A Critical Assessment on SPC Implementation in the UK Food Industry

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ABSTRACT

Statistical process control (SPC) is one of the most widely applied techniques to control and improve processes in manufacturing industry, but very few studies have reported on the successful application of SPC in the food industry. This paper aims to critically assess the status of SPC in the UK food manufacturing industry and suggests avenues for future research. By surveying the UK food-manufacturing companies, forty-five percent of them were identified implemented SPC, with $\bar{x}$-R and $\bar{x}$-*S* charts found to be the most commonly applied SPC charts in this industry. Top management commitment was identified as the most critical factor, while lack of SPC training is the most significant challenge and lack of awareness of SPC as the main reason for food manufacturing companies not implementing SPC. The paper provides information to food companies in the UK on most common practiced and useful quality tools, SPC charts and critical success factors in the food industry. Furthermore, based on the process performance parameters, SPC companies were observed to achieving better results compared to non-SPC companies.

Keywords: Statistical Process Control, Food Industry,Critical Success Factors, Challenges, Process Performance. Continuous Improvement

1.0 INTRODUCTION

Since the 1980s the manufacturing industry has witnessed a revolution in quality practices and a considerable change has been initiated with increasingly new manufacturing practices and technologies. The manufacturing industry has shifted its focus on detection of product defects to the prevention of the instability and incapability of the processes through the reduction of process variability. In order to facilitate such purpose, W.E. Deming popularised a statistical based technique developed by Walter Shewhart, Statistical Process Control (SPC). SPC is referred to as a powerful collection of problem-solving tools useful in achieving process stability and improving capability through the reduction of process variability [1].

Although SPC is not a mandatory requirement in the food industry, its implementation has been argued to be valuable to organisations in the manufacturing industry regardless of the type of commodities and size of the company. However, the food industry rarely invests additional activities or programme other than activities to fulfilling the mandatory legalities and regulations [2]. Moreover, it is difficult to illustrate a clear picture of process performance in the food industry and its relation to the application of new practices such as SPC [2].

The aim of this study is to explore the status of SPC implementation and quality tools and techniques in the UK food industry. The objectives of the study include: determining the widespread of SPC implementation in the UK food industry, assessing the different types of quality tools and control charts applied in the UK food industry, determining the critical factors for a successful SPC implementation, assessing the key challenges in implementing SPC, understanding the most common reasons for not applying SPC, and determining the impact of SPC towards the process performances.

2.0 LITERATURE REVIEW

The existing literature supported the applicability and advantages of SPC implementation in the food industry not only in processing, but also in packaging. For example, Grigg [3] facilitated a food company establishing an SPC system for weight and measurement control in fish product manufacturing. In this case, from the usage of control chart under SPC, the lower control limit avoids the underfill and the upper control limit prevents 'overfill'. From the usage of histogram and $\bar{x}$-*S* chart, the company was able to reduce giveaway and unnecessary rejection at the checkweigher stage (package weight are measured at this stage). Ooi and McFarlane [4] depicts the usage of SPC in a non-normal condition by demonstrated the application of non-standard SPC procedures in sugar quality (grain size) monitoring. Other perceived benefits of the application in the food industry include improving food safety (e.g. integration with Hazard Analytical Critical Control Point (HACCP)), increasing accountability of correction action, continuous opportunity for improvement of the process performance and enabling to supply accurate quality information to the customers.

The results of empirical studies on SPC implementation in the food industry highlight quality and safety benefits as the dominant motivational factor for implementation [3, 5]. This was shown by the fact that quality certifications in the food industry focused highly on the procedures, assuring the food safety aspects such as the HACCP. Some of the applications of SPC were directed to food safety purposes. Cinar and Schlesser [6] demonstrates the application of multivariate SPC chart in a

food processing plant to monitor the Critical Control Point (CCP) under the HACCP implementation. Also, within the same period, the SPC users are able to assess the process trend that may cause their processes to violate the control limit. The integration of multivariate SPC and HACCP in the food processing operation plays a dual role of quality control and safety assurance [6]. The case study by Cinar and Schlesser [6] illustrated the food company reduced its production cost permitting detection and prevention outwith the control of CCP and subsequently avoiding the production from stopping or reprocessing.

