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INVESTIGATING WEIGHT VARIABILITY OF FOOD PRODUCTS-A SIX SIGMA APPROACH

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ABSTRACT

Overweight in the net product content is commonly observed in the food manufacturing industries in order to avoid the risks of non-compliance regulations. Excessive weight in the products above the specified and legal minimum weight is passed on free to the customers. This giveaway weight is a potential waste leading to variation in product quality, an increased manufacturing cost and reduced profitability. This paper addresses a case study on the implementation of Six sigma approach in a frozen food manufacturing company in order identify the root causes of variation in the net weight of the products, to minimise the variation and to reduce the waste. Necessary data was gathered after each stage of the manufacturing process. The results showed that the poor water control in the forming machine, the damaged state of the forming plates and the poor state of the batter enrobing machine could be responsible for the variation.

Keywords: Giveaway weight, Six sigma, Food manufacturing

1 INTRODUCTION

In the present context of global competition, food manufacturing industries are facing steep challenges of reducing product cost, complying with the government standard, providing better quality of food in terms of taste and food content etc. to maintain the minimum profitability target. Traditionally, the food manufacturing companies fill the product with a higher content than the target weight in order to avoid the risks of non-compliance regulations. The strategy of overfilling can also reduce the rigorous quality checking effort. A term giveaway weight is frequently used to indicate the excessive weight in the products above the specified and legal minimum weight. The giveaway weight is a waste caused by inefficiencies during manufacturing leading to variation in product quality, an increased manufacturing cost and reduced profitability (Bower 2013; Wachs 2011; Wischhusen *et al.* 2012). Therefore, the manufacturers need to ensure an optimal balance between complying with the minimum guaranteed weight and avoiding overfilling through elimination of waste, developing more efficient processes and creating a continuous improvement culture in the workplace.

Six sigma is an innovating approach for enhancing product quality focusing on process improvement (Antony 2005). Six sigma DMAIC (Define, Measure, Analysis, Improvement and Control) is a methodology widely applied in a variety of industries to systematically solve quality related problems. Evidences were also found in the literature about the implementation of DMAIC technique to improve the performance and quality in the food manufacturing industries (Knowles *et al.* 2004; Mu *et al.* 2011; Hung and Sung 2011). Quality management through product control is an expensive and inefficient approach, which focuses on only checking the final product at the end of the operation. However, quality management by process control at each step in the process can ensure that the product is manufactured with a built-in consistency in quality that can satisfy customers and help in avoiding unnecessary quality cost incurred owing to defects and reworking. Statistical Process Control (SPC), which is also a core element of DMAIC technique, has been applied in food industries to keep the manufacturing processes under control (Grigg *et al.* 1998; Gauri 2003; Lim *et al.* 2014). The aim of this work is to reduce the weight variability in a food company using DMAIC method.

2 INVESTIGATION FRAMEWORK

2.1 Background of the Case Company

The case company manufactures a range of vegetarian and vegan (meat-free) ready meal products in the form of burgers, sausages, cutlets etc. in a large purpose-built factory. The company produces its own brand as a key supplier in vegan products and also produces for major supermarket chains. Although the company's main business is focused on manufacturing supermarket brands (90%), the launching of own branded products has opened up opportunities to increase the customer base, to promote brand image and to strengthen the company's competitive offering.

2.2 Methodology

Six sigma DMAIC approach was applied in this investigation. At the beginning, a project team was formed with engineer, production manager, operator and maintenance technician. In the define phase, the problem statement related to the giveaway weight in the products and the aim of the project were defined. In the measure phase, process sequence was mapped and a Pareto analysis of the products was carried out to identify the suitable products for this investigation. The company manufacturers over 100 products, therefore, the team decided to focus on category A products that represent only 20% of all products but 80% of the total sales. A benchmark on the giveaway weight for different products was established through statistical analysis of the data from product weight measurement. Data was also gathered from the product weight measurement with the change in parameters in manufacturing operations. A Cause and Effect diagram was drawn in the Analysis phase to identify the root causes of product giveaway. In the Improvement phase, several improvement activities were carried out to reduce the giveaway weight. Finally, several measures were considered to maintain the manufacturing operations with consistent product quality in the Control phase.

