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# Quality and Packaging Analysis of Fresh Strawberry (*Fragaria* Sp) During Storage in Controlled Environment

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**Abstract:** Strawberry fruit (Fragaria sp) is highly perishable fruit fast deteriorate of their quality in tropical conditions and common technique to delay their senescence process was stored in controlled environment. Strawberry fruit in Indonesia generally packaged using plastic to easy handling of strawberry fruit and also to maintain their quality from physical damage. However, the effect of this plastic packaging on quality of the strawberry fruit is often neglected. The strawberry from supermarket in Yogyakarta was chosen from the first day, then continue to store in controlled environment using temperature at 4°C and 10°C with RH varied between 85-95% in a laboratory. Quality parameters of the strawberry were measured, such as water content, pH as acidity indicator, texture of the skin, color of the skin, and total plate count test. Taguchi Method was applied to determine the most appropriate plastics packaging that used for maintaining quality of fresh strawberry. Our results showed, strawberry fruit have shelf-life around 7 days at controlled environment. Water content, acidity and texture of the strawberry can be maintained their quality during storage in controlled temperature conditions. Best combination using Taguchi Methods in plastics packaging of strawberry with plastic are using 10 $cm^2$ plastic holes, none of the use of carton paperboard, not to wash strawberry before being pack , using plastic packaging size (15,8 x10x3,8) $cm^3$, 18 strawberry fruits per packaging, 4°C showcase temperature and tight packaging conditions.

**Keywords:** controlled environment, packaging, quality, strawberry, tropical conditions

## 1. Introduction

Strawberry (*Fragaria sp*) is non-climacteric fruit which has an attractive appearance due to its conical shape fruit and striking red colour. Strawberry has a potential prospect to develop as a fresh or processed food in Indonesia because many consumers like this kind of fruit and there are so many foods which use strawberry as its ingredients. Strawberries grown in Indonesia have many varieties such us Sweet Charlie (from the United States), Oso Grande (from California), Tristar (West America), Nyoho (from Japan and South Korea), Hokowaze (Northen Japanese), Rosa Linda (from Florida), Chandler (from California) . Those varieties have been cultivated in Indonesia especially in the plateau areas as Lembang, Cianjur, Cipanas and Sukabumi (West Java), Batu and Situbondo (East Java), Magelang and Purbalingga (Central Java), Bedugul (Bali), and Brastagi (North Sumatra, also with other varieties of Osogrande in Purbalingga, Central Java, Selva in Karanganyar, Earlibrite (Holibert) in Garut and Bandung Ciwidey, Rosa Linda, Sweet Charlie, Aerut and Camarosa in Bedugul Bali, Dorit, Lokal Brastagi and California in Brastagi,Chandler in Bondowoso PTPN XII, Lokal Batu in Batu, Malang [1].

However, development strawberries in Indonesia still have some problems, especially during the post-harvest handling from farmer or wholesaler during distribution, which can lead into faster decay of strawberries and become rotten. Post-harvest handling of strawberry fruit must be done properly

and should not be arbitrary because it has different characteristics to another fruit . Several parameters of strawberry are important to maintain their quality during their postharvest handling. According to [2] water content is the largest part in strawberry fruit which is for about 92 g water per 100 g strawberry, and other substantials content of strawberries are protein, total lipids, carbohydrates, fiber, and ash. [3] shown that there are two notions of maturity of fruits and vegetables which are physiologically mature and commercially mature. Physiologically mature means that fruit has reached exact levels of growth and development. Meanwhile, commercially mature is the current state of the commodity which reach desired quality of the market. Quality parameters that can be used as a basis for determining the maturity of fruit [4]. Previous experiment for storage of local strawberry from West Java Indonesia as a tropical conditions in were strongly recommended to store in controlled environments with lower temperature conditions, to extend their shelf life and maintain their quality [5].

