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The Implementation of Statistical Process Control in the Food Industry: A Systematic Review

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Abstract

This study is to illustrate a systematic review application in investigating common issues emerging from Statistical Process Control (SPC) implementation in the food industry. A total of 41 journal articles were rigorously selected from four databases and reviewed. The most common themes emerge in SPC implementation in the food industry is the benefits while the remaining themes are motivation, barriers and critical success factors (CSF). This review found that the evidence of SPC implementation in the food industry is beneficial; however, a lack of both awareness and guidelines relating to SPC implementation in the food industry has resulted in a slow adoption. This paper also provided a critical review of the existing SPC implementation framework. This systematic review concluded that there is a need for further research into the SPC deployment aspect addressing how to deploy SPC in the food industry in a systematic manner. The development of practical and useful guidelines to assist food manufacturers with the implementation of SPC is suggested able to address such issue.

Keywords
Statistical Process Control, Food Industry, Systematic Review, Operation Management

1. Introduction

Statistical process control (SPC) is a technique developed based on Shewhart's conception of process variability, which widely applied not only in manufacturing processes but also in service operations for quality sustainability purposes. SPC is defined by Montgomery (2009) as a powerful collection of problem-solving tools useful in achieving process stability and improving capability through the reduction of variability. The primary purpose SPC implementation is to detect and reduce special cause variations for process stability.

It has long been acknowledged that the benefits of Statistical Process Control (SPC) can be expanded to the industrial processing industry and has an obvious significant share in quality aspects of manufacturing industry especially the food industry. The quality control in the food industry is scientifically related to technology, sensory attributes, physical, safety, chemical make-up and nutritional value (Grigg and Walls, 2007).

Today's food manufacturing businesses are heavily challenged by consumer-oriented markets that require continuous improvement and development in food product quality (Pable et al., 2010). Consumers' strict purchase behaviour has forced companies to invest in adopting quality initiatives such as total quality management (TQM), Six Sigma, Zero Defects, Lean, Kaizen and just in time (JIT), not only to prepare safe and quality food, but also to avoid breaching food legislation and to gain consumers' trust.

Variations in food products have been challenging food technologists and food scientists for more than 80 years. Hence, there is evidence that some modern statistics originate from food processing and agricultural production. The foundation of statistical application in quality control was partly established through work within Guinness breweries by technologist and statistician, W.S Gosset, who clearly demonstrated the opportunities of elements of statistical techniques applicability in the food industry (Grigg and Walls, 2007b, Grigg, 1998, Surak, 1999a).

Quality control evolution in manufacturing started with the inspection (Dooley, 2000). Mechanism in inspections is based on detection, and causes arguments regarding how these methods fail to facilitate economical quality control procedures. This is due to detection of product defects and variations in the production line being considered too late to be solved (Deming, 1986). Therefore, a systematic quality control technique such as SPC is required in food quality control. With the emphasis on prevention of problems, SPC has a significant advantage over inspection as a quality control technique (Paiva, 2013).

Although SPC has been proved its advantages in business performance in other industries, food industry does not apply a systematic approach to achieving business excellence to the same extent as other industries (Mann et al., 1999). Hence, this review attempts to assess emergent issues related to SPC implementation within the food industry

in order to get a better understanding of the critical concerns issued within the practical implementation of improvement in quality and performance.

2. Methodology

A structured systematic review was applied to investigate common issues in SPC implementation within the food industry settings and organisations published between 1980 and 2012. This review is conducted by following four phases: planning, sampling, analysis and reporting. Such phases are based on systematic review stages by Tranfield et al. (2003) for evidence-based research in management studies. The overall process of the review is summarized in Figure 1.

