expectation. Such attempts are useful in helping to achieve benchmarks that could be used to evaluate the performance of a firm against industry-wide standards.

Therefore, this study was focused on the implementation of Six Sigma into the process improving performance of the foodservice industry so that the company was able to improve the customer satisfaction and ultimately the profitability of business. By implementing Six Sigma, specifically the technology of DOE(design of experiments) successfully in this study, people could understand how to quantify the quality program in the foodservice industry. Then we might be able to understand how to measure the foodservice quality, and how to improve and retain it.

1. Six Sigma

The concept of implementing Six Sigma processes was introduced at and popularized by Motorola in 1987 in their quest to reduce defects of manufactured electronics products to as low as 3.4 parts per million opportunities.[7] Their approach was based on rigorous Japanese theories of TQM for use in the manufacturing process, where defects are relatively easy to spot and count and thus well suited to the high-volume, high precision electronics industry that has highly complex processes.[8] While the utility of Total Quality Management(TQM) as an overall quality programme has had a tenuous acceptance by the hospitality industry such as the Ritz-Carlton, there is a dearth of systematic quality-systems in existence in foodservice operations, excepting for the likes of McDonald's and more recently the Starwood hotel group. And yet, other service organizations have adopted sophisticated quality initiatives some decades ago.[5]

The goal of Six Sigma is to control all processes at the outset well before they get to the customer.[8] Improving all of an organization's individual processes could actually have a detrimental effect on the company's ability to satisfy the customer's needs and provide product and services at the right time at the lowest cost. The realized savings to the system might be less than the cost of all the improvements.

While the original goal of Six Sigma was to focus on the manufacturing process, it became clear that the distribution, marketing and customer order processing functions also needed to focus on reaching Six Sigma quality standards. Six Sigma claims that focusing on reduction of variation will solve process and business problems. By using a set of statistical tools to understand the fluctuation of a process, management can begin to predict the expected outcome of that process. If the outcome is not satisfactory, associated tools can be used to further understand the elements influencing that process. Through a rigid and structured investigation methodology, the process elements are more completely understood. The assumption is that the outcome of the entire process will be improved by reducing the variation of multiple elements.[9]

Some companies implement Six Sigma in order to improve financial performance and profitability of business. Most manufacturers in the USA operate at about three sigma levels, churning out 66,000 bad parts for every million produced. These companies lose up to 25 percent of their total revenue due to defects.[10] Another reason to choose Six Sigma is to be able to quantify its quality programs. Thus, implementation of Six Sigma within a business's processes eliminates "I think" and "I feel" from conversations and enables companies to manage by fact.

Six Sigma approach includes a disciplined process of five phases: Define, Measure, Analyze, Improve, and Control(commonly known as DMAIC), and the purpose of each step in the DMAIC process is[9]:

1. Define select appropriate project, define the problems and the metrics with their baseline and optimal levels. Practitioners ask who the customers are and what their problems are. They identify the key characteristics important to the customer along with the processes that support those key characteristics. They then identify existing output conditions along with the process elements.

2. Measure select the appropriate responses to be improved, based on customer inputs and other considerations, ensure that they are quantifiable, and that we can accurately measure them. Determine what unacceptable performance is. Gather preliminary data to gauge current performance.

3. Analyze analyze the preliminary data to document current performance(baseline) that provides insights into the process and to begin identifying the fundamental and most important root causes of defects or problems and

their impact, and act accordingly.

4. Improve determine how to improve the process to significantly reduce the defect levels. Solutions to the problem are developed, and changes are made to the process. Results of process changes are seen in the measurements. In this step, the company can judge whether the changes are beneficial, or if another set of changes is necessary.

5. Control once the process has been performing at a desired and predictable level, put a system into place to ensure the improvements. This last step is the sustaining portion of the Six Sigma methodology. The process is monitored to assure no unexpected changes occur.