Despite the clear evidence of advantages achieved through the application of SPC in the food industry, it was observed that the implementation rate is still lagging behind other manufacturing industries. Surak [7] labels the food industry as a conservative industry and argues that the resistance to change within the industry is one of the main reasons for this alarming issue. Hersleth and Bjerke [8] suggested the lack of understanding of statistical thinking in the food industry causes reluctance and a lack of awareness of the statistical based quality tools. However, the primary reason for this issue has not yet been empirically studied.

Although many case studies suggest that variation reduction is achievable due to the effective application of control charts to control and monitor variations, the applications of other SPC tools to reduce the variation were rarely credited for the success of its implementation. Furthermore, there is no information on the type of SPC charts commonly applied and perceived as beneficial to the food manufacturing industry.

The literature of SPC mainly comprises of the mathematical literacy of SPC, indicating the lack of resources on the managerial and operational aspects of SPC such as the critical success factors (CSFs), and challenges faced by the food industry to adopt SPC in the company. By drawing on the survey data, this study intends to fill the void in current research on the SPC implementation issues in the food industry and discuss its impact on the operational performances.

3.0 METHODOLOGY

The objective of this study is to critically assess the expansion of SPC application in the UK food industry and to test the assumptions gathered from the literature. In the field of operation management, there are common approaches undertaken for empirical research which include surveys, case studies, action research, ethnography and grounded theory.

A survey is the most appropriate method to gain an understanding of the relevance of the application of SPC in the food industry [9]. The survey instrument was developed and adapted from the published literature of quality improvement [9-11]. The final version of the survey listed 25 questions divided into five sections: demographics, quality tools and techniques, SPC tools, process performance measurement and reasons for not applying SPC in the food companies.

Financial Analysis Made Easy (FAME) database was used to build the sample framework and to retrieve contact details of potential respondents in the food companies. The questionnaire was completed by the CEOs, Directors, Quality Managers, Production Managers, Continuous Improvement (CI) Managers, General Managers, Six Sigma Black Belt and Six Sigma Green Belt.

A pilot questionnaire was sent to two academics and two CI practitioners (from the food industry) to validate the questionnaire, test its effectiveness, and to ensure that it was understood. Due to the survey questions being adopted from a non-food industry survey, some of the recommended amendments included rephrasing terminology to suit the food industry and modifications to the formatting of the questions were undertaken to increase the respondent's understanding and to achieve a higher response rate. The four respondents who pretested the survey were excluded from further participation in the survey. There were several types of questions in the survey: open-ended questions, Liker-scale questions and dichotomous questions. In order to achieve the purpose of this survey, descriptive analysis and other statistical testing analysis was undertaken as below:

- Chi-Square analysis: the data contained categorical/ordinal (e.g. small, medium, large) variables for a single population with a large number of samples, n>30 [12].
- Paired Wilcoxon Signed Ranked test: Involved two dependent samples and were treated as an alternative test for paired t-test as the population distribution differences was non-normal (Shapiro-Wilk Test *p*-value=0.018<0.05) [12].
- Mann-Whitney U test: applied due to the violation of the data to the assumption of Independent t-test, where data is not normally distributed (Shapiro-Wilk Test *p*-value=0.010<0.05) [12].

4.0 KEY FINDINGS OF THE SURVEY

The response rate for the survey was 15% (59 food manufacturing companies), which 56% of these were large companies (more than 250 employees), 27% were medium-sized companies (51-249 employees), and 17% were small companies (11-50 employees). The sample size was comparable to previous surveys published in the quality management field. For example: 11% (48 respondents) (Scott et al., 2009), and 15% (35 respondents) (Dora et al., 2009). The respondents of this survey consisted of CEOs, Directors, Quality Managers, Production Managers, CI Managers, General Managers, Six Sigma Black Belt and Six Sigma Green Belt.