3 RESULTS AND DISCUSSIONS

3.1 Define

The first phase of the DMAIC process deals with defining the potential quality problem to solve. Initial studies and data collected from production indicated that weight variability in the products was the principal cause of giveaway weight. Reducing giveaway weight by only 2% could save the company an estimated £100,000 per annum across all product lines based on current material spend of £5M per annum. Therefore, the continuous improvement team realised that there was an opportunity to reduce the product weight variability, which would help to solve the giveaway problem. The top management was very clear about both the short and long term goals of the project and the team was given the full support in terms of resources required to get to the bottom of the problem.

3.2 Measure

In this phase, different measurements and observations were carried out to identify the evidence of product weight variability and giveaway in the manufacturing shop floor. The process flow of burgers family type products starts with weighing and mixing of ingredients (cooked or non-cooked) and they are transferred to a forming machine to form the product into a burger shape with forming plates and knock-outs. The subsequent operations are as follows: battering, crumbing, frying, freezing and packing. Data of pack weight was gathered from a burger production batch to estimate the amount of giveaway. Fig. 1 shows a histogram of the pack weights with 4 burgers and a nominal weight of

454.00 g. The graph showed that 82.48% of the packs were above the nominal weight. The mean weight was 467.50 g, which represents almost half a tonne of giveaway for the whole production run. For the SPC analysis, data was gathered for 17 products by measuring the weight of 5 products from the forming machine, crumber, fryer and freezing tunnel after every 10 minutes. 25 samples were considered for each product. As an initial step the study was mainly focused on the samples from the forming machine as the weight variability in other processes were considerably lower.

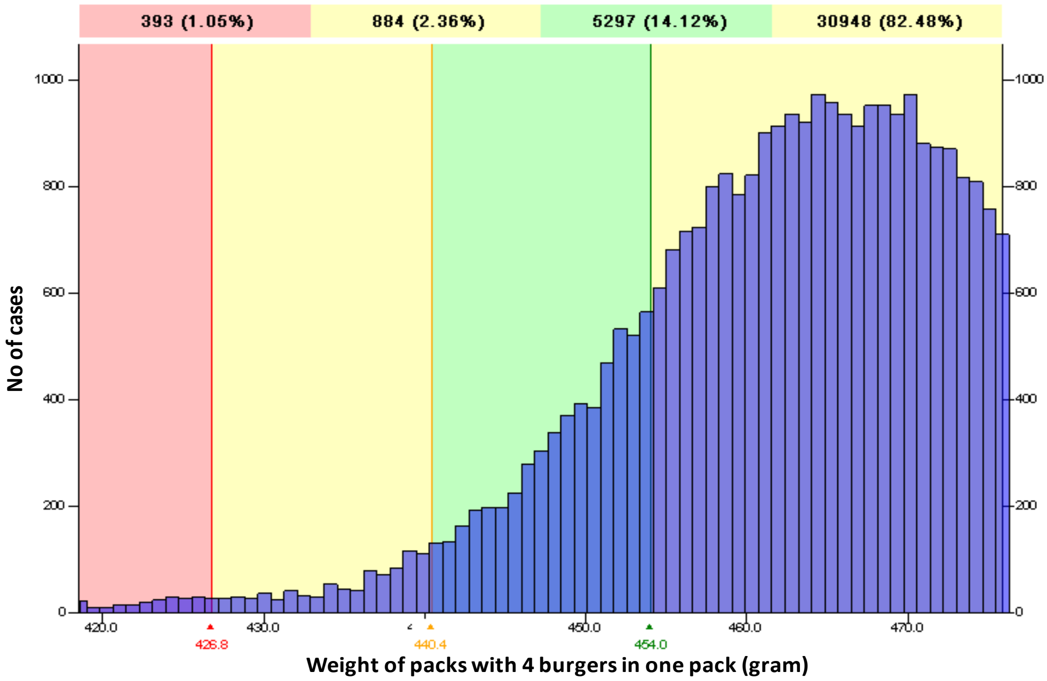

Figure 1: Histogram of burger pack weights from a production run.

Fig. 2 shows the control charts for a type of burger during a period of 4 hours. The process is out of control as indicated by two points outside control limits and poor distribution of data around the mean, higher variation range (1.98) and process standard deviation (0.85).

