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Value Engineering for Optimization PET Bottle Packaging with Taguchi and SPC (Statistical Process Control) Methods

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***Abstract*: In the cost breakdown structure, the packaging cost of Beverage Tea products has several details, namely PET Bottle, Screw Cap, Shrink label, Carton Box, Ink Cartridge, and Ink Roll. Based on the principle (Value Engineering) that underlies this research is the existence of a large packaging cost phenomenon in PET Bottle Packaging. This research gets Results Factors affecting the stacking strength of PET Bottle Packaging Beverages are the thickness of the body obtained for the optimal level setting, optimal weight and keep performance quality. QLF (Quality Loss Function) value that will describe how quality is maintained but there will be a more efficient and effective cost impact, the Taguchi method is one of the tools used to get design optimization. SPC (Statistical Process Control) for stability of the process and all test processes of this research so that the industrial implications are more actual and applicable.**

***Keywords*: Optimization, Cost, Thickness, Quality Loss Function, Weight, PET Bottle Packaging, Taguchi, Value Engineering, Statistical Process Control, Packaging Material, Industry.**

1. Introduction

The packaging needs to be perceived as a highly important marketing communication tool in communicating the brand message, and has to be utilized to the fullest at the point of purchase in order to attract consumer attention (Cahyorini, A., & Rusfian, E, 2011). There are many FMCG companies that have variety products. The packaging costs have to adjust with the product for packaging optimization (Chuan, Z., & Mingke, J, 2017). Therefore, it needs a method to increasing the cost efficiency with the appropriate standard for packaging optimizing. in a previous research explained that in an effort to reduce the existing packaging cost, some methods carried out by reducing the weight of the plastic that used in the packaging of the product, either in primary or secondary packaging material (Claire, K, 2016). Thin-walled plastic bottles are manufactured by using an injection stretch-blow moulding (ISBM) process, The mechanical properties of the material after the manufacturing process, such as the chain orientation of the polymer molecules, depends on many factors and operating conditions (Irene, V, 2018). The high use of plastic bottles also leads to increased waste and endangers our nature (Mariam, C, 2018). Currently, in the food packaging industry, PET is mainly used for the manufacture of bottles but is also used in the making of films, sheets and trays to a lesser degree (Vijaykrishna, 2016).

In the cost breakdown structure, packaging cost has several details, included PET bottle cost (44,17%), screw cap cost (29,22%), shrink label cost (13,97%), carton box cost (9,90%), ink cartridge cost (0,73%), and ink roll cost (0,50%). The background of this research is the first case that occurs due to increasing packaging cost in Tea Beverage product, that is A product. Polyethylene Terephthalate (PET) is one of the most important and extensively used plastics in the world (Anoop, K., Reddy, R., Sasidhar, C, 2014).

The result of this research can be obtained the factors that affect the stacking strength of PET beverage bottle packaging is the thickness of the bottle body in T1 and T2 section. In the case above, when we will do the efficiency of packaging cost, we also need an appropriate method in the process of improvement from the gap that occurs namely with stability of thickness (Singh, A., & Kansal, R, 2014). Stability of thickness affect the ovalization in chiller and stability of bottle strength when product stacking (Bortolino, S, 2019). The aim is to obtain the optimum setting for determination of CCP (Critical Control Point) at the point of stability of thickness in bottle packaging by using the Value Engineering concept approach from the information-functional-creative-analysis stage with the calculation of Taguchi method then implemented stage with the SPC (Statistical Process Control).

2. Literature

NPD (New Product Development) is very important in creating new products that aim to increase the growth and success of a company (Ruan, 2014). Innovative product development is needed to satisfy various groups of consumers to help maintain the company's market share (Christin, 1997). Consumer ratings are needed to exploit new markets based on preferences knowledge. R&D projects, according to (Barnes, T. A., Pashby, I. R., Gibbons A. M, 2006), can be categorized as a complicated and independent matter. In this context, managing R&D projects is the task of Innovation Management. R&D projects consist of basic research, technology development,

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new product development, prototyping, and technology transfer etc. It develops and involves new ideas, concepts, and techniques (Cooper, R, 2011). To develop new systems or products, R&D staff must encourage the advancement of science and technology (Barrie, D. S., & Paulson, B. C, 1984).

The Cost of Quality (CoQ) model then integrates the proposed approach, a model that is required to understand the overall costs incurred during sampling strategies, as well as the cost impact of the solution proposed (Dobrzanski, L. A., Domagala, J., & Silva, J. F, 2007). This in turn affects the distribution of the bottles wall temperature, thickness, crystallinity and orientation. These distributions are responsible for the final products, mechanical, barrier, optical and orientation properties (Firas, A., & Pavel, D, 2015). Optimising certain bottle properties depends on the bottles final application and its storage conditions (Hung, A, 2014). VE (Value Engineering), Value Engineering comes from the business of Larry Miles and Harry Erlicher. They are considered the fathers of VE. As engineers, they were tasked with obtaining material to produce equipment for military purposes that was difficult to obtain in traditional ways (Crum, L. W, 1971). Then they begin to make specifications about the functions and criteria of the material needed. With a mechanism based on this function, spare parts can be obtained. There are 5 phases in conducting Value Engineering analysis namely the Information Phase, the Creative Phase, the Analysis Phase, the Development and Recommendation Phase (Hutabarat, J. (1995). However, owing to transportation and stacking, the pressure is applied vertically on PET bottle and compressed by an axial force (Hsing, H, 2018). The vertical load is mainly affected due to the failure of bottles supported the statistically check statistics (Harshath, C., Chandan, R., Reddy, V. (2018).