Tropical storage conditions greatly affected shelf life of strawberries during postharvest, storage, distribution or display in the modern supermarket or traditional market. In addition, the condition of packaging also affected strawberries shelf life because packaging material will have direct contact to the fruit. In retail market of Indonesia, strawberries is packed using plastic from polyethylene terephthalate (PET) . Packaging is useful to facilitate the handling of fresh strawberries that have been harvested. Packaging can help and prevent or reduce damage and protect the inner materials from pollution and physical disturbance like friction, shock, or vibration and also their used to simplify the process of handling fresh strawberries. In terms of marketing view and promotional objective, packaging may serves as an incentive or attraction to the buyers [6]. However, the influence of packaging on the physical, chemical, and biological conditions of fresh strawberries have less attention especially effects on quality of strawberry during their display and storage in the market.

Furthermore, Taguchi method was used to determine the most appropriate setting of the PET strawberries packaging based on principled on quality improvement by reducing variations without eliminating the cause. Taguchi Method suitable to be applied in this research because it is one of the tool for a quality improvement with principle to minimize the effect of variation without eliminating its cause.It can be obtained through the optimization of the design of products and processes to make the performance robust to various causes of variation in a process called parameters design [7] Taguchi method is a methodology for engineers or improve productivity during the research and development so that high quality products can be produced quickly and at low cost.

Objectives of this research was to determine the effect of packaging on the quality of fresh strawberries in accordance with storage temperature in controlled environment and the best setting of the combination between several types of packaging which is storage in tropical environmental conditions.

## 2. Materials and Methods

### *2.1 Plant Materials*

Local fresh strawberry (*Fragaria, sp* cv Holibert) were obtained from a local farm in Dusun Barudua, Malangbong District, Garut Regency, West Java Province, and fruits were transported under ambient temperature conditions (25-30 ◦C) within 12 h after harvest to reseller or fruit distributor in Yogyakarta using train. In fruit distributor, these fruits were divided into two groups, first group for traditional market and second group for modern market in Yogyakarta, usually based on their size. Strawberry were wrapped with 0.7 mm plastic polyethylene terephthalate (PET).

### *2.2. Measurement Quality Parameter of Strawberry*

Quality evaluation of fresh strawberry fruit were measured based on their physical and nutritional characteristics. For physical evaluation, , texture of skin strawberry fruit as a fruit firmness was determined using a texture analyzer (UTM, Model Zwick Tipe DO FB0 5TS, Germany) and then color of strawberry fruit (fruit surface color) was measured using a chromameter (Minolta, CR-400, Japan)

and expressed on L-a-b value (dark to light, on a scale of 0–100). All of physical measurements were evaluated and the average data from 7 samples for each measurement were used with triplicates. For nutritional evaluation, water content was evaluated using a thermogravimetri method, acidity of fruits was measured using value of pH, then simple microbial evaluation was also measured using Total Plate Count (TPC ) method. All of nutritional measurements were evaluated and the average data from 7 samples for each measurement were used with triplicates. Data obtained from the experiment results were tabulated and calculated using Microsoft Excel 2007 (Microsoft Corporation). Further statistical analysis utilized SPSS version 14.0 (SPSS Incorporation) to obtain optimum treatments and significance of the obtained results through analysis of variance (ANOVA) and LSD interpretations.

### *2.3. Taguchi Method Application*

In this experiment, Taguchi Method was chosen because of its excellence and more structured than the conventional statistical methods.This method have several step, where several quality parameter of the process or product related to the control factors and noise were analyzed. Principle design strategy of the design parameter were determined through the best value of control factor, which is able to minimize the sensitive function process for all noise factors [7-8]. The following are the common steps of Taguchi Method using four phase (Figure 1).

