Proceedings of the 11th International Conference on Manufacturing Research (ICMR2013), Cranfield University, UK, 19th – 20th September 2013, pp 593-598

STATISTICAL PROCESS CONTROL IMPLEMENTATION IN THE FOOD INDUSTRY: A SYSTEMATIC REVIEW AND IMPLICATIONS FOR FUTURE RESEARCH

Sarina Abdul Halim Lim
Design, Manufacture and Engineering Management,
University of Strathclyde
131 Rottenrow
Glasgow, G4 0NG, UK
sarina.abdul-halim-lim@strath.ac.uk

Jiju Antony
Design, Manufacture and Engineering Management
University of Strathclyde
131 Rottenrow
Glasgow, G4 0NG, UK
jiju.antony@strath.ac.uk

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 34 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 systematic review concluded that there is a crucial need for further research into the SPC deployment aspect addressing how to deploy SPC in the food industry in a systematic manner.

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

1 INTRODUCTION

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).

Food technologists and scientists have been challenged by the variations existing within food production for more than 80 years. The foundation of statistical quality control (SQC) was partly established through work within Guinness breweries, by a technologist and statistician, W.S. Gosset who clearly demonstrates opportunities of SPC element implementation in the food industry (Grigg and Walls, 2007 and Surak, 1999).

2 METHODOLOGY

A systematic review was applied to investigate issues emerging in SPC implementation within the food industry published between 1990 and 2012. Although SPC was initially pioneered by W.E. Deming in 1950 who elaborated on the principles developed by W. Shewart in 1924, it was not until 1980 that the Western manufacturing industry rapidly adopted the technique for their applications and later the first article of SPC in the food industry 1990 was published (Srikaeo et al., 2005).

Developing the research objective is the first fundamental step of this systematic review. In order to set the objectives, review questions were established. The suggestion leads to the application of the CIMO (context-intervention-mechanisms-outcomes) framework (Tranfield et al., 2003).

CIMO is the management study version of the PICO (population-intervention-comparisons-outcome) framework in healthcare to formulate the review questions and specify studies.

Articles searched in this study also included those listed in the key article bibliographies. After screening the key articles and developing review questions, key words for searching inputs in the database were generated. In a systematic review, the outcome of the decisions in the planning phase will be reported in a formal document called review protocol (Tranfield et al., 2003). Therefore, in the review protocol, the review scope entails questions and objectives of the review, background, inclusion and exclusion criteria, language of article, search and selection strategy and study design (Tranfield et al., 2003). The information in the review protocol will be used through the rest of the review process.

The search of the research literature was undertaken through four databases using Boolean logic and parentheses to generate the following search strings: [(statistical process control) OR (six sigma) OR (total quality management) OR (quality control) AND (food industry) OR food OR agricultur* NOT service] or (total quality management) AND (food industry OR food OR agricultur*)) OR (statistical process control) (food industry OR food or agricultur*)) or (six sigma) AND (food industry OR food OR agricultur*).

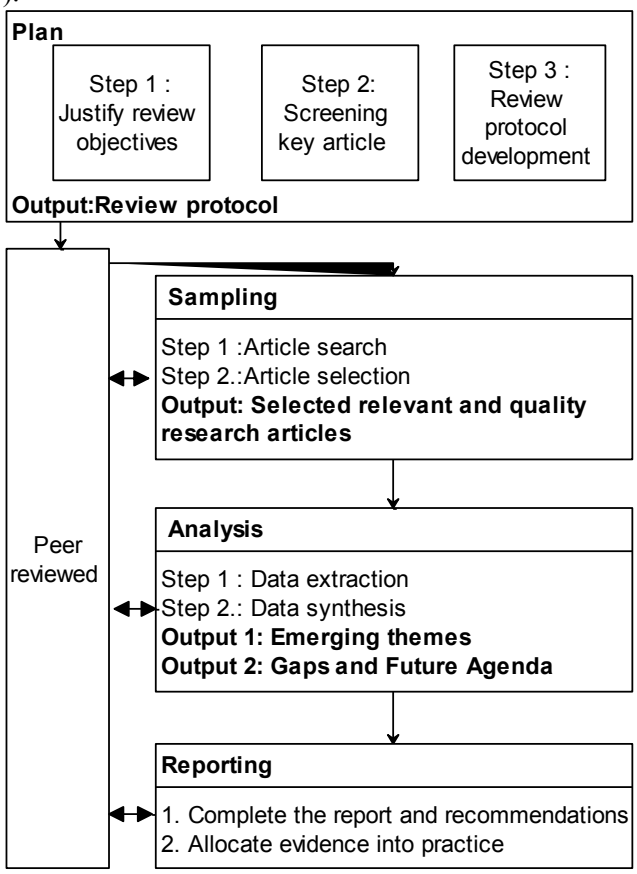

Figure 1: Summary of systematic review process

The databases used are Emerald Insight, IEEEXplore, Science Direct and ABI/Inform. Although, Igenta Connect and JSTOR were initially considered but dropped due to a very low number of article hits within the scope of this review and all remaining relevant articles listed which were redundant (duplicate) with articles found in other databases were excluded as well.