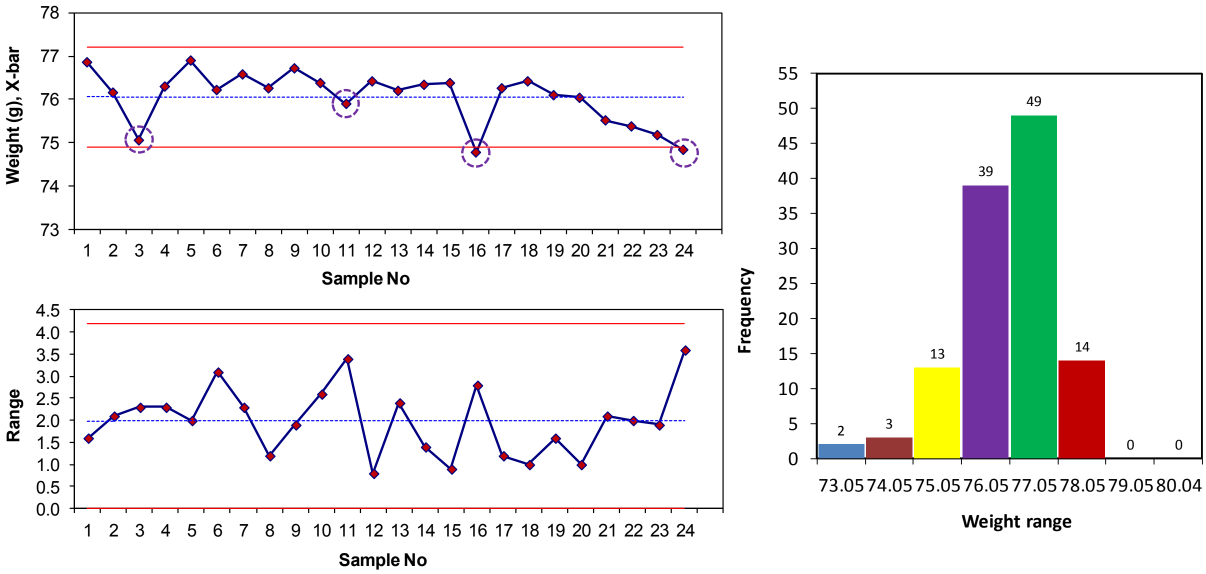

Figure 2: Xbar chart, R chart and histogram of product weight after forming-initial measurement.

It was found that a thinner plate in the forming machine produced underweight products. After changing the thinner plate with a thicker one, the product weights increased significantly. This indicated that the design of the forming plate could contribute to the variation in product weight. Fig.

3 shows the Xbar chart of the product weights measured after producing with different plates in the forming machine. It was also noticed that the shapes and sizes of the products from the forming machine were not very uniform.

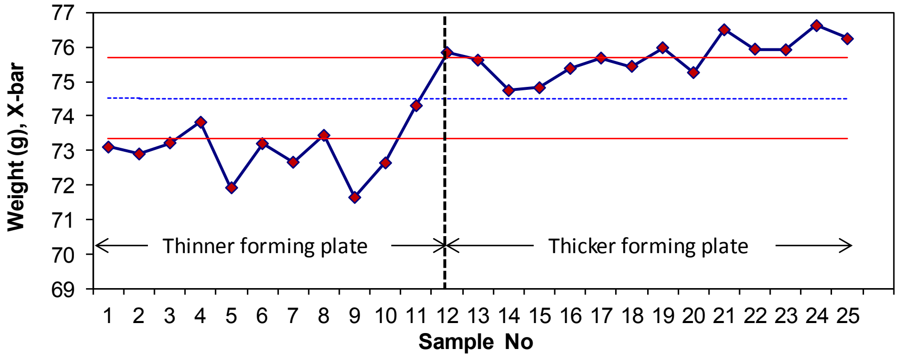

Figure 3: Xbar chart for product weights with thinner and thicker plates in the forming machine.

3.3 Analysis

Fig. 4 shows the cause and effect diagram developed for identifying the root causes of the product weight variability. Several interviews were carried out with food technologist, engineers, shift team leaders and operators to find out possible causes of weight variability. It was found that tools, operating parameters, functioning of the auxiliary systems etc. in the machinery could be the major factors contributing to the variation in product weight. The difference in skills and experience between operators in different shifts can also contribute to the weight variability. The raw materials and working environment were considered to be the factors with a lower impact.