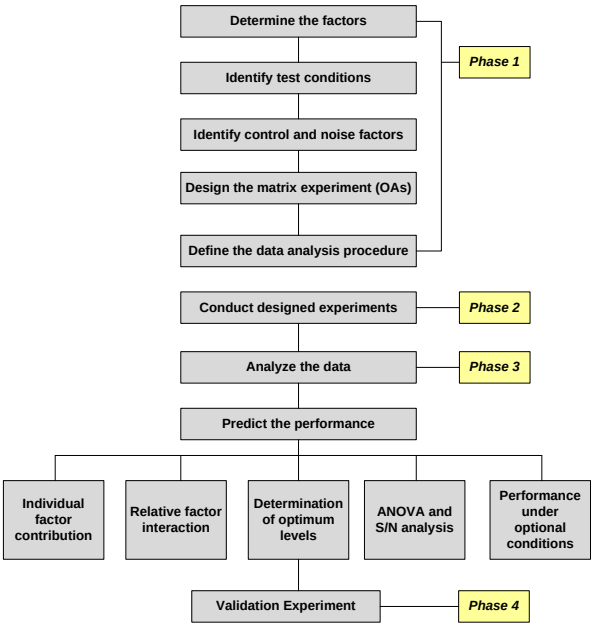


**Figure 1.** Steps of Taguchi Method Approach [9]

In this experiment, we use similar phase, firstly determination the factors, as show in the table 1, then next step is determine Signal to Noise Ratio (SNR). There are three types of Signal to Noise Ratio according to the parameter used to define strawberry quality characteristic, smaller the better, nominal the best and larger the better. In this research orthogonal array $L_8(2^7)$ is used because of its ability to reduce the number of experiments significantly and a large number of decision variable can be learned through the minimum experiments so that it become more effective. Then, two-way analysis of variance (ANOVA) is used to able for outline and calculate the total variance into factor variance so the contribution of each factor to the total variance will be known. The last step is analysis of multi-response characteristic with validation of experiment.

**Table 1.** Controlled Factors and Levels of Taguchi Method Approach

| | Controlled Factors | Level | |
|---|---|---|---|
| | | **1** | **2** |
| A | The width of the air holes surface of the packaging | 10 $cm^2$ | 2 $cm^2$ |
| B | Temperature of showcase | 4°C | 10°C |
| C | Tightness of packaging | Not tight | Tight |
| D | The numbers of strawberries/package | 15 fruits | 18 fruits |
| E | Pretreatment fruit storage | Fruit do not need to be washed | Fruit need to be washed |
| F | PET packaging size | (15,8x10x3,8) cm | (13,8x7,5x) cm |
| G | The use of bottom cardboard | In use | Not in use |

In this experiment, it can define and conduct eight different experiment based on the controlled factor and level using taguchi method for orthogonal array. This orthogonal array for the experiment can be found in the table 2.

**Tabel 2.** Orthogonal Array of controlled factors and experiments for Taguchi Methods

| | Controlled factors | Experiment Number | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| A | The width of the air holes surface of the packaging | 10 $cm^2$ | 10 $cm^2$ | 10 $cm^2$ | 10 $cm^2$ | 2 $cm^2$ | 2 $cm^2$ | 2 $cm^2$ | 2 $cm^2$ |
| B | Temperature of showcase | 4°C | 4°C | 10°C | 10°C | 4°C | 4°C | 10°C | 10°C |
| C | Tightness of packaging | Not Tight | Not Tight | Tight | Tight | Tight | Tight | Not Tight | Not Tight |
| D | The numbers of strawberries/package | 15 | 18 | 15 | 18 | 15 | 18 | 15 | 18 |
| E | Pretreatment fruit storage | Fruit do not need to be washed | Fruit need to be washed | Fruit do not need to be washed | Fruit need to be washed | Fruit need to be washed | Fruit do not need to be washed | Fruit need to be washed | Fruit do not need to be washed |
| F | PET packaging size | (15x8x3) cm | (12x8x3) cm | (12x8x3) cm | (15x8x3) cm | (15x8x3) cm | (12x8x3) cm | (12x8x3) cm | (15x8x3) cm |
| G | The use of bottom cardboard | In use | Not in use | Not in use | In use | Not in use | In use | In use | Not in use |

According to author [10], the optimal storage temperature for fresh strawberries is 0oC with relative humidity or RH of 90-95%, they will be able to survive for 5-7 days of storage. Strawberries for daily consumption were stored at a temperature of 2-3oC, and the recommended temperature for storage of strawberries on showcase maximum is 4.4$^{o}$C . However, if it is stored in the large number of the best temperature is below 4.4$^{o}$C or temperature ranges between 2-3$^{o}$ C. Unfortunately, the survey showed that storage temperature for fresh strawberries supermarkets in Yogyakarta Indonesia, showcase in the range of 0$^{o}$C to 10$^{o}$C that was used to display strawberry in the modern market and without temperature controlled for traditional market with ambient temperature in the range of 26-30$^{o}$C.