From the data analysed, 45% of the sample implemented SPC, regardless of the size of their company. Among the respondents that applied SPC, 18% were from small companies, 24% from medium and 58% from large companies. Trienekens and Zuurbier [13] argued that quality management adoption in the food industry depends on organisational factors such as size of the company, type of suppliers and customers and type of products. Hence, the authors validating a similar statement for SPC implementation through the proposition below (H_1).

H_1*: Size of company has a significant impact on the adoption of SPC in the food-manufacturing sector.*

Based on the Chi-square analysis, it was determined that the p-value=0.011<0.05, hence there was sufficient evidence to validate an impact of the size of the company towards the adoption of SPC [12] .

Table 1 depicts the result of the applied SPC charts in the food industry and rate its 'practice' (1=Never implement to 5=Frequently implemented) and 'usefulness' (1=Extremely not useful to 5=Extremely useful). Results show both $\bar{x}$-R chart and $\bar{x}$-S chart were the most frequent control charts applied with mean scores of 4.6 and 4.9. Although there are gaps between practice and usefulness, both charts consistently topped the mean score as the most useful control charts in the food companies (H_2).

H_2*: There are significant differences in the degree of practice of SPC charts and its usefulness in the food industry.*

Paired Wilcoxon Signed-Rank test was carried out to assess the significance of the gaps between 'practice' and perceived 'usefulness' mean score for the SPC charts applications.

Table 1. SPC charts application in the food industry

Control charts	Practice	Usefulness	Asym. Sig. (2-tailed)	Statistical significance
$\bar{x}$-S chart	4.900	3.850	0.001	Significant
np-chart	4.350	3.476	0.001	Significant
c-chart	4.315	3.588	0.001	Significant
Moving Averages	4.625	3.824	0.004	Significant
$\bar{x}$-R chart	4.600	3.9167	0.012	Significant
EWMA	3.727	2.667	0.018	Significant
Multivariate charts	3.800	2.286	0.019	Significant
p-chart	4.188	3.500	0.021	Significant
u-chart	3.077	2.377	0.030	Significant
CUSUM	2.800	2.455	0.096	Not significant
Individual/Moving Range(x-MR)	3.778	3.00	0.157	Not significant

The results show that the differences between 'practice' and 'usefulness' of CUSUM and x-MR chart are not statistically significant as both of the p-values > 0.05. This also means that other than aforementioned charts, food companies did not find other SPC charts as useful as the degree of its implementation in the company.

Similarly, SPC users were asked to rate the 'importance' and 'practice' of CSFs of SPC implementation within the company according to their experiences (Table 2).

Table 2. Critical Success Factors of SPC implementation in the food industry

Factors	Important	Practice	p-values	Statistical Significance
Availability of SPC expertise	4.153846	3.230769	0.004	Significant
Continuous training sessions	4.098462	3.384615	0.010	Significant
Understanding of statistical thinking	4.198461	3.621538	0.016	Significant
Reliable measurement system	4.269231	3.629630	0.034	Significant
Top management commitment	4.461538	4.038462	0.046	Significant
Leadership	4.192308	3.884615	0.084	Not significant
Empowerment	4.076923	3.653846	0.098	Not significant
Project management	3.000000	3.769231	0.249	Not significant
Prioritisation of process	3.100001	3.869232	0.458	Not significant

The result is consistent with the SPC literature, where top management is predominantly viewed as the most critical factor [5, 9, 14]. Table 2 show there are gaps between importance of the factors and the degree of its implementation (practice) with significance showing higher mean score for every CFSs listed. Further analysis of the gaps was placed under the hypothesis (H_3):

H3*: There are significant differences on the perceived importance of CFSs to the degree of practice for SPC in the food industry.*

The results for paired-sample Wilcoxon Signed Rank test to address the hypothesis H_3 are shown in Table 2. Factors such as a sound measurement system, continuous training sessions, availability of SPC expertise and statistical thinking were statistically significant for the above mentioned hypothesis with the p-value= 0.034, 0.01, 0.004, and 0.017, respectively > 0.05. The results demonstrate that the FMC struggled to practice the components related to statistical knowledge and engineering skills to the equal level of their importance.

Table 3 shows the mean score on the common challenges that were considered to hinder the SPC implementation in the food industry (from 1= Strongly disagree to 5=Strongly agree).