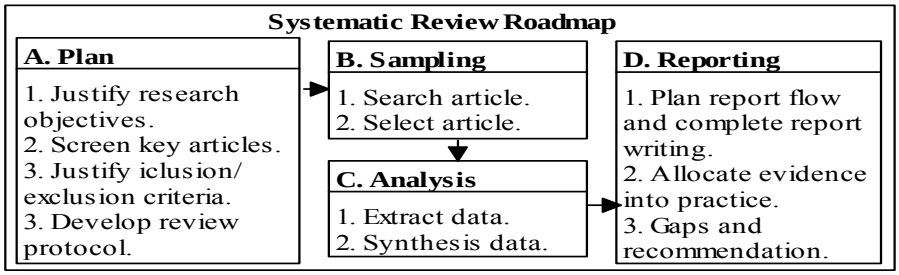

Figure 1: Summary of systematic review process

The advantage of conducting a systematic review is to reduce bias in the selection by the comprehensiveness of the search strategy and transparency of the relevant articles (Figure 2.) included in the review (Tranfield et al., 2003). From CIMO (context-intervention-mechanism-output) logic, inclusion criteria of context are food industry, food manufacturing, food processing and food production while the exclusion context is found in food service and laboratory trials. Interventions included in this article are SPC, Six Sigma, TQM and Continuous Improvement (related to SPC). However, quality function development (QFD), Zero Defects and Just-In-Time (JIT) are excluded due to the absence of SPC techniques underlying the respective methods.

Inclusion criteria (Mechanisms) involve aspects of SPC introduction and implementation efforts and the exclusion criterion is mathematic theoretical development articles. Inclusion criteria (Output) are outlined to include issues emerging in SPC implementation and exclude articles with an outcome of mathematical theory. Only complete articles in English will be assessed while book reviews, dissertation, letters, commercial web pages and brochures are excluded as the experts insufficiently assess the contents of such sources.

The databases used for searching the articles are Emerald Insight, IEEEXplore, ScienceDirect and ABI/Inform. IgentaConnect and JSTOR were initially considered, but were dropped due to very low numbers of hits within the scope of this review. Thematic synthesis is chosen instead of meta-analysis due to the qualitative nature of this research; the extracted data that shaped the finding synthesis related to motivation, benefits, limitation, barriers, and the CSF of SPC implementation.

3. Results and Discussion

Forty-one original studies were selected after a careful and systematic selection process in the sampling phase of this review.

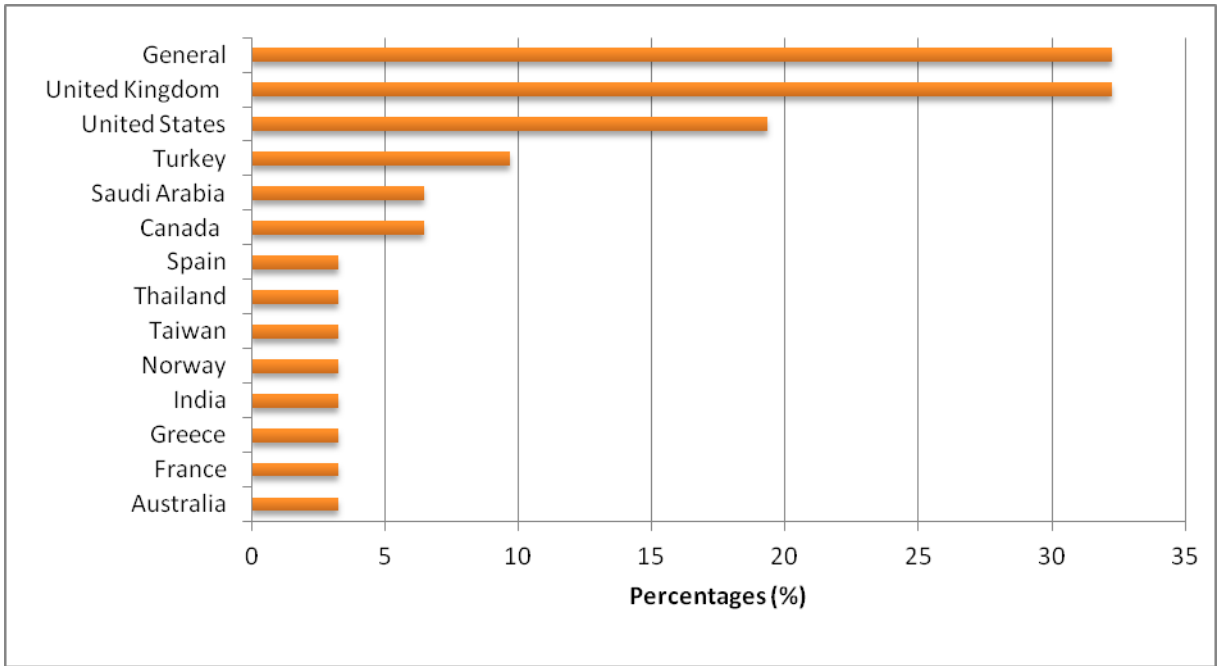

Figure 2: Percentage of country

Based on the figure 2, it shows most of the journal articles published SPC application in the United Kingdom and followed by the United States. However, most of the publication also did not claim any specific country and depicted generalization of their results in SPC implementation.