*3.1. Quality Parameters of Fresh Strawberry in Controlled Temperature Storage*

In the this study, the storage temperature was used is 4$^{o}$C according to modern market temperature and 10$^{o}$C according to fresh fruit seller in the street. During temperature at 4$^{o}$C, strawberries have a longer shelf life than the temperature of 10$^{o}$C and several microbes like fungus or mold will be slower to grow at 4$^{o}$C. According author [11] when the fruit storage temperature increased from 0$^{o}$C to 10$^{o}$C , the fruit will rot faster 2 to 4 fold, it means that the strawberries were stored at a temperature of 20$^{o}$C only has a ¼ or ½ life of fruit stored at 0$^{o}$C and if stored at a temperature of 30$^{o}$C berries will last only a few hours so it only has a short shelf life. In this experiments strawberry's shelf life is 3 days at ambient room temperature (26-30$^{o}$C) and it will extended to 7 days in lower temperature storage conditions.

Table 3 show the average value of the quality characteristics of strawberry fruit during storage for 7 days. We can find that water content, the experimental results showed that the water content has a downward trend, with average about 91-92%, and similar with author [2] which said that the water content of strawberries is 92% as common. pH value of strawberries ranged 3,4 – 3,8, this indicated that the local fresh strawberry have a high acidity value. At 100 grams dry weight of oranges contained 32 mg of vitamin C, while the strawberries contained 53 mg of vitamin C [12].

Table 3. Quality Parameter of Fresh Strawberry Using Plastics Packaging for 7 Days

| No. | Quality Parameter | Exp 1 | Exp 2 | Exp 5 | Exp 6 | Ex K4 | Exp 3 | Exp 4 | Exp 7 | Exp 8 | Exp K10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Water Content (%) | 91,1 ± 0,9 | 91,2 ±1,2 | 91,5 ±0,5 | 91,2 ±0,9 | 91,4 ±0,7 | 91,0 ± 0,8 | 90,3±0,8 | 91,0±0,7 | 91,3±0,7 | 90,8±0,9 |
| 2. | pH | 3,57± 0,09 | 3,61± 0,06 | 3,67± 0,11 | 3,71± 0,12 | 3,71± 0,11 | 3,65± 0,08 | 3,66± 0,09 | 3,70± 0,15 | 3,72± 0,13 | 3,47± 0,1 |
| 3. | Texture (N) | 16,61±2,2 | 17,53±2,4 | 17,44±4,3 | 17,34±3,4 | 17,14±3,2 | 18,74±3,3 | 18,36±3,6 | 17,59±2,8 | 18,57±3,5 | 18,43±2,6 |
| 4. | Color (L) | 27,27±2,1 | 27,32±2,5 | 26,71±3,0 | 28,95±1,8 | 28,09±2,1 | 28,60±1,1 | 27,21±0,9 | 26,73±1,6 | 27,48±1,9 | 28,75±2,1 |
| 5. | Color (a) | 23,21±3,9 | 21,79±2,7 | 22,66±4,8 | 24,66±2,7 | 24,61±2,8 | 23,11±1,5 | 22,54±2,6 | 21,79±1,6 | 23,32±3,1 | 24,41±2,3 |
| 6. | Color (b) | 12,06±1,8 | 12,43±2,5 | 12,11±2,7 | 13,65±1,5 | 12,96±1,3 | 12,98±0,9 | 11,83±1,3 | 11,49±1,1 | 11,97±1,5 | 13,19±1,7 |
| 7. | TPC (x 10-3 cfu/g) | 101 | 59 | 103 | 124 | 46 | 80 | 75 | 118 | 69 | 5 |

Texture of the skin of strawberry that storage at lower temperature were changed gradually and appeared to be dried and wrinkle due to the ripening and senescense process. Lightness (L), Redness (a), and Yellowness (b) as a color indicator of the strawberries skin were also changed . TPC which measure the number of living microbes in the fruit at the 7th day after storage were varied depend on the treatments. Diseases that often attacks strawberry fruit are gray mold caused by the fungus *Botrytis cinerea*, rotten fruit by the fungus *Colletotrichum fragariae*, white fungal mycelium infection caused by the spores of the fungus Rhizopus stolonifer black [13] . In this study a lot of decay caused by *Rhizopus* sp. and *Botrytis cinerea* that was appeared on 8th day then this indicated that the strawberries can not be eaten.

