IOP Conference Series: Earth and Environmental Science

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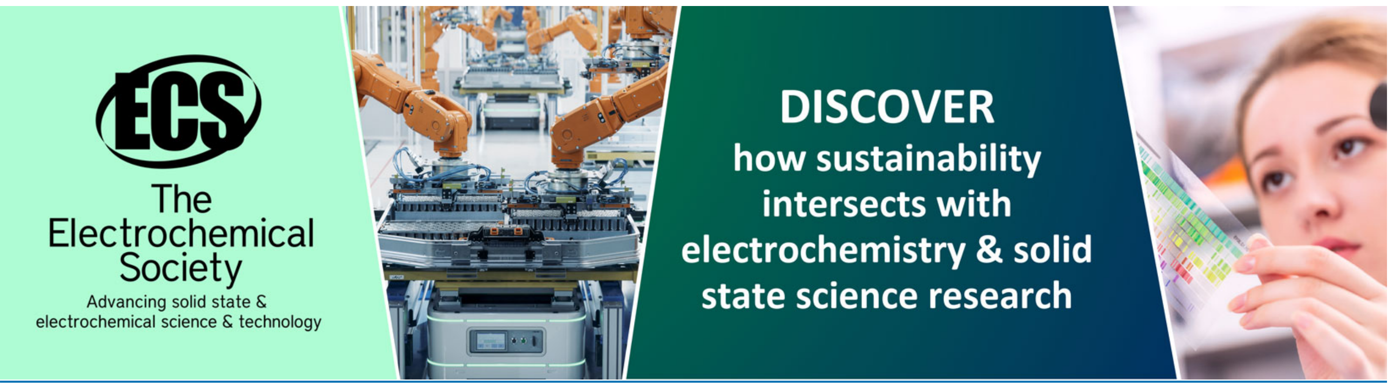
To cite this article: M H F Arifin *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **924** 012056



IOP Conf. Series: Earth and Environmental Science **924** (2021) 012056 doi:10.1088/1755-1315/924/1/012056

Application of the six sigma DMAIC in quality control of potato chips to reduce production defects

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Abstract. To produce competitive products, Small Medium Enterprises (SMEs), one of which is Agronas as a potato chip producer in Batu City, must continue to improve the quality of their products by minimizing production defects. Quality defects on potato chips occurred in color, crispness, wholeness, and size consistency indicators. This study aimed to identify and analyze the factors causing defects in potato chips and to design alternative improvement strategies. The research method used is Six Sigma Define, Measure, Analyze, Improve dan Control (DMAIC), with a sample size of 15 packs for each variable. The results showed that the main priority of the defined stage for quality improvement was crispness and size consistency with a Critical To Quality (CTQ) value of 80.2%. In the measuring stage, based on the process capability value, the final result is 82.3% which has a value above the industry standard in Indonesia of 69.2%. The result of the analysis of the DPMO value of 177,425 is equivalent to 2.43 sigma. The priority of improvement is the two highest defect levels of crispness and size consistency. Factors causing defects in potato chip crispness include limited manpower, lack of supervision and training, different levels of quality, manual packaging, and less than optimal frying. Alternative improvement strategies are labor controlling from the manager, providing training and process SOPs, supervising the selection of raw materials, and checking packaging equipment regularly. Factors causing defects in potato chips' size consistency include limited manpower, lack of supervision and training, and the absence of a chip rating machine. Alternative improvements include training and process SOPs, supervision in grading chips, and procurement of grading machines.

1. Introduction

Batu City is one of the potential areas for horticultural production, which impacts a significant increase in the amount of food processing Small Medium Enterprises (SME). The number of SMEs increased by 61.6% from 14,570 units in 2018 to 23,544 units in 2019 [1]. The increase of SMEs in Batu City as an agrotourism city was caused by the abundance of horticultural commodities such as cabbages, cayenne peppers, mustard greens, carrots, tomatoes, and potatoes. Potatoes have 80% water content [2], so they are not durable and easily damaged [3]. Converting potatoes to potato chips can preserve the commodity and create a new product. Potato chips' quality includes color [7], shape integrity, crispness, consistency of shape, size [8], and packaging [9].

