STATISTICAL QUALITY CONTROL AND PROCESS ANALYSIS ON THE PRODUCTION OF TRASH BAGS GOING THROUGH EXTRUSION PROCESS

JOHN JOSEPH C. FERNANDO, DYAN G. RODRIGUEZ,
DABIELYN D. JUMAQUIO, AND ERROL G. RICAFORT

Bulacan State University

Abstract: This study evaluated the extrusion process of trash bags of a plastic manufacturer in Marilao, Bulacan. According to the data that the company has provided, the process produced an average of 3,400 kilograms of scraps every month. The objective of the study is to determine the causes of this significant waste and recommend ways to mitigate or eliminate them. The study analyzes the process using descriptive statistics. Using Laney P'-charts, a type of statistical diagnostic tool that tries to see patterns in a data set, the proponents investigated seven months of trash bag production. The charts showed that there are days when a significant amount of scraps goes way beyond of what to be expected. Upon further examination of the events that happened on those days, it was found out that the changing of the pellets' color caused the wastes. The charts also showed other noticeable patterns, and causes were found related to these arrangements like damp pellets, wrong machine configurations and more. The results showed that statistics are a powerful tool that can help with quality control and find the causes of defects in the production. Recommendations were made with proper planning of when to put on certain colors of plastic pellets as the main suggestion.

Keywords: *extrusion, Laney P'-chart, overdispersion, quality control, trash bags*

1. INTRODUCTION

Quality means different things to different people (Speegle, 2009). It does necessarily mean that a product is the very best of its kind. Consumers may focus on the specification quality of a product or service; how it likens to competitors in the marketplace. Producers, on the other hand, measure their conformance quality; the degree of which whether the product or service was produced appropriately. However, one good definition of quality is meeting the customer's requirement.

The main objective of Statistical Quality Control (SQC) is to achieve quality in production and service organizations with adequate statistical techniques (Gomes, 2011). Descriptive statistics are used to describe certain quality characteristics, such as the central tendency and variability of the observed data. Variation in the manufacturing process leads to quality defects and product inconsistency. An important task in quality control is to find out the causes of variation in the production process. Variations that can be exactly identified and eliminated are called assignable causes of variation. One reliable tool under the SQC is the control charts that commonly analyzes historical data and fully shows variations in operation.

Plastic Production Lim Ang (PPLA) Films in Marilao, Bulacan is a new company that manufactures pelletized recycles to produce plastic products. These products are classified into three – (1) high-density plastics, (2) polyethylene plastics, both made from petroleum, and (3) trash bags that were made out of recycled plastics and low-density polyethylene. Trash bags come in a wide variety of sizes, strengths, and colors. The most commonly used color is black.

As a newcomer in the industry, the company should be making its name known by securing the quality of the products they are manufacturing. The extrusion process is one of the most important processes in plastic filmmaking as it converts plastic pellets into sheets of plastic. However, the company is generating an average of 3,400 kilograms of scraps per month in this process alone (Figure 1). The main problem extracted from the data below is that the company is losing approximately ₱ 34,772.72 (based on the cost analysis where a kilogram of plastic costs around ₱ 10.23 per month) in their monthly income. This analysis indicates that there is something wrong in the extrusion process and the company has no idea why this problem occurred.

The proponents aim to help the company in identifying the unknown problems in its extrusion process using SQC tools and try to evaluate if it needed interventions. Production firms are the organizations most-concerned in maximizing their production while also eliminating wastes and extra costs. Defects tend to hurt a business much but with descriptive statistics, it is possible to pinpoint the causes of the process that produce defective goods. SQC is an instrument that could benefit PPLA Films well if used correctly.