### *3.2. Taguchi Method Approach for Selection of Packaging Strawberry*

#### 3.2.1. Result of MEAN and SNR Calculation

Data mean shows the mean response for each sample strawberries experiment of each quality attribute parameter. Data for the calculation of mean taken from the last day of the experiment which was the 7th day. The reason why the data taken at the 7th was due on the day which began to be found indications of rotten strawberries and also the fungus began to grow on the surface of a strawberry fruit at the 7th day so it did not proper to be saved anymore. Showcase strawberries at 4°C looked fresher than strawberries at a temperature of 10 °C. Decreasing value in fruit quality due to decay processes that occur was mentioned in the table 1 above. Decreasing water content causes strawberries to shrivel due to water loss. Strawberries pH difference was not much different from the first day, but showed an upward trend in the past seven days of storage. Strawberry fruit texture textured tight at the beginning of storage, but then became mushy and the texture increasingly diminished because of the bumping or shaking when strawberries were transported or moved into another storage. Another quality attributes such as color brightness or lightness (L) went down because the skin color of strawberry fruit was getting dark. Similarly happened to attribute redness (a) and yellowness (b) that were getting decline every day. For the quality attribute change of the color (△E) showed an increasing trend due to the differences that became more visible from the first day of strawberries until the last day when the strawberries were stored.

In addition, each quality parameters of strawberries Mean and the SNR calculation of the strawberries were water content, pH, texture, color (L, a, b, △E). Then the value of calculation for Mean and SNR can be known through the Mean and SNR predetermined formula which was larger the better, nominal the best, or the smaller the better. Furthermore, also can be known the value of the factor effects from the calculation of the formula given .

#### 3.2.2. Analysis of MEAN Factor Effect and SNR Factor Effect

Analysis of MEAN Factor Effect and SNR Factor Effect are used to calculate how much each factor that has been determined before influenced the quality parameters. In the analysis of taguchi effect factor with taguchi L8 orthogonal matrix will be known effect of seven factors that shown in the table 4.

Table 4 show analysis of MEAN Factor Effect and SNR Factor Effect . It can be seen that the effects of factors that most influence the MEAN of fresh strawberries water content was G factor with difference value or effect factor value of 0,50152. Based on the calculation it can be seen that the best combination of water for MEAN's calculation was G1, A2, D1, E2, B1, F2, C2. Meanwhile, the best combination for SNR's calculation of water content was G1, D1, E1, F1, A2, B1, and C1. Then, Taguchi's quality characteristics response used is nominal the best for water content. pH of the strawberry can be identified as acidity level of the strawberry product that influence quality of fresh strawberries. From the Figure known that the best combination for the calculation of MEAN factor effect was E1, D2, F1, A2, G1, C1, and B2. For SNR factor effect, the best combination was E1, D2, F1, A2, G1, C1, and B2. Taguchi's quality characteristics response used is larger the better for pH. Other quality parameter is a texture of the skin of strawberry. For skin texture the most influential factor was G factor with difference

2,80250 for MEAN factor effect and SNR factor effect can be discovered that the most influential or the biggest influence come from G factor with difference vaue of 0,19030 and the least value come from C factor with difference value of 0,06222. The best combination for MEAN factor effect of texture quality parameter for fresh strawberries was G2, D2, E2, A2, F2, C2, and B2 while the best combination for SNR factor effect was G2, D2, E2, A2, B2, F2, and C2, based on the calculation skin texture of the strawberry used is larger the better.