Agronas is a potato chip producer in Batu City, producing 200 kg per day. Agronas products have defects, such as changing color from golden to brown due to changes in the rainy season because the drying is not optimal. In the integrity aspect, the defects were caused by workers' negligence in packaging. The size of potato chips is not consistent due to the chopping process with a less sharp knife. Varied crunchy texture due to drying with unstable weather causes high water content exceeding 4.66%, frying less than 13 seconds at 170 ^oC, and less tight plastic packaging. This condition harms the company, so it is necessary to conduct quality control to reduce product defects.

The Six Sigma quality control analysis method has the advantage of increasing average productivity, saving production costs, and reducing costs [10], having DMAIC analytical process stages (define, measure, analyze, improve, control) which will reduce defects in the production process [10]. The DMAIC concept helps companies to test the existing processes [11]. It achieved 3.4 failures per million opportunities for defects per million (DPM) and achieved zero failure rates or zero defects [12]. Based on Ficalora et al. research in a Thailand company that implements Six Sigma to reduce defects per million opportunities from 195.09 to 83.750, and the sigma value increases from 2.4 to 2.9, which proves the company's production process is getting better [12]. Six Sigma increases the production target by reducing production time and reducing process variation [13]. This study aims to identify and analyze the factors that can cause defects in potato chips and design alternative improvements.

2. Material and methods

Determining the sample of this study is based on the production capacity of SMEs Agronas of 2,000 kg for 160 packages with 3 grades of potato chips. Based on the normal inspection of ANSI/ASQCZ1.9 (1993), the units produced are 151 – 280 packs, therefore the sample is 15 packs. Every day 3 samples were retrieved with grades A, B, and C for 5 days (June 2021). Grade A is the largest chip size with a diameter of 7–9cm, grade B is a medium chip size with a diameter of 5–7cm and grade C is the smallest chip size with a diameter of 3-5cm. This study uses the Six Sigma DMAIC method which is carried out until the Analysis stage because it will continue at the Improve and Control stage with QFD and AHP analysis in the subsequent study. Six Sigma analysis variables are shown in Table 1, meanwhile, six sigma stages can be seen in Table 2.

Table 1. Variables used in Six Sigma DMAIC analysis.

No.	Physical attributes	How to measure	Parameter standard
1	Wholeness	Testing was carried out by calculating the percentage weight of product quality [14]	The integrity of potato chips is at least 80% in each package [14]
2	Color change	Tests using a color reader to determine the color level of potato chips [15]	The L* value of potato chips is between 51.27 – 57.67 [15]
3	Crispness	Tests using a penetrometer to determine the level of crispness of chips [16]	The hardness of potato chips is 219.69 – 514.95 gf [15]
4	Size Consistency	Testing by measuring the diameter of chips in one package [17]	The sizes of potato chips A, B, and C are respectively 7 - 9 cm, 5 - 7 cm, 3-5 cm [17]

Table 2. Six Sigma steps.

Steps	Activities
Define	Create a SIPOC diagram and determine the CTQ of the potato chip production process at Agronas
Measure	Create a control chart of potato chips production Calculate the DPMO Calculate the sigma level
Analyze	Analyze a dominant defect in potato chip production Create the fishbone diagrams Making alternative solutions in quality control of potato chips in Agronas

3. Results and discussion

3.1. Profile of Agronas

Agronas is one of the SMEs in Batu City that produces potato chips, selling with the "Gizi Food" brand. Agronas have 8 employees and 3 product grades with original flavors. Grade A is the largest size of chips with a diameter of 7–9cm, grade B is the size of medium chips with a diameter of 5–7cm, and grade C is the smallest chip size with a diameter of 3-5cm. Per day, the production capacity is ± 200kg potato as raw material supplied from Batu City, reaching ± 5 tons of potatoes per month. The increasing growth of SMEs makes tighter competition, suggesting technological origination in the production process, one of which is product quality control. Quality control is a well-planned technique to maintain and improve product quality according to established standards [11].

