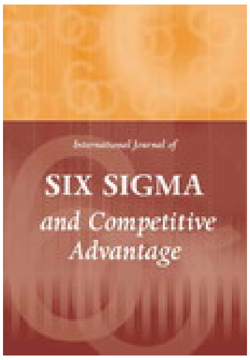

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The minimisation of giveaway and underweight in poultry proportioning process

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Abstract: Food processing organisations are always looking for ways to reduce their operational cost without sacrificing their product safety or quality. One of the critical processes in food industry is the final portion cutting and packaging. If not optimised properly, the portion cutting and packaging process of poultry results in large quantities of unaccounted giveaways or underweight packages leading into profit loss. This paper utilises the DMAIC Six Sigma approach to minimise giveaway and underweight simultaneously for one of the large-scale poultry organisations in UAE. A manual sorting process is implemented and resulted in a giveaway reduction from 9.7% to 4.81% while an automated sorting machine is expected to decrease it further to 0.80%. The results can be scaled to other food organisations regardless of the company size and demonstrates the effectiveness of Six Sigma approach to reduce waste while complying with quality and governmental standards.

Keywords: Six Sigma; proportions giveaway; poultry industry; packaging; process improvement; weight variations.

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1 Introduction

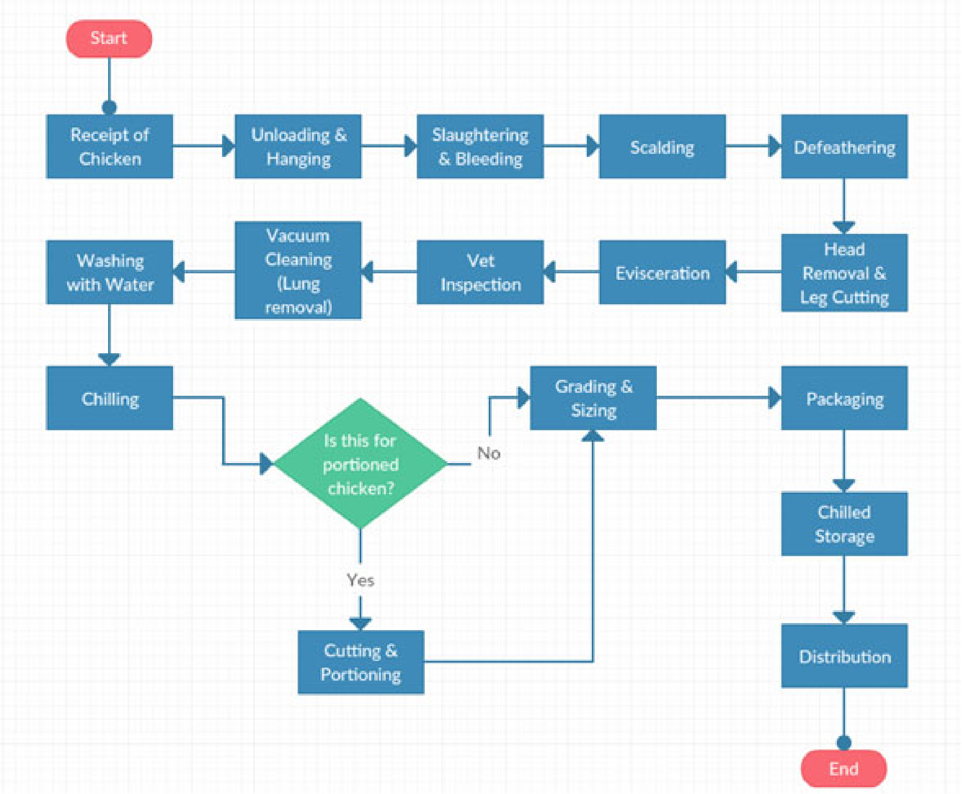
The food processing industry is one of the most steadily increasing industries in the world due to the stable increase in world population and consumption. According to the North American Meat Institute (NAMI), the meat and poultry industry is the largest segment of US agriculture. US meat production totalled 52 billion pounds in 2017 and US poultry production totalled 48 billion pounds in 2017 (NAMI, 2020). In addition to competition, food industry is faced with several challenges such as keeping up with ever-increasing complicated customer requirements and health and safety regulations. As a result, food companies need to improve their operational performance while maintaining high quality and safety standards.

In any packaging process, there is a possibility that packages are filled over the nominal weight. This is referred to as 'giveaway' of a 'product', which is commonly occurred in the packaging industries such as poultry. Mathematically, giveaway overweight weight (O_w) ratio is defined as the difference between the average pack weight (μ_{pw}) and declared weight (W_D) divided by the declared weight as shown in equation (1). Giveaway is a major source of waste which obviously impact profitability (Cronin et al., 2003).

$$O_w = \frac{\mu_{pw} - W_D}{W_D} \tag{1}$$

There have been many legislations governing the average packaged goods weights. For example, in the UK, the weights and measures regulations 2006 (UK Legislation, 2006), control the overall average quantity batches using three main rules. The first rule states that the actual contents of packages must not be less, on average, than the declared weight. The second one states that the proportion of packages that are below the declared weight tolerable negative error (TNE) must be less than a specified amount. For example, the TNE for packages of declared weights range of 300 to 500 should be within 3% of declared weight. Finally, the last rule states that no package should be below the nominal quantity by more than twice the TNE.

Figure 1 CPC chicken packaging process map (see online version for colours)



One of the approaches that food industry can greatly benefit from is Lean Six Sigma (LSS). LSS is an effective approach to reduce waste which leads to productivity improvement, cost reduction and profitability enhancement. Shokri et al. (2021) conducted a detailed scoping review of LSS literature which demonstrates the positive impact that LSS has on green manufacturing in terms of waste reduction. Despite its wide application, LSS gives limited insight on any framework catering quality and cost together especially in price-sensitive markets (Mahato et al., 2017). Moreover, although many researchers proposed conceptual frameworks for LSS implementation, the validation through case studies seems to be lacking (Anand and Kaushik, 2021). The objective of this paper is to utilise LSS methodology to reduce giveaway problem for one of the leading chicken packaging companies in United Arab Emirates (UAE). The case is used to demonstrate the effectiveness of LSS in improving the financial bottom line of organisations without scarifying quality performance. The chicken packaging company will be referred to as CPC, an anonymised name. The identity of the company is protected for confidentiality. CPC is a medium size chicken farming and packaging company with an average production of 25,000 Kg/day and around 400 employees. The company employs many processes in their poultry operations that start from poultry farms and feeders to poultry processing, portioning, and packaging. Figure 1 depicts the process map at CPC which starts from the moment a living chicken arrives and includes the portioning, packaging, and sending the packaged whole or portioned chicken off for distribution. The poultry portioning and packaging process is a vital part of the company's poultry operations and selected by CPC management as a good potential candidate for process and quality improvement.