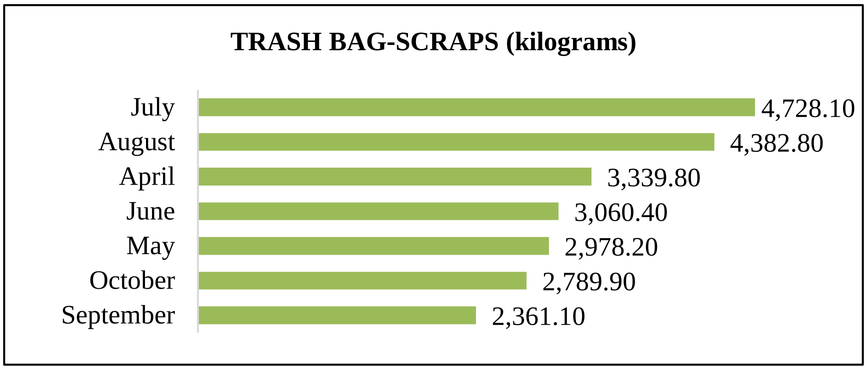


Figure 1. Scraps collected each month from extruder.

2. METHODOLOGY

2.1 Study site and data selection

The study focused on the quality of the trash bags product going through the extrusion process. Data from the months of April to October 21, 2016 were considered in the statistical analysis and were generated from the historical records of the company. The samples that were included are the company's production for the whole month. Considering that there are 30 or 31 days (may vary due to holidays and other events) in a month, it summed up to 210 days to be analyzed by statistics.

The data gathered are the weights of the total output and the scraps taken each day. Analyzing the proportion of scraps and the totality of the trash bags is too complicated with only the weight data given, as weights have no definite countable units to study. Equation (1) shows the conversion of weight into units.

$$Number\ of\ Units\ =\ Weight/(0.044\ kg/unit) \qquad (1)$$

As per the company's policy, the film will be scrapped if its surface has wrinkles, discoloration, or damage. The films will also be branded as scraps if they failed the elasticity and strength tests performed by the quality checkers, or if its dimensions were not sufficient as per the client's order.

2.2 Statistical tools and their compatibility with the data

P-chart is a type of control chart used to observe the proportion or percentage of defective units in a sample. It is the appropriate tool for the analysis of the company's situation because of its ability to find patterns in a set of data points. However, a preliminary data test was performed using statistic software called Minitab 16 (Figure 2). Figure 2 shows that only one day is within the limits of what is considered an acceptable amount of defects. The result shown is less likely to happen. It is highly improbable for a normal company that is still generating a profit to show that its operation is faulty with all tested sample data being unreasonable. This may mean that the P-chart approach is not applicable to the case.

Based on a study done by Laney (2002), the company's data may exhibit a case of overdispersion with P-chart because it displays thousands of units in number. The traditional P-chart tends to become more sensitive with data that has large numbers in it and deems the samples out of control even if they are not. Therefore, a P-chart diagnostic was conducted (Figure 3). P-chart diagnostic examines overdispersion or underdispersion in the data. Overdispersion is an unexpected phenomenon where almost all the points in a chart were out of control.

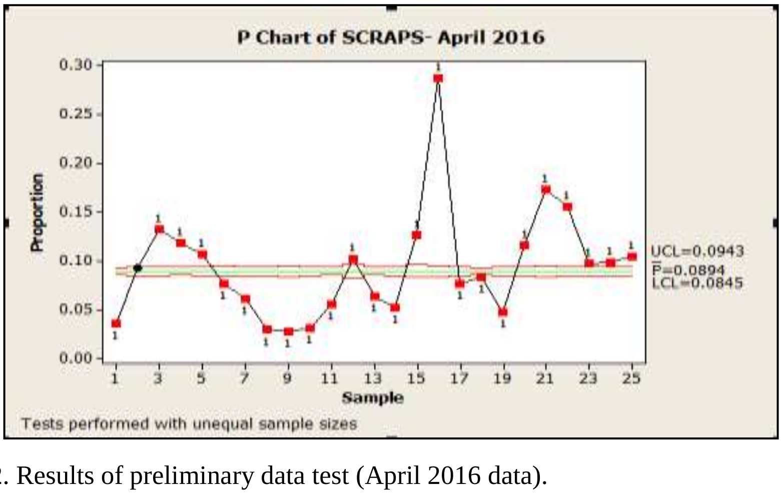


Figure 2. Results of preliminary data test (April 2016 data).