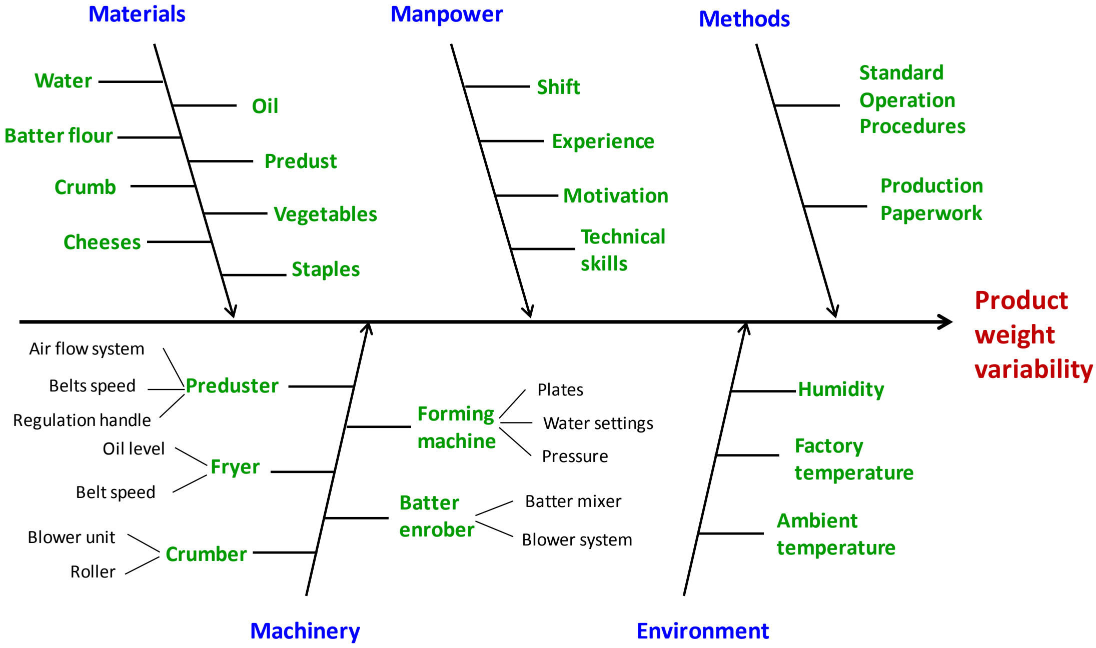

Figure 4: Fishbone diagram for identifying the root causes of the product weight variability.

The water in the forming machine is needed to lubricate the forming plates and to help forming the product. If the water flow is not enough, the product does not form evenly in the different holes of the forming plate causing weight variability. When the batter mixer was being filled with water, it was noticed that there was a decrease on water pressure/flow in the forming machine. Fig. 5 shows pressure drops in the forming machine when filling batter mixer with water. The water pressure drops can be correlated with the lower product weight points as marked in Fig. 2. A similar effect was also identified when water was being used in the other production line. Poor preventive maintenance and lack of operator training and continuous improvement culture on water control in the forming machines could also be reasoned for the weight variation. In order to identify the causes of inaccurate shape and size of the products after forming, forming plates and knock-outs were investigated. A critical observation revealed that they were worn, damaged or broken due to poor maintenance, smaller racks and incorrect storing procedure. Evidences were also found that inconsistent performance of the blower system in the batter enrober could cause weight variability in the products.

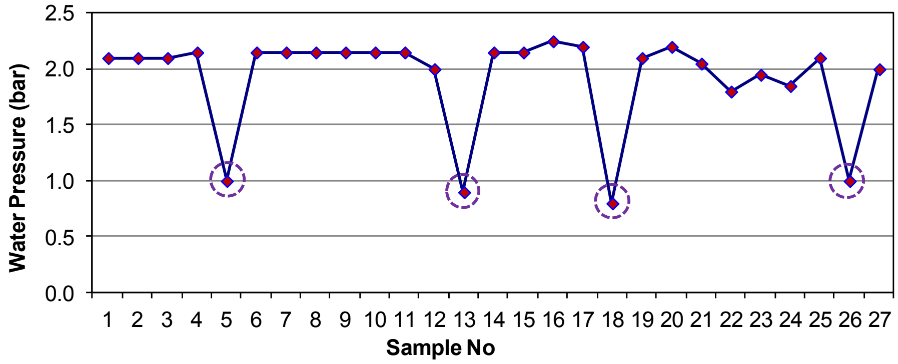

Figure 5: Pressure drops in the forming machine when filling batter mixer with water.

3.4 Improvement

The team decided that improvement in the water pressure control was the critical part of the improvement phase to reduce the weight variability. A new water piping system was installed to ensure consistent water pressure and flow in the forming machine. Other improvement activities for water control include installing new spray bar, new solenoid valves etc. Experiments were carried out to verify this even when water was drawn to other machines. Product weight data were collected after the improvement activity and SPC analysis were carried out as presented in Fig. 6. The results showed that the variation in the product weight was reduced and the process was in control as indicated by good distribution of data around the mean, lower variation range (1.83) and processes standard deviation (0.79) as compared to the initial measurement presented in Fig. 2.