3.2. Results of six sigma analysis

Referring to Table 2, the results of the six sigma analysis in this study reached the analysis stage. In the defined stage, analysis is carried out by making Supplier, Inputs, Process, Outputs, Customer (SIPOC), and Pareto diagrams. At the measurement stage, analysis is carried out using a control chart and calculating the DPMO value [12]. At the analysis stage, fishbone diagram analysis is carried out.

3.2.1. SIPOC Diagram. SIPOC is a diagram that completely describes the production process flow from suppliers, inputs, processes, outputs, and consumers in one diagram. The results of the SIPOC diagram are shown in Figure 1 which is the entire process from beginning to end consisting of suppliers, inputs, processes, outputs, and customers [12]. The supplier comes from a cooperative which is the sole supplier because the price is lower than other suppliers. The input stage uses potatoes as the main ingredient. The process stage consists of preparing raw materials (potatoes), peeling, washing, cutting, soaking in lime water, draining, boiling, soaking in spices, drying for 2 days under the sunlight, frying, packaging, and labeling. The output of the production process is potato chips with original, crispy taste and yellowish-white in color, which are ready to be marketed to consumers such as gift shops and small shops.

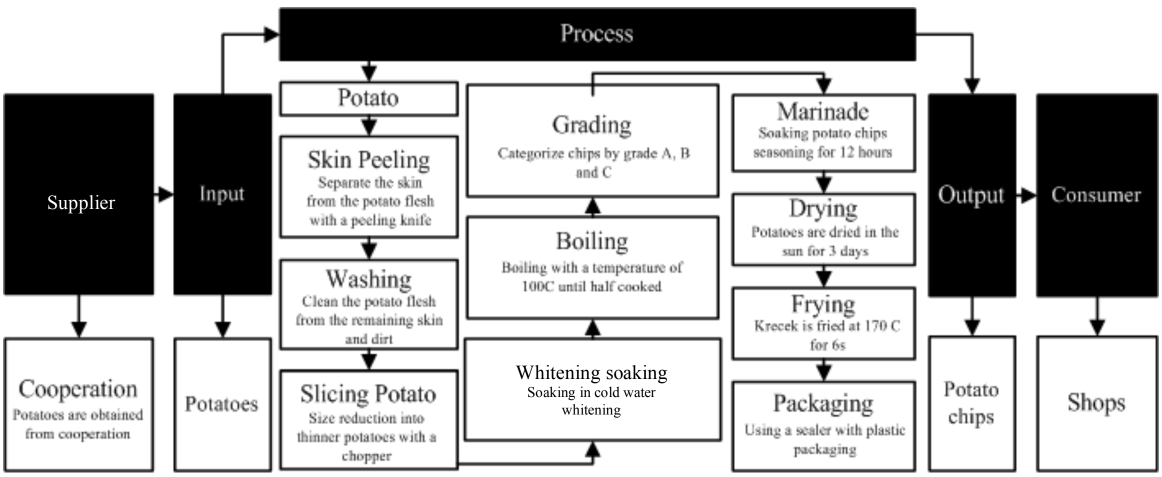


Figure 1. SIPOC diagram of potato chips.

3.2.2. Pareto diagram. Pareto diagrams were analyzed to determine the most dominant defects in potato chips as a quality control tool to identify the main causes of product failure as a basis for quality improvement. The percentage of the total percent of products is the defective products divided by 2000gr of potato chips. Quality defects that occur in potato chips are changes in color, integrity, crispness, and size consistency of each grade A, B, C can be seen in Table 3. The Pareto diagram for each grade of potato chips can be seen in Figure 2**.**

Table 3. Percentage of defects in each variable on potato chips.

