Efficient Consumer Response in Fast Food Supply Chain Management of Hamburgers for Compliance, Health and Marketability

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Abstract— **Foods of animal origin are a good source of high-quality protein. However, determining fat content in hamburgers is important in order to minimize the adverse effects on health. Cardiovascular disease and obesity are known to be caused by high consumption of saturated fatty acids and cholesterol. Efficient consumer response in fast food Supply chain management is a strategy designed to make fast food industry more efficient, safe and responsive to the consumer's needs. Statistical methods of data analysis and insemination are known to provide accurate and meaningful information to create general awareness to consumers of fast foods. This study conducted confidence interval estimation to assess variation in the fat content of hamburger samples from a restaurant, using Minitab. The standard for mean fat content was set at 15 grams as per accepted regulatory requirements, with a standard deviation of 1 gram. In this study twenty samples were selected at random and statistical process control was determined by the individual moving range (I-MR) test. The I-MR chart conducted on twenty individual hamburger samples showed that the fat content was in statistical process control. A graphical summary was conducted to check for normality by the Anderson-Darling test and 95% confidence interval of the mean and standard deviation were determined. The p-value for Anderson-Darling was not significant indicating that the samples were normally distributed. The mean read at 16.48 grams with a standard deviation of 2.09. The confidence interval for the mean registered between 15.50 to 17.46grams. A variance test was carried out to determine a less than 1 gram variation in the samples. The upper bound was detected in a Chi square test at 8.24. A confidence interval estimation for population proportion showed 0.16 for the upper bound. An automatic oil dispensing machine was installed to standardize the oil applied for frying each hamburger. Another 20 samples were taken and were found to be in statistical process control by the I-MR test. A graph summary report indicated a mean of 14.92 grams and standard deviation of 0.49 grams. The Anderson-Darling test was not significant at p-value of 0. 924.Thus confirming a normal distribution. The 95% confidence interval now registered at 14.69 to 15.15, which was close to the expected value of 15 grams. A survey conducted on 100 and 350 customers selected at random, before and after the installation of the automatic oil dispensing machine showed that there were now less dissatisfied customers. A simulation test carried out with twenty samples of 10 subgroups each showed that the process was in control in an X-bar S-chart. An interval plot conducted using a simple multiple Ys chart showed that all the samples were within the 95% confidence interval for the mean indicated by the reference line. A process capability analysis conducted before and after the installation of the automatic oil dispensing machine indicated that the process could be improved further. This study generally indicates that the preparation and sales of hamburgers by restaurants may be improved significantly for more efficient and cost-effective means of production in order to enhance its economic value to the stakeholders.**

Keywords— *Fat content, hamburgers, confidence interval, variation, statistical process control*

1. Introduction

The intake of meat is essential in order to ensure a balanced diet. This is particularly so in developing countries where a high consumption of cereals and other vegetable crops form the main part of the diet. Meat and meat products are an excellent source of protein where the texture and taste depend largely on the value and quality of the fat content [1]. Thus, among foods of animal origin, hamburgers deserve special mention as children and teenagers prefer these together with a combination of French fries and a cold drink to match. Many fast-food outlets such as McDonalds, Burger King and other such like providers thrive on the eating habits of the younger generation of individuals. However, although