The rest of the paper is structured as follows: relevant literature reviewed is presented in Section 2 followed by proposed methodology in Section 3. In Section 4, results of DMAIC methodology implementation on the case study is presented while conclusions are provided in the last section.

2 Literature review

Literature is full of case studies demonstrating the effectiveness of LSS implementation by many manufacturing and service organisations to improve quality and productivity (Kaushish and Kumar, 2015; Jirasukprasert, 2012; Oguz and Kim, 2014). For example, Kaushish and Kumar (2015) utilised Six Sigma methodology to reduce the number of defects in piston manufacturing from 9.9% to 5%. Similarly, Valles et al. (2009) claimed a 50% improvement in semiconductor plant that manufactures ink-jet printers circuit cartridges using Six Sigma methodology. In food processing industry, few studies were conducted to improve food processing quality. The next two sections present studies focused on food in general and poultry in specific respectively.

2.1 Six Sigma in food industry

Six Sigma has been utilised in food industry to improve profitability and enhance customer satisfaction. For example, Periaswamy and Heap (2010) used Six Sigma to reduce the breakdown rate of a labelling machine that has a reject/rework percentage of 7%. The Six Sigma team was able to reduce the rate to 2% using traditional DMAIC methodology. Similarly, Scott et al. (2009) conducted a quantitative investigation of structured continuous improvement programs applying SS and LSS approaches in the Canadian food sector. Similarly, Besseris (2014) provided a method for LSS projects to plan and conduct robust process optimisation studies for complex and constrained products encountered in food industry. The same authors demonstrated the method with the cocoa-cream filling for a large-scale croissant production operation. In this case, both viscosity and water activity were optimised since both impact performance and safety of final product. Sánchez-Rebull et al. (2020) provides several examples of SS implementation in food can industry to improve cash flow of these companies. Similarly, Hakimi et al. (2018) used SS methodology to control acidity of plain yogurt production process for a plant in Iran.

Several studies have addressed the problem of fill variation in the packaging process. For example, Noorwali (2013) introduced a model aiming at variability reduction in food flow processing systems using lean and Taguchi designs. The model was applied to a biscuit processing system where examples of the seven types of waste in the biscuit flow processing is identified. Knowles et al. (2004) identified the same problem in a medicated sweet manufacturing process in southern UK. They pointed out that the process is out of control and one in every five sweets produced at the plant had to either be scrapped or reworked. The team implemented the DMAIC approach and claimed a new reduced scrap/rework rate of one in 1,000 unit produced. Such reduction provided £290,000 per annum savings to the company. Desai et al. (2015) faced a similar variation problem in a milk powder packaging process in an Indian food processing company. The process was suffering from weight variation which was causing a considerable amount of loss in profit. Once again, the successful implementation of SS project resulted in a waste reduction of 800,000 INR per annum and a substantial increase in the process output. Similarly, Cronin et al. (2003) investigated the reduction of over-weight of an extruded food product using subsequent packaging operation. They concluded that variability in the product width dimension is the most significant source of weight variation which is not practically possible to eliminate. As a result, an alternative packing strategy may be more successful in reducing product overweight instead.

Although LSS has been utilised extensively in manufacturing industry, food engineering has not received the exposure that deserves in terms of showcasing enough successful LSS deployment projects (Besseris, 2014).

2.2 Six Sigma in poultry industry

Despite the wide success of SS implementation in different industries, studies concerned with poultry processing are scarce. One interesting case is conducted by Mataragas et al. (2012) who explored the ability to utilise statistical process control (SPC) tools to monitor and improve the quality of carcasses in a poultry slaughterhouse. The researchers applied the SS principles on the Hazard Analysis Critical Control Point (HACCP) system implemented at the slaughterhouse to compare process stability and capability before and after automation. The process capability analysis revealed poor microbiological quality in the process before automation; with the process performance indices P_{pk} below 1.0. In contrast, the process capability analysis of the process after automation resulted in a P_{pk} equal to 2.0, indicating that the process is capable of production within the specification limits.

Overfilling or giveaway reduction of product packages significantly results in reducing costs and thus profitability improvement of the company (Everett, 2017). Several proposals were provided by several researchers and practitioners to reduce fill or packaging variations. For example, Omar and de Silva (2000) proposed a nonlinear optimisation model (NLP) to address the portioning problem. The objective function was to minimise overfilling and under filling of packages in an automated fish canning industry and achieve a target can weight subject to a set of constraints. Consequently, their application resulted in a higher filling accuracy by cutting and assembling the portions according to the optimal procedure. Similarly, Young (2000) used statistical sampling along with simulation to reduce over and underweight of chicken breast fillets packages.

Since giveaway minimisation may impact production throughput, Peeters et al. (2019) proposed index policy with power function and target throughput algorithm to control the poultry batching grader giveaway and throughput. They used simulation to illustrate how the target throughput impacted giveaway for various throughputs and target weights. Finally, Fernandes and Pinto (2020) developed a simulation model to optimise a large size slaughter line balancing to increase productivity. The authors applied LSS principles to reduce idle time and balance all steps to have consistent cycle time at each step. They claim 11.89% productivity increase through manpower optimisation.

Despite the limited few studies on food giveaway minimisation and its significance, there is a lack of research on the subject in poultry production using LSS. The objective of this paper is to utilise LSS methodology to minimise giveaway while meeting productivity targets of chicken packaging production process in one of the major poultry plants in UAE.

3 Methodology

The main methodology followed in this study is the DMAIC methodology; a structured approach with the goal of improving quality, production, and productivity while minimising costs of operation (Singh and Rathi, 2019). The DMAIC methodology consists of the following five steps:

- *Define:* in this step a clear description of problem, objectives, and potential benefits are identified along with project plan and team (Mandal, 2012). The main tools used in this step are project charter, stakeholder analysis and SIPOC.
- *Measure:* the current performance is assessed after measurement system analysis (MSA) is conducted and translate the problem into a measurable critical to quality (CTQ) or critical to delivery (CTD) characteristic.
- *Analyse:* in this step, the search for critical factors causing waste including defects, delay in the process, variation and prioritise them is conducted. Brainstorming tools such a cause and effect diagram along with passive data analysis tools such as hypothesis testing and ANOVA are used in the analyse step.
- *Improve:* further active investigation of input variables effect on CTQ or CTD is conducted using designed experiments or multi-variate analysis. Once these factors are identified, corrective actions to reduce waste, defects, and variability reduction are established and verified using simulation or actual pilot studies.
- *Control:* in this step standard procedures, control plans and charts are used to control the system and sustain the gained improvement due to corrective actions.