2. DOE(design of experiments)

With computer software, formulators can take advantage of a powerful statistical tool: design of experiments (DOE). DOE methods employ test arrays that produce maximum information from minimal runs. Industrial experimenters typically turn to two-level factorials as their first attempt at DOE. These design consist of all combinations of each factor at its high and low levels. With large numbers of factors, only a fraction of the runs need to be completed to produce estimates of main effects and simple interaction.[11)]

For purposes of learning, using, or teaching Design of Experiments (DOE), one can argue that an eight run array is the most practical and universally applicable array that can be chosen. There are several forms of and names given to the various types of these eight run arrays (e.g., 2^3 Full Factorial, Taguchi L8, 2^4-1 Half Fraction, Plackett-Burman 8-run, etc.), but they are all very similar.

A free Microsoft Excel spreadsheet with a 2^3 Full Factorial array showing the mathematical calculations accompanies this article (click the Microsoft Excel icon below to download it). Generic steps for using the spreadsheet, precautions, and additional advice are included below.

Viewing Tip: Usually, you can click on the icon link above to view the document in a new window-it may open within your browser using the application (in this case either Word or Excel). If you are having difficulty, try right clicking the link and selecting "Save Target As..." or "Save As..." to save it to your computer hard drive.

1) Generic Steps For Using The Attached Spreadsheet

There are many different articles in the literature that outline steps that should be taken to complete a DOE. The following steps are recommended for using the accompanying spreadsheet:

Determine the acceptance criteria you need (i.e. acceptable alpha error or confidence level for determining what you will accept as passing criteria). This is typically alpha=.05 or 95 see additional advice below.

Pick 2-3 factors to be tested and assign them to columns A, B, and C as applicable (advise using the key provided).

Pick 2 different test levels for each of the factors you picked (i.e. low/high, on/off, etc.).

Determine the number of samples per run (room for 1-8 only; affects normality and effect accuracy, not confidence).

Randomize the order to the extent possible.

Run the experiment and collect data. Keep track of everything you think could be important (i.e. people, material lot numbers, etc.). Keep all other possible control factors as constant as possible as these may affect the validity of the conclusions.

Analyze the data by entering the data into the yellow boxes of the spreadsheet and reading the results. A review of the ANOVA table will show you those effects that meet the acceptance criteria established in step number one. If the alpha value in the table is greater than the acceptance criteria, accept the result; if it is less, reject the result. Similarly, the higher the confidence, the higher the probability that factor is statistically different from the others. Signal to noise measurements are helpful to use when selecting factors for re-testing in subsequent experiments.

Confirm your results by performing a separate test, another DOE, or in some other way before fully accepting any results. You may want to more closely define results that are close to your acceptance criteria by retesting the factor using larger differences between the levels.

However, when the response depends on proportions of ingredients, such as in chemical or food formulations, factorial designs may not make sense. For example, look at what happens with experiments on lemonade (Table 1).

<Table 1> Misleading Factorial Design for Lemonade

Run	Lemons	Water(cups)	Ratio(lemon/water)	Taste
1	1	1	1.0	Good
2	2	1	2.0	Sour
3	1	2	0.5	Weak
4	2	2	1.0	Good

Runs 1 and 4 do not provide any taste contrast. It would make more sense to look at taste as a function of the ratio of lemons to water. Mixture design accounts for the dependence of response on proportionality of ingredients. If you formulate chemicals, food or other products, consider using mixture design rather than factorials or related optimization methods.[11]

II. METHOD

This study was performed in an environment in which Six Sigma Operating System has been already launched for 4 year. Therefore the scope of this study was defined only to the improvement of the specific problem which will be identified next.

The data for this study came from a foodservice company operating over 300 accounts in South Korea. Food production managers and line cooking employees were selected for this study, and a project team was organized with the managers of those units that cooperated in this study.

Food production managers have traditionally relied on output measures such as sales volume to gauge the effectiveness of their organizations. And line cooks have experienced with several cooking tests for the better food taste.