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hamburgers provide high quality proteins, fats, vitamins, and minerals, they are the main source which contribute to obesity and various forms of cardiovascular diseases. The high consumption of saturated fatty acids contained in beef burgers is mainly responsible for this [2]. The fat content of animal proteins provides texture and flavour to the hamburgers [1]. However, the food codex in certain countries stipulate that the fat content in hamburgers should not exceed 20% (ww-^{1}) [3]. Thus, it is essential for the fat content in these foods to be regulated. As a result of constantly growing consumer expectations for meat quality, the meat industry is placing more and more emphasis on quality assurance issues. Fat content in meat influences some important meat quality parameters and meat marketability [1]. Important analytical techniques such as image analysis have been used in the prediction of fat content [4]. It is evident that the regulatory requirements of certain foods have been made more stringent in some countries. Various topics such as efficient consumer response (ECR) initiatives transformed the supply chain from a push system to pull system where channel partners form new interdependent relationships [5]. Quick and accurate flow of information through the supply chain enabled suppliers and distributors to anticipate demand requirements far more accurately [6]. The ECR helps in increasing the level of service to consumers and the efficiency in supply chain management, thereby increasing the quality and reducing the cost of production by enabling timeliness of the process. Thus, the introduction of efficient consumer response in the supply chain management in the hamburger industry has a definite advantage in the sales, safety and marketability of the product. Processed meat (PM) products are whole pieces or mixtures of comminated meats consisting of mainly pork and beef, less often poultry, and with other animal parts [7]. Processing steps vary widely and may include salting, curing or cooking, to improve colour, flavour, and shelf-life. In some countries, technical specifications for processed meat products are compiled in an industry manual and serve to standardize composition, processing, and quality [7]. Processed meat is associated with higher health risks than fresh, unprocessed meats (UPM) [8]. In comparison, PM has lower levels of protein and iron, compared to red UPM, and has higher total and saturated fats [9]. Another important difference is that both red and white PM contain salt at high levels, as well as preservatives such as nitrate and nitrite which are introduced during processing [10]. Studies have shown that consumption of PM and red meat is associated with higher risk of colorectal cancer (CRC), which led to the recent classification of PM as carcinogenic to humans by the International Agency for Research on Cancer [11]. Worldwide, CRC is the second and third most common cancer in women and men, respectively. From a public health perspective, the assessment of PM intakes at population level is therefore an important priority worldwide. This study focuses on the statistical analysis of beef hamburgers from a local restaurant mainly based on the nutritional concerns of consumers. Both descriptive and inferential statistical analysis were conducted by the Minitab software to determine the confidence interval estimate of the mean of selected samples to assess the variation in the fat content in hamburgers at the restaurant. As the hamburgers did not meet the standard allowable fat content in the hamburgers, an automatic oil dispenser was installed to standardize the frying of individual hamburgers and subsequent analysis of fat content in twenty samples taken at random showed a marked improvement by way of reduction of fat content. A survey conducted on the satisfaction level of customers before and after the installation of the automatic oil dispensing machine showed an improvement in the result. A simulation study using the Minitab software indicated the system was in statistical control. However, a process capability study showed that the operations could be improved further, perhaps by applying studies on the design of experiment. Such data will contribute to better nutritional recommendations and guidance for public health interventions.

2. Materials and Methods

2.1. Study Design

2.1.1 A cross sectional study was conducted by taking twenty samples of hamburgers at random from a local restaurant. This was with a view to assess the variation of fat content in the hamburgers by the confidence interval estimation of the mean.

2.1.2 After the data had been collected and analysed, an automatic oil dispenser was installed in order to standardize the quantity of oil used to fry individual hamburgers. Subsequently, another batch of twenty hamburgers were selected randomly for a similar

analysis to observe the effect of the automatic oil dispenser on the fat content.

2.1.3 A simulation study consisting of twenty samples of ten sub-groups each was conducted to verify the improvement made in the fat content of hamburgers after the installation of an automatic oil dispensing machine.

2.1.4 Efficient consumer response in the fat content of hamburgers was determined by surveys which were conducted in order to evaluate the level of dissatisfaction in the quality of the fast food.

2.1.5 In any type of field, the goal of statistics is to gain understanding from data. Any data analysis should contain certain steps to be followed to ultimately achieve the goal of the research proposed [12, 13].

2.2. Data Handling and Statistical Analysis To conclude an analysis in processed food of its quality, it should be noted that the major objective of statistics is to make inferences about processed food or population from an analysis of information contained in sample data [14]. This includes assessments of the extent of uncertainty involved in these inferences.