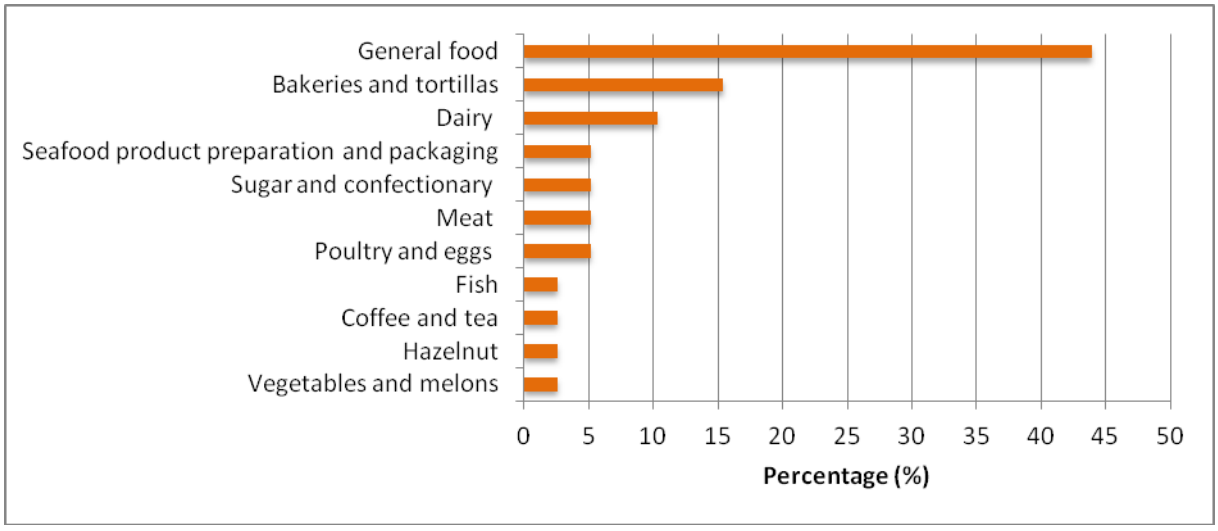

Figure 3: Percentage of food commodities

Based on Figure 3, the highest commodity cited implemented SPC is in bakeries and tortillas and followed by the dairy industry. Processes in bakeries are less complex and require smaller numbers of processes, which leads to a wider application of SPC compared to other commodities. The dairy industry strictly abides by food safety law,

which has forced food producers in this sector to implement powerful quality control techniques, such as SPC and HACCP (or a combination of both). This is due to the nature of dairy products are easily contaminated (Hayes et al., 2001).

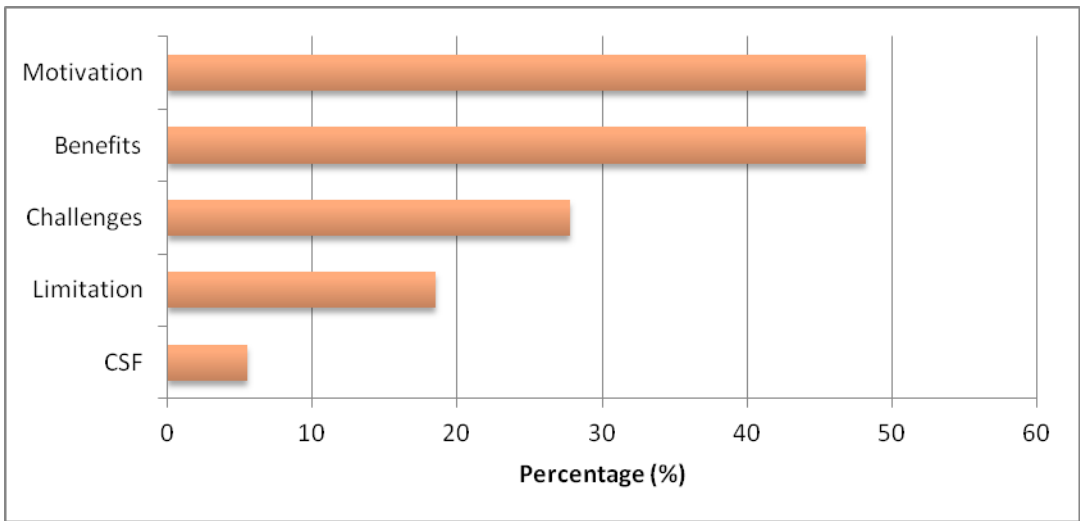

Figure 4: SPC implementation's themes emerged

Based on the 41 journal articles reviewed, motivation and benefits were shown to be the most discussed themes, while CSF is the least discussed theme in the review (Figure 4). Such results are due to most of the journal articles clearly provided their motivation for implementing SPC and subsequently reported the outcome (benefits) of the implementation as well to illustrate the effectiveness of the implementation in their respective research.