Antony et al. (2012) provided a good summary of LSS DMAIC process and reasons for its wide application and success. The next section provides a summary of the main findings of deploying the DMAIC process for the giveaway problem at CPC.

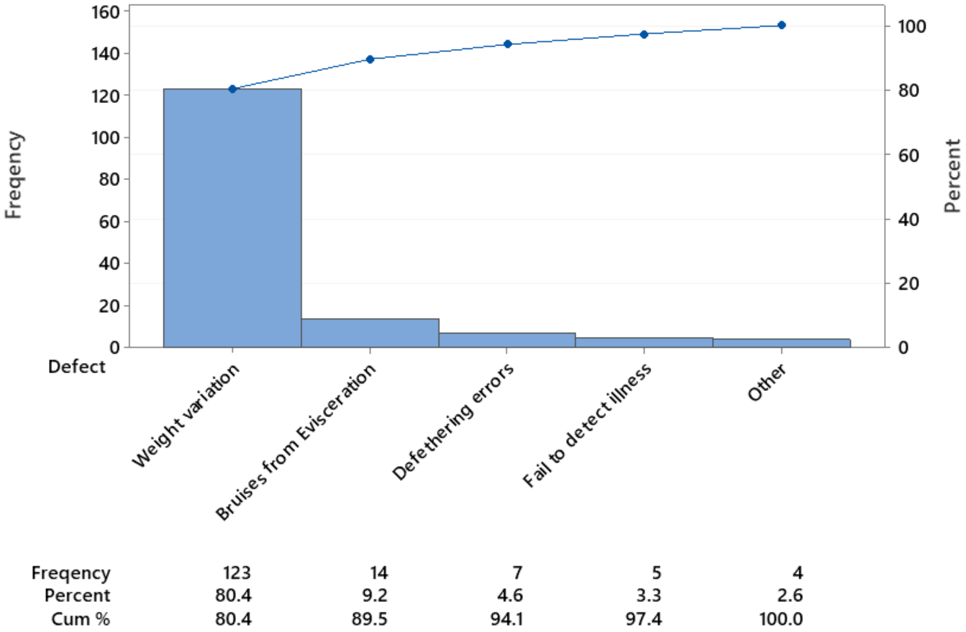
4 Case study

The proposed DMAIC methodology is followed to reduce giveaway percentage at CPC. Details on implementation of each step is provided below.

4.1 Define phase

To identify and quantify defects in CPC production process, a Pareto analysis is conducted and shown in Figure 2. The analysis was done based on inspection reports conducted during various checkpoints throughout the poultry processing line for four months period. Based on the data collected, it is evident that giveaway is a major issue since 80% of inspected packages show a weight higher than target which mainly impact organisation revenue.

Figure 2 Pareto analysis of CPC defects (see online version for colours)



A monitoring system for pre-delivered trays is implemented because of this finding. Data was collected during the July–October 2015 period and summarised in Table 1. Variation takes two forms in the process of portioning and packaging of poultry: waste and giveaway. Waste includes whatever part of the poultry neither treated nor prepared for selling. Giveaway is any additional quantity being released for free when in fact holds a specific monetary value. Based on the monitoring system, CPC recorded a total giveaway of 78,056 Kg from the initial total amount of portioned meat consisting of 804,718 Kg during the four months period which translates into a substantial 9.70% giveaway. The giveaways add up to a total of $361,335 in just four months of operation and represent a great opportunity for saving. As a result, top management took the reduction of giveaway without jeopardising safety and quality as a top priority. A LSS project targeting the portioning process was initiated with a goal of reducing giveaway to only 5%. The 5% goal was deemed possible by top management.

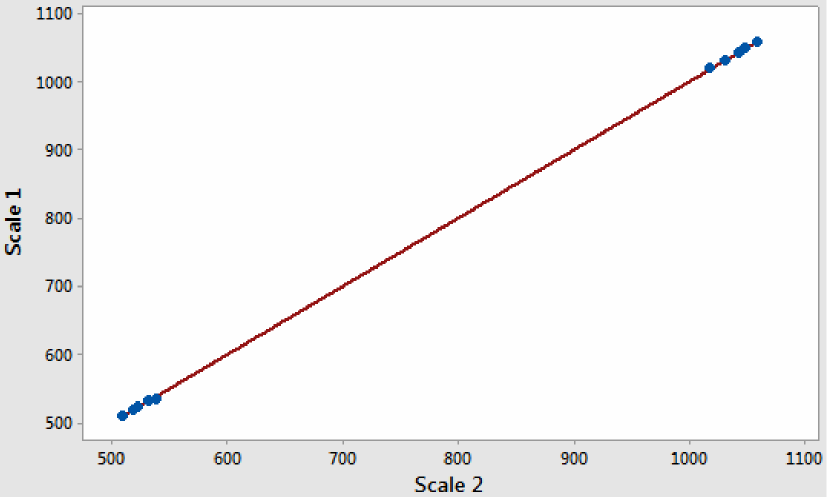
Table 1 CPC giveaway and waste percentages

Month	*Total meat (Kg)*	*Packaged meat (Kg)*	*Waste (Kg)*	*Waste %*	*Giveaway (Kg)*	*Giveaway %*
July	375,606	174,706	9,343	5.35%	18,139	10.38%
August	381,932	201,793	10,336	5.12%	19,078	9.45%
September	421,273	204,817	11,102	5.42%	20,111	9.82%
October	437,064	223,401	12,915	5.78%	20,729	9.82%
Total	1,615,875	804,717	43,696	5.42%	78,058	9.28%
Average				5.42%		9.73%

4.2 Measure phase

In this phase, MSA was conducted to validate weighting measurement and investigate any sources of variability. The MSA includes checking the linearity of scales first, then conducting a gage repeatability and reproducibility (gage R&R) to investigate the contribution of part-part variability, testing under same conditions, and testing under various conditions on total variability. Measurement of packages is currently fully automated; operators place packages on one of several scales and print a sticker of package weight. The scales are first tested to investigate the precision of the scales across the used range of the scale which is 400–1,100 gm. Two scales were selected randomly and five random 500 g packages along with another five random 1,000 g packages were tested using both scales. A paired t-test suggests no significant difference between the two scales with 0.000 p-value. Figure 3 show a correlation plot between the scales. The sample Pearson correlation coefficient is 1.000 along with a p-value of 0.000 indicating that correlation between the two scales is significant.