2.2.1 This study focuses on the statistical analysis of the data collected on the fat content of hamburgers from a local restaurant before and after installing an automatic oil dispensing machine. The machine was to standardize the individual frying of the hamburgers. A Minitab 17 software was used throughout the study.

2.2.2 Efficient consumer response in the supply chain management of the hamburgers was evaluated by survey of the number of dissatisfied customers to the quality of the fast food.

2.2.3 I-MR charts conducted before and after the installation of the automatic oil dispensing machine for statistical process control of the hamburgers are indicated in Figs 1 and 3, respectively.

2.2.4 A summary report of the fat content in the initial twenty samples collected at random from a local restaurant was created. Along with this another summary report of the fat content of twenty hamburger samples was conducted after the installation of the automatic oil dispensing machine (Figs 2 and 4) respectively.

2.2.5 The summary reports indicate mainly the mean, standard deviation, the confidence interval (CI) and the Anderson-Darling tests for the normality check.

2.2.6 A 1 variance test using the Chi square method was conducted similarly on the two sets of hamburger samples to indicate a variance of less than 1 gram as proposed in the population (Tables 1 and 3) respectively.

2.2.7 A simulation test on twenty hamburger samples of ten sub-groups each is indicated by an X bar - S chart (Fig 5) to determine statistical process control.

2.2.8 Integral plots of the CI of the X bar - S chart is indicated in Figures 6 and 7 before and after inserting a reference line to indicate statistical process control.

2.2.9 Process capability studies before and after the installation of the automatic oil dispensing machine are given in Figures 8 and 9, respectively.

2.2.10 A 1 proportion test was carried out to determine dissatisfied customers among one hundred customers in order to determine improvement issues (Table 2).

2.2.11A 1 proportion test was carried out subsequently to determine dissatisfied customers among three hundred and fifty customers in order to determine improvement issues after the installation of an automatic oil dispensing machine (Table 4).

3. Results

A local restaurant which sells hamburgers amongst a few other items claims that the average fat content in the hamburgers is 15 grams. This is in line with the regulatory requirements which stipulate that excessive fat content in processed meat products may contribute to detrimental health consequences in their consumption [9]. This is particularly so as a large number of children and young adults in their teens have a preference for consuming fast foods, particularly hamburgers. Excessive consumption of beef burgers is known to be the primary cause of obesity and heart disease in some countries [9].

There has been concerns amongst the restaurant's management that the fat content in the hamburgers may be in excess of the 15 grams that has been stipulated as the regulatory standard [3]. Therefore, a study was conducted in order to verify the fact that

the fat content in the hamburgers served in the restaurant met the regulatory requirement of 15 grams. The study aimed to verify this by using 95% confidence interval (CI) to test the restaurant's claim of 15 grams average of fat content in their hamburgers. The study also wished to verify the assumption that the standard deviation of the fat content was less than 1 gram. In this study beef burger samples were used throughout in determining the fat content in the hamburgers.

In this study 20 hamburger samples were selected randomly from a local restaurant and the fat content of each sample was measured by a reference laboratory. Before constructing a confidence interval for the data it was deemed necessary to check if the data was in statistical control. Because each reading was for one hamburger, the individual - moving range (I-MR) chart was constructed using Minitab. In this study Minitab was used throughout the analysis. The data in Figure 1, shows that the readings were in statistical control.