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 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 contents of such sources are insufficiently assessed by the experts.

In the selection process (Figure 2), titles and abstracts were reviewed to select the articles based on inclusion/exclusion criteria and articles, which meet exclusion criteria will be discarded. Full articles of the remaining selected articles were retrieved for full article screening and discarding of the articles that did not meet inclusion criteria. Similarly, the same articles appearing several times (duplicate) due to the use of various database searches were excluded.

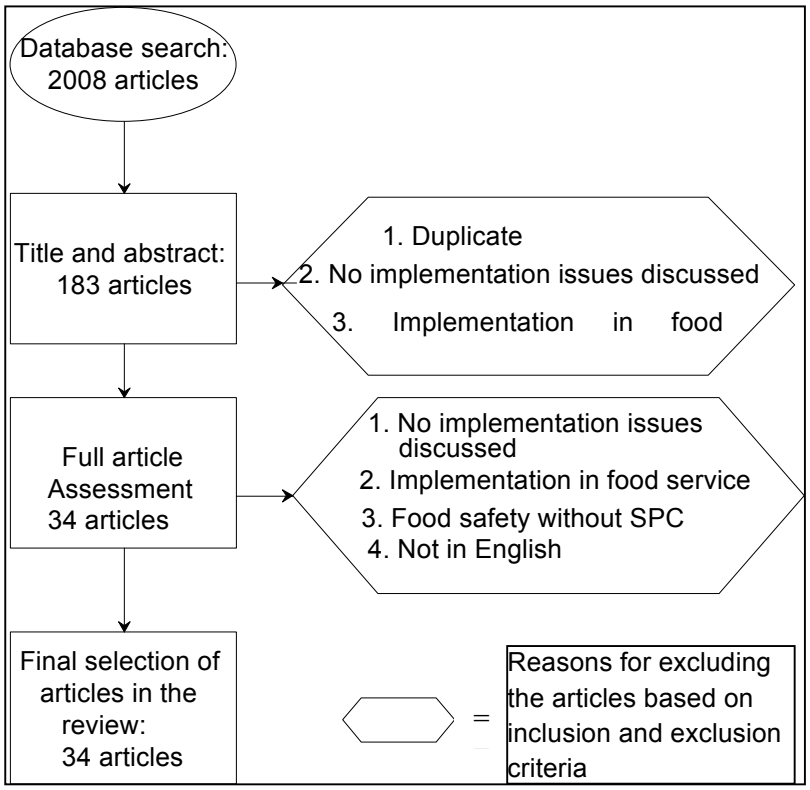

Figure 2: Article selection process

Systematic review does not only offer an exhaustive literature review, but an assessment of quality criteria was also carried out. Quality appraisal was conducted which focuses on whether the result of the study is reliable, a standard procedure in systematic reviews (Booth et al., 2012). The form for quality appraisal, which represents an internal validity, was developed and tested and as for external validity, impact factors or ranking of the journal can be applied.

The reviewer decided to develop a data extraction form using inclusive or selective extraction of the qualitative findings. This approach is more comprehensive and resource intensive. This approach offered only particular types of data that are extracted, such as data meeting pre-specified quality standards, data that are supported by interviews or observations or data related to specific issues or questions. Considering articles collected in this review are based on implementation issues, which mainly involve observations and interviews, this data extraction approach is the most appropriate.

Following this, to ensure data consistency, the author reviewed data extraction forms to clarify and check for any missing or incomplete review subsequently initiated by data synthesis, which was then reviewed by the team. The extracted data were then transferred descriptively and thematically containing key issues of SPC implementation within the food industry. Thematic analysis was conducted by using a data extraction form where articles were coded using Nvivo qualitative research package software (Booth et al., 2012). This technique was chosen instead of meta-analysis due to the

qualitative nature of this review question. However, there is no standard manner of assessing and synthesising operations management research, as it is derived from diverse epistemology philosophies, and proposed for different types of audiences (Dixon-Woods, 2006).

