Chapter 9

Quality Management: Important Aspects for the Food Industry

Caroline Liboreiro Paiva

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/53162

1. Introduction

Certainly, with the advent of globalization, the market has become more competitive, because it has opened the opportunity for new competitors. This does not necessarily mean risk for the survival of local businesses, but a challenge that they must consider. This challenge relates to the need to create greater consumer loyalty to products and services, greater suitability of the product to the consumer's needs and greater concern about the social impact of the company. Moreover, this global scenario represents some opportunities for the companies to act in the new markets. It is clear that this action will depend mainly on the quality of their own products and services offered.

However, first, the concept of product quality is not so immediate and obvious. Although not universally accepted, the definition for quality with greater consensus is that "suitability for the consumer usage." This definition is comprehensive because it includes two aspects: characteristics that lead to satisfaction with the product and the absence of failures. In fact, the main component consists of the quality characteristics of the product features that meet the consumers' needs and thus it provides satisfaction for the same. These needs are related not only to the intrinsic characteristics of the product, such as the sensory characteristics of a food product, but also to its availability in the market with a compatible price and in a suitable packaging. The other part is the absence of faults, which is related to the characteristics of the product according to their specifications, making the consumer inspired by the reliability of the product, i.e., the consumer is sure that he will acquire a safe product, without health risks, and with the properties claimed on the label.

For these objectives to be achieved it is required an efficient management of quality, which implies continuous improvement activities at each operational level and in every functional area of the organization. The quality management combines commitment, discipline and a

growing effort by everyone involved in the production process and fundamental techniques of management and administration, with the goal of continuously improving all processes. For that, the industries need to be structured organizationally, establish policies and quality programs, measure customers' satisfaction and even use more quality tools and methodologies. Specifically for the food industry, also involves the knowledge and application of techniques and programs for product safety.

With all that, the purpose of this chapter is to describe the potential use of quality tools in food companies. The study initially intends to contextualize the quality management in the food industry and the activities related to the quality function. In addition, support tools related to quality control in process will be suggested with practical examples of application.

2. Evolution of the quality management: A brief history

It can be said that each company has a particular stage of maturity on the issue of quality management. In general they tend to evolve in four stages, the similarity of ages or how the quality management in the world has evolved over the years. Thus, it is important to highlight these stages of evolution of quality that began with the inspection of products, have passed the statistical quality control, the stage of quality systemic management until the strategic quality management.

Garvin, a scholar of quality management, highlights four ages or stages through which the way to manage the quality has evolving over time in the U.S [1]. The first stage of development was called "era of inspection." In this stage the quality control of products was limited to a focus on corrective inspection, i.e., was a way to check the uniformity of the final product by separating the non-conforming products. According to Garvin in the U.S. only in 1922 the inspection activities were related more formally with quality management, after the publication of the book "The Control of Quality in Manufacturing". For the first time, the quality was seen as managerial responsibility having distinct and independent function in the companies.

Later, the year of 1931 was a milestone in the quality movement and the beginning of the second phase, the Statistical Quality Control. This phase had a preventive approach, centered on the monitoring and control of process variables that could influence in the final product quality through the development of statistical tools for sampling and process control.

The next phase was called Quality Assurance, that was associated with broader control and prevention, which sought through systematic management, ensure quality at all stages of obtaining the product. The quality management became a practice restricted to industrial production management applied to all production support functions. In the U.S., this time started in the late 50's when the quality of the instruments have expanded far beyond the statistics, now covering the quantification of quality costs, total quality control, reliability engineering and zero defect.

http://dx.doi.org/10.5772/53162

Finally, quality management has been incorporated within the strategic scope of organizations, this phase called Strategic Management of Quality. It represented a vision of market-oriented management, i.e., with a view of opportunities before the competition and customer satisfaction, where market research has become more important for evaluating the market needs and how the competition stands. The strategic approach is an extension of its predecessors, but with a more proactive approach.

Several scholars of quality management are unanimous in emphasizing that the companies in general, and also the food industry, through its organizational structure, the policies adopted, the focus given to the business and the practice of quality control, demonstrate a certain degree of maturity in how to manage quality. Some companies may present practices related to more advanced stages, mature, such as quality assurance and strategic quality management, others may prove more practices related to inspection and process control. Through observation of tools and methods currently adopted in the food industry, it can be inferred that this quality management company is based on the characteristics of a particular stage of the quality evolution.

For example, the control of the raw material and products for inspection, with special attention to satisfy the governmental health rules, is a characteristic of the inspection stage. Likewise, the product control only by laboratory analysis is a feature of this stage. Moreover, quality control practices in process, application of statistical methods for quality control and the adoption of Good Manufacture Practices (GMP) and Hazard Analysis and Critical Control Points (HACCP) denote that the company has a slightly broader approach that inspection, i.e., a more preventive approach control in the production process. But when practice inspection and process control are well established in the company and efforts are directed towards continuous improvement, it can be inferred that the company is evolved into a system of quality assurance. Practices consistent with this era are shown by performing quality audits in different sectors of the company, adoption of quality systems across the supply chain and also implementation of programs for the development of quality suppliers of products and services. Companies that take a strategic quality management are those that use market research and specific indicators to measure customer satisfaction, such as consumer complaints, returns by wholesalers for the time of the product in the inventory and sales below target. Further, evaluate their products compared to competitors' products and apply techniques of sensory analysis to compare products and find sensory qualities required by the market. Concerned to improve their production processes, automate production lines and constantly launch new products into the market.

3. Tasks quality of the sector in the food industry

In general, the operating system of quality control in the food industry must meet some specific tasks. One of the tasks is to ensure compliance with sanitary standards and compliance requirements of the legislation, including with regard to food safety standards, the Good

Manufacturing Practices (GMP) and the system Hazard Analysis and Critical Control Points (HACCP). For this, there is need for procedures to control insects, rodents, birds and other pests, and procedures for cleaning and sanitizing equipment, industrial plant and storage areas. Still, personal hygiene of staff working on process lines and proper habits on food handling should be implemented and monitored to ensure that food safety standards are met. In cooperation with the departments of production, research and development, engineering or operations, the department of quality control analyzes manufacturing processes to "Hazard Analysis and Critical Control Points." The integrity and safety of food products should be ensured through the identification and assessment of all unit operations of the process in order to prevent potential contamination and adulteration that could expose consumers to health risks.

In cooperation with the department of research and development (R&D), production, purchasing and sales, should be prepared written specifications for raw materials, ingredients, packaging materials, other supplies and finished products. Furthermore, should be established in writing form and in cooperation with the departments of production and R&D the procedures for each unit operation of all manufacturing processes of the fashion industry that can be implemented in processing lines. The participation of staff from other departments of the company occurs by the virtue of their expertise in relation to consumer demands or knowledge of product technology and process, and the participation of the operators of the process, because of its experience in the production.

The quality control personnel works in different laboratories performing physical, chemical, microbiological and sensory properties of raw materials, ingredients, packaging materials and finished products. They also work in the factory or processing areas, collecting samples for performance evaluation processes, unit operations, sanitary conditions or levels, verifying compliance with the requirements of food safety and all other operating specifications. It is the responsibility of the department of quality control implementation of Statistical Quality Control (SQC), in which statistical techniques are applied to assessments of control for scientific analysis and interpretation of data. The SQC's functions include the selection of sampling techniques, control charts for attributes and variables, the use of analysis of variance and correlation, among other statistical tools. The methods, procedures and selection of instruments used to measure quality attributes of products and processes are the responsibility of the department of quality control. These techniques can be developed for specific purposes within the production process, to product development or troubleshooting and optimization standards.

The quality control personnel must interact cooperatively with the personnel of the standards and inspection agencies to ensure that the official food law is understood and met. It should also watch the production department in its efforts to increase revenues, reduce losses and improve efficiency of operations. It should also develop, conduct and assist in an organized program, training of supervisors, operators and workers in general, into specific concepts of quality.

The development of an appropriate plan of "recollect" adulterated or defective product in marketing channels and the planning of internal traceability of products is also a function of

http://dx.doi.org/10.5772/53162

the quality control department. Another assignment of quality control includes reviewing and responding to consumer complaints.

Thus, faced with so many responsibilities, it remains to note that the dynamics of intervention and performance of those who are responsible for the quality department is paramount to the success of the food industry and customer satisfaction.

4. Methodologies in support of the quality management in the food industry

The quality management applies systems and tools that are intended to assist the implementation of quality-oriented way to improve the product and the process, increasing the levels of quality business and ensuring customer's satisfaction.

The purpose of this topic is to describe some tools, techniques and systems that have been more widely used in quality management in the food industry. Besides the methods mentioned, there are others that could be employed by companies. The choice of which implement depends on the company's strategies and know-how of its employees.