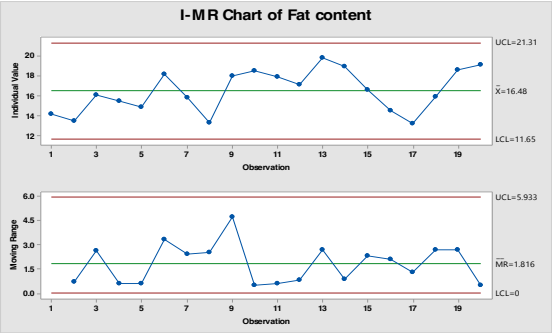

Figure 1. An individual-moving range (I-MR) chart of the fat content in the twenty hamburger samples indicating statistical process control

In this study, once it was determined that the data were in statistical control, a 95% confidence interval (CI) was constructed for the mean of fat content in the samples. A normality check was also conducted simultaneously using the Anderson-Darling method in a summary report [16]. This was with a view to determine the reliability of the confidence interval of the mean of the samples. Figure 2 shows the summary report with the 95% CI, the mean, standard deviation and the result of the Anderson-Darling test for the 20 samples of the hamburgers which were taken randomly. The Anderson-Darling test which was not significant at p value of 0.393for <0.05 level of significance indicated that the data for the samples was normally distributed. The population mean was observed at 16.480 grams with a CI of 15.500 grams to 17.461 grams. Thus, the entire confidence interval of the mean (15.500, 17.461) was greater than the stipulated level at 15.00 grams. Therefore, this was an issue to be addressed.

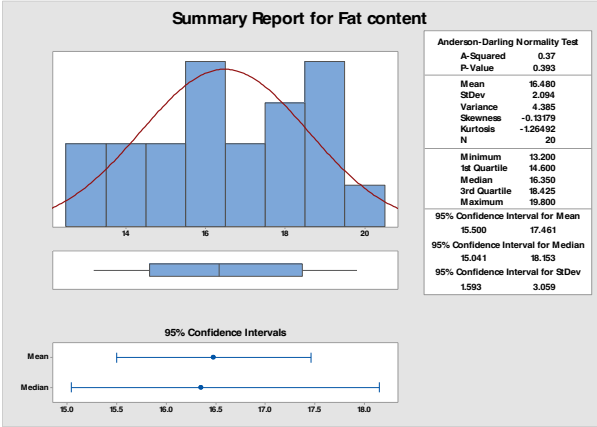

Figure. 2 A graphical summary of the twenty samples of hamburgers for Anderson-Darling normality check and confidence interval (CI) of the mean

Then the assumption that the standard deviation was less than 1 gram was verified by taking the upper bound of the Chi square by the Bonett's method (Table 1). Because the data were normally distributed, the upper bound (2.87 grams) of the standard deviation given by the Chi square method and 2.66 grams of the Bonett's method were considered. However, both the readings were found to be unsatisfactory in terms of the less than 1 gram stipulated in the study. Thus, 95% of the hamburgers had a variation in the fat content of approximately 2.87 grams by the Chi square method as compared to the specified amount of 1 gram.

Table 1. Test and CI for One Variance at less than one gram of fat content.

Variable	N	St Dev	Variance
Fat content	20	2.09	4.39

Variable	**Method**	**Upper bound for St Dev**	**Upper bound for variance**
Fat content	**Chi-Square**	**2.87**	**8.24**
	Bonett	**2.66**	**7.07**

95% One-Sided Confidence Intervals

Now the management was interested in determining as to how many customers were dissatisfied with the results. Therefore, one hundred customers were

randomly selected, and the results showed that 10 were dissatisfied with the quality. This survey was in response to the evaluation of the efficient consumer response to the quality of the hamburgers in the supply chain [6]. For this, a confidence interval of the proportion of all the dissatisfied customers was determined with a view to lower the number of dissatisfied customers. The normal distribution of the hamburger samples was also determined to this end. It was evident that there was a 95% probability that of all the customers who were dissatisfied was less than 0.16 or 16% on the upper bound (Table 2).

Table 2. Test and CI for one population proportion of fat content

An observation was conducted on the process and an evaluation supposed that the high fat content and its variation could probably be due to the amount of oil used by the operators on the different grills used to fry the hamburgers. This probably contributed to the excessive fat content and its variation in the hamburgers. The management decided to standardize the process so that the use of oil in the different grills used by the employees was controlled. For this an automatic oil dispensing machine was bought and installed in order to standardize the amount of oil dispensed by the machine and to homogenize the application of oil for frying each hamburger by the employees.