Figure 3 Two scale correlation plot (see online version for colours)



Since the poultry portions packages are only available in two sizes which are the 500 g and the 1,000 g; the test could not be conducted on a wider range of points. Nevertheless, these two package sizes show the performance of the scales at two different ranges and the packages used were chosen to construct a range for the 500 g packages and another range for the 1,000 g packages to ensure the accuracy of the test. Next, a GR&R for weighing process was conducted using three operators measuring ten different packages twice. The measuring system is expected to be capable since the measurements are conducted automatically after an operator places the package on an electronic scale which in turn records the weight of the poultry directly into the system. Once again, the ten parts are divided equally between 500 grams and 1,000 grams. The results are summarised in Figure 4. Results suggest that variability is mainly due to parts (99.98%) with zero contribution due to reproducibility and 0.2% due to repeatability. The R-chart suggests that repeatability can be further enhanced by assuring that operators, especially operator 1, wait for half a second before they remove package off the scale to have stable reading. The results are deemed acceptable since gauge R&R contribution is below 2% threshold adopted by many organisations.

Figure 4 Weighing gage R&R results (see online version for colours)

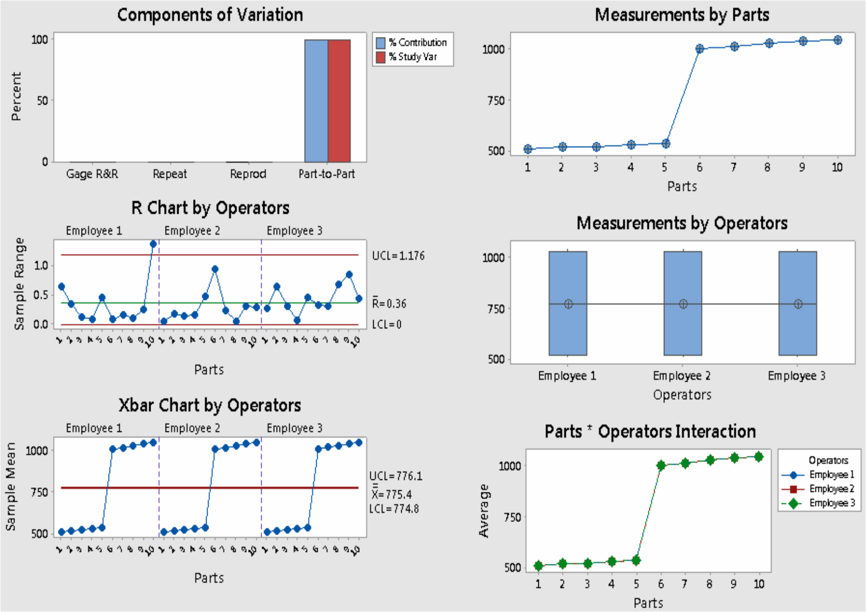
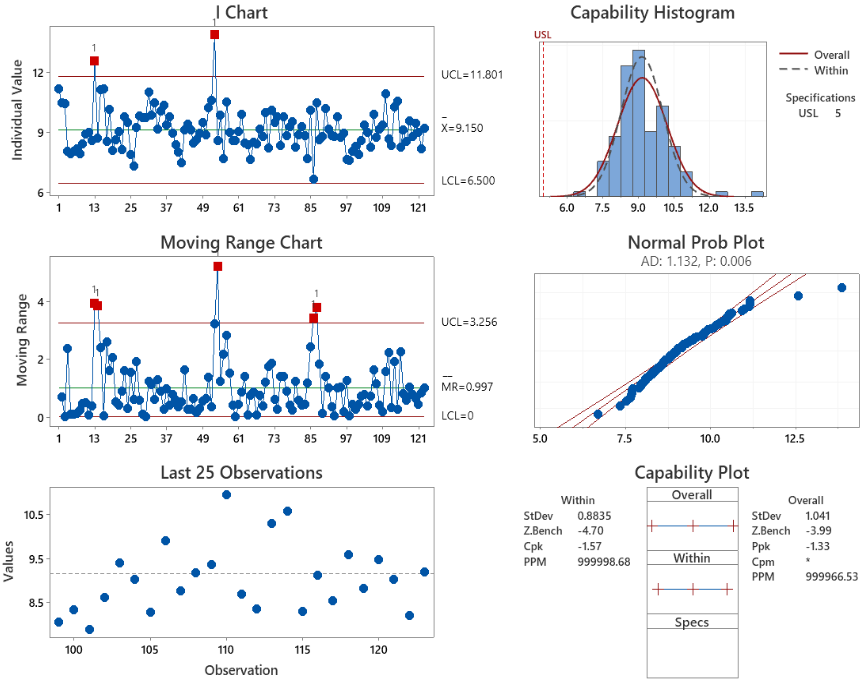
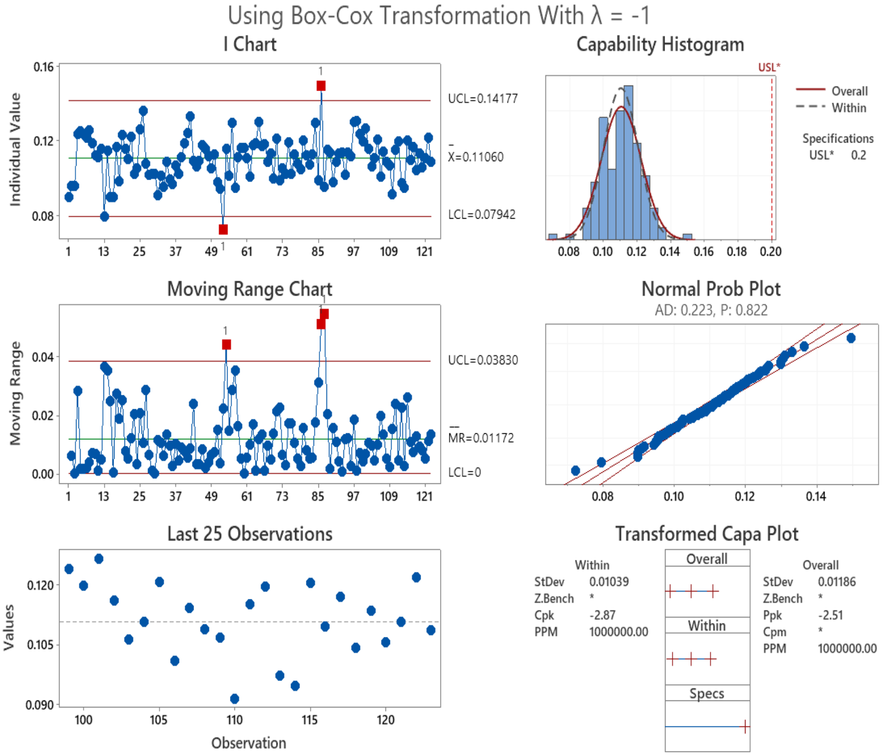


Figure 5 Process capability of %Giveaway (see online version for colours)



To measure capability of current process, the process was monitored for four months (123 days). Every day, packages are weighed and %Giveaway is estimated. Figure 5 depicts the capability analysis of the portioning and packaging process using six pack plots. Normality test indicates strong evidence of non-normality with p-value of 0.006. As a result, a Box-Cox transformation was conducted with optimal $\lambda = -1$. Figure 6 summarised stability and capability of transformed data using six pack formats. The I-MR chart indicates that the process is unstable since there are days where %Giveaway is beyond three sigma control limits. The data also exhibits a cyclical trend, implying a need to monitor specific parameters such as shifts or influential seasonality factors. Assuming that process can be stabilised by removing special causes, the process is uncapable of meeting the 5% upper specification limit and all production days have more than 5% giveaway. In summary, the process is neither stable nor capable.