Table 3. SPC challenges factors

Challenges	Mean scores
Insufficient training sessions of SPC implementation	4.33
Employees' lack of awareness of SPC and its benefits	4.30
Lack of top management support	3.11
Poor measurement system	3.11
Lack of data collection system	3.11
Lack of experience in quality improvement tools/techniques/methods	3.07
Lack of knowledge of SPC implementation	3.04
Lack of ability to apply SPC in the real world	3.00
Lack of systematic and practical guidelines for SPC implementation	3.00
Resistance to accepting SPC as a process improvement technique	2.89
Lack of employee empowerment	2.85

Insufficient training sessions and employees' lack of awareness of SPC and its advantages are the most critical challenges. This indicates shortage of skills in implementing CI technique, especially statistical technique such as SPC, which is an alarming issue in the food industry.

Many other industries have been reaping the benefits of SPC implementation. For example, in the last 30 years western countries, especially the automotive industry has gained the benefits of such implementation. However, the rate of SPC adoption in the food industry is reported to be low and slower compared to other manufacturing industries [15], which suggest the need to understand the reasons for not implementing SPC as a process control and quality improvement technique.

Table 4. Reasons for not implementing SPC in the food industry

Factors	Mean
Unaware of the benefits of its application	4.30
Inadequate statistical knowledge to apply SPC	3.66
SPC is a too advanced quality improvement technique to be applied	3.34
Lack of understanding of the concepts of SPC	3.38
Lack of financial resources	3.28
Insufficient time	3.17
Top management does not support the implementation	2.41

The main reason food companies do not apply SPC are due to unaware of the benefits of SPC and the lack of statistical knowledge to apply SPC'.

In the current literature, there is a dearth of publications addressing the performance metrics reflected in the success of SPC implementation. Therefore, the performance variables listed in Table 5 were built based on the literature in CI related to SPC (e.g. Six Sigma, TQM) [16-20].

This survey was intended to differentiate the performance advantages between companies that implement SPC and non-SPC companies. The respondents were required to rate the improvement level of their business against the criteria in Table 6 by using a Likert scale (1=Very poor, 2= Poor, 3=Fair, 4=Good, 5=Very good). The most applied performance metrics in the food industry are the customer satisfaction (64%) and customer complaints (63%). A majority of the respondents agreed that waste reduction was the greatest advantage gained from SPC implementation and this was followed by the improvement in product consistency. Underfilling is a crucial issue, which leads to customer complaints and penalties. Hence, the most typical strategy to overcome such a problem is by exceeding the target amount (overfilling) which leads to waste of raw materials.

Table 5. The difference between SPC and non-SPC companies process performance in the food industry

Process performance measurement	SPC companies	Non-SPC companies	Mann-Whitney U test (Asymp. Sig)
Waste reduction (Overfill/giveaway/ underfill)	4.64	3.32	0.000
Product consistency	4.32	3.67	0.000
Customer complaints reduction	4.24	3.48	0.000
Defects rate reduction	4.12	3.18	0.001
Productivity improvement	4.09	3.43	0.002
Rework percentages	4.08	3.20	0.002
Quality awareness	4.05	3.53	0.044
Process cycle time	3.95	3.51	0.052
Cost of Quality	3.90	3.36	0.054
Customer satisfaction	3.52	3.34	0.180
Competitive advantage	4.14	3.79	0.273
Company's image	4.06	3.92	0.276
Customer loyalty	3.94	3.90	0.975

Table 5 also demonstrates that the SPC companies achieved better performance scores for all performance metrics compared to the non-SPC companies. This study carried out an assessment on the differences of SPC and non-SPC companies on the process performances through Mann-Whitney U test.

H4*: There are significant differences between SPC and non-SPC companies on the key performance metrics.*

The results show that there were significant differences between SPC and non-SPC companies for waste, product consistency, customer complaints, defects rate, productivity, rework percentages, and quality awareness. Based on Grigg [3]'s cognitive mapping, the chain of benefits was started from the reduction of variation of the key processes through a statistical process monitoring and improvement system. Furthermore, the use of such a process control system allows the opportunity to improve the awareness of the quality aspects of the processes instead of only focusing on the product quality.