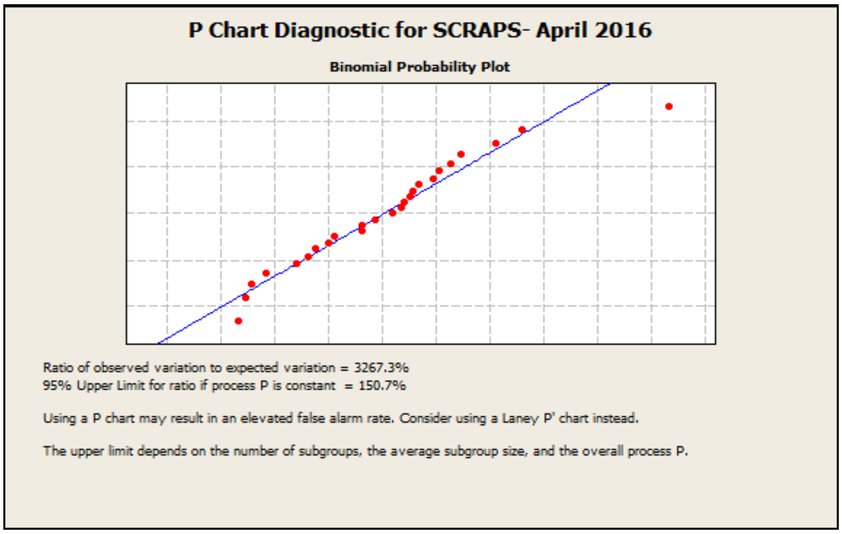


Figure 3. P-Chart diagnostic (April 2016 data).

The result shown in Figure 3 indicates that the data may lead to an elevated false alarm with P-chart. Minitab shows that the ratio of observed variation to expected variation is at 3,267.30% which suggests overdispersion. So to analyze the data, Laney P'-Chart (as also suggested by the diagnosis) was used to help them analyze the proportions of scraps to the totality.

Laney P'-Chart or p'-chart is like the traditional p chart but it is used so the charts will adjust to the overdispersion or underdispersion phenomenon. To create a Laney P'-chart, the following formulas were considered:

$$Center\ Line = \frac{\sum x_i}{\sum n_i} \tag{2}$$

$$\sigma_z = \frac{p_i - p}{\sqrt{p(1-p)/n_i}} \tag{3}$$

$$Lower\ Control\ Limit = p - k\sigma_z\sqrt{p(1-p)/n_i} \tag{4}$$

$$Upper\ Control\ Limit = p + k\sigma_z\sqrt{p(1-p)/n_i} \tag{5}$$

where the center line is the average defects of the data, x_i is the number of defects in the subgroup, n_i is the size of the subgroups, p_i is the proportion of the defects for subgroup, σ_z is the value used to adjust the control limits so you could have realistic control limits. The limits are the line that indicates the area of accepted number of defects, p is the process proportion, and k is the parameter for testing that is commonly 3.

3. RESULTS AND DISCUSSION

Seven months' worth of data is used for the analysis. Table 1 shows the result calculated by the Minitab 16 that conforms to the formula.

The table displays each month and their allowable percentage of scrap on the operation. It shows that for the month of April, the allowable percentage of scrap that could be gotten from an entirety of the plastic film is only 22.55%, while the average defect that they have gotten each day in that month is around 7.75%. For the month of May, the allowable scrap is only 15.67%, while the average scraps gotten per day is 6.07%.

If you can notice, each month has different allowable scraps and average scraps per day. This is due to the fact that the control charts are trying to reflect what is given by the historical data. The charts are trying to adjust the allowable scraps from the defects recorded so the result will be as close to reality.

The points the study are trying to analyze are those that will exceed on the upper control limits or what the statistics deemed as acceptable failures. These points will show what day has a high amount of scraps and it will show how much amount of scraps for each day.