4.1. Food security programs

The issue of food safety has been in the public eye as never before. Foodborne disease has an enormous public health impact, as well as significant social and economic consequences. It is estimated that each year foodborne disease causes approximately 76 million illnesses, 325,000 hospitalizations and 5,000 deaths in the U.S., and 2,366,000 cases, 21,138 hospitalizations and 718 deaths in England and Wales [2]. Thus, many food safety programs have been published in order to ensure safe food production and consumer protection.

Safety food programs can be set as the measures to be taken to ensure that food can be eaten without adversely affect to the consumer’s health. These measures aim to prevent food contamination, such contamination are chemical, physical or microbiological. The programs commonly used in this area are Good Manufacturing Practices (GMP), Hazard Analysis and Critical Control Points (HACCP), British Retail Consortium (BRC) and Global Food Safety Initiative (GFSI), frequently found in the food industry, are obligatory by law, and others are implemented voluntarily by the food chain members [3].

4.1.1. Good Manufacturing Practices (GMP)

The Good Manufacturing Practices program is composed of a set of principles and rules to be adopted by the food industry in order to ensure the sanitary quality of their products. The GMP program came at the end of the last century when the U.S. pharmaceutical industry began to define optimal manufacturing practices based on technological knowledge available. In the late 60's, organizations such as the WHO (World Health Organization) and the Food and Drug Administration of the United States, the FDA (Food and Drug Adminis-

tration) adopted the program as a minimum criterion recommended to the manufacture of food products under adequate sanitation conditions and routine inspection. Later in 2002, FDA forms Food GMP Modernization Working Group and announces effort to modernize food GMP's [4].

The rules establishing the so-called Good Manufacturing Practices involves requirements for industry's installations, through strict rules of personal hygiene and cleanliness of the workplace to the description in writing form of all procedures involved in the product. These standards are characterized by a set of items summarized below.

The projects and industry facilities, in addition to requirements engineering/architecture, must meet requirements to ensure food safety, such as the installation of devices to prevent the entry of pests, contaminated water, dirt in the air, and still be designed to avoid the accumulation of dirt or physical contamination of food that is being manufactured. The equipment and the entire apparatus of materials used in industrial processing should be designed from materials that prevent the accumulation of dirt and must be innocuous to avoid the migration of undesirable particles to foods. On the production line, the procedures and steps for handling the product have to be documented, in order to ensure the standardization of safety practices. Also running records should be implemented as evidence that the job was well done.

Otherwise, the cleaning and sanitizing phases are inherent to the processing and handling of foods, and thus programs for execution on a routine and efficiently must be implemented. Similarly, is required a plan for integrated pest control in order to minimize access vector and reduce the number of possible focus of insects, rodents and birds.

Regarding food handlers, the GMP recommend that training should be given and recycled so the concepts of hygiene and proper handling are assimilated as a working philosophy and fulfilled to the letter.

A control of raw materials should be developed with suppliers, not only in the laboratory, but in a gradual and continuous improvement work, where food security is split with suppliers. Guidelines for the safe packaging of raw materials, inputs and finished products should be followed and extended to the storage and loading area, and to the transportation that reach the consumer.

The Good Manufacturing Practices have wide and effective application when all the elements cited are effectively deployed.

4.1.2. Hazard Analysis and Critical Control Points (HACCP)

HACCP is a system based on prevention of hazards to the industry to produce safe food to consumers. The HACCP involves a complete analysis of the dangers in the systems of production, handling, processing and consumption of a food product. HACCP is widely acknowledged as the best method of assuring product safety and is becoming internationally recognized as a tool for controlling food-borne safety hazards [3].

http://dx.doi.org/10.5772/53162

In short, this system has a systematic and scientific approach to process control, designed to prevent the occurrence of failures, ensuring that the controls are applied in processing steps where hazards might occur or critical situations. For this, the HACCP system combines technical information updated with detailed procedures to evaluate and monitor the flow of food into an industry.

The new sanitary requirements and quality requirements dictated by the main international markets, led since 1991, to the deployment experimental stage of the HACCP. There are new rules governing the international market, established during the Uruguay Round of Trade Negotiations and applicable to all member countries of the World Trade Organization (WTO). The Codex Alimentarius has become the regulatory body for matters of hygiene and food safety in the WTO. The Codex Alimentarius reflects an international consensus regarding the requirements for protection of human health in relation to the risks of foodborne illness. This measure is accelerating the process of harmonization of food laws of the countries, process that is oriented concerning food security, with the recommendation of the use of the system Hazard Analysis and Critical Control Point, to ensure food safety.

Generally the HACCP system initially involves the creation of a multifunctional team, supported by senior management of the company, and the characterization of all food products that will be included in the system. Also a set of programs, such as Good Manufacturing Practices (GMP) and Sanitation Standard Operating Procedures (SSOP) are universally accepted as prerequisites for the implementation of the HACCP system and therefore should be consolidated. Only then each step of the production process of a product will be analyzed for the possibility of a chemical, physical and microbiological contamination. Thereafter preventive measures are described and identified the Critical Control Points (CCPs). For each critical point is necessary to establish critical control limits, which allow the monitoring of hazards. As there is always a possibility of failure, it is essential to provide corrective measures in order to ensure the process return into a controlled situation. It should also establish procedures for verification of CCP's and their respective records. After the HACCP plan drawn up, it is validation occur through discussions among team members [5].

Finally, the HACCP plan is disseminated to the production employees and for those responsible for assessing the products quality on the factory floor. Internal and external audits are recommended for periodic maintenance and continuous improvement of the system [5].

4.2. Standardization of processes

Standardization is a management tool involved in the preparation, training and control standards within the company. Such standards are documents containing technical specifications or specific criteria that will be used as a guide in order to ensure that products, processes and services are designed with quality [6]. The main objective of a program of standardization for the food industry is to minimize the variations in quality of production. For this, it is necessary to provide means to standardize both the operational and analytical procedures, as raw materials, machinery and equipment used in the manufacturing process.

The patterns are instruments that indicate the goal and procedures for accomplishment of the work and can be classified as follows:

- Standards of Quality (SQ): refer to the parameters related to quality of products, raw materials and inputs.
- Operation Standards: describe the manufacturing process of a product, the technical parameters of control by the operators and operating procedures. These are divided into Standard Process Technician (SPT) and Operational Procedure (OP). The first document describes the process of manufacture of a product, the quality characteristics and the control parameters. Operating procedures standards are prepared by managers and operators to achieve the objectives proposed in the SPT and SQs.
- Standards Inspection: describe methods and criteria for assessing the degree of success achieved in carrying out an activity, compared to planned levels of quality for the product. The inspection may occur in the process, the finished product and in the raw material.

Through standardization it is achieved greater standardization of products, improved productivity and product quality, cost reduction, simplification and optimization of production processes, increase the technical capacity of operators of process, greater job security, reduction of inventory levels of raw materials and inputs, reducing the preparation time of the machines and self-management by the workers.

Also noteworthy is that the patterns facilitate the transfer of knowledge since all the people and functional units involved in a particular pattern should collaborate, as far as possible, be trained in their preparation and for their use.

4.3. PDCA cycle

The PDCA originated in the 30´s in the laboratories of the United States, becoming known in the fifty decade due to the expert quality, Deming, who was responsible for implementing and disseminating tools of control and quality management in several countries. The PDCA cycle is a method of managerial decision-making to ensure the achievement of goals related to a process, product or service [7].

The letters that form the acronym PDCA mean Plan, Do, Check, Action. The Plan (P) consists in establishing goals, and procedures to achieve them. The stage Do (D) consists in performing the tasks as planned and collect data that will be used in the step control. Thus, in the stage of "implementation" are essential trainings at work. Check (C) consists of comparing the results achieved with the planned goals through quality control tools. Finally, Action (A) is to act correctively in the process in order to correct an unexpected result.

As can be seen in Figure 1, a schematic representation of PDCA cycle translates the dynamism steps purposes. The conclusion of a turn in the cycle continues back to the beginning of the next cycle, and so on. Following in the spirit of continuous quality improvement, the process can always be renewed and a new change process can be started. Continuous improvement occurs the more times the PDCA cycle is run, and optimizes the execution of

http://dx.doi.org/10.5772/53162

processes, enables cost reduction and increases productivity. Moreover, the gradual and continuous improvements add value to the project and ensure customer satisfaction.