Figure 6 Process capability of transformed %Giveaway (see online version for colours)



4.3 Analyse phase

A cause and effect analysis was conducted through brainstorming potential root causes and utilising the input of company operators and quality manager. Figure 7 shows the fishbone diagram of all the potential root causes of the excessive giveaway problem. To prioritise potential causes, each one was assessed based on each factor's fix difficulty of implementation and the effectiveness of that fix relative to solving the problem. Both difficulty and effectiveness were assessed based on a five-point Likert scale with

0 implies that root cause is easy to change or least effective while five implies very difficult to change or most effective. The ratings were based on average ratings of four subject matter experts involved in the project representing quality and production. Accordingly, all causes are plotted in the pay-off matrix shown in Figure 8. The most effective change and easy to implement is cause 1.2 which refers process design. Specifically, this refers to weighing the final package only and not weighing the portions that make the package. Another relevant potential cause is the random selection of portions to be placed in tray prior to packaging (2.3). The team believed that trays could be filled based on portions weights instead of first in first out (FIFO) current approach. Another important potential cause is 4.2 which refers to employee motivation and incentives. Employees are paid based on production quantities, i.e., the higher the packaged quantity the higher the pay. As a result, one of the potential quick fixes was to include giveaway and underweight in the pay as well. To investigate the impact of productivity on %Giveaway, a box plot of daily %Giveaway by daily packaged weight supported by ANOVA analysis is conducted. The box plot is shown in Figure 9 does not indicate that productivity influence %Giveaway. ANOVA analysis shown in Table 2 resulted in p-value of 0.256 which confirms the lack of evidence of productivity and %Giveaway association.

Table 2 %Giveaway by daily packaged weight ANOVA

Source	*DF*	*Adj. SS*	*Adj. MS*	*F-value*	*P-value*
Factor	3	4.406	1.469	1.37	0.256
Error	119	127.804	1.074		
Total	122	132.210			

Figure 7 Fishbone diagram (see online version for colours)

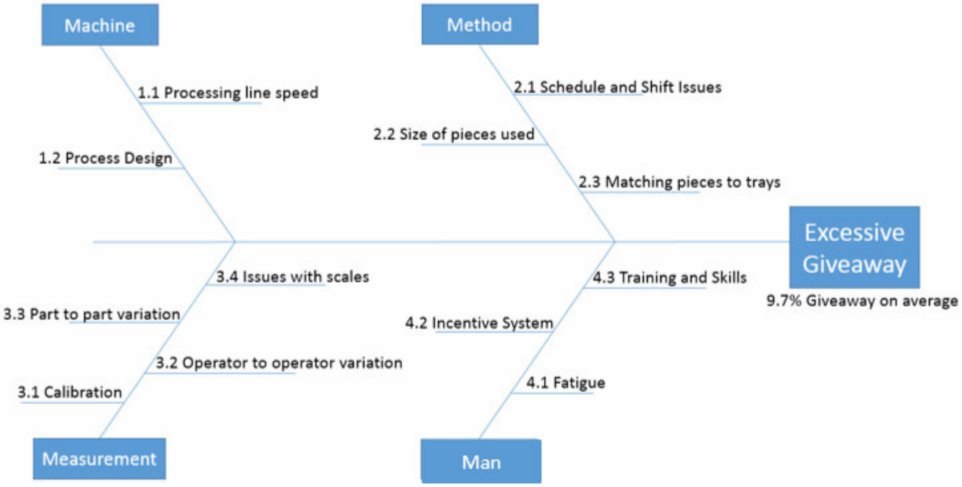
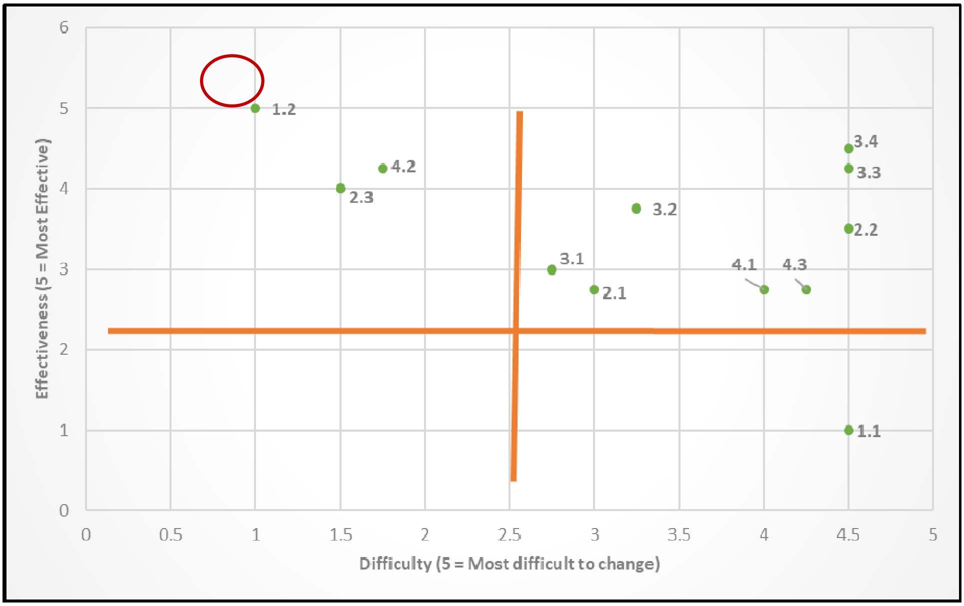


Figure 8 %Giveaway pay-off matrix (see online version for colours)