To pinpoint the strange days within the seven months of data given, seven P'-charts (each for every month) were constructed. However, before proceeding to analyze the charts, we need to understand how to interpret the charts. According to standard interpretations of statistical charts (Minitab Inc., 2016), there are four types of violation in P'-charts to see if there are abnormalities in the system.

Table 1. Calculated results of Laney P'-Charts.

Months	Center Line or Average Defects per Day (p-bar, %)	Control Limits	
		Upper Control Limit (%)	Lower Control Limit (%)
April	7.75	22.55	0
May	6.07	15.67	0
June	5.45	12.61	0
July	7.60	21.28	0
August	7.56	18.32	0
September	5.75	15.73	0
October	6.42	18.52	0

Violation 1 occurs when there are points outside the limit lines (Upper Control Limits and Lower Control Limits). The points outside the line are called outliers and it signifies an unacceptable amount of flaws in a system. Violation 2 occurs when nine points in a row are on the same side of the centerline. It shows that there may be something happening that maintains this amount of flaws. Violation 3 occurs when there are six points in a row, all increasing or all decreasing. This shows trends in the system. Lastly, Violation 4 occurs when there are 14 points in a row, interchanging up and down. When this anomaly occurs, it means that there is a systematic variation.

In the control chart for April (Figure 4A), it is noticeable that there is a day that has Violation 1 (outlier). The outlier shows that the entire proportion of scraps in that day is around 29%. The chart was deemed unacceptable as it only allows 22% scrap. For a quality analyst, this value that went beyond the control limits indicates that a significant event happened, which generated scraps and incurred cost to the company. On that day, pellets fed to the extruder changed the color of the trash bags. The company also mentioned that the collected scraps on that day have some kind of discoloration.

According to Giles *et al.*, (2005), color contaminations in the plastic films happened when extruder and die are not properly cleaned from a former run. Supposing a light color product is followed by a dark color product, the darker color in most situations will cover any lighter color contagion. In the event a dark color is followed by a light color, any material or coloring left in the extruder or die takes a long time to remove. Aside from that, it will also be harder to clean it and the discolored trash bags will become scrap as the company has no use or market for them. It will be a waste for the company in terms of money, labor, and time. As the control chart for April shows variations and violations, statistical process control is therefore necessary.

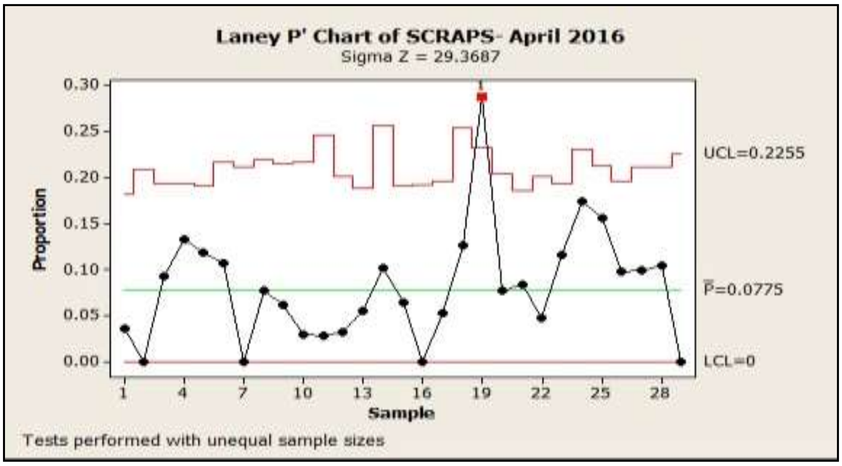


Figure 4A. Laney P'-Chart for April 2016 data.

In Figure 4B, during the month of May, an outlier was also observed in one day with a scrap proportion of 20% considering that the allowable scraps proportion is only 15%. As expected, the management confirmed that this occurred when they changed their pellets. Violation 3 has also been seen in this month. Six days in a row formed a noticeable decreasing line in the first part of the chart. It shows that the proportion came from 20% and decreased per day until it became 0% on the sixth day. This means that a trend happened within these days that lessened the number of scraps the extruder is producing per day. Interpreting this scenario, this may mean that after they changed the color of the pellets in the extruder, the scraps have occurred and as the system became more stable per day, fewer scraps were formed.