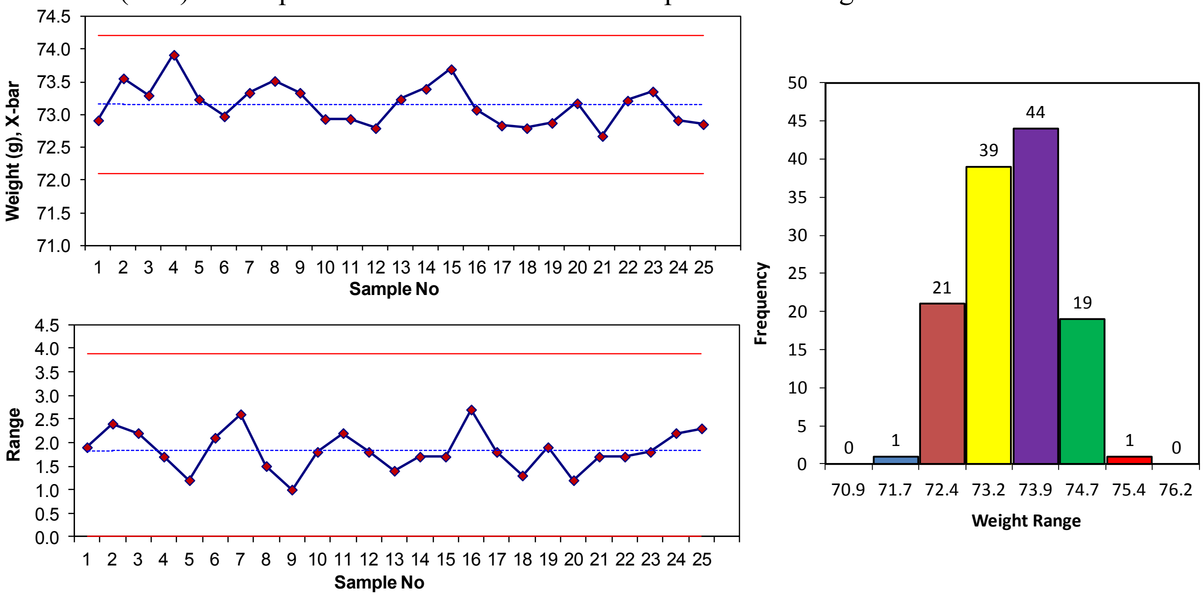

Figure 6: Charts of product weights from forming machine-measurement after the improvement.

After the observation of existing storage racks for the forming plates and knock-outs, the team anonymously agreed that new design of racks were necessary to prevent any unwanted damage while handling and storing. New racks were designed, manufactured and labelled to organise the knock-outs for easy access without damaging during collecting and storing. The racks for the forming plates were modified to accommodate each forming plate in a separate room to avoid any possible damage. An improved design of the forming plate was also proposed to reduce the weight variability. The upgrading of the blower system in the batter enrobing machine is currently underway.

3.5 Control

The suggested improvement activities were implemented in the manufacturing operations in order to reduce the variability and giveaway weight in the food products. Training documents for water control in forming machine has been prepared and appropriate training sessions were conducted with the operators to maintain the process under control. A control plan through regular data collection and monitoring were also prepared. The responsibility was distributed among the relevant production operators in order enhance the employee involvement, which would create a solution for sustainable process control for a longer term. Instruction preparation and operator training were also carried out for storing and handling of the knock-outs and forming plates to enhance their life span.

4 CONCLUSIONS

Six sigma DMAIC problem solving technique has been implemented in a ready meal manufacturing company to identify the root causes of weight variability in the food products. Several improvement activities were implemented to enhance the manufacturing process. Statistical analysis was carried out on the data collected in each stage of the manufacturing process before and after the improvement activities to find a correlation between the manufacturing variables and weight variability. The case study very clearly demonstrates that DMAIC approach can be applied to improve the consistency of the product quality and to reduce the giveaway weight through process control. In addition, the cost savings with the activities will put the company into a better position as a manufacturer to expand their product range and grow their business. All causes of the weight variation could not be explored within the given timeframe; however, a problem solving culture and control mechanism have been embedded within the company environment to continue with the continuous improvement activities.

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