Variable	Defects (gr)	Percent (%)	Defect percent (%)	Cumulative presentation (%)
		Grade A		
Crispness (1)	198.3	9.9	47.3	47.3
Size Consistency (2)	137.8	6.9	32.9	80.2
Wholeness (3)	50.2	2.5	12.0	92.1
Color (4)	33	1.7	7.9	100
Total	419.3	21.0	100	100
		Grade B		
Crispness (1)	66	3.3	55.9	55.9
Size Consistency (2)	29	1.5	24.6	80.4
Wholeness (3)	23.1	1.2	19.6	100
Color (4)	0	0.0	0.0	100
Total	118.1	5.9	100	100
		Grade C		
Size Consistency (2)	146.3	7.3	42.1	42.1
Crispness (1)	132.3	6.6	38.1	80.1
Wholeness (3)	36	1.8	10.4	90.5
Color (4)	33	1.7	9.5	100
Total	347.6	17.4	100	100

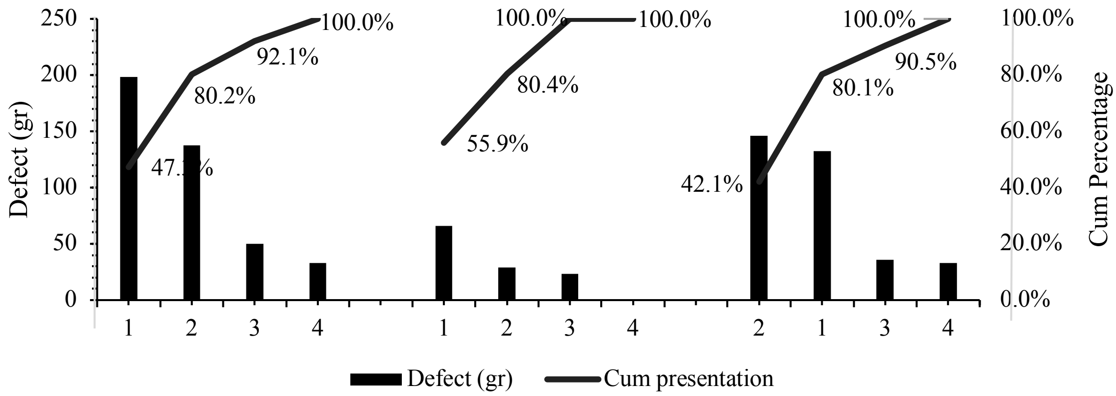
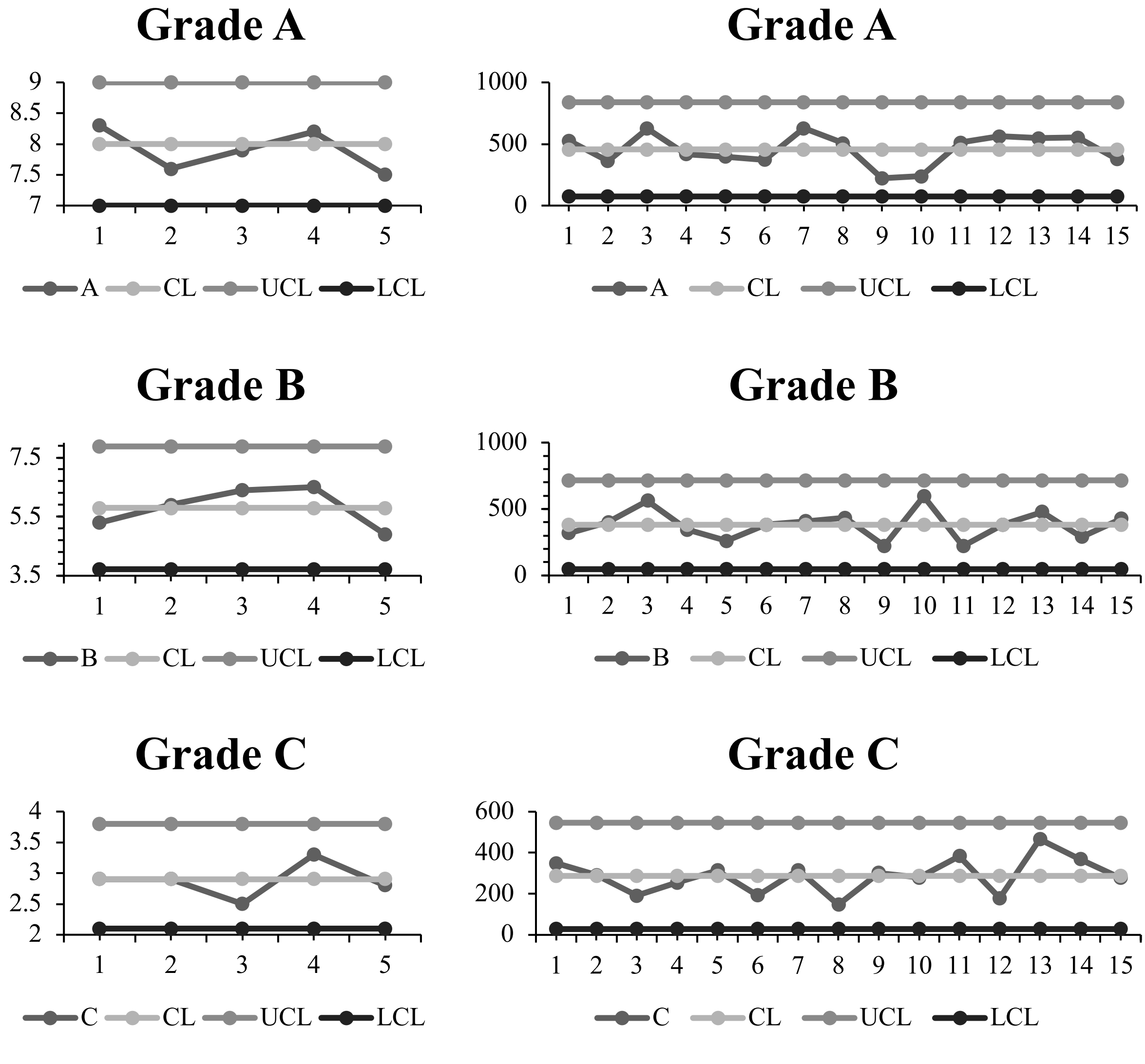