3 RESULTS AND DISCUSSIONS

The first two SPC implementation articles in the food industry were published by Bidder (1990) and Sanigar (1990) in which they both show the experience of introducing and implementing SPC in confectionery and sugar production companies. In the food industry, SPC has been applied for process trend analysis (Mataragas et al., 2012), quality control and monitoring (Gauri, 2003). Recently SPC was also used for food safety purposes while some have incorporated SPC with other quality initiatives such as HACCP, Six Sigma and Design of Experiment (DOE). This result depicted how SPC can be applied as more than merely a monitoring and control technique in the food industry.

The review of the selected studies shows that benefit (34.14%) is the most commonly discussed topic in SPC implementation in the food industry (Table 1). The most reported benefit is food manufacturers' ability to reduce variation in their process and this also led to other related benefits as stated by Schippers (2001) that in order to achieve other benefits, variations in processes have to be controlled in the first place.

Table 1: Benefits of SPC implementation in the food industry

Benefits (%)			
Variation reduction	18.18	Improved customer satisfaction	6.06
Cost saving	15.15	Business growth	6.06
Defect prevention	12.12	Predicting process behaviour	6.06
Increased information from data	9.09	Increased quality awareness	3.03
Increased level of knowledge	9.09	Reduce product giveaway	3.03
Improved decision making	9.09	Consumer confidence	3.03

The popularity of SPC within quality management practice is generated by a wealth of publications dominated by the benefits of its implementation. Comparably, the reviewers did not find any study that reported SPC failure cases, which may be due to publication bias. The reviewers strongly believed that reports describing the failure of SPC projects and studies would significantly contribute to SPC implementation literature.

The failure and slow adoption of SPC implementation may be caused by various barriers (Table 2). There are many cases reporting that lack of statistical knowledge not only causes the failures of SPC projects (Hersleth and Bjerke, 2001) but that it also contributes to the fear of SPC implementation within the food industry. Appropriate training sessions are able to improve knowledge and awareness of SPC in the food industry (Grigg and Walls, 2007) and subsequently generate successful SPC projects.

Table 2: Barriers of SPC implementation in the food industry

Barriers (%)			
Lack of appropriate statistical knowledge	26.09	Lack of empowerment culture	8.70
Lack of management support	17.39	Lack of continuous learning	4.35
Lack of interest	13.04	Lack of allocated time	4.35
Lack of guidelines and manuals	8.70	Resistance to change	4.35
Lack of in-house expertise	8.70		

According to the results in Table 3, most food companies are aware and motivate to improve their business through quality in which variations are recognised as the crucial issue. Nonetheless, most of quality initiatives application in the food industry is circulated to comply with food safety regulations since they are mandatory in the first place (Grigg and Walls, 2007) which forced many food producers to apply quality initiatives such as SPC in the production line and the company as a whole.

Table 3: Motivations for SPC implementation in the food industry

Motivation (%)			
To reduce variability	17.5	As defence for prosecution	5.0
Legal mandate	12.5	To improve company's image	5.0
Market competition pressure	10.0	To improve operational performance	5.0
To improve productivity	10.0	Customer pressure	5.0
To gain consumer confidence	7.5	Desire to gain knowledge	5.0
To gain more information from the data	7.5	As a validation technique	5.0
Financial force	7.5	To characterise the process	2.5

There are only two papers that specifically addressed CSF of SPC deployment in the food industry. Hersleth and Bjerke (2001) developed a contextual model of statistical thinking which entails explanatory variables affecting the extent of statistical thinking as depicted in Table 4. The other study (Grigg and Walls, 2007) divided SPCs CSFs in two categories; internal and external facilitators.

Table 4: Facilitating factors for successful SPC implementation in the food industry

Critical success factors (CSF)	
The factors cited by both articles	Description
Management commitment	The most prominent CSF for any CI initiatives
Continuous education	Formalised and regular quality training for SPC implementation.
Organisational resource base	Relates with financial, human, technological, physical resources.
Data collection procedure	A procedure specific for sampling activities from process, production and product attributes.
IT system availability	Availability access to PC, intranet and software solution.
The factors cited by single article	Description
Empowerment	The opportunity for each employee to influence his or her own working environment.
Quality maturity level	The adoption of the established quality initiative (TQM, Six Sigma, Lean, Lean Six Sigma, IS0 9000, Quality circles).
Strategy for quality improvement	Organisation's goals and strategies for quality improvement.
Ability to change the culture	Degree of cooperative culture, interest, and acceptance for new ideas and motivation for statistical thinking.
Project prioritisation	High impact and urgent projects should be given the priority for quality improvement initiative implementation projects.
Employees competence level	Staff's level of education and knowledge of statistical technique.
Organisational size	The smaller companies used fewer statistical techniques compared to bigger companies
SPC facilitator	SPC facilitator generally has the repository of knowledge on SPC methods and systems.
Availability of relevant information	(Department of Trade and Industry) DTI code of practice is the major source advising SPC deployment in UK food packaging.