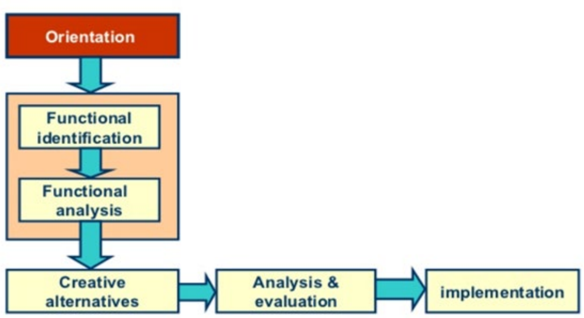

Fig. 1. Value engineering step applications
Source: Value Engineering Steps, Hutabarat 1995

PET Bottle Packaging is a marketing industry technique used to protect, identify and seal consumer products that are distributed or marketed (Brody, 1997). Meanwhile, packaging involves designing and producing the container or wrapper for a product, it means packaging process has the main function is to protect the product so that the product can be maintained for its quality (Kotler and Amstrong, 2012). Taguchi Method is a quality characteristic, that is measured through losses incurred by the public (not just customers) during product use as a result of deviations in product performance from the target value in the design (functional variation), and side effects arising during product use, which are not related to product function. The smaller the loss by society, the higher quality of a product (Irwan Soejanto, 2009). The robust design concept developed by Genichi Taguchi can be used to improve productivity and system performance through a research and development. The purpose of a design in the manufacture of products is to minimize the deviation of the quality characteristics of the target value (Sower, V. E., Quarles, R., Broussard, E, 2007). Quality characteristics (response variables) are interesting objects of the product or process (Belavendram, 1995). Quality characteristics can be grouped according to the target value as follows: nominal-the-best, smaller-the-better, larger-the-better, signed target and classified attribute.

SPC (Statistical Process Control) is a method of measuring, understanding, and monitoring variations in a manufacturing process. According to Wayworld (2001), Statistical Process Control is a methodology of collecting and analyzing quantitative data, then determining and interpreting measurement results that describe processes in an industry, to improve the quality of output to meet customer needs and expectations (Goetch, D.L., & Davis, S, 1994). Process capability is the relationship between natural variations of the process and product design specifications. The process is said to be stable if the value of Cpk and Ppk is> 1.00 or> 1.33 (Kalumire, K. (2011).

3. Methodology

Research design is a framework or plan for conducting studies that will be used as a guide in collecting and analyzing data. This research was designed explorative and descriptively, with each research design having complementary emphases. The use of this quantitative research can produce CCP (Critical Control Point) on PET Bottle Packaging Reliability (Brody, A. L., & Mash, K. S, 1997). The CCP will obtain the weight efficiency of PET Bottle Packaging which can be used after optimization. After that, packaging cost can be reduced so that it will increase the profit margin of the products that produced by the company.

This research methodology will look for problems that occur due to packaging costs, with the main focus of improvement on PET Bottle Packaging (Elena, B., 2017). A method is needed to find the CCP (Critical Control Point) on the PET Bottle Packaging so that it can be more efficient while still paying attention to the existing Packaging Performance with the Taguchi and SPC (Statistical Process Control) methods (Montgomery, C, 1990).

A. Information and Data

The variable of this research is to identify the Packaging Reliability that focuses on the specifications for PET Bottle Packaging (Schiffauerova, A., Thomson, V, 2006). This will determine the method that can be done in doing efficiency by using the concept of Value engineering approach and the Taguchi method used to calculate the value of efficiency (cost savings) that can be obtained. Meanwhile, the indicators used include the categories of Weight of PET Bottle Packaging, Top Load Strength (Kgf) and Thickness of PET Bottle Packaging

Table 1
Description of research variable

Data Type	Population	Sample	Notes
Primary	Result of *Top Load Strength PET Bottle Packaging*	5 pcs bottle samples	Taguchi and confirmation experiments each condition of setting process *Body wall thickness of PET Bottle Packaging*
	(Cp and Cpk) Stability of *Thickness*	Based on: AQL (Acceptance Quality Level) 4.0 GI: C Total size 114 pcs.	
	Variance of *Weight of PET Bottle Packaging*		
Secondary	Result *Top Load Strength PET Bottle Packaging*	Report data taken: 30 data (from data during: 5 months)	Current production data and *Quality Control*. Based on the amount of cavity that is as many as 16 pcs
	(Cp and Cpk) Stability of *Thickness*		
	Variance of *Weight of PET Bottle Packaging*		
	Packaging Material Cost	Finance Report	Packaging Material Cost

Source: Data processed, 2019

(Elena, B, 2017).