5.0 DISCUSSION ON THE KEY FINDINGS

Food companies that integrate SPC into their manufacturing and quality programme can improve process excellence through gaining process stability. Diverse advantages, including reduction of defects, minimising waste and improving quality, and safety of the food products have been reported in various food commodity sectors[21, 22]. The objective of this study was to explore the application of SPC in the UK food industry and the issues relevant to its implementation such as CSFs, types of SPC charts, CSFs, challenges, reasons for not adopting SPC, and impacts of SPC on process performance measurement.

Size of company

Based on the responses to the survey, almost half of the responding food companies had applied SPC in their processes. Consistent with the literature of CI, the number of food companies using SPC increases with the size of companies [23]. It was articulated from the literature of quality management in the food industry that the adoption of SPC may differ due to the different levels of the quality maturity depicted relative to the size of the company [15]. Furthermore, the main restriction for small organisations in adopting SPC is the lack of resources in the form of time and personnel [10]. The lack of resources may force small food companies to prioritise the adoption of quality techniques, which results in more food safety techniques being adopted instead of embracing advanced process control techniques such as SPC (due to their obligation to comply with food laws and regulations). This is also true for the medium sized food companies because they were known to be more agile compared to small and large companies in adopting new techniques [23]. Moreover, it was observed in an empirical study that the management in small companies does not have the sufficient fundamental knowledge to see the potential of statistical techniques such as SPC in their companies [24].

The issues in the implementation of SPC

This study also focuses on the challenges faced by the food practitioners to implement SPC. Firstly, we focus on the lack of SPC training provided to the employees. In the food industry, although training has no influence on basic quality tools/techniques adoption, it influences the advanced tools/technique such as SPC [15]. The first issue with SPC training in the food industry is the training is typically a one-time event, with no further recurrent training. The second issue is most food companies have given little attention towards training in quality improvement and statistical skills despite the employee's low qualification levels and high skills shortage in quality improvement tools throughout the industry [25]. Critical barriers to training in the FMC are time-released sectors and financial resources, usually indebted to the lack of top management support. The impact of insufficient training leads to other inhibitor factors depicted in the survey result, such as the lack of awareness and knowledge of this technique, and the resistance of employees to its adoption.

Top management has been a prominent factor in the data. Management support in SPC implementation is viewed as the actions performed and policies instituted by the top managerial personnel to drive the implementation of SPC in the company [26]. However, it was their degree of understanding, time allocated SPC, and the concomitant involvement, which includes personal dedication towards its implementation. Realistically, SPC implementation may initiate from the bottom level of the organisation where an SPC pilot project can be carried out with the production/quality team. However, it was observed there was a need for it to be led and supported from the top of the organisation not only for its successful companywide deployment but to sustain the application within the company.

The results highlighted that the food industry has been struggling to practice the activities that required statistical knowledge, although such activities (establish reliable measurement system, continuous training sessions, availability of SPC expertise) were perceived as critical in ensuring a successful SPC programme. The literature shows that statistical thinking was not explicitly introduced in the food manufacturing practices [15].

According to Davis and Ryan [25], there is a critical need for the employees to be involved in ensuring the products' consistency and reduction of wastage whereby knowledge should then be provided. Reluctance of adopting SPC could be reduced by providing provisional training to increase the awareness of SPC and its advantages to the employees and company. The system and the theoretical background of SPC can be daunting to those without sufficient training and can cause resistance to its application [27]. Davis and Ryan [25], stated that the low qualifications of the employees within the industry were attributed to the lack of awareness of SPC and its benefits.

SPC success and process performance improvement

To this point, the study has encountered the link between SPC success and its process performance improvement. It was argued that the perceived success of the pilot project was crucial for SPC continuance [28]. This perception of success could well be based upon the product quality and the operational criteria rather than on business performance criteria such as customer satisfaction, company's awareness, and customer loyalty. The encouraging results obtained from the SPC users compared to non-SPC companies showed that SPC has an advantage on the operational performance measures (e.g. waste reduction, product consistency, defects rate, rework rate). The analysis of this study highlighted the lack of appropriate measurement applied for process performance measurement, especially the capability indices (Cp/Cpk and Pp/Ppk) in the non-SPC companies. Most researchers agree that the central tenet of SPC management is that the data and facts should be the heart of SPC activities; the authors stress the need to study further the process performance variables to verify the success of SPC implementation in this industry [1].