After installing the automatic oil dispensing machine, twenty hamburger samples were selected randomly to check if there was any improvement in the process. Before constructing a confidence interval for the data, it was important to check whether the data were in statistical control. Because each reading was for one hamburger an I-MR chart was constructed in order to determine this. The I-MR chart indicated that the data were in statistical process control (Figure 3).

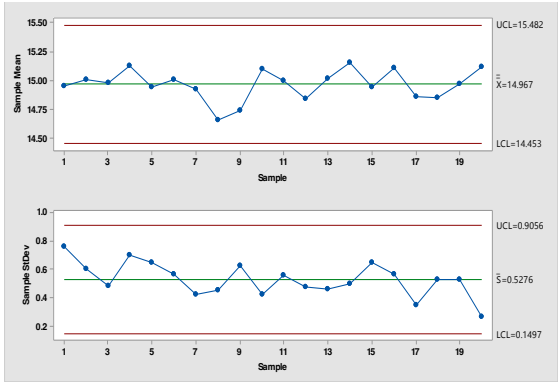

Figure 5. X bar – S chart of the simulation test with twenty random samples of ten sub-groups each

A common aim in many studies is to check whether the data agree with certain predictions. These predictions are hypotheses about variables measured in the study. Hypotheses arise from the theory that drives the research. When a hypothesis relates to characteristics of a population, such as population parameters, one can use statistical methods with sample data to test its validity [20].

Sample	X	N	Sample p	95% Upper bound
1	10	100	0.10	0.16

Statistical methods can also be applied to evaluate the trustworthiness of data obtained by any method of measurement [20]. Food research application brings in analysis of differences and relationships, where hypotheses can be put forward on the basis of previous work or new ideas and then magnitudes of effects in sample statistics can be assessed for significance.

With regards to this, an interval plot was plotted for 95% confidence interval for the 20 samples of 10 subgroups each shown using a simple Ys chart in Minitab (Figure 6).

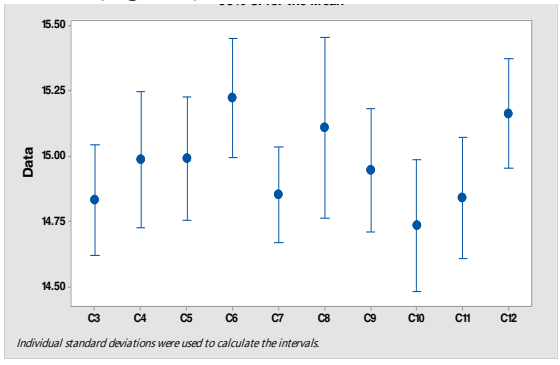

Figure 6. Interval plot using a simple Ys chart of the simulation test of the ten sub-groups

A reference line inserted subsequently indicated that the simulated data generated for a larger sample size showed a marked improvement in the fat content of hamburgers, whereby, most of the confidence intervals of the means were within the stipulated range of compliance of 15 grams with a standard deviation of 0.5 grams (Figure 7).

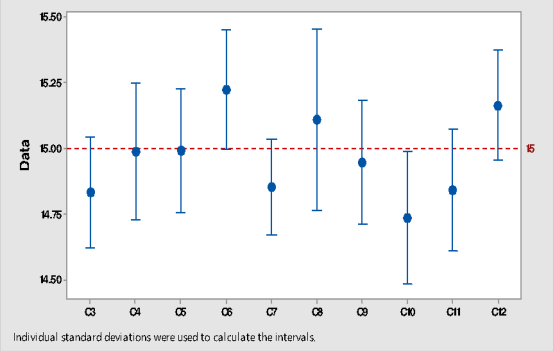

Figure 7. Interval plot using a simple Ys chart of the simulation test of the ten sub-groups with a reference line indicating control within specification