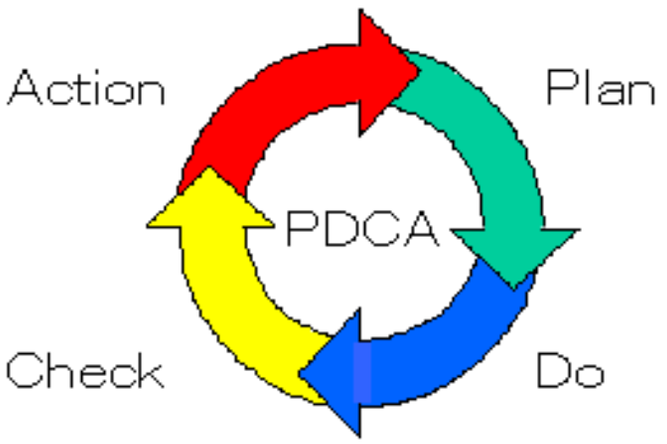

Figure 1. PDCA Cycle

In using the PDCA method may be necessary to use various tools, such as the basic tools for process control as stratification, check sheet, Pareto chart, cause and effect diagram, and scatter plots, histograms, control charts. Other techniques could include analysis of variance, regression analysis, design of experiments, process optimization, multivariate analysis and reliability [8].

Within the food industry, the PDCA cycle can be applied to the standardization or improvement of any product, process or activity the support the production, such as the standardization of procedures for cleaning and sanitizing, pest control, production processes, or improvement in the set-ups of equipment, reduction in losses in production, among others.

4.4. Traceability

The concept of traceability of products originated in the aeronautical and nuclear industries and it is widely practiced in industries. The tool aims to locate the source and the root causes of a particular problem of quality or safety, by the information recorded from a particular product, regardless of the stage of production where it is - whether raw material, in-process product or finished product. Through the traceability of products is possible to develop prevention and improvement actions, so that a specific problem does not occur again.

Traceability can cover only internal actions of the company, or otherwise, may be complete, when it involves the entire chain of production, allowing identifying even basic raw material that led to the final product and locations outside the company where finished products are stored. Consideration as the consumer safety, as the demands of the institutional environment and the costs of implementation of the traceability system will define the scope more suited to be deployed by the company.

4.5. Statistical quality control

The Statistical Quality Control uses statistical tools to control a product or process. To do this, it works with data collection and the interpretation thereof, acting as a fundamental tool to solve problems in critical product and process. Thus, ensures the quality sector the product conformity with the specifications defined as ensures the production sector the information needed for effective control of manufacturing processes providing subsidies to decision making in purchasing processes, receiving raw materials and shipment of products and also in reducing cost and waste. From the identification of the market requirements it is collected sufficient statistical information necessary for the development of new products and assists in monitoring the quality profile of competing products.

Although not a mandatory requirement in the food industry, statistical quality control can prove beneficial to organizations in the sector regardless of their particular specialism and size [9]. According Grigg, the initiatives of training of new graduates entering the industry in the principles of quality assurance and statistical methods and training the existing workforce and management in applying statistical control procedures to processes will make this methods more use of it than they are [9, 10].

The industrial statistic includes descriptive statistics, process capability analysis, measurement system analysis, basic graphics as histogram, scatter, box-plot, Pareto diagram, cause and effect, design of experiments, linear regression and correlation, multiple regression, hypothesis testing, confidence intervals, analysis of variance, analysis of process capability, among other tools [8]. It also covers the sampling techniques and control charts that will be described below, to be very useful to inspection and process control.

4.5.1. Inspection by sampling

The inspection process is to analyze or examine units of a product in order to verify with its quality characteristics are in accordance with technical or contractual specifications. Upon inspection of the product by sampling units are randomly selected to compose the sample batch. Depending on the number of defectives in the sample or the level of quality, that lot is accepted or rejected. Thus, sampling allows, by analysis of a small part of the whole or lot it is possible to draw conclusions about the rest not inspected. Therefore, in the sampling inspection an absolute conclusion about the quality of the lot will never be achieved, there is always a risk rate inherent in the sampling plan and dependent on its discriminatory power.

The current continuous improvement programs that evolve throughout the production chain, call for reducing the use of inspection techniques for the evaluation of the product or process, based on the idea that efforts should focus on "getting it right" in the first time and not in check it, then add value to the product, if it was done properly. However, these inspection techniques for acceptance have restored the importance of quality of audits.

There are two types of sampling plans, sampling plans by attributes and sampling plans by variables. The sampling rate by attributes consists in classifying units of a product just as acceptable or unacceptable based on the presence or absence of a particular feature in each

http://dx.doi.org/10.5772/53162

unit qualitative inspected. The results of the inspection by attributes are expressed in terms of defective/not defective, conforming/nonconforming. In the inspection by variable the characteristics or indicators of quality of the product unit are analyzed and the results are expressed by some continuous numeric scale. While inspection by attributes takes values from the set of integers, inspection by variable takes values in the set of real numbers [11, 12]. Upon inspection by attributes the probability of acceptance of the lot is based on Poisson Probability Distribution. The Poisson Probability Distribution is sometimes used to approximate the binomial distribution when the sample size (n) is too large and the proportion of defectives (p) is small. Otherwise, the use of sampling plans by variable assumes that the Normal Probability Distribution fits well with the distribution of the values of the quality characteristic under study.

Inspections by sampling can be used in finished products, raw materials, manufacturing operations, products in intermediate stages of processing, stored materials, among others. There are situations when only one plan by variable applies, for example, when the buyer will accept the product, but will pay different prices depending on the level of product quality. Also when the analysis result of the product will be expressed as quantitative values. For example, in the determination of chemical composition, weight, volume, and physical and rheological measurements. Therefore, measures such as pH, acidity by titration, soluble solids, fat, objective measurements of color and texture, among others, are typical of the sampling variable. The sampling by attributes can be implemented when it wanted to analyze a quality parameter in qualitative terms. Thus they are quite applied, for example, in visual analysis of packaging, the presence of dirt and physical damage in fruit and vegetables.

The following hypothesis test is linked to inspection for acceptance:

$$H_0 : p = p_0$$
$$H_1 : p > p_0 \quad (1)$$

Being "p" the proportion of defectives that the process produces. If the process is in control properly, this ratio is around p_0 (hypothesis H_0 true). The risk α, also known as producer's risk is likely rejection of a batch of a process whose average is equal to p_0 defective, that is, the risk that the producer suffers as a result of inspection or analysis of sample can lead to a rejection of a good plot (which meets the specifications). The risk β, also known as consumer's risk is the probability of acceptance of a batch of a process in which the proportion of defectives is greater than p_0, i.e., the result of inspection or analysis of the sample can lead to the acceptance of a batch inadequate; i.e., which does not meet the specifications [13].

A single sampling plan by attributes is defined by two parameters: sample size and acceptance number. The likelihood of acceptance of batches relates to the sample size, the severity in the acceptance criterion and the quality level of the products being analyzed in relation to the predetermined quality parameter [11]. In the sampling plans by variables, the probability of acceptance is related to the quality level of the product under examination and de-

pends on the average of the quality parameter in question and its variability. It also depends on the severity criterion for acceptance of the lot [12].

Finally, it is worth noting that the Codex Alimentarius recommends the use of the ISO 2859 series relating to the procedures for sampling by attributes and the ISO 3951 series for the procedures for sampling by variables [14].

4.5.2. Control chart

The formal start of statistical process control occurred around 1924, when Shewhart developed and applied control charts at *Bell Telephone Laboratories*, a telephone company in the United States [1, 7, 13]. As in the entire production process variability occurs, Chart Control or Control Chart, or Map Control, aims to monitor these changes in processes, as well as to evaluate the stability of this process and eliminate or control the causes of variations. A Control Chart (Figure 2) consists of a Central Line (CL), is a pair of control limits: one above Upper Control Limit (UCL) and one below, Lower Control Limit (LCL), and characteristic values marked on the graph. If these values are within limits, without any particular trend, the process is considered under control. But if the points relate outside the control limits or submit an atypical arrangement, the process is judged out of control.

Variability in process may be classified into two types: the variability caused by random or common cause, which are inherent in the process and will be present even considered that this process is fully standardized. If only this kind of cause is acting in the process, it is said that the manufacturing process remains in statistical control. The other type of variability is caused by remarkable and special causes that arise sporadically due to a particular situation which causes the process to behave in a completely different way than usual, which can result in a displacement of the quality level. Thus, it is said that the process is out of statistical control.