Figure 2. Pareto diagram of potato chips; (Note: 1: Crispness; 2: Size consistency ; 3: Wholeness; 4: Color).

Based on the Pareto diagram in Figure 2, there are 3 grades, each grade has 4 variables, namely crispness, size consistency, wholeness, and color. Two variables are the focus of this study, the crispness variable, and the size consistency. The crispness variable in grade A was 47.3%, Grade B 55.9%, and grade C 42.1%. The crispness of grade A has the greatest defect value because the surface of the grade A chip is wide, which makes it easy for air to enter the chips, making them not crunchy. The crispness variable has a dominant number because crispness is an essential thing in potato chip products [8]. Meanwhile consistency of size at grade A 32.9%, grade B 24.6%, and grade C 38.1%. The consistency of size grade C has a high defect value because grade C is the leftover of the other grades which results in inconsistency from the size of grade C. Each grade of potato chips has a different price, the lower the grade of chips, the cheaper the price of potato chips. [13]. If the two variables are combined, then the percentage value is more than 80%, which means that this value can be a priority for improving the 80-20 Pareto diagram [15].

3.2.3. Control Chart



(a) Size consistency (b) Crispness

Figure 3. The control chart for (a) the size consistency of grades A, B, C and (b) the crispness of grades A, B, C of the product.

The control chart, the process capability value, DPMO, and the Sigma value are determined in the measuring stage. Based on the value of the Pareto diagram, there are 2 dominant variables, namely the crispness variable and the size consistency. The control chart fluctuates due to the unstable product processing process, operator factors, machines, and methods used [15].

Based on the control chart in Figure 4, there are two variables, i.e., crispness and size consistency based on each grade. In Figure 4, there is Control Limit (CL), Upper Control Limit (UCL) , and Lower Control Limit (LCL). The size consistency variable grade B has a stable value compared to other grades.