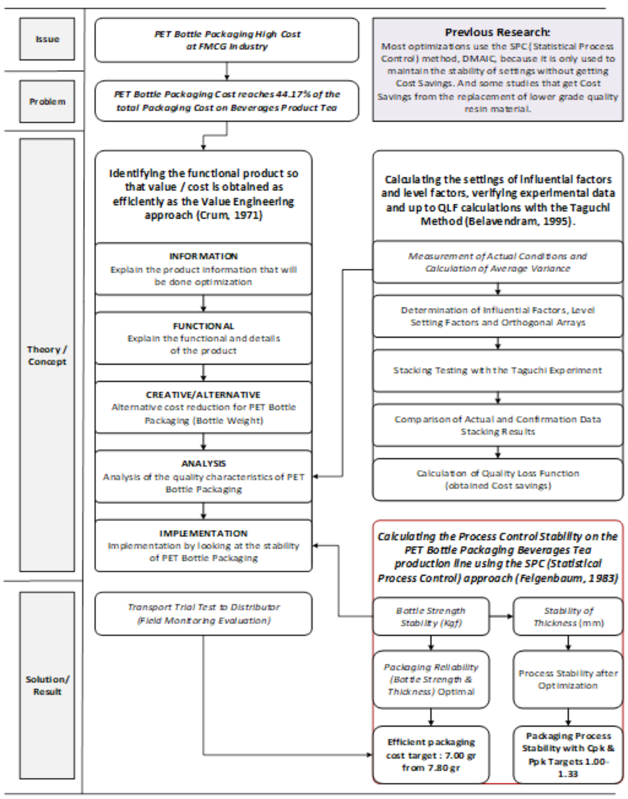

Fig. 2. Research methodology
Source: Research Methodology

B. Value Engineering

1. Information Phase: Describes product information that will be optimized using the Value Engineering approach. It is expected to get an efficient bottle weight without reducing the critical function of the PET Bottle Packaging.
2. Functional Phase: Explains all the details of functions that are the main focus in the production process, so that Value Engineering will be maximized.
3. Creative Phase: Performs the stage where the product will be carried out several alternative cost reductions in the aspects to be addressed because it has the largest percentage (material, process or direct labor cost).
4. Analysis Phase: Tools are used to analyze the quality and loss characteristics with the Taguchi Method.
5. Implementation Phase: The process will be continued with the help of tools that fit the existing problem with SPC (Statistical Process Control) tools, which are used to see the stability of specifications and variations that exist after optimization of the whole process by looking at the value of Cpk and Ppk.

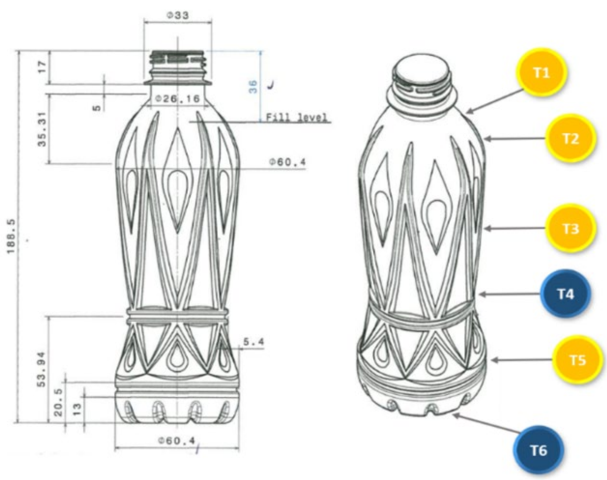

Fig. 3. A Product of tea beverage bottle 330 ml (CCP)
Source: Internal Supplier of PET Bottle Packaging, 2018

4. Data Processing and Analysis Results

A. Information Phase

The data collected in this study includes the identification of quality characteristics, specimen preparation, actual condition data, optimization experimental data and confirmation experimental data.

Table 2
Information stage of tea beverage product

No.	Product Parameter	Description
1	Kind of Product	Tea Beverage 200 ml
2	Packaging Line	Aseptic Line
3	Total Packing	1x24 pcs (carton box)
4	Screw Cap	Long neck PCA 1881
5	Appearance Bottle	Transparent
6	Bottle weight	7,80 gr

Source: Tea Beverage Product Data of FMCG Company, 2019

Table 3
Packaging cost detail of tea beverage product 200 ml

Carton in 24 pcs	A Product (S1)
PET Bottle	44.17%
Screw Cap HDPE	29.22%
Shrink Label	13.97%
Carton Box	9.90%
Hot Melt Glue	1.49%
INK Cartridge	0.73%
INK Roll	0.50%
PM COST	100.00%

Source: A Product of Tea Beverage Finance Report, copyright 2017-2018

B. Functional Phase

Actual Stacking Test, the actual condition data below is the actual condition of the bottle used. This functional phase is the phase where the Top Load Strength (Kgf) value becomes the most important strength of PET Beverage Bottle Packaging.