In Figures 4C, the data for the months of June and July 2016 showed the absence of outliers, which mean that both months are statistically in control. However, sudden "spikes" in the proportion of scraps can still be seen like in day 11 in June and day 6 in July. Interestingly, the higher ones involved the changing of pellets again. Among the average totality of scrap plastic films collected per month, roughly 7.78% are caused by the changing of pellets. With four months of p'-charts, it is now safe to deduce that the changing of pellets is a factor that affects the occurrence of scrapped parts of the plastic film. This result needs further validation and the company should focus on how to remedy this problem. It will affect the quality of plastic and increase the cost of production if this event persists for consecutive months. Hence, a statistical process control is necessary for both months.

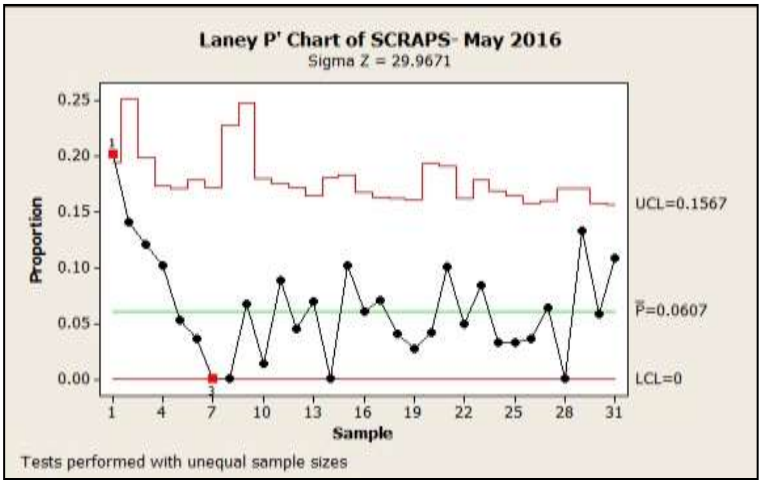


Figure 4B. Results of Laney P'-Chart for May 2016 data.

It is disturbing, though, that even if some subgroups are within the control limits like the control chart for August (Figure 4D), there are still variations in those days and produced scraps. The company cannot specify what happened in each day, more so if the variation is a small one. However, the production management stated that the majority of scraps collected are caused by having the temperature of the extruder too hot, the speed of the pulling rotor is too fast or too slow or due to minor accidents (the film snapped, the extruder suddenly stopped, etc.). They also identified the reasons for examining the non-conforming parts. The extruder may be too hot if the film is disfigured or burned. The rotor may be too fast if the scrap is too thin or fragile. These small events are also a big part of the problem. Collectively, they formed great amounts of scraps that become a waste even though they are small. Statistical process control is needed for this month to watch the small events that may cause non-conformities.

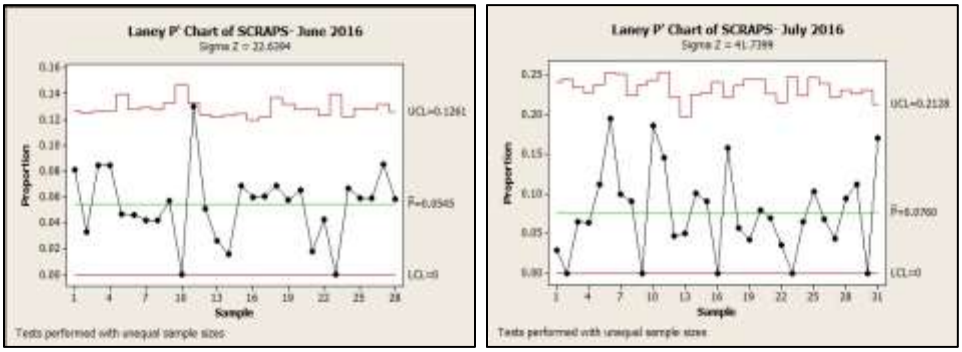


Figure 4C. Results of Laney P'-Chart for June 2016 (left) and July 2016 (right) data.