In this research, a qualitative approach was undertaken to ascertain chain foodservice attitudes in the menu quality improvement. Although the acceptance of qualitative research methodology is less prevalent than the quantitative research,[12] it is argued that the choice of qualitative research would fulfil the needs of the purpose of this research project. Quite simply, the interest of this research is a phenomenological approach, an approach to understanding how menu quality improvement is conducted by foodservice operators rather than the use of a positivist approach, which is largely based on measurable variables and provable propositions.[13]

This qualitative research approach to inquiry also involved a case study approach, where people and setting were explored in-depth and described in a series of mini-case studies reports. It is believed that a series of mini case studies reports would enhance the body of knowledge in understanding the intended research objectives. Thus, personal interviews were deployed to explored the phenomenon of interests form the foodservice operators with the use of a semi-structured questionnaire, which was based on the secondary research and piloted in predetermined sampling settings.[14]

The researcher and project team members had a meeting to understand how to collect the related data and what they should do for this study. The measurement methods and reporting tools were specified and standardized. To increase the reliability of the data, the data was double-checked by the authorized data collectors.

In the Define phase we focused on a customer requirement and identified our project CTQ(critical to quality). CTQ(s) are the key measurable characteristics of a product or process whose performance standards must be met in order to satisfy the customer. Translating CTQ(s) directly from the VOC(voice of customer) data gives you an unbiased view of customer needs. Prioritizing the CTQ(s) with respect to business strategy guarantees that project results will be valued by the customer and the business.

III. RESULTS AND DISCUSSION

The first task was to clearly define how the project would be successful by the company. First, the project team brainstormed and then used a relationship diagram to understand which process was related to their goals. We found the "Efficient Operations" outnumbered from many of other goals and should be the primary focus of the project. Also, "Food control" was identified as a primary control process to work with those goals(Table 2).

The scale was given according to the important level between subjects and control process. The most important relationship got 9 points, the moderate relationship got 3 points, and the less important relationship got 1 point. For

<Table 2> Prioritization of Research Subjects

Subjects	Labor Control	Food Control	Expenses Control	Production Control	Service Control	Financial Control	Total
Customer Satisfaction	3	3	1	9	9	1	26
Efficient Operations	6	9	9	3	3	9	39
Cost Reduction	9	3	9	3	1	9	34
Employee Satisfaction	1	9	1	3	9	1	24
Increased Sales	1	1	3	3	1	3	12
Total	20	25	23	21	23	23	135

<Table 3> Importance between Subjects and Food Control Items

Run	Lemons	Water(cups)	Ratio(lemon/water)		Taste
Employee Satisfaction	3	1	1	1	6
Customer Satisfaction	9	9	9	9	36
Cost Reduction	3	3	1	1	8
Increased Sales	9	3	3	6	21
Efficient Operations	1	1	1	1	4
Total	25	17	15	18	75

<Table 4> Factorial Design for Fried Pork Chilly Paste

Factors	High Level(+)	Low Level(−)
Cooking utensil	Sauteed Pan	Steam Pot
Amounts of Sesame Oil	20 g	40 g
Amounts of Chilly Powder	None	40 g
Amounts of Garlic	25 g	35 g

example, customer satisfaction has the most important relationship with production control, and service control. Therefore they got 9 points each.

The next step was to drill down the specific food control items with other potential varieties in order to identify the key factors that might lead to "Efficient Operations" in the contract foodservice management.

The food control items were prioritized in a matrix from the project subjects and their priority weights. The analysis was done to determine which food control items would contribute most to the success of the project goals. From this, taste was finally selected for the project's CTQ(Table 3). The scale was also given according to the important level between subjects and food control items.

The most important relationship got 9 points, the moderate relationship got 3 points, and the less important relationship got 1 point. For example, customer satisfaction and increased sales have the most important relationship with taste and it got 9 points. Total points for customer satisfaction with food control items were 36, which was the highest score from the subjects.

Finally we found out the "taste" was the most important process to be improved for the "customer satisfaction and increased sales."

In the Define phase we focused on a customer requirement and identified the project's CTQ. The next step is to decide how best to measure outputs of the process, which is called the project Y, to determine how well it satisfies the customer's requirement. Once the project Y is decided, a performance standard also should be specified to know what constitutes acceptable and unacceptable performance for the project Y. In this research, the definition of the project Y is the consistency of food taste which must meet the best quality.