4.4 Improve phase

The improve phase deals with developing ideas and techniques responsible for removing the root causes of variation as well as testing and standardising those techniques or solutions. This process involves the identification and verification of critical inputs, or KPIV's, for possible manipulation or alterations. One of the main root causes of the excess giveaway is the process of matching poultry pieces or parts to the trays to get the desired package weight. This process requires the use of judgement and experience to match the best combination of parts to the trays to get the weight as close as possible to the target. The dependence of this process on the judgement and experience of the operator is a main source of variability and produces significant room for error and excess giveaway. Although the effect of the problem can be reduced by applying training to the employees, it still does not ensure the continuity of the improvement. These reasons dictate that a better solution must eliminate the need for the operator to use his experience and judgment to match the parts to trays. As a result, a manual solution is proposed which can be automated later to remove human judgment away from the process. The proposed manual solution will utilise a certain number of bins to classify the poultry portions into ranges based on their weight. After that, the classified parts from the bins will be grouped together based on a set of predetermined rules which will be optimised to give the minimum amount of giveaway per tray. The decision variables here are number of bins and number of pieces that should be drawn from each bin to reach the target weight. Therefore, a set of scenarios and combinations of these aspects were tested and simulated to find the best possible combination which will give the most reduction in the giveaway. The downsize of this solution is slowing down productivity since a new step of the process should be added to weigh the portions before placing it in the bins. This requires allocating some of the workers to do the weighing which come with time and cost implications. Nevertheless, the proposed solution will eliminate the need to weigh the package itself after filling them with portions.

Figure 9 %Giveaway box plot by daily packaged weight (see online version for colours)

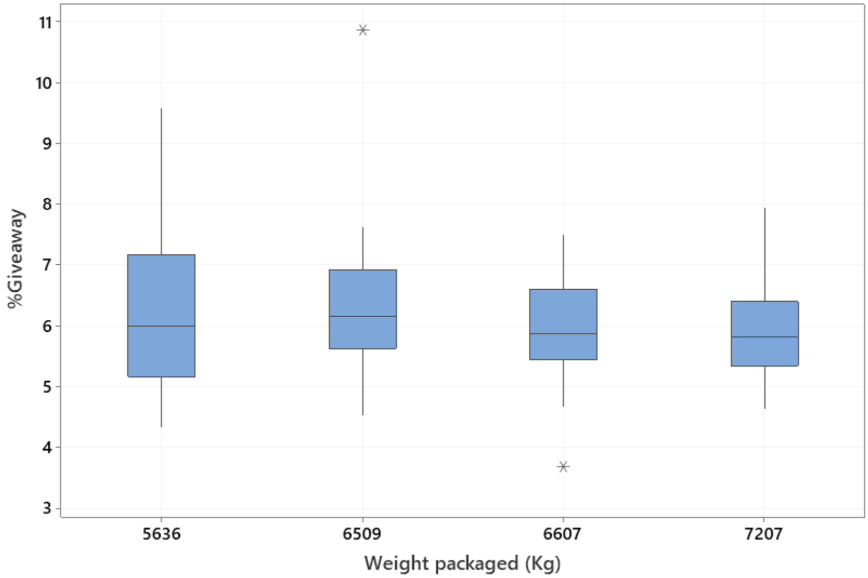
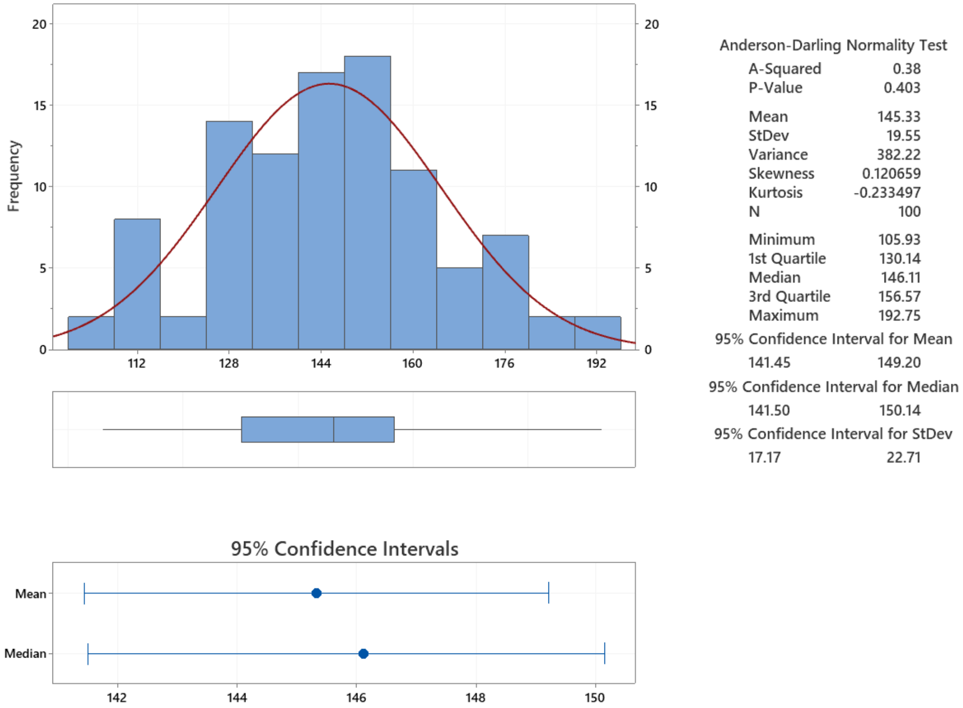


Figure 10 Portions weights graphical summary (see online version for colours)



```
Anderson-Darling Normality Test
   A-Squared              0.38
   P-Value               0.403

   Mean                 145.33
   StDev                 19.55
   Variance             382.22
   Skewness           0.120659
   Kurtosis          -0.233497
   N                       100

   Minimum              105.93
   1st Quartile         130.14
   Median               146.11
   3rd Quartile         156.57
   Maximum              192.75
 95% Confidence Interval for Mean
   141.45               149.20
95% Confidence Interval for Median
   141.50               150.14
 95% Confidence Interval for StDev
   17.17                 22.71
```

To propose and verify solutions, the weight of 100 poultry portions were measured and fitted using a normal distribution with a mean of 145 g and a standard deviation of 19.55 g. A graphical summary of portions weights is shown in Figure 10 along with Anderson Darling normality test results.