Table 4
Actual condition data of stacking test

No. Specimen	Weight (gr)	Top Load Strength Mean (Kgf)
1	7.83	20.80
2	7.79	19.20
3	7.82	20.70
4	7.72	18.90
5	7.81	19.40

Source: QA Production Line Lab Report

Table 5
Functional phase of tea beverage product

No.	Parameter Function	Standard
1	Top Load strength	Min. 17 Kgf
2	BCT (Compression Test)	Min. 30 Kgf
3	Chiller tested	No dented
4	Stability of Thickness	Cpk, Ppk : 1.00-1.33
5	Transport Test	No deformation
6	PAT Test	No Leaking
7	Shrinkage Test	No Wrinkle

Source: Tea Beverage Packaging Standard Data of FMCG Company, 2019

C. Creative Phase

At this phase, several alternative cost reduction will be carried out on the product and the referred aspects because it has the largest percentage (material, process or direct labor cost).

Table 6
Creative phase – cost breakdown packaging

No.	Parameter Cost	Value (%)
1	PET Resin & Masterbatch	40
2	Carton Box & Plastic Pack	10
3	Testing dan Inspeksi	5
4	Engineering	5
5	DLOH (Direct Labor Overhead)	15
TOTAL COST		**75**
Estimated Profit Margin (%)		**25**

Source: One of PET Bottle Packaging Data from FMCG Company, 2018

From the information above, this phase focuses on engineering design and improvement with the object of research being PET Resin & Mastebatch because it is related to its use which can later be minimized by regarding the standards that have been set so that quality issues will not arise in the future when large production.

D. Analysis Phase

At this phase, the factors that affect quality characteristics and brainstorming with the company are identified.

Some parts of the bottle have a very important function in the process of use. The parts of the bottle include:

1. *T1*: The thickness of the bottle in this section is critical for the sealing capping process.
2. *T2*: The thickness of the bottle in this section is critical for the filling process.
3. *T3*: The thickness of the bottle in this section is critical in the inflate section at the bottom edge.
4. *T5*: The thickness of the bottle in this section it is critical in the expanding part at the bottom.

Table 7
Measurement of mean and variance value of actual condition results

No. Specimen	Top Load Strength (Kgff)
1	20.80
2	19.20
3	20.70
4	18.90
5	19.40
Mean	**19.80**
Variance	**0.785**

Source: Data Processing

The four parts of the bottle will be obtained which factors or parts that most affect the strength of PET Bottle of Tea Beverages 200 ml that are described in the following table. The design of blow molds, parison and the specification of process parameters are important and it combined of science, art and skill (Ufuk, S, 2017). A small change in die and mold design, die temperature and blow pressure can greatly effect on the molding results, plastic forming behaviour, materials parameters (Suraya, S, 2015).

Table 8
Factors Effect

No.	Controlled Factors
1	*Thickness* T1 (A)
2	*Thickness* T2 (B)
3	*Thickness* T3 (C)
4	*Thickness* T5 (D)

Source: Data Processing

The experiments carried out in this research used three factor level settings that showed high, medium, and low level (Karol, P, 2018). The level settings for the factors involved in the experiment are described in the following table.

Table 9
Assignment of influential factors

No.	Controlled Factors	Level 1 (mm) / *Low*	Level 2 (mm) / *medium*	Level 3 (mm) / *high*
1	*Thickness* T1 (A)	0.45	0.85	1.25
2	*Thickness* T2 (B)	0.55	0.75	0.95
3	*Thickness* T3 (C)	0.45	0.65	0.85
4	*Thickness* T5 (D)	0.85	1.25	1.65

Source: Data Processing

From the data above, obtained standard experiments will be carried out, based on company recommendation of PET Bottle Packaging Tea Beverage 200 ml.

- *Level 1*: Level with the target will be low category.
- *Level 2*: Level with a heavy target including the medium category.
- *Level 3*: Levels with specifications represent the current actual conditions.

The stacking test is carried out in the R&D Packaging Development Laboratory. The data for the Taguchi experiment of 27 replications can be seen in detail in the table 10 and 11.

Table 10
Taguchi experiment result

No.	Controlled Factors				R1 (Kgf)	R2 (Kgf)	R3 (Kgf)
	A	B	C	D			
1	1	1	1	1	18.40	17.30	16.10
2	1	2	2	2	18.10	17.10	17,00
3	1	3	3	3	17.10	19.60	19.80
4	2	1	2	3	19.00	18.90	20.34
5	2	2	3	1	19.80	20.00	20.40
6	2	3	1	2	19.70	20.40	19.10
7	3	1	3	2	20.40	20.00	21.30
8	3	2	1	3	20.40	21.30	20.40
9	3	3	2	1	20.30	19.80	19.95

Source: Data Processing

The mean value and SNR above are then further analyzed using analysis of mean and analysis of signal to noise ratio to find the optimal level settings, namely conditions with high target values and low variance largest to smallest (Verma, J., Agrawal, P., & Bajpai, L, 2012).