The manufacturing control is exercised by the manufacturer during the industrialization process. The goal is to maintain the quality of the product satisfactorily uniform, preventing the production of items outside specification. The proofing that the process is in control or not is, made by examining unit samples taken periodically out of the production line. If the process is under control, samples that present variability corresponding to samples taken from a normal population, i.e., the variability is attributable only to product that is the sample. The "under control process" supposes, therefore, that the quality characteristic of all units produced has Normal Probability Distribution (Figure 3). Moreover, it also implies that this distribution remains stable, i.e., that its two parameters, medium (μ) and standard deviation (σ), remain constant, which is verified by extracting a sequence of samples. So it is said that in a process under statistical control, the variability is attributed solely to random causes. These causes of variation do not cause appreciable variation in product quality; its elimination is impossible or anti-economical, and therefore, random causes are considered a natural part of the manufacturing process [8].

http://dx.doi.org/10.5772/53162

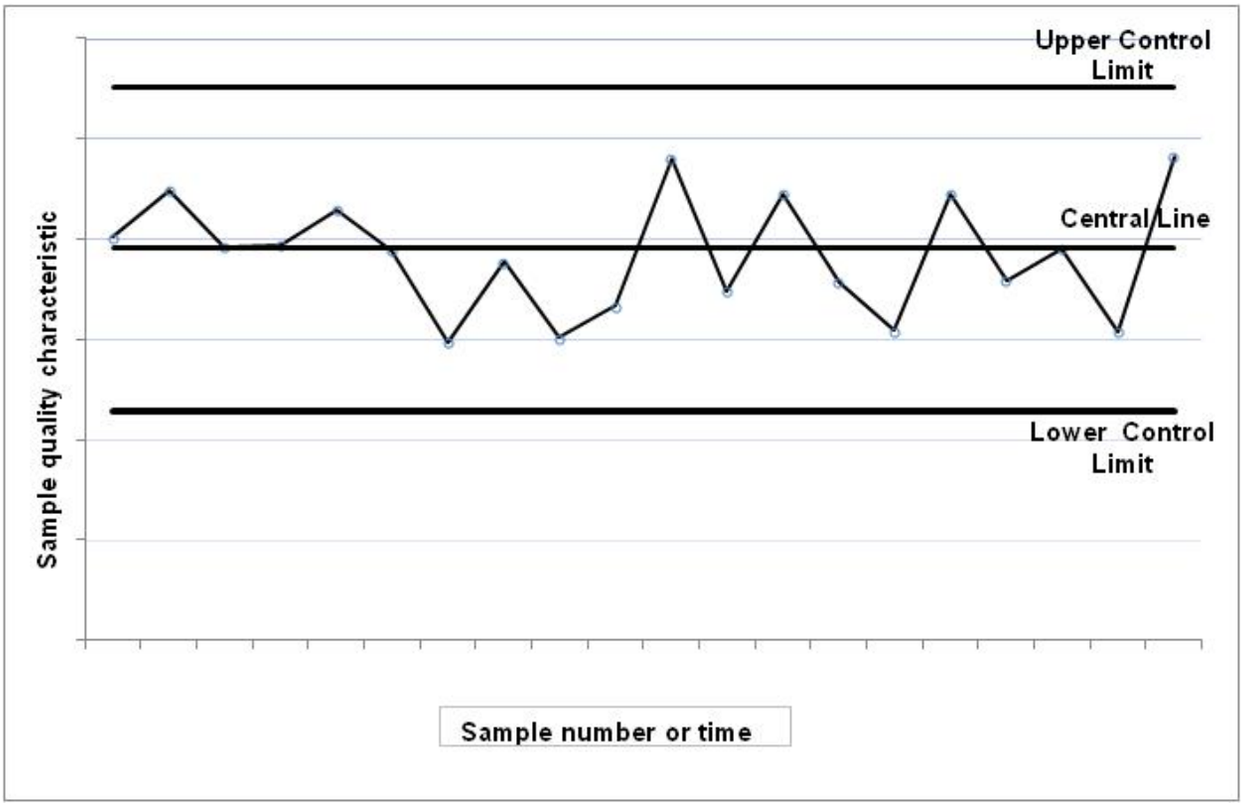

Figure 2. A typical control chart [8]

The Normal Distribution consists of an essential notion in statistical quality control rational. It is known that the items of a Normal Distribution (average μ and standard deviation σ) are distributed around the average, approximately by the following proportions: 68% of the values in the range $\mu \pm \sigma$, 95% in interval $\mu \pm 2\sigma$ and 99.7% in the range $\mu \pm 3\sigma$. Consequently, differences between an observed value X and the average μ, greater than $\pm 3\sigma$ are separated, three times to every 1000 observations, and therefore, the range of variability "normal" in the process under control is $\mu-3\sigma$ and $\mu+3\sigma$ (Figure 3).

When the variability becomes "abnormal" changes in the quality characteristics of the product are sensitive. The causes of modification can be discovered and are therefore called "identifiable causes". These causes require prompt corrective action, in order to eliminate them. In these situations the samples indicate that the manufacturing process has changed and that the units were produced out of control. Some typical situations in process out of control occur when can be seen points outside the control limits. This is the clearest indication of lack of control of a process, which requires an immediate investigation of the cause of variation. Also can happened of points of the chart represent a trend, which consists of a continuous motion of the points of the control chart in one direction (ascending or descending). Also there is a configuration in sequence in several successive points of the control chart shown in only one side of the center line (eight or more consecutive points on one side of the center line). Another approach is the normality of the control limits, where 2 out of 3 consecutive points are outside the limits of 2σ [8].

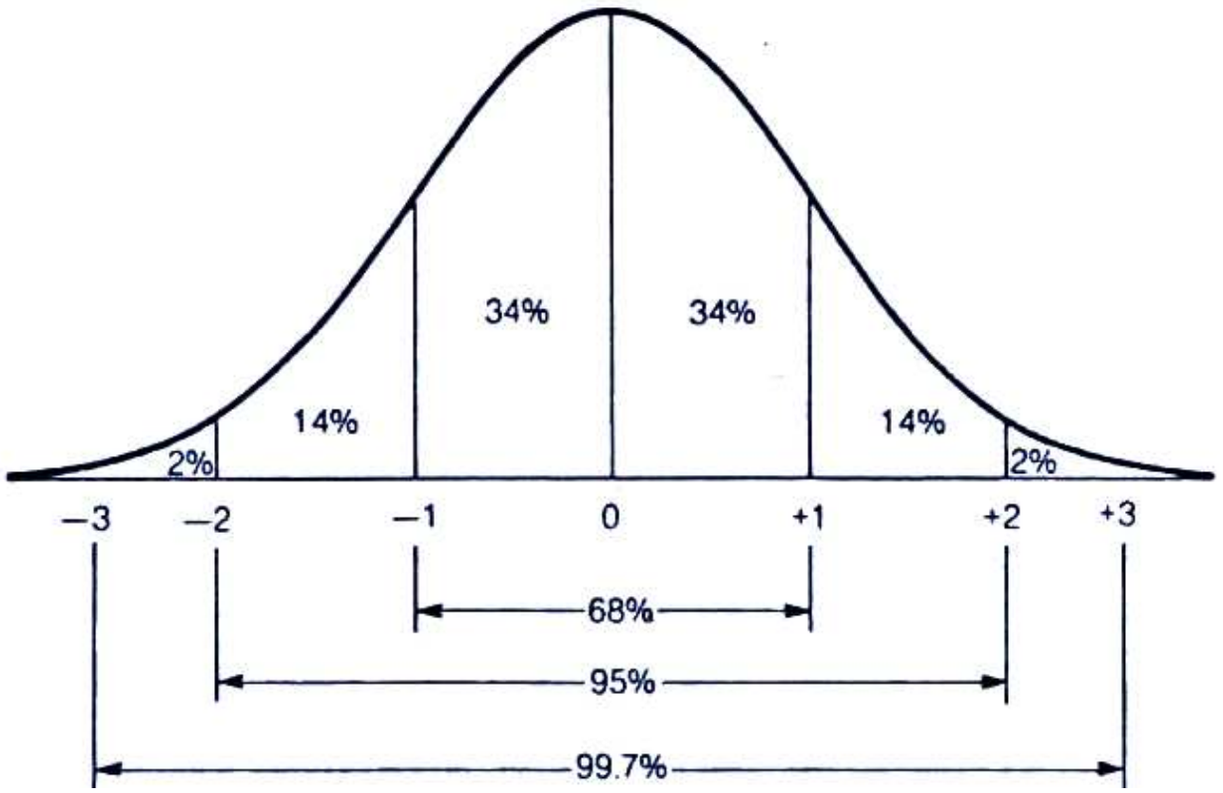

Figure 3. Scheme of Normal Probability Distribution

The food industry use control charts in different ways depending upon their level of maturity in statistical thinking [15]. In a survey conducted in UK food industry, revealed that while there are large differences in process types, quality priorities and key measures among different sub-sectors of the industry, the use of control charts was broadly similar. This generally extended to the use of control charts for recording or monitoring product net weight and volume data [15].

There are two types of quality control charts: control charts for variables and control charts for attributes, which will be described below.

4.5.2.1. Control charts for variables

Control charts for variables are named due to the fact that the quality characteristic being analyzed is expressed by a number on a continuous scale measures. Some examples of control charts are to yield a formulation, to verify the volume of a drink during their bottling, the soluble solids of a sweet after its cooking and the time to deliver a product to the customer.