A survey was conducted to check as to how many customers were now dissatisfied after the process had been improved with the installation of the automatic oil dispensing machine. For this, 350 customers who bought hamburgers were selected randomly and on enquiring, it was found that 8 of them were dissatisfied with the quality after the improvement with the automatic oil dispenser had been made (Table 4). A confidence interval was constructed for the proportion of all the customers who were now dissatisfied. It was now evident that there was a 95% probability that the proportion of all customers who were dissatisfied was less than 0.04 or 4%. Thus, the management was satisfied that the process had improved and met the compliance as stipulated in the regulatory requirements.

Table 4. Test and CI for one population proportion of fat content after the installation of the automatic oil dispenser

Sample	X	N	Sample p	95% Upper bound
1	8	350	0.02	0.04

Finally, the management was interested to determine whether the overall process of preparing and serving hamburgers was operating at its optimum as this could contribute to saving of costs for the overall process and result in the increase in the efficiency of the process. For this a process capability check was carried. On analysing, it was observed that the overall process was operating way below par. The six-pack analysis for the initial 20 samples indicates a negative Cpk value of - 0.15 which is even more evident in the histogram (Figure 8). The sample mean and standard deviation in the six-pack process capability check indicate that the overall process capability of the hamburger preparation process needs a lot of improvement, although the installation of the automatic oil dispensing machine managed to standardize the fat content in the hamburgers subsequently.

In this regard, it would be fair to conclude that an analysis in processed food quality, and safety, it should be noted that the major objective of statistics is to make inferences about processed food or population from an analysis of information contained in sample data [14]. This includes assessments of the extent of uncertainty involved in these inferences. However, in this study, the data appeared to conform to valid standards and appeared reliable for interpretation.

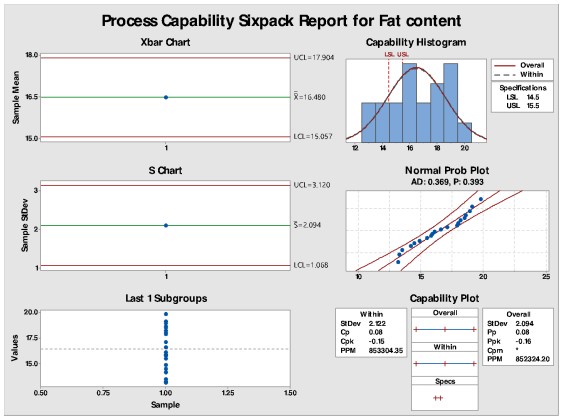

Figure 8. A six-pack process capability report for the hamburger preparation process based on the initial twenty samples

Another process capability report conducted after the installation of the automatic oil dispensing machine showed an improvement on the overall process capability. The Cpk value improved to 0.29, while the mean and standard deviation were 14.925 and 0.4897, respectively. The histogram showed that the lower specification and the upper specification levels were now within the overall specification limits specified in the mean of 15 grams with a standard deviation of 1 gram. The recommended Cpk level for a process working at its optimum is 1.33. Therefore, further research may be necessary in order to get a better understanding of the overall

process in a problem-solving exercise using statistical methods and analysis in order to improve this process.

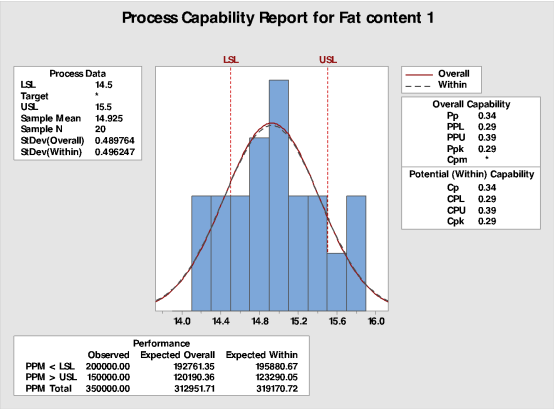

Figure 9. A process capability report for the hamburger preparation based on the twenty hamburger samples after the installation of the automatic oil dispensing machine