Table 1: Results for each theme

Themes	Results
Benefits	• Reduction of variation • Prediction of process behaviour • Increase knowledge and awareness in statistics and process.
Motivation	• To reduce variability • To comply food law and regulation • To increase productivity
Limitation	• Lack of statistical thinking culture • SPC is too advanced for non-statistician • Lack of useful and practical guidelines
Challenges	• Resistance to change • Lack of sufficient knowledge of SPC • Lack of management support
CSF	• Management commitment • Continuous training • Statistical thinking culture

Based on the table 1, each the top (most cited) results were presented. Although most articles reported that variation reduction is due to effective application of control charts to control and monitor variations, the use of other SPC tools to reduce variation are not regularly reported, which highlights the common myth of SPC being only about

control charts. Such results are aligned with motivation theme, as reduction of variation is the most cited motivation of SPC implementation in the food industry.

Highest cited limitation is the lack of statistical thinking, which it is a culture entails the generation of data, extraction of relevant data, and then utilizing this data for optimal decision-making (Snee, 1990). Such culture would able to reduce the fear of statistics, and the perception that SPC is too complex for the users without a statistical education background. Although, food industry is categorized as the industry with small ability to accept change, integration of statistical thinking culture able to reduce the resistance to change (Hesleth, 2001). Glasgow et al. (2010) stated that change acceleration process (CAP) literature uses the equation (1) below:

$$E = Q \times A \qquad (1)$$

where effectiveness (E) of a project is the product quality (Q) multiplied by the acceptability (A) of the solution. Therefore, even a robust technique is not effective if there is lack of acceptability of the respective technique.

Management commitment and training were cited as the most cited critical success factors (CSF) for the implementation of the food industry, which is similar to many other CSF studies (Anotny and Taner, 2003). However, statistical thinking culture is not common CSF in the context of SPC implementation in other industry (Grigg and Walls, 2007b). This is due to the educational background of employees in the food companies acquired minimal knowledge of statistical techniques.

4. SPC frameworks and Critical Remarks

The implementation of SPC is one of the complex activities since it involves a change of working culture (Krumwiede and Sheu, 1996; Zailani and Fernando, 2001), integration of new skills and evolution of peoples mind set. Therefore, it is only appropriate that a sound implementation framework to be developed prior to the actual implementation process. However, the literature in SPC is dominated by the technical aspect of SPC while the implementation aspect is hardly to be found (Does et al., 1997). Although there are existing SPC implementation framework, but each step contains their strengths and weaknesses which discussed in Table 2 below.

Table 2: SPC implementation frameworks

Authors	Strength	Limitation
Krumwiede and Sheu (1996)	• This framework has depicted training material appropriate for each step. • Team members will be able to increase their understanding of the mechanism of each step due to the training session with prior the execution of each step.. • Awareness of the SPC technique with an SPC introduction into the organization is suggested to be initiated with the establishment of suitable culture such as statistical thinking culture which will provide the needs for data in decision making. Setting vision in the initial stage the project will provide a clearer view where the project headed.	• This framework is the lack of discussion of operational aspects of SPC • The importance of teamwork has not been mentioned at all. Teamwork is considered as an important component (Antony and Taner, 2003) in SPC application due to input from the team which normally consists of multidisciplinary team members brings better results (Does et al. 1997). • Lack of communication of results aligns with value for business.There is no such step in measuring and communicating the benefits of the project to organization. If results are visible, this will not just provide solid evidence of the SPC programme effectiveness, it also enhances motivation for other employees to involve with SPC implementation projects.
Kumar and Motwani (1996)	• This framework provided a control chart selection framework. The procedure is provided with the assumption measurement system has been assessed and is appropriate for the collected data. Such framework is	• An essential part of SPC implementation steps, namely the prioritization process, has not been discussed at all for real practical implementation. • Some of the steps in this framework are in an incoherent manner. For example,