6.0 CONCLUSIONS

This study explored the status of SPC implementation in the food industry through the distribution of an online survey to the food manufacturing companies. From 59 companies, 45% of the food manufacturing companies adopted SPC. Compared to the past three decades where SPC was introduced in the manufacturing industry, the implementation in the food industry is considered slow and still at the infant maturity level. The adoption of SPC was highly influenced by the size of the company, where larger companies had the ability to support and invest in training and education of their employees to use SPC under their current quality management system compared to the medium and smaller companies.

For SPC user, the most common SPC charts implemented were Shewhart's $\bar{x}$-R and $\bar{x}$-S charts and those were also rated to be the most useful charts. With respect to the implementation, top management commitment was found to be the most prominent factor contributing to a success SPC implementation. Meanwhile, lack of training sessions and lack of SPC awareness critically inhibited the SPC implementation in this industry. For the non-SPC companies, lack of awareness on SPC benefits have largely caused companies reluctance towards its implementation. Overall, compared to non-SPC companies, SPC companies were perceived have achieved higher scores on the process performance metrics and this was particularly significant in terms of waste reduction, product consistency, customer complaints, defects rate, productivity, and rework percentages. This performance comparison between SPC and non-SPC companies strongly suggests that SPC is an integral component of quality management system within this sector. Verification of the results with larger and better representative sample size of the food industry is recommended.

One of the limitations of this study is the majority of the respondents were managers, who may not have had access to confidential financial information. The information provided can be interpreted by the respondents from the approximate value in the state of the true value. Information gained from this survey is also limited and lack of descriptions/reasoning on the results. Therefore, a qualitative study is highly advised to determine more explanations reflected towards the outcome of this survey. The sampling framework for the survey focussed only on the food manufacturing companies. This study discarded the food services or food laboratory companies as the potential sample. Quality in the food service companies may have faced different challenges, using processes with different parameters and required unique approaches of SPC implementation to improve the quality. This will prevail similarities and differences compared to the results of this study and for subsequently to gain a better in-depth understanding of the significance of variability reduction using SPC principles in this sector.

7.0 REFERENCES

[1] D. C. Montgomery, **Introduction to statistical quality control.** New York: John Wiley & Sons, 2012.

[2] P. E. Waterson, C. W. Clegg, R. Bolden, K. Pepper, P. B. Warr, and T. D. Wall, "The use and effectiveness of modern manufacturing practices: A survey of UK industry," **International Journal of Production Research**, vol. 37, pp. 2271-2292, 1999.

[3] N. P. Grigg, "The use of statistical process control in food packing research agenda," British **Food Journal** vol. 101, pp. 763-784, 1999.

[4] G. Ooi and D. McFarlane, "Non-standard application of SPC in sugar quality monitoring," in Control'98. UKACC International Conference on (Conf. Publ. No. 455) vol. 1, ed: IET, 1998, pp. 485-490.

[5] S. A. H. Lim, J. Antony, and S. Albliwi, "Statistical Process Control (SPC) in the food industry–A systematic review and future research agenda," **Trends in food science & technology**, vol. 37, pp. 137-151, 2014.

[6] A. Cinar and J. E. Schlesser, "HACCP with multivariate process monitoring and fault diagnosis techniques: application to a food pasteurization process," **Food Control**, vol. 16, pp. 411-422, 2005.

[7] J. G. Surak, "Quality in commercial food process," **Quality progress**, vol. February, pp. 25-29, 1999.

[8] M. Hersleth and F. Bjerke, "Introducing statistical thinking to the food industry-facilitating and inhibiting factors," **Quality Management Journal**, vol. 8, pp. 49-60, 2001.

[9] B. S. Scott, A. E. Wilcock, and V. Kanetkar, "A survey of structured continuous improvement programs in the Canadian food sector," **Food Control**, vol. 20, pp. 209-217, 2009.