Scraps also arise whenever damp pellets are fed to the extruder and they show in the charts during the rainy seasons. Figures 4C (right) and 4D show the p'-charts for the months of July and August, which have higher probability of wet weather conditions as per the Philippines' climate. In addition, these two months have the most scraps produced compared to the other months according to Figure 1. It can be interpreted that damp raw materials significantly influence the occurrence of scraps. The management claimed that the suppliers have trouble delivering the pellets into the production area when it is raining while the management has problems in inspecting them.

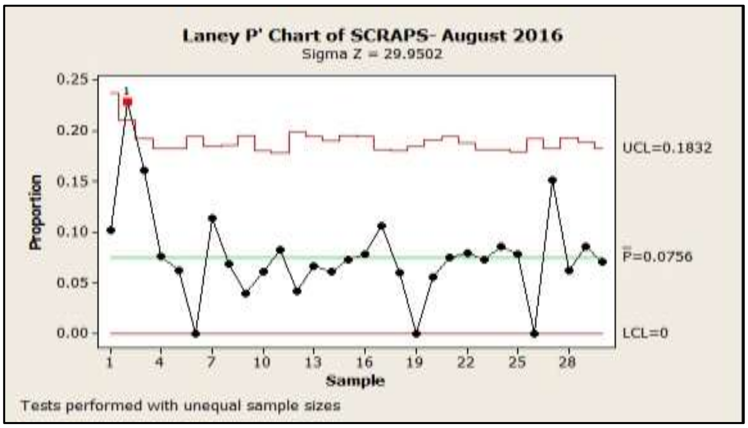


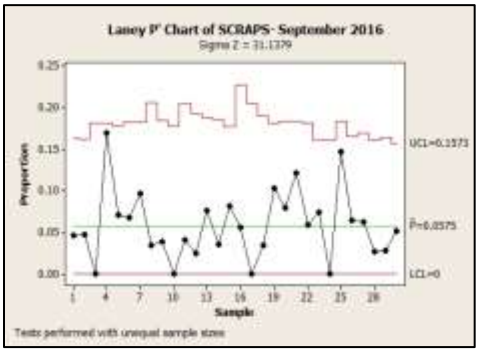
Figure 4D. Laney P'-Chart for August 2016 data.

When wet raw materials are fed to the extruder, variations in the quality of the plastic films cannot be specified though it is noticeable. To melt the damp pellets, the energy input to the plastic during manufacturing must be changed over time; it means that the energy required to melt the polymer must be altered over time. This results in the polymer melting area moving in the extruder or the polymer viscosity in the mixing, conveying, or pumping section changing. Eventually, the polymer did not proceed the same as it does previously; the product attributes have changed and the product is not the same as when production started.

This kind of event will affect the quality if left unattended. Inspection of the raw materials is the first step in every production. Defective raw materials will result in flawed products, which means waste for the company. It is also important to secure the suppliers as they are the one handling the materials especially transportation. Quality control also includes how and where the raw materials come from and it is necessary for these months.

According to Figure 1, the months of September and October (Figure 4E) have the least scraps produced among the seven months. The sudden spikes still indicate the changing of pellets while the other variations may be caused by other factors that have no visible pattern in the p'-charts but are still present in the production. However the upward and downward line among all the p'-charts could be interpreted. When the subgroups form a downward line, it is possible that the extruder is getting stable. On the other hand, when the subgroups form an upward line, something may have happened to shift the stability of the extruder to cause scraps.

In this study, we proved that statistical process control is necessary for the extrusion process of PPLA Films. We expected a new manufacturing firm to have scraps, but it needs to control the production to ensure the quality of the plastic it produces. In summary, some variations are noticeable because patterns emerged from the charts constructed. The outliers can still be assessed and then eliminated to make the extrusion process statistically in control. Some variations, which are within the control limits, can still be studied to remedy them or prepare things whenever they occurred.