The next quality parameter is color and the first color parameter atribute is lightness (L), redness (a) and yellowness (b) . Taguchi's quality characteristics response used is larger the better for lightness (L), redness (a) and yellowness (b). Another color response observed was change of color (△E) which is the combination of the previous three color atribute (L, a, b). The figure showed that the biggest MEAN factor effect was 12,45651 reached by G factor. Besides, the smallest MEAN factor effect was 0,64273 reached by F factor. This difference was bigger rather than another quality response. Meanwhile, for SNR factor effect G factor reached the biggest difference value which was 0,89829. The smallest effect for SNR was D factor with difference value of 0,04800.Graph ilustration showed that the best combination for quality parameter change of color (△E) in MEAN factor effect was G2, B2, E2, C2, A1, D2, and F2 while best combination for SNR factor effect was G2, B2, A1, C2, E2, F2, and D2. Taguchi's quality characteristics response used is smaller the better which is the opposite of L, a, b color atribute because △E is combinated parameter.

Total Plate Count or TPC is the last quality parameter for this research. From the figure can be known that the most dominant MEAN factor effect was reached by G factor while the least effect comes from E factor, with difference value of 26,5 and 4,66667 respectively. Those two values had wide range because of the big difference of colony forming unit for microbes in petridish in the 0-day until 7-day. Moreover, the best combination for SNR factor effect was G2, D2, A1, B2, C1, E2, and F1 and Taguchi's quality characteristics response used is smaller the better.

**Table 4.** Analysis of MEAN Factor Effect and SNR Factor Effect

| No. | Quality Parameter | MEAN Factor Effect | | SNR Factor Effect | | Best Combination (Mean, SNR) |
|---|---|---|---|---|---|---|
| | | Max | Min | Max | Min | |
| 1. | Water Content | G: 0,50152 | C: 0,00099 | G: 0,30227 | C: 0,04213 | G1,A2,D1,E2,B1,F2,C2<br>G1,D1,E1,F1,A2,B1,C1 |
| 2. | pH | E: 0,04167 | B: 0,02167 | E: 0,00988 | C: 0,00553 | E1,D2,F1,A2,G1,C1,B2<br>E1,D2,F1,A2,G1,C1,B2 |
| 3. | Texture | G: 2,80250 | B: 0,89417 | G: 0,19030 | C: 0,06222 | G2,D2,E2,A2,F2,C2,B2<br>G2,D2,E2,A2, B2,F2,C2 |
| 4. | Color (L) | C: 2,00333 | D: 0,35 | C: 0,06694 | B: 0,01069 | C2,G2,F2,A2,E2, B1,D2<br>C2,G2,F2,A2,E2,D2,B1 |
| 5. | Color (a) | E: 3,93333 | D: 0,84667 | E: 0,15950 | D: 0,01587 | E2,A2,F2,G2,C2,B1,D1<br>E2,F2,A2,C2,G2,B1,D1 |
| 6. | Color (b) | C: 1,57500 | D: 0,09833 | C: 0,11850 | D: 0,00409 | C2,G2,F2,B1,A2,E2,D1<br>C2,F2,G2,B1,A2,E2,D1 |
| 7. | Color (△E) | G: 12,45651 | F: 0,64273 | G: 0,89829 | D: 0,04800 | G2,B2,E2,C2,A1,D2,F2<br>G2,B2,A1,C2,E2,F2,D2 |
| 8. | TPC | G: 26,5 | E: 4,66667 | G: 0,26528 | F: 0,03707 | G2,A1,D2,B2,C1,F1,E2<br>G2,D2,A1,B2,C1,E2,F1 |

Based on the calculation of the effect of these factors can be seen the best combination of factors and levels from every quality parameter of fresh strawberries experiments that have been done. The greater the value of effect factors indicate the greater influence to the sample. Best combination showed that between mean and SNR level have factors sequence which almost identical on every quality attribute of parameter.

*3.3. Result Comparison of Each Parameter Analysis*

The order of best combination of factors and level can be known for every fresh strawberry fruit quality parameters which is water content, pH, texture, color (L, a and b), and TPC were compare each other. Calculation results indicate that the effect of factors and levels of factors that affect the quality of each parameter mostly have the same level between the analysis of factor effect for Mean and SNR. However, there are differences in sequence between one factor to another. This sequence shows that there are differences in the influence of the average (mean) and also the influence of signal to noise ratio.