In order to make a solution for the project Y, we tried to find some causes by using the function of Y equals to f(Xs). The big X contains many of small Xs which composed the big Y. In this research, the big Y is the taste of a certain food item and the small Xs are the group of compositions which made the final taste. In this case, we chose the fried pork chilly paste as a certain food item, and the small Xs are as follows; cooking method(utensils), chilly powder, sesame oils, garlic, chilly paste, aging time.

We chose the main factors, which are the cooking utensil, sesame oil, chilly powder, garlic, and the 2 different test levels to get the 8 kinds of test models(Table 4).

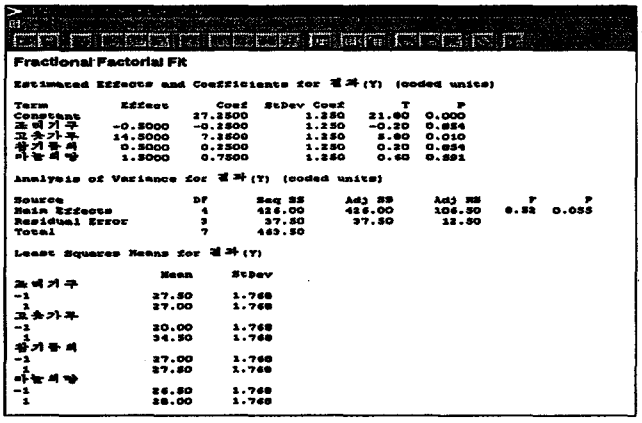
Based on this factorial design for Fried Pork Chilly Paste, the cooking team tested 8 times of the food with different cooking recipes. The results of One Factor at a Time was showed at <Table 5>. In order to get the results, factor A(cooking utensil) set the sauteed pan as (+) and the steam pot as (-). Factor B(chilly powder) set the 20g added

<Table 5> Results of One Factor at a Time(OFAT)

Test	Factor A	Factor B	Factor C	Factor D	Result
1	−	−	−	−	16
2	+	−	−	+	20
3	−	+	−	+	38
4	+	+	−	−	34
5	−	−	+	+	22
6	+	−	+	−	22
7	−	+	+	−	34
8	+	+	+	+	22

as (+) and the non added as (-). Factor C(sesame oil) set the 0.06ml added as (+) and 0.04ml added as (-). Factor D(garlic) set the 2.5g added as (+) and 1.5g added as (-). The numbers of results were from the total scores of pre-approved food evaluators.

<Fig. 1> showed the estimated effects and coefficients for the results of tests. From the analysis, we found that only chilly powder had the significant correlations with the results.


Fractional Factorial Fit

Estimated Effects and Coefficients for 결과(Y) (coded units)

Term	Effect	Coef	StDev Coef	T	P
Constant		27.2500	1.250	21.80	0.000
조미기구	-0.5000	-0.2500	1.250	-0.20	0.854
고춧가루	14.5000	7.2500	1.250	5.80	0.010
참기름의양	0.5000	0.2500	1.250	0.20	0.854
마늘의양	1.5000	0.7500	1.250	0.60	0.591

Analysis of Variance for 결과(Y) (coded units)

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Main Effects	4	426.00	426.00	106.50	8.52	0.055
Residual Error	3	37.50	37.50	12.50		
Total	7	463.50				

Least Squares Means for 결과(Y)