Table 12
Response table of mean value of Taguchi experiment

	A	B	C	D
Level 1	17.83	19.08	19.23	19.12
Level 2	19.74	18.39	18.94	19.23
Level 3	20.43	19.53	19.82	19.65
Deviation	2.59	1.14	0.88	0.53
Ranking	1	2	3	4

Source: Data Processing

Response graph for the mean value is illustrated in the figure 4.

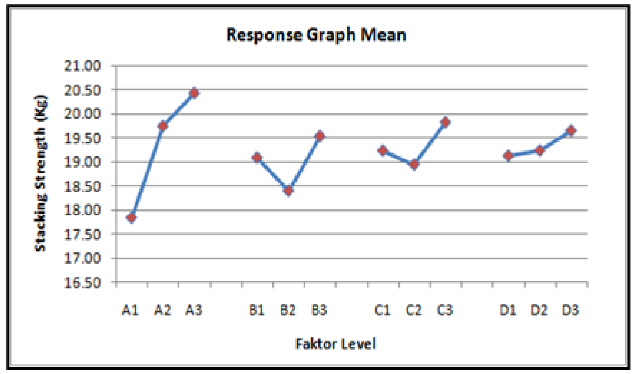

Fig. 4. Response graph of mean value of Taguchi experiment
Source: Data Processing

Based on the graphic, it can be seen that factor A3 has the highest mean stacking strength compared to A1 and A2, the highest factor is B3, the highest factor is C3 and factor D3.

Based on the analysis of variance (mean) table, it is known that factors A and B significantly affect the stacking strength of PET Bottle Packaging Tea Beverage 200 ml. This can be seen from the comparison between the values of the F-ratio with the value of the F-table, if the value of the F-ratio and Mq is greater than the value of the F-table then these factors significantly affect the response variable.

Table 11
Measurement of the mean and SNR value of the Taguchi experiment

No.	Controlled Factors				R1 (Kgf)	R2 (Kgf)	R3 (Kgf)	Mean	SNR
	A	B	C	D					
1	1	1	1	1	18.40	17.30	16.10	17.27	24.71
2	1	2	2	2	18.10	17.10	17,00	17.40	24.80
3	1	3	3	3	17.10	19.60	19.80	18.83	25.44
4	2	1	2	3	19.00	18.90	20.34	19.41	25.75
5	2	2	3	1	19.80	20.00	20.40	20.07	26.05
6	2	3	1	2	19.70	20.40	19.10	19.73	25.89
7	3	1	3	2	20.40	20.00	21.30	20.57	26.25
8	3	2	1	3	20.40	21.30	20.40	20.70	26.31
9	3	3	2	1	20.30	19.80	19.95	20.02	26.03

Source: Data Processing

Table 13
Analysis of variance (mean) before pooling up

Source	Sq	v	Mq	F-ratio	Sq´	rho%	F-table
A	35.60	2	17,80	111.25	35.28	56.49%	3.35
B	12.80	2	7.20	45.00	12.48	19.98%	3.35
C	6.70	2	2.35	8.94	6.38	10.22%	3.35
D	4.50	2	2.25	4.06	4.18	6.70%	3.35
e	2.85	18	0.16	1	4.13	6.61%	
St	62.45	26	2.40		62.45	100.00%	
Mean	10141.87	1					
ST	10088.52	26					

Source: Data Processing

Table 14
Response table for SNR value of Taguchi experiment

	A	B	C	D
Level 1	24.98	25.57	25.64	25.59
Level 2	25.90	25.72	25.52	25.65
Level 3	26.20	25.79	25.93	25.91
Deviation	**1.22**	**0.07**	**0.41**	**0.32**
Ranking	**1**	**4**	**2**	**3**

Source: Data Processing

Response graph for SNR values is explained in the figure 5.

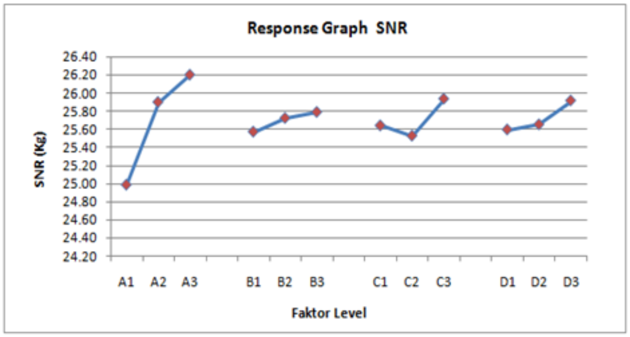

Fig. 5. Response graph for SNR of Taguchi experiment
Source: Data Processing

The value of factor A3 has the highest SNR compared to A1 and A2. Factor B3 has the highest SNR compared to other levels, factor C3 and D3 also have the highest SNR value compared to levels 1 and 2. Quality characteristics optimization uses two stages of the optimization process, namely reducing variance and adjusting targets according to desired specifications. Here is a comparison table of factors effects.