*3.4. Analysis of Variance (ANOVA)*

Based on the calculation using analysis of variance, to determine which is the large contributions of the factor for each quality parameter. The largest contribution of fresh strawberries for water content quality parameter was the factor G with contribution of 7,432%. Greatest contribution for the fruit pH quality parameter was factor E which was with value of 24,462% and texture quality parameters indicated by factor G had value of 19,238%. For parameter of fruit brightness or lightness the biggest contribution was the factor C with contribution of 29,126%. The largest contribution for the redness (a) color parameter was the E factor with value of 20,783%. Contribution of yellowness (b) color parameter and change of color (△E) was factor C 18,472% and factor G by 7,003% respectively. Meanwhile, the last but not least quality parameter TPC had the largest contribution by factor G with percentage as much as 13,157%.

*3.5. Multi Response Characteristic Analysis*

**Table 5.** Priority Factor for Fresh Strawberry Fruits According to Multi Response's Calculation

| | Controlled Factors | Level 1 | Level 2 | Difference | Rank |
|---|---|---|---|---|---|
| A | Width of the air holes surface of packaging | -2,01021 | -2,16714 | 0,15693 | 1 |
| B | Temperature of showcase | -2,04553 | -2,13181 | 0,08628 | 6 |
| C | Tightness of packaging | -2,13161 | -2,04573 | 0,08588 | 7 |
| D | The numbers of strawberries/package | -2,13713 | -2,04021 | 0,09692 | 5 |
| E | Pretreatment fruit storage | -2,02317 | -2,15417 | 0,13099 | 3 |
| F | PET packaging size | -2,02318 | -2,15416 | 0,13098 | 4 |
| G | The use of bottom cardboard | -2,15802 | -2,01932 | 0,13870 | 2 |

From the table above can be known the sequence of most influential factors in the cold storage of fresh strawberries which is factor A, G, E, F, D, B, and C. The bigger the effect, the wider also the line that represent each factor:

**Table 6.** Factor Effect of Multi Response SNR

| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| Level 1 | **-2,01021** | **-2,04553** | -2,13161 | -2,13713 | **-2,02317** | **-2,02318** | -2,15802 |
| Level 2 | -2,16714 | -2,13181 | **-2,04573** | **-2,04021** | -2,15417 | -2,15416 | **-2,01932** |
| Difference | 0,15693 | 0,08628 | -0,08588 | -0,09692 | 0,13099 | 0,13098 | -0,13870 |
| Rank | 1 | 6 | 7 | 5 | 3 | 4 | 2 |

SNR calculations factors using multi-response were resulted and determined the priority ranking difference factor that specify the best condition for strawberries storage . It is known that the difference or the biggest effect factor found in the factor A 0.15693, which is followed by factor G, E, F, D, B, and

C in accordance with factor's order priority for fresh strawberries storage. Meanwhile, levels that affected each factor are A1, B1, C2, D2, E1, F1, and G2. Thus, the order priority for factors and levels final combination of fresh strawberry fruit storage is A1, G2, E1, F1, D2, B1, and C2.

## 4. Discussion

*The Relationship Between Fresh Strawberry Fruit's Quality During Cold Storage and Its Parameter Response with Taguchi Method Approach*

Fresh strawberries cultivar Holibert (Earlibrite) continues for metabolic process after picked up from the field until storage through postharvest handling. Storage at cold temperatures is one way to inhibit the metabolic processes and it could be identified that fresh strawberries which were stored at 4°C has better physical condition than those which were at the temperature of 10°C. This is a match corresponding with statement [10] who says that for daily storage strawberries are best stored at a temperature of 2-3°C. Moreover, recommended cold storage temperature for strawberries on showcase or refrigerator maximum is 4.4°C. This is also indicated by the storage conditions of fresh strawberries with Taguchi Method with combination level 1 at temperature of 4°C which was better than level 2 at temperature of 10°C. Similarly to other factors for instance air holes, tightness of packaging, synchronization of the quantity of strawberries fruits per packaging PET plastic's size, treatment before storage, and the use of the bottom cardboard base. Cardboard base that directly contacted with the strawberry fruit can be accelerate growth of the microbes through the water condensation which resulted from fruit surface and plastics packaging. The condensation on the inner film surface was especially influenced by the flow conditions, the external temperature amplitude and the inner air volume, furthermore condensation processes on fruit surfaces were caused primarily by temperature amplitude and cycle time [14].Microbes that often arise in cold storage in this showcase are fungus of *Rhizopus* and *Botrytis cinerea*, both of them cause an infection in strawberry fruit and accelerate the damage of fruit so that the decay became faster. Rhizopus cause watery fruit, rotten fruit, because of the fungus' mycelium evolve on the surface of strawberries fruit. Meanwhile, Botrytis cinerea caused dry rot strawberries with a brownish color.