[10] M. Dora, M. Kumar, D. Van Goubergen, A. Molnar, and X. Gellynck, "Food Quality Management system: Reviewing assessment strategies and a feasibility study for European Food Small and Medium-sized Enterprises," **Food Contro**l, vol. 31, pp. 607-616, 2013.

[11] J. Antony, M. Kumar, and C. N. Madu, "Six sigma in small-and medium-sized UK manufacturing enterprises: Some empirical observations," **International Journal of Quality & Reliability Management**, vol. 22, pp. 860-874, 2005.

[12] D. J. Sheskin, **Handbook of parametric and nonparametric statistical procedures**: CRC Press, 2003.

[13] J. Trienekens and P. Zuurbier, "Quality and safety standards in the food industry, developments and challenges," **International Journal of Production Economics**, vol. 113, pp. 107-122, 2008.

[14] N. P. Grigg, "Statistical process control in UK food production: an overview," International **Journal of Quality & Reliability Management**, vol. 15, pp. 223-238, 1998.

[15] N. P. Grigg and L. Walls, "Developing statistical thinking for performance improvement in the food industry," **International Journal of Quality & Reliability Management**, vol. 24, pp. 347-369, 2007.

[16] K. Jeyaraman and L. K. Teo, "A conceptual framework for critical success factors of lean Six Sigma: Implementation on the performance of electronic manufacturing service industry," **International Journal of Lean Six Sigma**, vol. 1, pp. 191-215, 2010.

[17] A. Neely, M. Gregory, and K. Platts, "Performance measurement system design: a literature review and research agenda," **International Journal of Operations & Production Management**, vol. 25, pp. 1228-1263, 2005.

[18] C. D. Ittner and D. F. Larcker, "The performance effects of process management techniques," **Management Science**, vol. 43, pp. 522-534, 1997.

[19] A. Kumar, S. O. R. Soreillyuccie, and F. Adam, "Action Research using Case Study Methodology for Implementation of Process Improvement Initiatives in Food SMEs," **Design**, pp. 1-6, 1998.

[20] E. E. Adam, B. E. Flores, and A. MacIas, "Quality improvement practices and the effect on manufacturing firm performance: Evidence from Mexico and the USA," **International Journal of Production Research**, vol. 39, pp. 43-63, 2001.

[21] A. C. Dalgiç, H. Vardin, and K. BelibaÄŸli, "Improvement of Food Safety and Quality by Statistical Process Control (SPC) in Food Processing Systems: A Case Study of Traditional Sucuk (Sausage)," in **Processing, quality control of herbal medicines and related areas**, Y. Shoyama, Ed., ed.

[22] D. Rábago-Remy, E. Padilla-Gasca, and J. Rangel-Peraza, "Statistical Quality Control and Process Capability Analysis for Variability Reduction of the Tomato Paste Filling Process," **Industrial Engineering Management**, vol. 3, pp. 1-7, 2014.

[23] N. P. Grigg and L. Walls, "Developing statistical thinking for performance improvement in the food industry," **International Journal of Quality & Reliability Management**, vol. 24, pp. 347-369, 2007.

[24] M. Deleryd, R. Garvare, and B. Klefsjö, "Experiences of implementing statistical methods in small enterprises," **The TQM Magazine**, vol. 11, pp. 341-351, 1999.

[25] A. Rungtusanatham, J. C. Anderson, and K. J. Dooley, "Towards measuring the "SPC implementation / practice " construct," **International Journal of Quality & Reliability**, vol. 16, pp. 301-329, 1999.

[26] J. Davis and M. Ryan, "Training in the SME sector of the food and drink manufacturing industries," **Management Services,**vol. Spring, pp. 38-42, 2005.

27] C. Hewson, R. Cox, and K. Stenning, "A study of SPC Training Needs in Small and Medium UK Companies ." **Starke,** pp. 1-58, 1997.

[28] J. Antony, "Ten key ingredients for making SPC successful in organisations," **Measuring Business Excellence**, vol. 4, pp. 7-10, 2000.