Some control charts for variables most commonly used are: chart of the average (x), chart of amplitude (R), chart of standard deviation (*s*). When a quality characteristic of interest is expressed by a number on a continuous scale of measurement, the two control charts most used are the chart of the average (x) and a chart of variability (R or *s*). The two charts should be employed simultaneously.

http://dx.doi.org/10.5772/53162

Although the benefits of the application of control charts can be obtained in various situations of the food industry, the construction of the charts by variables will be exemplified by a typical situation of the food industry, in a packing operation. Imagine that a poultry slaughterhouse want to control the process of packaging of poultry cuts. In practice, the parameters average μ and standard deviation σ are unknown and must be estimated from sample data. The procedure to estimate μ and σ is to take *m* preliminary samples, each containing *n* observations of quality characteristic considered. These samples, known as rational subgroup should be taken when one believes that the process is under control and the operating conditions kept as uniform as possible. It is usual to consider m = 20 or 25 at least and n = 4, 5 or 6 [7,8].

The procedure for construction of the chart is:

1. Collect the data

Table 1 shows the values x_{ij}, weight of "j" cutting belonging to "i" sample, for 25 rational subgroup size of 4 (m = 25 and n = 4). Therefore, "i" varies from 1 to 25 and "j" from 1 to 4. The sections were collected when the machine was operating within normal procedure, i.e. no stops or apparent defects.

Samples	x_{i1}	x_{i2}	x_{i3}	x_{i4}	R_i
1	250,11	250,30	249,50	248,60	1,70
2	248,00	248,60	249,78	250,15	2,15
3	249,19	250,02	250,84	250,84	1,65
4	251,29	248,86	251,00	249,39	2,43
6	249,33	251,80	249,65	248,31	3,49
7	250,26	248,56	250,43	251,21	2,65
8	250,31	249,11	249,54	249,95	1,20
9	250,72	250,80	249,35	249,35	1,45
10	250,21	248,78	248,99	250,20	1,43
11	251,21	251,45	249,34	250,55	2,11
12	249,22	250,43	250,45	250,78	1,56
13	251,89	250,87	249,65	249,00	2,89
14	250,98	249,01	249,51	249,51	1,97
15	249,00	249,00	251,45	250,00	2,45
16	249,98	249,55	249,67	249,23	0,75
17	248,88	250,43	249,76	249,11	1,55
18	251,65	249,76	249,12	250,32	2,53
19	248,65	248,32	249,00	250,12	1,80

Samples	x_{i1}	x_{i2}	x_{i3}	x_{i4}	R_i
20	248,12	248.15	249,45	249,67	1,55
21	251,13	250,21	249,11	247,88	3,25
22	250,44	251,17	250,01	250,01	1,16
23	250,12	251,98	251,13	251,93	1,86
24	248.56	248.90	248,20	248,98	0,78
25	248,12	248,45	248,90	250,16	2,04

Table 1. Values of x_{ij} and R_i.

2. Calculate the amplitude of each sample R_i

$$R_i = \text{highest sample value - lowest value of the sample} \tag{2}$$

See the values of R_i in Table 1.

3. Calculate the average amplitude of the sample R

$$R = \frac{R1 + R2 + \ldots + Rm}{m} \tag{3}$$

Thus the value of R (average amplitude) is R = 1,93.

4. Establish the boundaries of the amplitude chart (Chart of R):

$$\begin{aligned} UCL &= D4 \times R \\ CL &= R \\ LCL &= D3 \times R \end{aligned} \tag{4}$$

The values of D_4 and D_3 are tabulated [7, 8]. Thus, $D_4 = 2,282$ and $D_3 = 0$.

Therefore:

$$\begin{aligned} UCL &= 2,282 \times 1,93 = 4,41 \\ CL &= 1,93 \\ LCL &= 0 \times 1,93 = 0 \end{aligned} \tag{5}$$

5. Build the chart of amplitude (Figure 4).

6. Analyze the chart.

http://dx.doi.org/10.5772/53162

Analyze the behavior of the points on the chart of amplitude and verify if the process is in statistical control. If necessary, recalculate the chart boundaries after the abandonment of the points there are out of control. Repeat this procedure until the control state is reached.

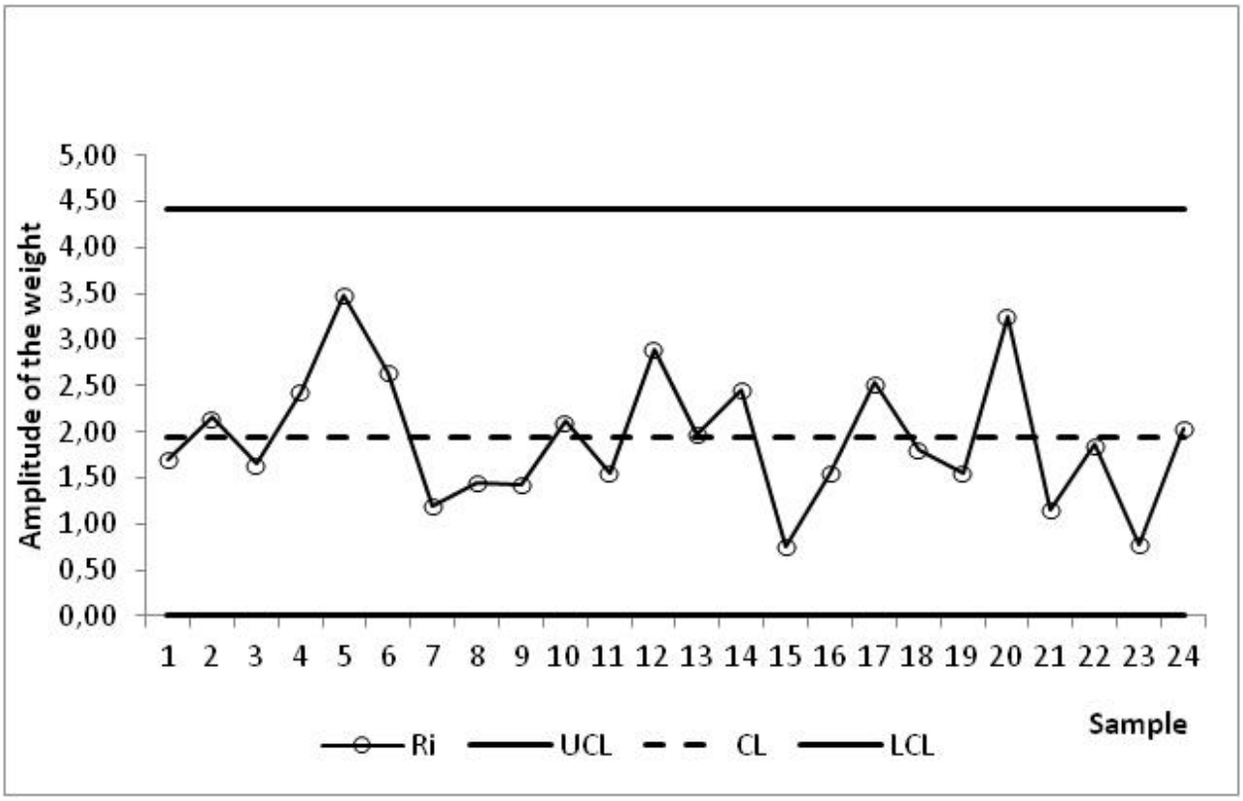

Figure 4. Chart of Amplitude (R) (25 points)

Analyzing the Figure 4, it can be seen that all points present within normal behavior. Now it is necessary to build the chart of average (x). To do this:

7. Calculate the average x_i of each sample (Table 2).

$$x_i = \frac{x_{i1} + x_{i2} + \ldots + x_{in}}{n} \tag{6}$$

8. Calculate the global average $\overline{X}$.

$$\overline{X} = \frac{x_1 + x_2 + \ldots + x_m}{m} = 249,83 \tag{7}$$

9. Calculate the control limits of the chart average.

$$
\begin{aligned}
ULC &= \bar{\bar{X}} + A_2 R \\
CL &= \bar{\bar{X}} \\
LCL &= \bar{\bar{X}} - A_2 R
\end{aligned} \tag{8}
$$

The value of A_2 is a constant tabulated [7, 8]. Thus, $A_2 = 0{,}729$. $\bar{\bar{X}}$ is the average of averages and R is the average amplitude found in the last chart of amplitude.