Management commitment is the most important factor not only in SPC implementation but mostly in other quality improvement systems and methods as well (Antony and Balbontin, 2000). However, since there are very few articles related to this issue, there is insufficient evidence to generalise the CSF of SPC implementation in the food industry.

4 CONCLUSIONS AND FUTURE AGENDA

The number of studies found is considered relatively low compared to other quality improvement initiatives and systematic reviews of SPC application in other industries. This limitation reflects the crucial need for research on the SPC deployment aspects within the food industry. The articles specifically discuss on SPC implementation has declined in recent years due to the increasing of Six Sigma application for process improvement purposes which SPC is embedded as one of the main technique within the DMAIC methodology.This review validates that there is potential for continuous quality improvement and financial advantage in implementing SPC in the food industry and more

research with rigorous design and detailed reports is needed to boost the methodological base for the implementation of SPC techniques within this industry. There is a significant gap in current literature where the control of operation is listed one of the criteria in food industry's good manufacturing practices (GMP) which match with the SPC's philosophical base, there is not a specific manual to apply the technique (Costa Dias et al., 2012).

This review shows that the challenging factor in implementing SPC for non-statisticians is not only related to theoretical issues but also involves nonmathematical levels such as cultural and human issues. The reviewers strongly suggest that this led to the fact that given a good data collection method, sufficient knowledge of systems, tools and methods, sufficient resources and high motivation, the key to success remains complex in the food industry. Therefore, there is a strong demand for investigation into SPCs CSF studies within the food industry where such research is insufficiently investigated up to this date. There are also very few guidelines available for SPC team formation where this has caused a great confusion, especially for the first time SPC users.

The reviewers strongly suggest that a roadmap should be developed which depicts practical food industry application guidelines incorporating all aspects of SPC implementation and the food industry including training and continuous education guidelines since from the review, up until now, there are no standardised training outlines developed for SPC implementation. Although there are limitations and impeding factors in implementing SPC within the food industry, SPC is proven as a powerful technique to manage quality changes in the food industry provided the implementation is driven towards a clear vision and goals and its deployment is facilitated by a strategic and systematic approach.

REFERENCES

Antony, J. and Balbontin, A. 2000. Key ingredients for the effective implementation of statistical process control. *Work study,* 49; 242-247.

Bidder, P. L. 1990. Experiences of introducing SPC in a confectionery factory. *Applied Statistical Process Control, IEE Colloquium on.* London, UK: IEEEXplore.

Booth, A., Papaioannou, D. and Sutton, A. 2012. *Systematic approaches to a successful literature review,* London, Sage Publications Inc.

Costa Dias, M. A., Sant'ana, A. S., Cruz, A. G., Faria, J. D. A. F., Fernandes De Oliveira, C. A. & Bona, E. 2012. On the implementation of good manufacturing practices in a small processing unity of mozzarella cheese in Brazil. *Food Control,* 24**,** 199-205.

Dellifraine, J. L., Langabeer, J. R. and Nembhard, I. M. 2010. Assessing the evidence of Six Sigma and Lean in the health care industry. *Quality Management in Health Care,* 19; 211-25.

Dixon-Woods, M. 2006. How can systematic reviews incorporate qualitative research? A critical perspective. *Qualitative Research,* 6; 27-44.

Gauri, S. K. 2003. Statistical process control procedures for controlling the weight of packets of biscuits. *Total Quality Management and Business Excellence,* 14; 529-539.

Grigg, N. P. and Walls, L. 2007. Developing statistical thinking for performance improvement in the food industry. *International Journal of Quality and Reliability Management,* 24; 347-369.

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

Mataragas, M., Drosinos, E. H., Tsola, E. & Zoiopoulos, P. E. 2012. Integrating statistical process control to monitor and improve carcasses quality in a poultry slaughterhouse implementing a HACCP system. *Food Control,* 28**,** 205-211.

Rungtusanatham, M., Anderson, J. C. and Dooley, K. J. 1997. Conceptualizing organizational implementation and practice of statistical process control. *Journal of Quality Management,* 2; 113-137.

Sanigar, K. 1990. Statistical process control-the British Sugar experience. *Statistical Process Control, IEE Colloquium on*, 1-5.

Tranfield, D., Denyer, D. and Smart, P. 2003. Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *British Journal of Management,* 14; 207-222.