	significant, since a wrong type of control chart is applied, it will impact the results with emerging false alarms. • In problem solving activities, this framework emphasizes it should be carried out using seven tools of quality and subsequently a framework of reaction plan was provided if the process is detected to be not capable.	top management is suggested to be involved in SPC program training after the team was established. However, logically without top management awareness and consent, developing SPC team itself is difficult. • This framework's component was collected and sorted according SPC implementation experience of the authors in case study without providing its added value compared to the existing SPC implementation framework. • After detecting out-of-control, this framework fails to provide guidance on how to react and remove the cause of the out-of-control point. • The framework description on how to bring this framework into implementation is relatively vague. For instance, in SPC training for operators, it does not provide a method and relevant training materials for SPC real implementation. • This framework is lacking in addressing culture change issues in the implementation of SPC technique.
Does et al. (1997)	• This framework suggested out of control action plan (OCAP) with the assistance of the implementation team. • The advantage of this framework is it provides detailed discussion information of implementation teams (top management, steering committee and process action team) with different respected roles and tasks. • This framework is able to provide a holistic plan of SPC deployment for the whole wide company through organizational part. Compared to other SPC implementation frameworks, there were addressing steps needed in pilot projects only, without a clear vision of how to integrate the SPC technique through the whole wide company.	• There is insufficient discussion on the importance of top management involvement, commitment and support for the implementation of SPC. • There is very little description on the importance of training and education aspects. Training could be a big issue in any organization especially for an organization that hardly deal with technical and statistics such as the food industry. Hence a better planning in the preparation phase (training) is required prior the implementation takes place due to specific environments and characteristics of an organization that have lack of statistical knowledge and skills. • This article fails to provide importance of process prioritization and method to operate the step. Prioritization of process plays an important head start of the project. The project that is prioritized must be considered according to a certain criteria set by the management and the expected results should obvious in order to illustrate the benefit of SPC implementation
Antony and Taner (2003)	• The framework was developed in order to overcome the limitation of previous existing frameworks.	• This framework is the lack of the discussion on how to operate in the framework. Although the steps were

	• This framework suggested training is not only a one step process. It is suggested that but training sessions should be revisited with follow-up training. Such process will ensure the employees will be updated with current information and better implementation of SPC in the future. • An out-of-control flowchart is provided to facilitate operators to implement an action plan to eliminate assignable causes detected earlier in the control chart and process capability study. • This framework suggests an evaluation of the benefits in results of SPC implementation as one of the important steps. An assessment of the results is included in order to provide clear evident benefits of the implementation.	sorted out, implementation issues and method to execute the steps is vaguely discussed. • The framework provides only a brief and general discussion for each step without practical details of how to operate the steps.
Noskievičová (2010)	• This framework discussed the problem solving process in detailed and a general structure of the problem solving process was given. Expert system was introduced as well to support problem-solving process in the frame of SPC implementation. • This framework also provided a method to evaluate the effectiveness of corrective or improvement action taken after out-of-control points detected. The result from this evaluation enables to facilitate the decision-making process.	• Although this framework provided factors underlying each step, however there is still scarce view how to operate the factors listed in each respecting step. • This framework gives a great attention in problem-solving process while management and cultural issues such as management commitment, SPC team and organizational cultural change are relatively omitted. • This framework has failed to mention the importance of the pilot project. Pilot project is an important factor for benchmarking and provide bank of knowledge of the implementation steps involved.

Framework developed by Does et. al (1997) set as the most comprehensive article compared to other articles. The framework is able to provide a detailed description of activities involved, target, results expected and suggestion in each implementation steps. Table 2 depicted most of the frameworks agree a few fundamental steps in implementing SPC. Such steps are training, SPC team formation, measurement system, data collection and control chart construction. However most of the articles lack of strategic steps for deploying SPC in the whole wide company and there is no existed framework outline plans for sustaining the SPC application in the company.

5. Conclusion

The objective of this paper is to investigate SPC implementation in the food industry setting by applying systematic literature review, and to explore the extensiveness of SPC application in the food industry. This review identified 41 studies published between 1980 and 2012, depicting evidence of SPC application sparsely spread throughout the industry and a need to pursue more research in this topic.