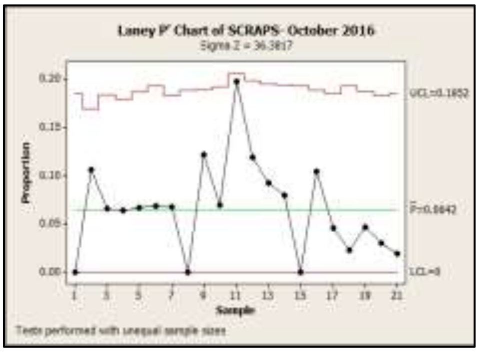


Figure 4E. Laney P'-Chart for September 2016 (left) and October 2016 (right) data.

4. CONCLUSIONS

Unexpected events in a process could halt a production firm if not handled correctly. With the help of Statistical Quality Control, the proponents have figured out the unknown problems that affect the extrusion process of trash bags of PPLA Films, which produced the defects. The causes are the following: changing of pellets to alter the color of the trash bags, the damp raw materials being fed to the extruder, the temperature condition of the extruder, the pulling speed of the rotor and other minor accidents. With the problems now known, it is clear to the analysts that the scraps PPLA Films were accumulating these past months are mainly because of the instability of the extruder and how the operators are managing it.

5. RECOMMENDATIONS

One major cause of the problem found is the unscheduled changing of the color of the pellets being fed to the extruder. Depending on the extruder size, it is fitting to clean the extruder and then run the colors in this order: natural, light colors, medium colors, dark colors, and finally black. After the color black is run, the extruder can be turned off, the screw pulled, and the die washed. Any material stagnating or staying up in the die, transfer pipes, screen, and breaker plate area or around the feed throat can lead to color smudging or color impurity in subsequent runs until it is completely expelled.

Another problem of the company that resulted in scraps is the damp pellets that were being fed to the extruder, especially during rainy season. The company should inspect the pellets and adjust the melting temperature and pressure of the extruder depending on the status of the raw materials.

6. REFERENCES

Bouvier, J. M. & Campanella, O. (2014). *Extrusion Processing Technology: Food and non-food biomaterials.* Indiana: John Wiley & Sons, Ltd.

Fox, G. & Martz, E. (2015). *On the Charts: A Conversation with David Laney*. Retrieved 2016, from Minitab: https://www.minitab.com/en-us/Published-Articles/Onthe-Charts—A-Conversation-with-David-Laney

Giles, H., Wagner, J., & Mount, E. (2005). *Extrusion: the definitive processing guide and handbook.* Norwich, NY 13815: William Andrew, Inc.

Gomes, M. I. (2011, January). *Statistical quality control.* Retrieved 2016, from Research Gate: https://www.researchgate.net/publication/279355662

Laney, D. B. (2002). Improved Control Charts for Attributes. *Qual. Eng.*, 14(4), 531-537.

Minitab Inc. (2016). *Interpret all statistics and graphs for P chart*. Retrieved 2017, from Minitab Express Support: http://support.minitab.com/en-us/minitab-express/1/help-and-how-to/control-charts/how-to/attribute-control-charts/P-chart/interpret-the-results/all-statistics-and-graphs/

Raju, G., Sharma, M. L., & Meena, M. L. (2014). Recent methods for optimization of plastic extrusion process: a literature review. *IJAME*, 4(6), 583-588.

Rauwendaal, C. (2014). *Polymer extrusion* (5th ed.). Carl Hanser Verlag GmbH Co KG.

Shah, S., Shridhar, P., & Gohil, D. (2010). Control chart: a statistical process control tool in pharmacy. *Asian J Pharm*, 184-192.

Shepherd, D. K., Champ, C. W., Rigdon, S. E., & Fuller, H. T. (2007). Attribute charts for monitoring a dependent process. *Qual. Reliab. Eng. Int.*, *23*(3), 341-365.

Sorooshian, S. (2013). Fuzzy Approach to statistical control charts. *Journal of Applied Mathematics, 2013*.

Speegle, M. (2009). *Quality concepts for the process industry* (2nd ed.). New York: Delmar Cengage Learning.