Table 15
Comparison of factor effects

Factor	ŷ	σ	Effect	Use
A	√1	√1	Mean of variance	A3
B	√2	√2	Mean of variance	B3
C	X	X	No effect	C3
D	X	X	No effect	D3

Source: Data Processing

Note: √ Indicates the factor is important and X indicates the factor is not important.

The number next to √ shows the ranking (based on the response table).

In the table above, an optimal combination of factor levels is generated: A3 and B3. From the data above obtained the following data, which is a summary of data that has been analyzed from 5 working days or assumed to work in 1 week. Each day was taken a mean of one data, with a mean of weight and strength of the stacking (after checking).

Table 16
Stacking strength result of Taguchi experiment

No. Specimen	Weight (g)	Stacking Strength (Kgf)
1	7.04	19.5
2	7.07	19.8
3	7.10	20.1
4	7.09	19.9
5	6.98	18.9

Source: R&D Packaging Development Lab Report

Calculation of the mean and variance of the confirmation experiment in the following table:

Table 17
Confirmation experiment result

No. Specimen	Stacking Strength (Kgf)
1	19.5
2	19.8
3	20.1
4	19.9
5	18.9
Mean	**19.64**
Variance	**0.281**
SNR	**25.86**

Source: Data Processing

The optimal conditions of confidence interval are then compared with the confidence interval of the confirmatory experiments, which is illustrated in this graph below.

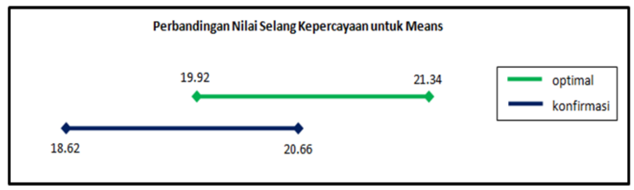

Fig. 6. Comparison of confidence interval value of mean
Source: Data Processing

Whereas the comparison of confidence interval for SNR values is as follows:

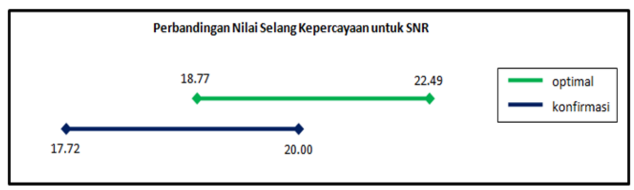

Fig. 7. Comparison of confidence interval value of SNR
Source: Data Processing

The picture above shows the results of the confirmation experiment for the SNR value can be accepted based on the consideration of the confidence interval. Comparison between actual condition experiments and confirmations is explained in the following table.

Table 18
Comparison of initial conditions with confirmation

	Initial	Confirmation
Mean	19.80	19.64
Variance	0.785	0.218

Source: Data Processing

The results of the mean and standard deviation calculation for the actual conditions with optimal conditions are explained in the following table.

Table 19
Total loss of previous conditions and optimal conditions

	Previous	Optimal
Mean	19.80	19.64
Standard Deviation	0.886	0.466

Source: Data Processing

Table 20
Calculation of A_0 actual value

No.	Material Name	(%)	Uses (g)	Price (IDR)	Total (IDR)
1	PET Plastic	98.50%	7.68	109,600	841.73
2	Master Batch (white)	0.50%	0.04	65,000	2.60
3	Material Recycle	1.00%	0.08	1,000	0.08
Total		100%	7,80	-	844.41

Source: Data Processing

Table 21
Calculation of A_0 optimal value

No.	Material Name	(%)	Uses (g)	Price (IDR)	Total (IDR)
1	PET Plastic	98.50%	6.9	109.600	756.24
2	Master Batch (white)	0.50%	0.03	65.000	1.95
3	Material Recycle	1.00%	0.07	1,000	0.07
Total		**100%**	**7**	**-**	**758.26**

Source: Data Processing

The results of the quality loss function in the conditions before and after optimization can be seen clearly in the following table.

Table 22
QLF Value for company

QLF	
Initial	**Optimization**
180.66	162.23

Source: Data Processing

E. Implementation Phase

The implementation phase is the final phase of Value Engineering that very detailed, from information to the concept of design improvement being carried out. The most important thing is how the implementation process of the optimization that has been carried out goes well until the final process so that it can be concluded that the optimization process is stable. In this research, monitoring of the stability of the bottle weight used in the experiment is 24.000 pcs bottles. However, in the measurement only uses 114 samples because there are only 114 pcs of cavity from mold.