Determining CSF for SPC implementation is crucial. However CSFs themselves does not depict a coherent implementation framework where they are required to be integrated into an implementation plan. A viable framework for SPC implementation should able to provide a framework that emphasised CSF and features of a good framework sufficiently not only in the context of the technique (SPC), but also in the context of the industry. Based on the literature review, there is no useful and practical guideline available in the context of the food industry.

Hence, future research will attempt to focus on developing an implementation framework that will instil

SPC's CSF in the food industry context and consideration to overcome the weakness and emphasised the strength of previous frameworks appropriate for the food industry. Hopefully, with this background on SPC implementation frameworks, systematic, useful and practical guidelines will be able to be developed for the food industry and subsequently the implementation efforts in the food companies will be much more accommodating.

This review indicates that SPC is applied in the food industry with huge benefits in the business to diverse stakeholders. Although there are limitations and barriers impeding the implementation, if the implementation was done correctly and greatly facilitated, SPC can be a versatile technique for managing quality improvement in the food industry and sustaining the quality of food products.

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Biography

Sarina Abdul Halim Lim is a Ph.D. candidate in the Department of Design, Manufacture and Engineering Management under Faculty of Engineering, University of Strathclyde, UK. She receives her MS in Quality and Productivity Improvement under Mathematical Centre, University of National Malaysia and B.S. in Mathematics, University of Technology Malaysia and currently working as an academician in University of Putra Malaysia. She presented and published in several conferences for the past few years and currently working on journal article publication in the area of SPC. She has taught classes in SPC and Design of Experiment in University of Strathclyde, UK. She is also a member of American Society for Quality since 2012. Her PhD research currently majorly involves with industrial integration. Her research interest is focused on the area of statistical process control (SPC), quality, operation management and continuous improvement.

Jiju Antony is a professor in University of Strathclyde, founded the Centre for Research in Six Sigma and Process Excellence (CRISSPE) in 2004, first research centre in Europe in the field of Six Sigma and he is also on the Editorial Board of 8 International Journals. He has authored over 225 journal and conference papers and text books. He is a Fellow of the Royal Statistical Society(UK), Fellow of the Institute for Operations Management(UK), Fellow of the American Society for Quality(USA) and a Fellow of the Institute of the Six Sigma Professionals. He has trained up over 800 people on Lean Six Sigma topics from various companies in the UK ranging from manufacturing, service to public sector organisations including NHS and Universities. He has worked on a number of consultancy projects with several blue chip companies such as Rolls-Royce, Bosch, Parker Pen, Siemens, Ford, Scottish Power, Tata, Thales, Nokia, Philips, GE, Nissan and Diageo.

The food processing industry is a subset of the manufacturing sector with unique challenges. Among these, ensuring food hygiene and preventing contamination are two issues of prime importance.Â critical to monitor and control in terms of contamination [13]. It is widely recognised in the food industry as an effective approach to establish good production, sanitation, and manufacturing practices that produce food items that are safe to consume [14]. Therefore, it can be concluded that QA and HACCP implemented in concert facilitate improvements in both production efficiency and product safety [15].Â A systematic process has to be followed in layout design to ensure that the design is in accordance with the production requirement. A systematic literature review on SPC implementation depicted a similar trend, as SPC case studies were mostly carried out in the dairy and bakery categories (Lim et al., 2014). On this basis, we suggest the following hypothesis: Critical observations on the statistical process control implementation in the UK food industry: A survey. Article. May 2017.Â Abstract The Statistical Process Control - SPC is a set of statistical techniques focused on process control, monitoring and analyzing variation causes in the quality characteristics and/or in the parameters used to control and process improvements. Implementing SPC in organizations is a complex task. The implementation of an automated SPC scale system would eliminate these manual user errors with only a few changes and a small capital investment. The Advantages of an Automated SPC System. Designing an automatic SPC system that eliminates human error begins by removing the manual element from employee responsibility. This will alleviate human recording errors and the fudging of actual weight results.Â The design of a system varies in response to the expected audience for the perticulare application. Some systems are intended for back rooms, some for the front office, and some are for the general public. They are designed for technical users, others for end users. This paper is a systematic review of the literature on statistical process control (SPC) implementation in the food industry. Using systematic searches across three decades of publications, 41 journal articles were selected for the review. Key findings of the review include motivations: to reduce product defects and to follow the food law and regulations (benefits); barriers: high resistance to change and lack of sufficient statistical knowledge; and (limitations) an absence of statistical thinking and a dearth of SPC implementation guidelines. Further findings highlight the predominance of pu