Table 3 Potential manual sorting solutions

Solution	*Number of bins (n)*	*Bin weight ranges*	*Rules*	*E(Wt$_p$)*	*%Giveaway*	*%Underweight*
M1	5	bin$_1$: $w_t \leq 120$	R$_1$: 5bin$_1$	559.4	12.87%	0.06%
		bin$_2$: $120 \leq w_t \leq 140$	R$_2$: 4bin$_2$	525.2		
		bin$_3$: $140 \leq w_t \leq 160$	R$_3$: 4bin$_3$	600.2		
		bin$_4$: $160 \leq w_t \leq 180$	R$_4$: 3bin$_4$	510.9		
		bin$_5$: $w_t \geq 180$	R$_5$: 3bin$_5$	562.8		
M2	6	bin$_1$: $w_t \leq 120$	R$_1$: 5bin$_1$	559.4	11.54%	0.17%
		bin$_2$: $120 \leq w_t \leq 140$	R$_2$: 4bin$_2$	525.2		
		bin$_3$: $140 \leq w_t \leq 150$	R$_3$: 4bin$_3$	581.6		
		bin$_4$: $150 \leq w_t \leq 160$	R$_4$: 4bin$_4$	616.3		
		bin$_5$: $160 \leq w_t \leq 180$	R$_5$: 3bin$_5$	510.9		
		bin$_6$: $w_t \geq 180$	R$_6$: 3bin$_6$	562.8		
M3	6	bin$_1$: $w_t \leq 120$	R$_1$: 5bin$_1$	559.4	4.81%	1.24%
		bin$_2$: $120 \leq w_t \leq 140$	R$_2$: 4bin$_2$	525.2		
		bin$_3$: $140 \leq w_t \leq 150$	R$_3$: 3bin$_3$ + 2bin$_1$	548.1		
		bin$_4$: $150 \leq w_t \leq 160$	R$_4$: 1bin4 + 1bin$_5$ + 1bin$_6$	512.0		
		bin$_5$: $160 \leq w_t \leq 180$				
		bin$_6$: $w_t \geq 180$				
M4	6	bin$_1$: $w_t \leq 120$	R$_1$: 5bin$_1$	559.4	7.21%	0.0%
		bin$_2$: $120 \leq w_t \leq 145$	R$_2$: 4bin$_2$	525.2		
		bin$_3$: $145 \leq w_t \leq 155$	R$_3$: 3bin$_3$ + 1bin$_1$	548.1		
		bin$_4$: $155 \leq w_t \leq 165$	R$_4$: 3bin$_5$	510.9		
		bin$_5$: $165 \leq w_t \leq 185$	R$_5$: 1bin$_4$ + 1bin$_5$ + 1bin$_6$	512.0		
		bin$_6$: $w_t \geq 185$				

Four manual sorting potential solutions (M1–M4) were proposed and investigated. Each solution is based on several aggregation rules set to minimise the expected %Giveaway and %Underweight of total package weight. The proposed solutions along with the set rules are summarised in Table 3. For example, M1 potential solution suggests sorting the portions into five different bins with specific weight as outlined in the third column in the same table. The final poultry package will be aggregated based on the set rules outlined in the fourth column. These rules were developed based on the expected weight estimated based on the expected weight of each bin. Based on the 100 portions weighed, the expected weight of the five bins in M1 solution are 111.9, 131.3, 150.1, 170.3, and 187.6 respectively. As a result, the expected package weight $E(Wt_p)$ of the first rule proposed (R1) is 5 * 111.9 = 559.4 g. A lower multiplier such as 4 or a higher one such as 6 will result in excessive giveaway or underweight, respectively. The expected weight of the resultant packages based on each rule for each potential solution are shown in the fifth column of Table 3. The four potential solutions were evaluated based on the following methodology:

1. Generate 500 random portions weights using the best fit normal distribution with average and standard deviation of 145 and 19.55 respectively.
2. Based on the portion weight, place the portion in one of the n bins.
3. Apply the potential rule by selecting specific number of portions from each bin.
4. Add the portions weights and estimate giveaway and underweight for each package.
5. Repeat steps 3–4 until all bins are empty.
6. Repeat steps 1–4 ten times. Each time 500 random portions are used.
7. Estimate the average giveaway and underweight for each rule and select optimal one with minimum giveaway and underweight.

Figure 11 Portion of M1 validation process

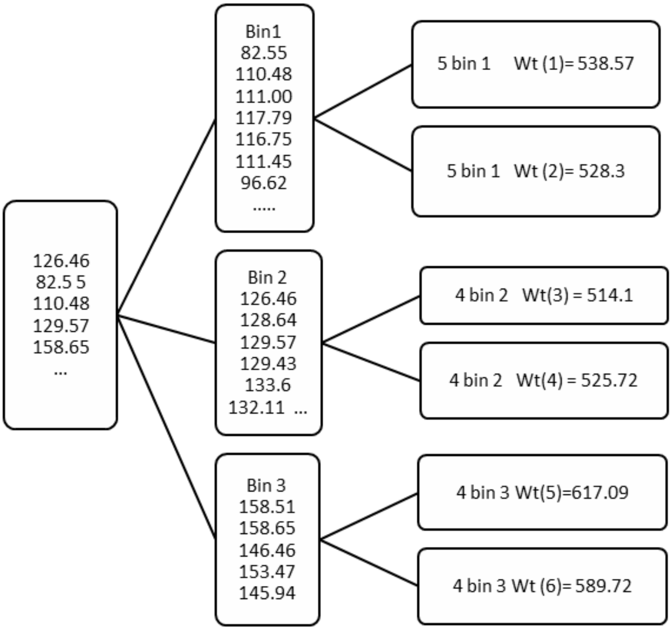


Figure 11 show a portion of implementation of the above methodology for M1 solution while results for all solutions are summarised in Table 3. For example, the first five portions of chicken are selected from bin 1 and used to make first package. This package has a total package weight of 538.57 which resulted in a giveaway of 38.57 g. Furthermore, the total number of packages is found by summing the number of packages produced by every rule. Finally, the total giveaway is calculated by summing the giveaway, excluding the underweight, and dividing this number by the total number of acceptable packages produced times targeted weight such as 500 g as shown in equation (2).

$$\%Giveaway = \frac{\sum Giveaway}{no.\ of\ \ packages\ \ produced \cdot 500} \cdot 100 \tag{2}$$

Similarly, underweight percentage can be found using equation (1) after replacing the summation of the giveaway with the summation of the underweight.

A quick review of results in Table 3 suggests that M3 solution is the best alternative in terms of %Giveaway. However, to overcome the hurdle of the underweight (1.24%), an extra step is required where the final package has to be weighed and re-packaged if it is underweight. It was noted that the main source of the underweight packages in M3 was using rule 4 to group the parts. So, the package weighing may be limited to packages from rule 4 only. M1 and M2 solutions are disregarded since their %Giveaway is higher than the current %Giveaway of the current process. Even though M4 has a %Giveaway higher than M3, it is preferred since it has no underweight packages and consequently does not need the extra final package weighing. As a result, M4 solution is deemed the best alternative among all simulated options. All manual solutions require adding an extra operator to help in the process of weighing and sorting the proportions into the bins. The average salary of the worker is around $500 per month.