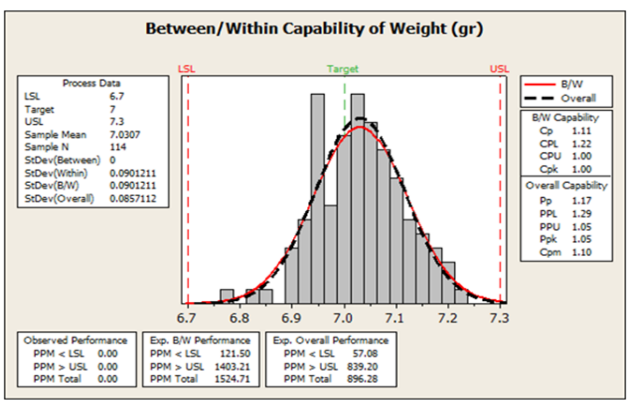

Fig. 8. PET bottle tea beverage 200 ml (7.00 g) weight distribution
Source: Data Processing

From the data above shows that Cpk and Ppk can describe the process quite well that is > 1.00 with a mean of 7.03 g, but it is still not above the standard ie Cpk and Ppk> 1.33. Based on discussions with the Project Team and the decision of the Manager Leader, this will continued to the next step, which is verification of application testing on the production line and transportation test. If all steps are successful it will be checked again from the stability of the PET Bottle Tea Beverage 200 ml weight distribution.

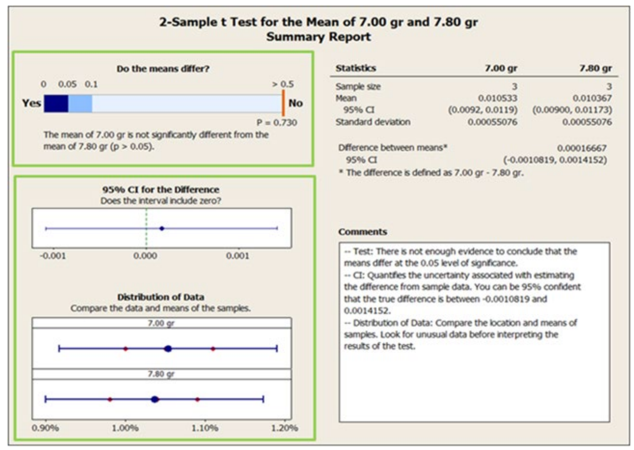

Fig. 9. Comparison analysis of trial and production result
Source: Data Processing

When viewed from the results of comparison of data using Minitab 16.0 with the Sample t-Test for the Mean method, namely by comparing the trial results data with production results, the final result is not significantly different from the existing condition.

Here are the results of the transportation test:

Fig. 10. Loading and unloading process of pet beverages bottle 200 ml
Source: Data Processing

From the results above, it can be concluded that the critical defect was not found at all in the results of sorting from cartons using a stack of 18 and 17 cartons. The conclusion is that verification of the 7.00 g bottle weight can still be achieved well and it is stated that verification of this distribution is successful.

5. Conclusion and Suggestion

A. Conclusion

1. Optimization was successfully carried out by getting the factors that affect the stacking strength of PET Bottle Tea Beverage 200 ml is the thickness of the body part of the T1 and T2 bottle section. The optimal level setting for the T1 (A3) bottle section is 1.25 mm and the T2 (B3) bottle section is 0.95 mm. Obtained optimal level settings with the optimal weight is 7.00 g. From the data, it was found that for bottles with a weight of 7.80 g it had a stacking strength of 19.80 Kgf while a bottle that had been optimized to a weight of 7.00 g had a stacking strength of 19.64 Kgf. It means not significantly difference than before. There is a change of QLF (Quality Loss Function) value from the previous of IDR 180.66 to IDR 162.23 after optimization (confirm). It means the cost reduction of the bottle is around Rp 18.43/pcs. Bottle consumption per month is around 2.500.000 pcs/day, so that it is save the packaging cost of IDR. 46.077.171,05/day or IDR 1.013.697.763,12/month
2. The results of the stabilization of this research were obtained from the transportation test which showed that data could still be accepted if using a stack of 18 cartons. Comparison of rejects in the production line is not significantly difference from the previous bottle, as in the results of the comparison of production for 1 day using a 7.00 g bottle. So, the conclusion from statistics is "Not Significantly Difference from 7.80 g".

B. Suggestion

Control needs to be conducted again and from there it can be seen the Quality Performance of PET Bottle Beverages 200 ml with a weight of 7.00 g in a period of at least 6 months – 12 months.

References

[1] Anoop, K., Reddy, R., Sasidhar, C. (2014). Experimental Investigations on The Flexural Strength of PET Reinforced Concrete. *International Journal of Emerging Technology and Advanced Engineering*. University College of Engineering, 2(4), 233-240.

[2] Barnes, T. A., Pashby, I. R., Gibbons A. M. (2006). Managing collaborative R&D projects development of a practical management tool. *International Journal of Project Management*, (24), 395-404.

[3] Barrie, D. S., & Paulson, B. C. (1984). Professional Construction Management. New York McGraw-Hill.

[4] Belavendram, N. (1995). Quality by Design Taguchi Techniques for Industrial Experimentation. London: Prentice Hall.

[5] Bortolino, S. (2019). Non-contact measurement of the temperature profile of PET preforms. Politecnico di Milano, Dipartimento di Meccanica, Lecco Campus, Via Previati 1/C, 23900 Lecco, Italy.

[6] Brody, A. L., & Mash, K. S. (1997). *The Wiley Encyclopedia of Packaging Technology*, 2nd Edition, John Wiley & Sons, Inc., New York, NY.