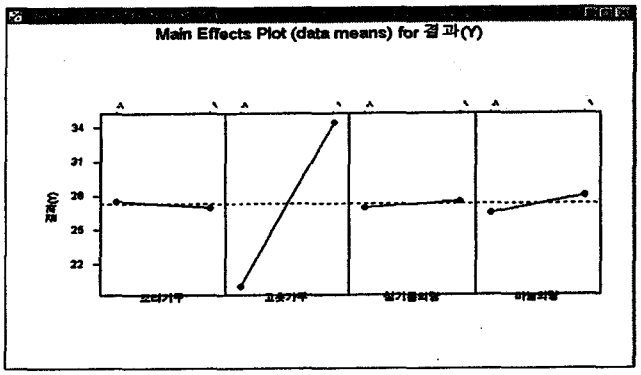
	Mean	StDev
조미기구		
-1	27.50	1.768
1	27.00	1.768
고춧가루		
-1	20.00	1.768
1	34.50	1.768
참기름의양		
-1	27.00	1.768
1	27.50	1.768
마늘의양		
-1	26.50	1.768
1	28.00	1.768

<Fig. 1> Effects and Coefficients for the results

(Effects and Coefficients are significantly different p=0.010, p-value<0.05)

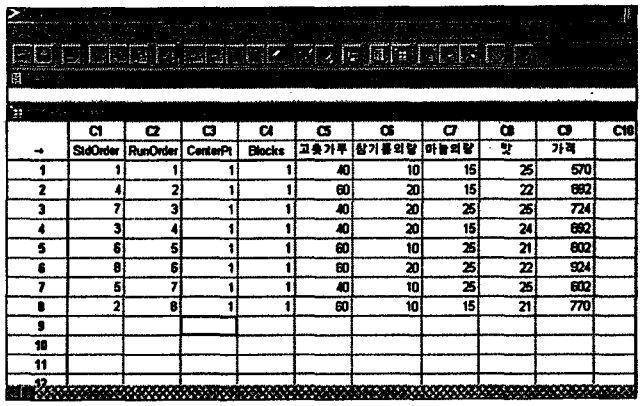
<Fig. 2> also explained the chilly powder showed the only correlations with the results. The other food items showed no significant correlations with the results. Main Effects Plot showed by box plot about any significant correlations with the experimental results.

The results showed that the amounts of chilly powder affected the final taste of the fried pork chilly paste. However, we found that we had to add one more factors to get the best results. It was a cost factor because this research was conducted in the foodservice business environment. Therefore the company should consider



<Fig. 2> Main Effects Plot for the results

both taste and cost for the dual customers, who are internal and external. So we tried to analyze the same tests under the cost factor as shown the <Fig. 3>.



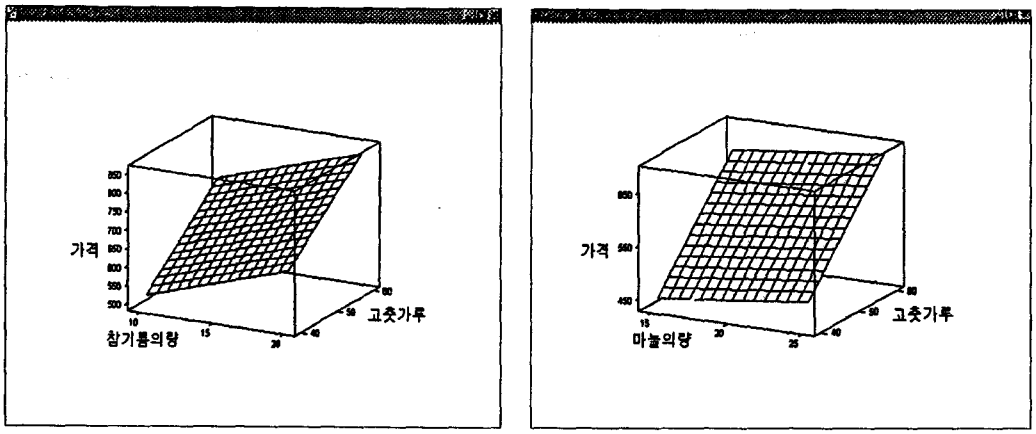
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
→	StdOrder	RunOrder	CenterPt	Blocks	고춧가루	참기름의양	마늘의양	맛	가격	
1	1	1	1	1	40	10	15	25	570	
2	4	2	1	1	60	20	15	22	882	
3	7	3	1	1	40	20	25	25	724	
4	3	4	1	1	40	20	15	24	692	
5	6	5	1	1	60	10	25	21	802	
6	8	6	1	1	60	20	25	22	924	
7	5	7	1	1	40	10	25	25	602	
8	2	8	1	1	60	10	15	21	770	
9										
10										
11										
12										