This is because grade B has a better size consistency value than grades A and C. In the crispness variable, variable A has a more stable value than other grades because grade A has a better crispness value than grades B and C. Furthermore, an analysis of determining the process capability value for the sample is carried out as seen from the % final yield of the related process. Process capability is an analysis of variability relative to product requirements or specifications and assists product development in eliminating or reducing much of the variability that occurs [16]. The final yield value is useful to see how much the process is capable of producing output without defects [17], a process is said to be good if the % final yield value is ≥99.99% for international standards and ≥69.2% for Indonesian standards [5]. The results of the final yield calculation for Agronas SMEs are 82.3%, which is above the Indonesian standard. This value shows the ability of the production process of 82.3% and the presence of defective products as much as 17.7%, which is still outside the control limits [4].

Referring to the results of the process capability value, the DPMO value can be used to determine product deviations in the production of potato chips based on a simple six sigma conversion in Table 5. The number of samples examined is 2,000gr and defective products are 709.7gr, then the results of the calculation of Defect per Unit (DPU) is 0.177425 and DPMO is 177.425 then the DPMO value is converted to a sigma value which is 2.43, which means that the value is already above the Indonesian standard of 2.00 and needs to be maintained by reducing the defects that occur [8].

Based on the results of the Pareto diagram, control chart, and DPMO value, a factor analysis that affects the quality of the production process is carried out through a fishbone diagram. The analysis stage in Six Sigma is used for determining improvement priorities, dominant types of defects, and identifies factors causing product defects using a fishbone diagram [10]. Fishbone diagram analysis was carried out on the 2 largest defect levels, namely crispness and size consistency based on Pareto diagram analysis which showed that these two defects caused more than 80% of the total defects [13]. The concept of the Pareto diagram meets the 80-20 rule or 80% of the activity is caused by 20% of factors [7]. The potato chip fishbone diagram for the crispness and consistency variables for each grade can be seen in Figure 4.

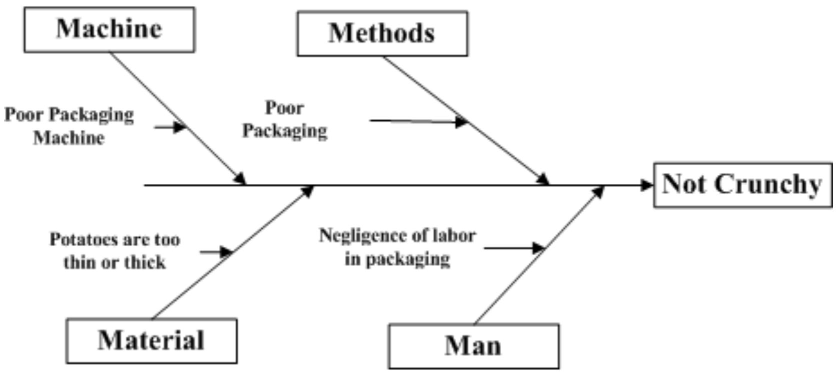


Figure 4. Fishbone diagram of crispness for grade A, B, C.

Factors that influence the crispness defects in SME Agronas potato chips are the method, human, material, and machine factors. The factor of the workforce is negligence in supervision which causes disability. At SME Agronas, there is still not enough supervision and control over the workforce which results in the negligence of the workforce. Human factors cannot be avoided in a production process, but errors due to human factors can be reduced by always being supervised in the drying process and packaging process [15]. The method factor that caused the change in the crispness of potato chips is the packaging process. The packaging process is carried out by using a sealer to seal the product to keep it crisp [14]. The level of crispness of the chips is also influenced by the machine factor during the packaging process using a manual sealer which makes it possible for the packaging to leak and cause air to enter the package [12], while the production process requires the right method for a smooth production process [13]. The materials used by SME Agronas are not properly sorted after being purchased from suppliers. Raw materials should be properly sorted to distinguish between suitable and unfit potatoes because later this will determine the standard for the thickness and crispness of the chips.