[7] Cahyorini, A., & Rusfian, E. (2011). The Effect of Packaging Design on Impulsive Buying, *Journal of Administrative Science & Organization*, 18(1), 11-21.

[8] Chuan, Z., & Mingke, J. (2017). Data Mining with Clustering Algorithms to Reduce Packaging Costs: A Case Study. Journal of John Wiley & Sons, Ltd. Packaging. Technol. Sci. 2017. Technology and Business University, Beijing, China.

[9] Christin (1997). PDMA handbook of new product development. John Wiley & Sons, US Press.

[10] Claire, K. (2016). Reducing the cost of food packaging food technology.

[11] Cooper, R. (2011), Winning at New Products: Accelerating the Process from Idea to Launch, (3rd ed), Perseus Publishing.

[12] Crum, L. W. (1971). Value Engineering the Organised Search for Value, Longman Group Limited.

[13] Dobrzanski, L. A., Domagala, J., & Silva, J. F. (2007). Application of Taguchi Method in the Optimisation of Filament Winding of Thermoplastic Composites. *Archives of Materials Science and Engineering*, 28(3), 133 140.

[14] Elena, B. (2017). Towards a bottle weight reduction - Evaluation in a selected milk plant in the United Kingdom. Division Of Packaging Logistics. Department Of Design Sciences Faculty of Engineering.

[15] Feigenbaum, A. (1983). Total Quality Control 3rd edition. USA: McGraw-Hill, Inc.

[16] Feigenbaum. (1992). Kendali Mutu Terpadu, Edisi Ketiga, Penerbit Erlangga.

[17] Firas, A., & Pavel, D. (2015). Statistical models for optimisation of properties ofbottles produced using blends of reactive extruded. RMIT University, Science, Engineering and Technology Portfolio. Australia.

[18] Goetch, D.L., & Davis, S, (1994). Introduction to Total Quality, Quality, Productivity, Competitiveness, Englewood Cliffs, NJ, Prentice Hall International Inc.

[19] Harshath, C., Chandan, R., Reddy, V. (2018). Buckling Evaluation of a Plastic Bottle Design. *International Research Journal of Engineering and Technology*. 5(10), Institute of Technology, Bengaluru.

[20] Hutabarat, J. (1995). Diktat Rekayasa Nilai (Value Engineering). Malang: Institut Teknologi Nasional.

[21] Hung, A. (2014). Structural Optimization of PET Bottle by Numerical Simulation. International Conference on Mechanical Engineering. Ho Chi Minh City University of Technology.

[22] Hsing, H. (2018). Design and Simulation Analysis of Lightweight HDPE Milk Bottle. Department of Vehicle Engineering, National Pingtung University of Science and Technology, Pingtung, Taiwan.

[23] Irene, V. (2018). Assessment of The Mechanical Properties of PET Polymer Material from Recovered Plastic Bottles. PESD, 1(12), University College Dublin.

[24] Kalumire, K. (2011). Investigating The Compressive Strength of Plastic Bottles as Masonry. A report submitted in part requirement for the degree of Bachelor of Environmental Design with Honours. Uganda University.

[25] Karol, P. (2018). Comparison of Bottle Wall Thickness Distribution Obtain in Real Manufacturing Conditions and in Ansys Polyflow Simulation Environment. Bydgoszcz University of Technology and Agriculture.

[26] Mariam, C. (2018). An Investigation on the Strength Development of Concrete Reinforced with PET Bottles. SSRG International Journal of Civil Engineering.

[27] Journal. ISSN: 1411-4348. Fakultas Teknik, Program Studi Teknik Mesin.

[28] Montgomery, C. (1990). Pengantar Pengendalian Kualitas Statistik. Gadjah Mada University Press. Yogyakarta.

[29] Schiffauerova, A., Thomson, V., (2006). A review of research on cost of quality models and best practices. *International Journal of Quality Reliability and Management*, 23, 647– 669.

[30] Singh, A., & Kansal, R. (2014). PET Bottles as Sustainable Building Material: A Step Towards Green Building Construction. *Journal of Civil Engineering and Environmental Technology*, 06, 1-3.

[31] Sower, V. E., Quarles, R., Broussard, E. (2007). Cost of quality usage and its relationship to quality system maturity. *International Journal of Quality Reliability and Management*. 24, 121–140.

[32] Suraya, S. (2015). Simulation on the Effect of Bottle Wall Thickness Distribution using Blow Moulding Technique. I*OP Conf. Series: Materials Science and Engineering*.

[33] Ufuk, S. (2017). An Image Processing Application to Detect Faulty Bottle Packaging, IEEE, Department of Computer Engineering Istanbul Commerce University.

[34] Verma, J., Agrawal, P., & Bajpai, L. (2012). Turning Parameter Optimization for Surface Roughness of ASTM A242 Type-1 Alloys Steel by Taguchi Method. *International Journal of Advances in Engineering & Technology*, 3(1), 255-261.

[35] Vijaykrishna. (2016). PET bottles seal quality testing using an on-line pressure differential detector. Department of Food Science and Technology, Ohio State University.