<Fig. 3> Factorial Correlations for Taste and Cost

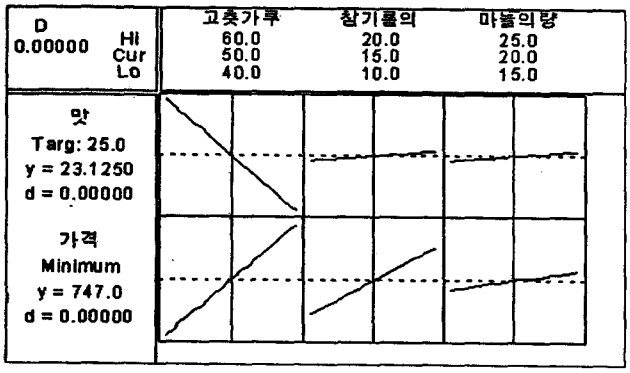
Under the cost criteria, we got the same results with the first trial. As shown the <Fig. 4>, the other factors-sesame oil and garlic- did not give any other main effects to the results than the chilly powder.

The next step is to find the best conditions to meet 2 different conditions, which are the taste and cost factors. To maintain the best score for the taste and the lowest cost, we got the final numbers of each factors for the best results. As shown <Fig. 5>, the target number for the taste was 23.125 and for the cost was 747.0, and the numbers of each factors were as follows; chilly powder 50.0, sesame oil 15.0, and garlic 20.0.

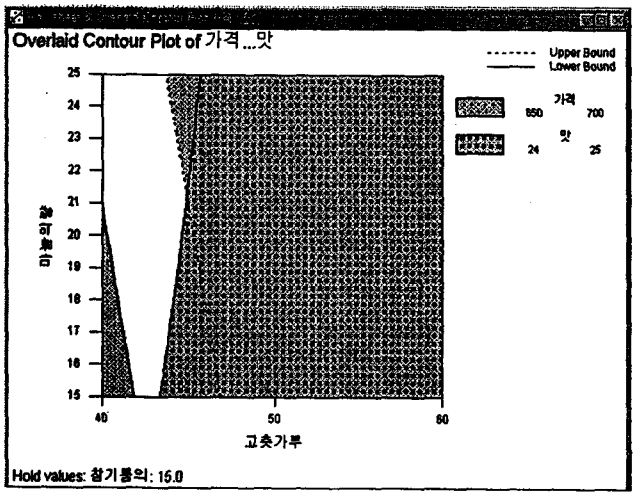
Finally, we got the graphic results as <Fig. 6> which showed the optimized area(white part) in the criteria of cost and taste with the critical factors of garlic and chilly powder. The criteria is the range of the optimized levels of factors for the best taste.



<Fig. 4> Effects and coefficients under the cost factor



<Fig. 5> Optimized factor's levels for the best results



<Fig. 6> Optimized area from the results

IV. CONCLUSION

In the foodservice industry, it has been performed for the food taste to optimize its consistency by using response surface methodology.[15] This study was focused on the real problem-solving procedures, and the business problem was defined, the related data was collected and measured the level of capability, the core causes were statistically found, the best solutions for the problem were suggested.

To make and keep the best quality in the foodservice industry, the critical factors were identified and factorial analysis and levels were tested. Finally, those identified factors were optimized under a certain conditions, which are cost and taste. In this study, we found out what kinds of ingredients were needed and how much of them were required for the best taste of the specific menu item.

Consequently, the benefits and possibilities of implementing Six Sigma to the foodservice industry were partially realized in this study. So far, the earlier studies have mainly focused on the methods about the measuring tools for the service quality and those studies concluded with the results of factors which is significantly important to the service quality. Because there were not enough studies regarding Six Sigma approach even in the foodservice industry, this study suggests the practical implications of Six Sigma technologies for the foodservice industry later.

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