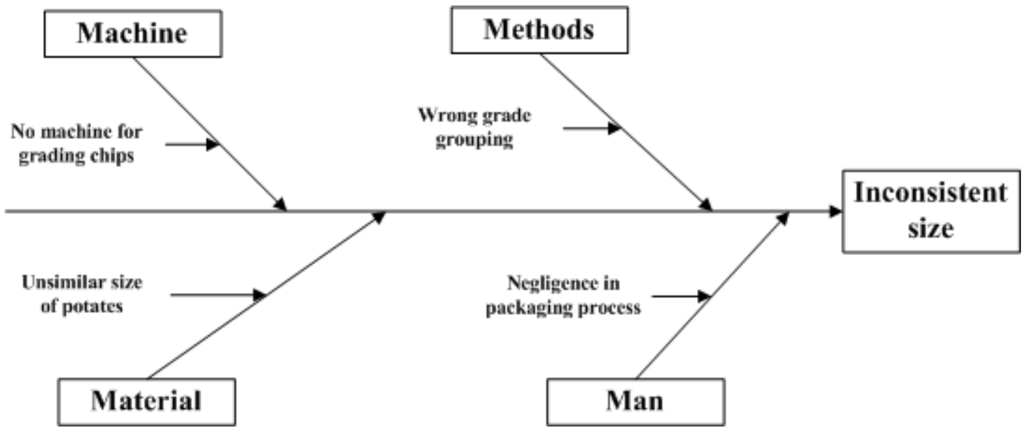


Figure 5. Fishbone diagram of consistency of size for grade A, B, C.

The labor factor in the size consistency defect is the negligence in packaging. Before the chips are put into the packaging, the chips will be categorized by grade. The packaging process carried out at the end of the production process makes the workforce tired, causing negligence in determining the grade of chips [9]. In the method factor, the wrong grade grouping results in the non-uniformity of products in one package. This results in product defects. SME Agronas potato chips have 3 different grades with different prices. If there are defects, it will reduce the price of potato chips [11]. In the raw material factor, potatoes have different sizes so that it affects the consistency of the size. Potatoes taken from the cooperative will be selected by the workforce to determine the grade. If the potatoes are small, the chips will be classified as grade C and can lower the price of the potato chips [15]. Factor grading machine is very helpful in the production process. In SME Agronas does not yet have a grading machine, so it is replaced by manual grading by the workforce. The grading machine will be very helpful in the production process because it can shorten the time and classify chips based on their grade specifications.

4. Conclusions

The quality control analysis result of SMEs Agronas's potato chips using the Six Sigma DMAIC method showed that the main priority for improvement was the crispness defect and the consistency of the product size of 80.2%. The Final Yield value is 82.3% and is above the industry standard in Indonesia (69.2%). The DPMO value of 177,425 converted to a sigma value of 2.43 which is above the industry standard in Indonesia (2.00). The priority of improvement based on the two highest results of the Pareto chart defect rate is crispness and size consistency. Factors causing lack of potato chips' crispness include limited manpower, lack of supervision and training, different levels of quality, manual packaging, and less than optimal frying. Alternative improvement strategies are labor supervision from the manager, providing training and process SOPs, supervising the selection of raw materials, and checking packaging equipment regularly. Factors causing defects in potato chip size consistency include limited manpower, lack of supervision and training, and the absence of a chip grading machine. Alternative improvements are the provision of training and process SOPs, supervision in grading chips, and procurement of grading machines.

References

[1] Abdel-Basset M, Manogaran G, Mohamed M and Chilamkurti N 2018 Three-way decisions based on neutrosophic sets and AHP-QFD framework for supplier selection problem *Future Generation Comp. Syst.* **89** 19–30
[2] Paramita M S, Dania W A P and Ikasari D M 2015 Penilaian Kepuasan Konsumen dengan

Metode Servqual dan Six Sigma (Studi Kasus Pada “Restoran Dahlia” Pasuruan) (Assessment of Customer Satisfaction with Servqual and Six Sigma Methods (Case Study on "Dahlia Restaurant" Pasuruan)) *Industria: J.Teknol. Manaj. Agroind.* **04** 3 [In Indonesia]