Thus:

$$
\begin{aligned}
ULC &= 249{,}83 + 0{,}729 * 1{,}93 = 251{,}24 \\
CL &= 249{,}83 \\
LCL &= 249{,}83 - 0{,}729 * 1{,}93 = 248{,}42
\end{aligned} \tag{9}
$$

10. Construct of the average chart (Figure 5).

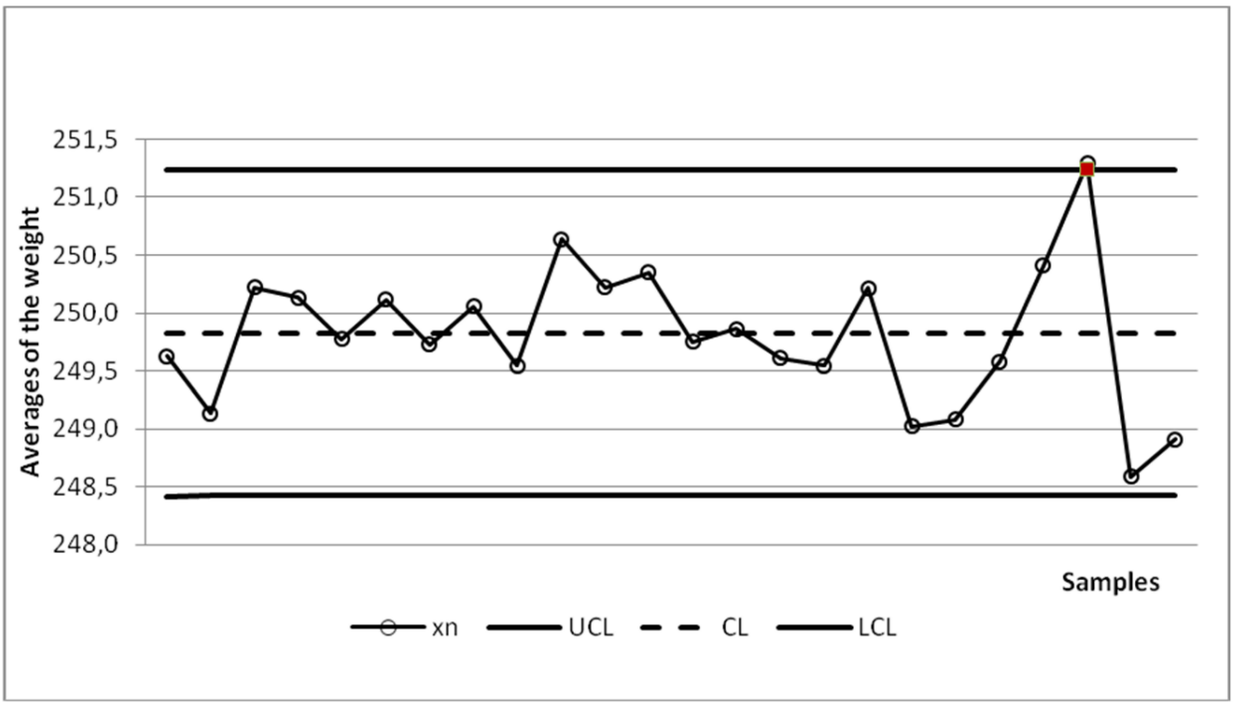

Figure 5. Chart of Average (x)

11. Interpret the chart of average built.

Analyze the behavior of the points on the average chart and whether the process is in statistical control. If necessary, recalculate the chart boundaries after the abandonment of the points there are out of control. Repeat this procedure until the control state is reached.

http://dx.doi.org/10.5772/53162

Analyzing the Figure 5, it can be seen that point 23 is above the UCL and therefore should be eliminated. The boundaries must be recalculated and a new chart of amplitude must be drawn (Figure 6).

New limits of the graph of the average (x) after removal of the subgroup 23.

$$\begin{aligned} ULC &= 249,76 + 0,729 * 1,93 = 251,17 \\ CL &= 249,76 \\ LCL &= 249,76 - 0,729 * 1,93 = 248,36 \end{aligned} \tag{10}$$

Samples	x_{i1}	x_{i2}	x_{i3}	x_{i4}	x_n
1	250,11	250,30	249,50	248,60	249,63
2	248,00	248,60	249,78	250,15	249,13
3	249,19	250,02	250,84	250,84	250,22
4	251,29	248,86	251,00	249,39	250,14
6	249,33	251,80	249,65	248,31	249,77
7	250,26	248,56	250,43	251,21	250,12
8	250,31	249,11	249,54	249,95	249,73
9	250,72	250,80	249,35	249,35	250,06
10	250,21	248,78	248,99	250,20	249,55
11	251,21	251,45	249,34	250,55	250,64
12	249,22	250,43	250,45	250,78	250,22
13	251,89	250,87	249,65	249,00	250,35
14	250,98	249,01	249,51	249,51	249,75
15	249,00	249,00	251,45	250,00	249,86
16	249,98	249,55	249,67	249,23	249,61
17	248,88	250,43	249,76	249,11	249,55
18	251,65	249,76	249,12	250,32	250,21
19	248,65	248,32	249,00	250,12	249,02
20	248,12	248.15	249,45	249,67	249,08
21	251,13	250,21	249,11	247,88	249,58
22	250,44	251,17	250,01	250,01	250,41
23	250,12	251,98	251,13	251,93	251,29
24	248.56	248.90	248,20	248,98	248,59
25	248,12	248,45	248,90	250,16	248,91

Table 2. Values of x_{ij} and $x_{n.}$

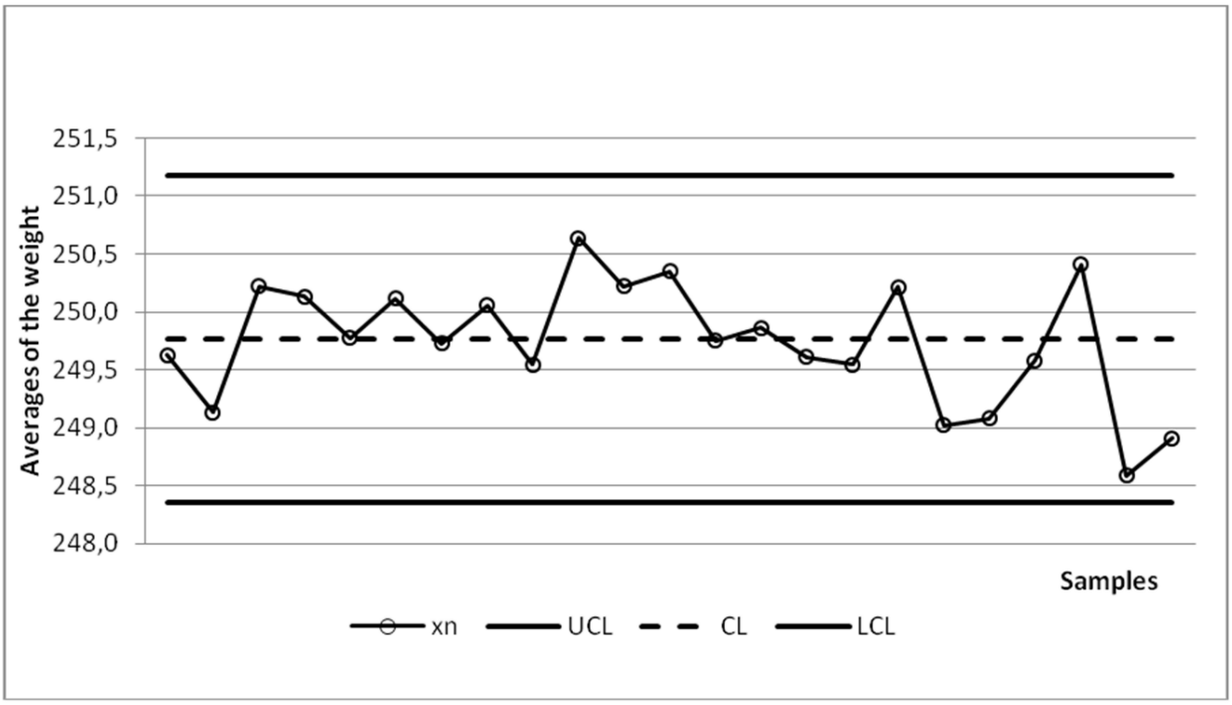

Figure 6. Chart of Average (x) (without the 23th subgroup)

12. Place the final charts of amplitude and average in the production line.

Note that for control of the packaging process of cuts of poultry, it chart has to be placed without padding, only with the UCL, CL and LCL, so that operators or responsible for quality control of packaging can monitor the process.

13. Periodically review the values of the control limits.

4.5.2.2. Control charts for attributes

It is not always by means of measurements that assess the quality of a product. For example, the color of a biscuit or of a sweet can be evaluated sensorially and the result is expressed as conforming or not conforming to a specified standard. Or, a PET bottle can be classified as not defective if it is whole in its structure or defective if it is crushed or broken.