Taguchi Method helps to determine the combination of controllable factors for the method of strawberries storage using PET plastic packaging. From this would be known the steps of packaging in strawberries fruit using PET plastics the most appropriate packaging can be obtained. With the combination of these step of packaging can be obtained the relationship between water content, pH, texture, color, and TPC of fresh strawberries' cold storage. Using ANOVA calculation known that water content was influenced by G factor (the use of bottom cardboard base) with the percentage of 7.432%. Strawberry fruit's pH was affected by E factor (treatment before storage which is washing fruit) in the amount of 24.462%. The texture of fruit was affected by G factor (the use of bottom cardboard base) as much as 19.238%. Color of fruit including fruit color lightness (L) was influenced by the C factor (tightness of packaging) with percentage of 29.126%. Redness (a) color index influenced by E factor (treatment before storage which is washing fruit) of 20.783%. Another color index which is yellowness (b) contributed by C factor (tightness of packaging) of 18.472%. Change of color (△E) and TPC influenced by E factor (treatment before storage which is washing fruit) respectively 7.003% and 13.157%.

Through the Taguchi Method can be known the proper way for packaging fresh strawberries using PET packaging at its optimum way. Surface air holes is 10 $cm^2$wide with plastic package volume size (15,8 x10x3,8) $cm^3$. With this PET packaging size the best number to fill with strawberries fruit was 18 pieces of strawberries. PET plastic packaging also set with not too much air circulation and to minimize itscotch tape on each side of the packaging was applied. Storage temperature was 2-3°C or 4°C for maximum in cold storage showcase to prevent rapid decay. Temperatures above 4°C causes fruit to rot faster several times higher than the initial conditions. This is consistent with the statement from [11,15] that when the fruit storage temperature increased from 0°C to 10°C , the fruit will rot faster 2 to 4 times. Before it is stored into the showcase strawberries do not need to be washed because it will add moisture to the fruit so as to accelerate the occurrence of fruit rot. In addition, the water attached to the fruit will

invite microorganisms to grow faster. If there is fungus or mold that grows on the surface of a strawberry fruit must be separated with other fruits because the fungus will very easily spread into the other fruits. If this happens then the decay on strawberries fruit in the cold storage can occur more quickly.

## 5. Conclusions

1) Local fresh strawberries type Holibrite (Earlibrite) in the cold storage have a shelf life for about approximately ± 7 days as indicated by the declining quality characteristics include moisture content, pH, texture, color (lightness, redness, yellowness, color change (△E), and the number of microbes counted in total plate count (TPC).
2) Combination of design factors and levels that influence the storage of fresh strawberries is A1, G2, E1, F1, D2, B1, and C2, namely:
   - A1 = The width of the air holes surface packing 10 $cm^2$
   - G2 = Do not use the bottom cardboard base
   - E1 = Pretreatment storage of fruits do not need to be washed
   - F1 = The type of PET plastic packaging size is (15,8 x10x3,8) $cm^3$
   - D2 = The number of strawberries/packaging is as much as 18 pieces
   - B1 = Temperature of cooling box/showcase is 4°C
   - C2 = Tightness of packaging is tight
3) Taguchi's quality characteristics response are used for parameter quality of strawberry are Water Content is nominal the best; Texture and Color index (L, a, b) are larger the better and Change of Color (△E) and Total Plate Count are smaller the better

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