[3] Allata S 2017 Implementation of traceability and food safety systems (HACCP) under the ISO 22000:2005 standard in North Africa: The case study of an ice cream company in Algeria *Food Control* **79** 239–53

[4] Baptista A, Silva F J G, Campilho R D S G, Ferreira S and Pinto G 2020 Applying DMADV on the industrialization of updated components in the automotive sector: a case study *Procedia Manuf.* **51** 2020 1332–9. https://doi.org/10.1016/j.promfg.2020.10.186

[5] Costa L B M, Godinho Filho M, Fredendal L D and Devós Ganga G M 2021 Lean six sigma in the food industry: Construct development and measurement validation. *Int. J. Prod. Econ.* **231** 2019 https://doi.org/10.1016/j.ijpe.2020.107843

[6] Brenesselová M, Koréneková B, Mačanga J, Marcinčák S, Jevinová P, Pipová M, and Turek P 2015 Effects of vacuum packaging conditions on the quality, biochemical changes and the durability of ostrich meat *Meat Sci.* **101** 42–7

[7] Çelik S, Taner M T, Kağan G, Şimşek M, Kağan M K and Öztek İ 2016 A Retrospective Study of Six Sigma Methodology to Reduce Inoperability among Lung Cancer Patients *Procedia – Soc. Behav. Sci.* **229** 22–32

[8] Ficalor J and Cohen L 2013 Quality Function Deployment and Six Sigma: A QFD Handbook *J. Chem. Inf. Model.* **53** 9 1689–99 Retrieved from https://doi.org/10.1016/j.promfg.2020.10.195

[9] Chen K S, Wang C H, Tan K H and Chiu S F 2019 Developing one-sided specification six-sigma fuzzy quality index and testing model to measure the process performance of fuzzy information *Int. J. Prod. Econ.* **208** **5** 7 560–5 https://doi.org/10.1016/j.ijpe.2018.12.025

[10] Sabir B, Bouzekri T and Mohammed B 2015 Using the integrated management system and sipoc approach in higher education for the evaluation and improving the quality students life *Quality in Higher Education J.* 2 3 141-56

[11] Costa L B M, Godinho Filho M, Fredendall L D and Ganga G M D 2020 The effect of Lean Six Sigma practices on food industry performance: Implications of the Sector’s experience and typical characteristics *Food Control* **112** 1 107110 https://doi.org/10.1016/j.foodcont.2020.107110

[12] Tunick M H, Charles I O, Audrey E T, John G, Sudarsan M, Shiowshuh, Cheng-Kung, Nicholas L, Mariana R and Peter H 2016 Critical evaluation of crispy and crunchy textures: A Review *Int. J. Food Prop.* **5** 16 949–963

[13] Bahri S, Rahmadani F N and Darmawan A 2020 Analysis on Product Quality of Semi Refined Carrageenan using Six Sigma and Cost of Poor Quality *Industria: J. Teknol. Manaj. Agroind.* **09** 3

[14] Liu N, Wu L, Chen L, Sun H, Dong Q and Wu J 2018 Spectral Characteristics Analysis and Water Content Detection of Potato Plants Leaves *IFAC-PapersOnLine* **51** 17 541–6 https://doi.org/10.1016/j.ifacol.2018.08.152

[15] Pheng L S and Hui 2004 Implementing and applying six sigma in construction *J. Construction Eng. Manag.* **130** 4 482-9

[16] Sucipto S, Sulistyowati D P and Anggarini S 2017 Pengendalian Kualitas Pengalengan Jamur dengan Metode Six Sigma di PT Y, Pasuruan, Jawa Timur (Quality Control of Mushroom Canning with Six Sigma Method at PT Y, Pasuruan, East Java) *Industria: J. Teknol. Manaj. Agroind.* **06** 1 [In Indonesia]

[17] Liu Y, Tian J, Zhang T and Fan L 2021 Effects of frying temperature and pore profile on the oil absorption behavior of fried potato chips *Food Chem.* **345** 12 2020 128832.https://doi.org/10.1016/j.foodchem.2020.128832