Control charts for attributes can be: chart of the proportion of defective items (Chart p), chart of the total number of defects (Chart np), chart of number of nonconformities in the sample (Chart C) and the chart of number of nonconformities by inspection unit (Chart u) [8, 13].

Also here the construction of a chart for attributes will be exemplified. Suppose a manufacturer industry of biscuits decides to build a control chart *p* to visually check whether the product color after baking, was established as a standard for quality control. The number of defective products is presented in Table 3 and is important to note that the samples were numbered according to the date of production.

http://dx.doi.org/10.5772/53162

Date	Lot	Nº. Biscuit inspectionated	Defective items (x_i)	Proportion of defective items (p)
01/mai	1	200	7	0,035
02/mai	2	200	9	0,045
03/mai	3	200	4	0,02
04/mai	4	200	5	0,025
05/mai	5	200	6	0,03
06/mai	6	200	9	0,045
07/mai	7	200	5	0,025
08/mai	8	200	6	0,03
09/mai	9	200	6	0,03
10/mai	10	200	4	0,02
11/mai	11	200	6	0,03
12/mai	12	200	7	0,035
13/mai	13	200	4	0,02
14/mai	14	200	6	0,03
15/mai	15	200	7	0,035
16/mai	16	200	8	0,04
17/mai	17	200	8	0,04
18/mai	18	200	4	0,02
19/mai	19	200	7	0,035
20/mai	20	200	6	0,03

Table 3. Number of defective biscuits in samples of 100 units

1. Collect the data

Collect m samples of size n. In general m = 20 or 25 at least. Collect the samples at successive intervals and record observations in the order they were obtained (Table 3).

2. Calculate the average proportion of defective items p (average).

$$\overline{p} = \frac{1}{mn}\sum_{i=1}^{n} X_i \tag{11}$$

X_i is the number of defective items in the "i" sample.

3. Calculate the control limits.

$$UCL = \bar{p} + 3\sqrt{\bar{p}(1-\bar{p})/n}$$
$$CL = \bar{p} \tag{12}$$
$$LCL = \bar{p} - 3\sqrt{\bar{p}(1-\bar{p})/n}$$

The LCL is not considered when the value is negative.

4. Draw the control limits. Mark left-hand vertical axis in the scale for horizontal axis p and the number of samples. Draw lines to represent full UCL, CL and LCL (Figure 7).

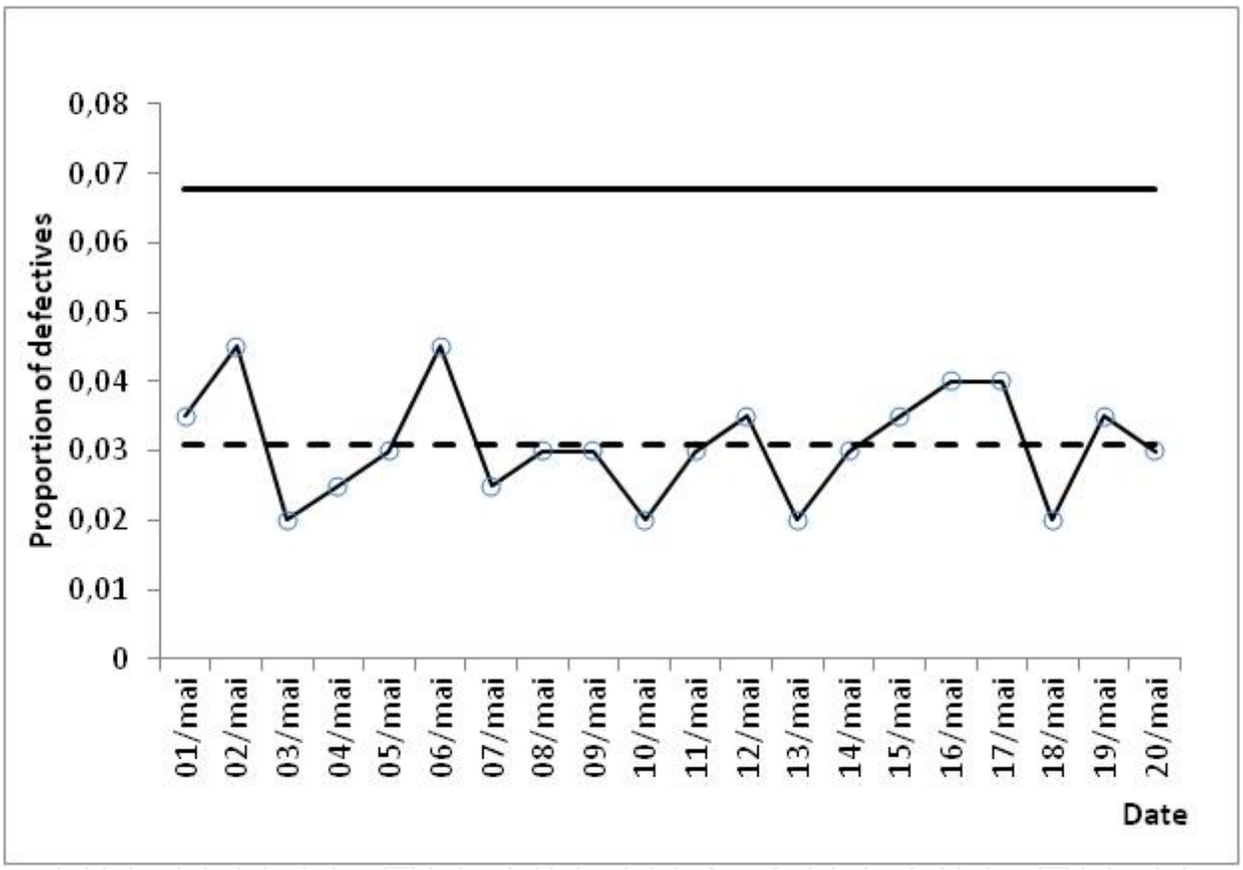

Figure 7. Chart p (proportion of defective products in the sample)

5. Mark the points on the chart.

Represent on the chart the m values of p (Figure 7).

6. Interpret the graph constructed.

To analyze the behavior points on the graph, and verify that the process is in statistical control. If necessary, recalculate the chart boundaries after the abandonment of the points there are out of control. Repeat this procedure until the control state is reached.

http://dx.doi.org/10.5772/53162

7. Check if the control state reached is appropriate to the process. If so, adopt the current control chart. Note that for control of the biscuit color, it chart has to be placed without padding, i.e., only with the UCL, CL and LCL.
8. Periodically review the values of the control limits.

5. Quality management systems

5.1. Total Quality Control (TQC)

In the '50s, the quality control was employed in Japan, by an intensive use of statistical techniques. However, the excessive emphasis on statistical techniques led to some problems, such as low interest shown by senior management of companies, by the quality control, which remained a movement of ground and plant, i.e., to engineers and workers [16].

In 1954 JUSE invited the engineer Juran, one of the masters of quality management, to deliver seminars to senior management. From the visit of Juran, the Quality Control came to be understood and used as an administrative tool, which represented the beginning of the transition of Statistical Quality Control for Total Quality Control as is currently practiced, involving the participation of all sectors and employees[16].

The quality management system proposed by the Japanese model shows how basic features to the participation of all sectors and all company employees in the practice of quality control, constant education and training for all levels of the organization, circles activity of quality control, audits, use of basic and advanced statistical techniques and national campaigns to promote quality control.

The TQC ideas developed by the Japanese were broadcast around the world, being this model capable of being deployed in companies of various sectors, with appropriate adjustments to the corporate culture.

5.2. ISO 9000 series

While the movement occurred in Japan by TQC, in Europe there was a movement around an organizational structure whose purpose was to develop standards for manufacturing, trade and communication in European countries for the increased levels of quality of activities. Thus, in 1947 the International Organization for Standardization was founded, based in Geneva, Switzerland. And in terms of quality control there was difficulty to unify standards that ensure that a product had been manufactured under quality criteria, after several trials, in 1989, was published the standard ISO 9000. The goal was to establish requirements for a quality management system, the implementation of which would extend to all types and business segments. The requirements of the series represented the consensus of different countries of the world.

More specifically, ISO 9001 deals with the requirements of the quality management system for an organization to produce compliant products and get customer satisfaction. Within the

rules of the certification ISO 9001, there are specific requirements regarding the responsibility and involvement of management with the quality system, requirements for preparing and controlling of the documentation, for the critical analysis of contracts and selection of suppliers, to traceability and processes control, for measurement, for inspection and testing, analysis of nonconformities and for continuous improvement, for audits and training.