To measure the impact of the additional step on productivity, a time and motion study was conducted on the new M4 process and results were compared with the current process. The time required to weigh and sort 25 proportions was recorded and resulted in an average of 3.5 seconds per proportion. The total additional time due to the weighing and sorting will be based on the average number of proportions per tray which is 4. As a result, the additional average time needed in M4 for one package is 14 seconds. The standard time for the rest of steps shown in Figure 1 is 44 seconds. As result, the productivity of M4 process can be estimated as:

$$M4\ productivity = \frac{3,600\ sec/hr}{\left(44+(3.5\cdot 4)\right)\ sec/package} = 62.07\ package/hr \tag{3}$$

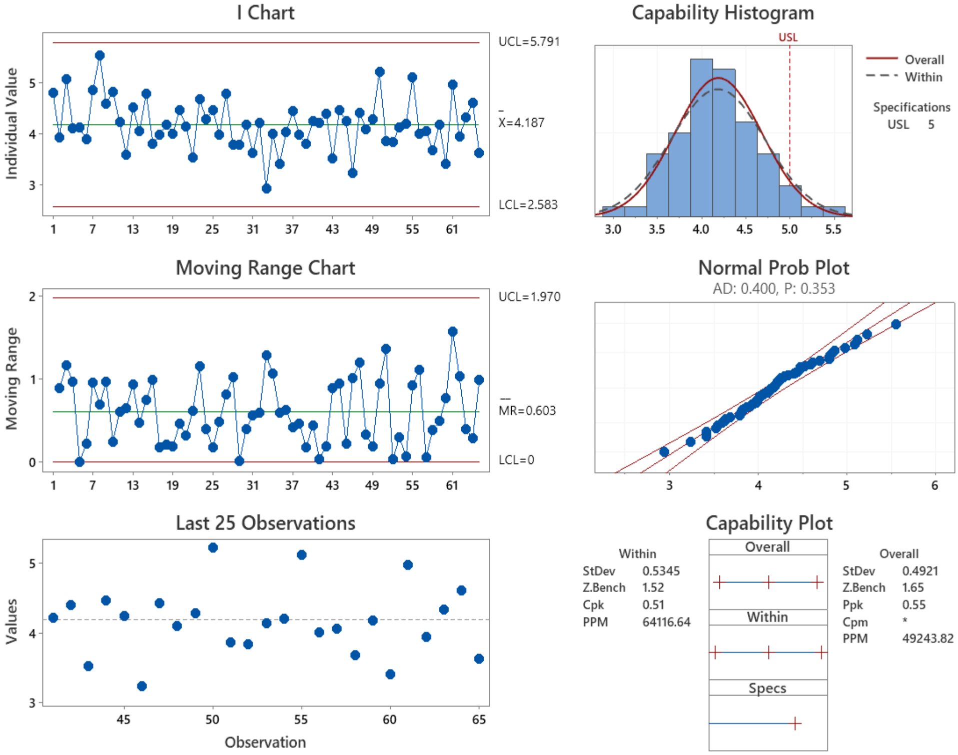
Similarly, the productivity of M3 solution is estimated 60 package/hr due to the additional two seconds required to weigh the package. Even though M3 is better than M4 in terms of giveaway, it is worse in terms of underweight, productivity, and cost. It is worth mentioning that the team also explored the idea of using automated sorters, also known as batchers or graders, that would provide significantly higher productivity with additional reduction in portion giveaways. The machine automatically weighs the portion and obtains a measure, then assigns the portion to one of numerous trays. The grader continues to distribute and accumulate parts of varying weights into different packages until the desired package weight is acquired. Once the package weight is close to the specified package weight mark, the grader will not assign a portion to that tray unless its accumulated weight is equivalent to the desired package size and giveaway allowance. The allowance varies from one grader to the other. Table 4 provides a comparison of three automated graders based on cost, benefit, giveaway, underweight and productivity. The cost includes procurement, power consumption, and maintenance while the benefit to cost (B/C) ratio and payback period (PB) is estimated using cashflow analysis over the useful life of the grader. Based on current local banks offers, the interest rate used for estimation is 7.5% and the lifespan of the graders is 12 years.

Table 4 Selected automated solutions comparison

Solution	*Cost (PC)*	*Payback period (months)*	*B/C ratio*	*Productivity (piece/hr)*	*%Giveaway*	*%Underweight*
A1	$1,204,571	27	6.94	15,000	0.8%	0%
A2	$959,781	19	9.12	12,000	2%	0%
A3	$741,385	14	12.10	7,000	3%	0%

Based on the performance metrics summarised in Table 4 and strategic plan of CPC, A1 is the best option if CPC is willing to invest $1,204,571. A1 provided the minimum %Giveaway and maximum productivity. The team discussed results with champion and top management who perceived the automated solution costs as high and opted for M4. Nevertheless, management was open to the idea of M4 implementation for six months and consider moving to A1 based on results.

Figure 12 Process capability analysis post M4 implementation (see online version for colours)



4.5 Control phase

The ‘control’ stage aims at standardising established measures to correct issues and maintaining desired performance. In our case, standard operating procedure (SOP) was developed to document M4 proposed solution. Moreover, the monitoring system of the final package was established and an individual-moving average range (I-MR) control chart is used for continuous monitoring. Since the proposed solution requires six bins which are used to classify portioned parts, training sessions were conducted for operators. Figure 12 summarises results of implementing M4 solution for 65 days. Results suggest that the process is stable with a Cpk of 0.51 and sigma quality level of 3.02 and PPM of almost 64,000. Comparing these results with current performance suggests a reduction of %Giveaway from 9.7% to 4.2%, indicating substantial improvement and meeting CPC goal of not exceeding 5% giveaway.

5 Conclusions and future work

In this paper, the systematic Six Sigma methodology was utilised to identify, analyse, and provide solutions to giveaway problem at medium size poultry packaging plant. The baseline average giveaway percentage is estimated to be 9.7% with a cost of more than three million dirhams annually. An economical manual sorting solution is implemented which is expected to provide savings of more than a 1 million dollar annually. An automated solution is also proposed which is expected to reduce the giveaway percentage to less than 0.8%. However, this solution represents a substantial investment of $1,204,571.

The project highlights the value that Six Sigma methodology can add to industry in general and food processing in specific. It also demonstrates the balance it provides between cost reduction and customer satisfaction. Providing the right amount of packaged food is not a trivial mission since giveaway needs to be minimised while avoiding reaching the underweight thresholds. Optimising the process requires a strategy that manage the uncertainty of the portioning process.

The proposed method was based on allocating the portions into separate bins based on their weights. Next the targeted weight of the package is accomplished using some set rules which are developed based on the expected weight of each bin. Although the choice of bins and rules development for the proposed solution provided substantial improvement over the base line, it still warrants further investigation. The use of stochastic optimisation to optimise the process further is highly recommended.

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