As ISO 9001 is a rule of general character it contains requirements to serve the most various sectors, it is necessary, once adopted by the food industry, some aspects can be considered in some cases insufficient. There's not in the standard, explicit references to the risks to consumer health, the safe products, the nutritional values, the critical control points, the good manufacturing practices. Food security can be seen as failures risk of deterioration and damage as a result of careless handling and storage inconvenient and not because of contamination and loss of sensory and nutritional values. Thus management systems for food safety have also been employed to address this need [17].

5.3. ISO 22000 series

Aiming to harmonize the international level, the various guidelines related to food safety systems, it was developed the ISO 22000:2005 - Food Safety Management systems - Requirements for any organization in the food chain. This applies the principles of a plan Hazard Analysis and Critical Control Points (HACCP) programs along with prerequisites, such as Good Manufacturing Practices (GMP) and Good Hygiene Practices (GHP). The standard has a similar format to the standard of ISO 9001 Quality Management. This similarity allows organizations to implement the specifics of food management system integrated to the quality management system. In this context the ISO 22000 presents as fact the benefits of being recognized internationally, to apply to all elements of the food chain and fill for the food sector, the gap between ISO 9001 and HACCP.

The ISO 22000 standards specifies the requirements to a safety management system that combines elements of food management system to ISO 9001 templates, as already said, and interactive communication, since communication along the supply chain is essential to ensure that all relevant safety hazards of food are identified and controlled. Finally, through concrete measures, tangible and that can be checked in audits, ISO 22000 combines the HACCP plan with prerequisite programs (PRP), since they are keys to an effective management system of food safety.

The ISO 22000 considers that the safety of food is related to the presence of hazards in food at the time of consumption. And because of the dangers that can occur at any stage of the supply chain, the security must be ensured at all levels of the supply chain. So it should be applied to producers of animal feeds and other agricultural products, food manufacturers, packaging, transportation and food warehouses to suppliers of retail and food services. So for its strong integrator character, the success of the implementation depends largely on the acceptance of the various links in the supply chain. Other barriers may arise in terms of local practices and investment cost.

http://dx.doi.org/10.5772/53162

5.4. Six sigma

The concept of 6-Sigma system was developed by Motorola in the mid 80´s. The 6-Sigma program involves the application of statistical methods to business processes, guided by the goal of eliminating defects. The 6-Sigma focuses on quality improvement (eg, waste reduction) to help organizations produce better, faster and more economical. More generally, the program focuses on defect prevention, reduction of cycle times and cost savings. Unlike careless cost cutting, which reduce the value and quality, Six Sigma identifies and eliminates costly waste, i.e., that do not add value to the customers. With this, the company increases operational efficiency reduces costs, improves quality, increases customer satisfaction and increases profitability [18, 19].

Sigma (σ) is a letter of the Greek alphabet used by statisticians to measure the variance in any process. The performance of a company is measured by the sigma level of their business processes. Organizations that employ the Six Sigma method aim to achieve 3.4 defects per million on manufactured products. This methodology is based on the implementation of a system based on the measurement and monitoring of processes so that deviations from 'normality' are avoided as much as possible.

The Six Sigma methodology is composed by a broad set of tools and techniques for quality improvement, among which there is a strong application of statistical tools and techniques. The cycle of phases, called DMAIC (Define, Measure, Analyze, Improve, Control) is used as a guide for professionals (mainly black belts and green belts) to implement projects that meet the goals most daring and radical pre-set by the company. The DMAIC can be resumed as follows:

- Define: define problems and situations to be improved, including the goals of the activities, as they will be the company's strategic objectives.
- Measure: to establish valid and reliable measurements for information and data.
- Analyze: analyze the information captured in order to identify ways to eliminate the gap between the current performance of the system or process and the desired goal. It should apply statistical tools to aid analysis.
- Increment: deploy processes, it can use management tools of projects or planning and managing to deploy a new approach,
- Control: control the improved processes in order to generate a continuous improvement cycle.

The statistical aspects of six sigma must complement business perspectives and challenges to the organization to implement six sigma projects successfully.In the list of tools and statistical techniques of DMAIC, are included: descriptive statistics, principles of sampling, control charts, process capability analysis, measurement system analysis, basic charts (histogram, scatter, box-plot, Pareto, etc..), cause and effect diagram, statistical process control (SPC), design of experiments, linear regression and correlation, multiple regression, hypothesis testing, confidence intervals, analysis of variance, capability process analysis, among others [18-20].

Factors influencing successful six sigma projects include management involvement and organizational commitment, project management and control skills, cultural change, and continuous training. It is a methodology that crosses the entire company, i.e., it is not the isolated involvement of a team, but the involvement of all in the pursuit of the implementation of continuous improvement and customer satisfaction [19, 20].

The adoption of the Six Sigma methodology as a quality program in all agribusiness chain in general is still new, but it is important to highlight the potential of this method for improving the quality of food products and reduce production costs.

6. Conclusion

The competitiveness of a company can be seen as a reflection of the strategies adopted as a means to adapt to the prevailing standards of competition in the markets in which the organization operates. Certainly, quality is a key factor for the food industry acts in a market increasingly globalized. For that companies must establish competitive strategies and develop an appropriate internal structure.

From these assumptions, this chapter talked about the important aspects and also specific to quality management in the food industry. The reality of each company, in financial terms, cultural, organization and motivation, will determine the degree of maturity and efficiency in quality management. What can be concluded is that the competitive advantage certainly goes through the constant search for new tools and learning management systems that improve the quality of processes and services and consequently the products offered by the food industry.

Author details

Caroline Liboreiro Paiva

Address all correspondence to: carolinepaiva7@gmail.com

Department of Food Science, University Federal of Minas Gerais, Belo Horizonte, Brazil

References

[1] Garvin, D. A. Managing Quality: The Strategic and Competitive Edge. Boston: Harvard Business School Press; 1988.

[2] Gurudasani, R., Sheth, M. Food safety knowledge and attitude of consumers of various food service establishments. Journal of Food Safety 2009;29: 364–380.

[3] Fotopoulos C, Kafetzopoulos D, Gotzamani K. Critical factors for effective implementation of the HACCP system: a Pareto analysis. British Food Journal 2011; 113(5): 578-97.

[4] Food and Drug Administration.FDA. Return to Good Manufacturing Practices (GMPs) for the 21st Century - Food Processing. www.fda.gov/Food/GuidanceComplianceRegulatoryInformation/CurrentGoodManufacturingPracticesCGMPs (accessed 10 August 2012).

[5] Codex Alimentarius Commission. Recommended international code of practice general principles of food hygiene. CAC/RCP-1 (1969); Rev.4; 2003.

[6] Campos VF. TQC: Controle da Qualidade Total (no estilo japonês). Nova Lima: INDG; 2004.

[7] Werkema MCC. Ferramentas estatísticas básicas para o gerenciamento de processos. Belo Horizonte: Fundação Christiano Ottoni; 1995.

[8] Montgomery, D.C. Introduction to statistical quality control. 5th edition, New York: Wiley; 2005.

[9] Grigg N. Statistical process control in UK food production: an overview. International Journal of Quality & Reliability Management 1998; 15(2): 223-38.

[10] Grigg N, Walls L. Developing statistical thinking for performance improvement in the food industry. International Journal of Quality & Reliability Management 2007; 24(4): 347-69.

[11] International Standard Organization. Sampling procedures for inspection by attributes - Part 10: Introduction to the ISO 2859 series of standards for sampling for inspection by attributes. ISO 2859-10:2006(E).

[12] International Standard Organization. Sampling procedures for inspection by variables - Part 2: General specification for single sampling plans indexed by acceptance quality limit (AQL) for lot-by-lot inspection of independent quality characteristics. ISO 3952-2:2006(E).

[13] Costa, AFB, Epprechi EK, Carpinetti LC. Controle estatístico de qualidade. São Paulo: Atlas; 2004.

[14] Codex Alimentarius Commission. General guidelines on sampling. CAC/GL 50; 2004.

[15] Grigg N, Walls L. The role of control charts in promoting organizational learning: new perspectives from a food industry study. The TQM Magazine 2007; 19(1): 37-49.

[16] Mizuno S. Company-wide quality control activities in Japan. Reports of Statistical Application Research 1969, 16(3): 68-77.

[17] Grigg N, McAlinden C. A new role for ISO 9000 in the food industry? Indicative data from the UK and mainland Europe. British Food Journal 2001; 103(9): 644-56.

[18] Tjahjono B, Ball P. Six Sigma: a literature review. International Journal of Lean Six Sigma 2010; 1(3): 216-33.

[19] Werkema, C. Criando a cultura Seis Sigma. Nova Lima: Werkema Editora; 2004.

[20] Kwak YH, Anbari FT. Benefits, obstacles, and future of six sigma approach. Technovation 2006; 26(5-6): 708-15.

IntechOpen