4. Discussion

Food issues are becoming important to consumers, most of whom depend on the food industry and other food workers to provide safe, nutritious and palatable products [13]. Data are usually obtained not only from laboratory experiments, but also via surveys on consumers, as they are the users and receivers of the end products [5]. Understanding such diverse information demands an ability to be aware of the process of analysing data and interpreting results [14]. In this way, communicating information is valid. This knowledge and ability not only give undeniable advantages in the increasingly numerate world of food technology, but it also requires that the practitioners have some experience with statistical methods [14].

Graphical displays are basic forms which provide indications of how the sample data are distributed [13]. This is also possible using table forms such as a frequency table. Graphs and tables can also be used to display descriptive statistics, which include a number of summary values such as the measures of central tendency and variation [13]. Graphs and charts have the advantage of giving a more rapid overview, and they can indicate possible trends, effects and relationships. Graph icons on their own will mean that values will have to be estimated from the axes, unless the software allows a numerical display superimposed on the icons as is the case with the Minitab software [13].

A variety of simple graphs and table methods are possible, which allow rapid illustration of results. These summaries are taken further in statistical quality control where measures such as the mean value are plotted 'live', as a process is ongoing [14]. The graphs such as control charts used include limit lines which are set by using other statistical methods, which allow detection of out-of-limit material.

The statistical process control as a methodology is applied for checking whether an actual measurement is within the normal range of variability as essential in order to determine the validity of the result [15]. The SPC methodology is based on control charts. These are plots of the data over time with control limits superimposed [15]. The plotting aspect is the most important, but the limits can also play a certain role for detecting drift and outliers. The assumption behind the most basic SPC control chart, the Shewart control chart, is that when the process is under control, within the normal variation range, all observations are independent and identically distributed [15]. Usually, they are assumed to have a normal distribution which was evident in this study.

Although, it is possible to evaluate scientific data without involving statistical analysis, once data accumulate and time is limited, such judgment can suffer from errors. In these cases, simple statistical summaries can reduce large data blocks to a single value. Now, both the enlightened novice and the experienced analyst can judge what the statistics reveal. Consequent decisions and actions will now proceed with improved confidence and commitment [12]. Thus, statistical techniques play a part in monitoring and reporting of such results. This gives confidence that results are valid, and consumers benefit in the knowledge that certain foods are safe and that diet regimes can be planned with surety [12]. This study has provided ample evidence as to the significance of statistical application in the fast-food industry.

Generally, in restaurants oil is applied at random by operators in the preparation of hamburgers. The application of the oil in the preparation of individual hamburgers appeared to contribute to high variation in the fat content of hamburgers during the consumption [21]. It was observed that the high fat content and its variation could probably be due to the

amount of oil used by the operators on the different grills used to fry the hamburgers [22]. This probably contributed to the excessive fat content and its variation in the hamburgers for consumption. The management decided to standardize the process so that the use of oil in the different grills used by the employees was controlled. For this an automatic oil dispensing machine was bought and installed in order to standardize the amount of oil dispensed by the machine and to homogenize the application of oil for frying each hamburger by the employees.

Thus, the installation of the automatic oil dispensing machine made a significant contribution to the improvement and streamlining of the fat content in the hamburgers [18]. Therefore, it was evident that the automatic oil dispensing machine which was introduced in the process in order to standardize the oil applied for the frying of the individual hamburgers was very effective in improving not only the process but also the quality of hamburgers with respect to the fat content [19]. This appears to be a breakthrough for reducing the fat content in hamburgers, thereby somewhat reducing the element of risk to the consumers. Thus, other vendors of hamburgers may apply this technique in order to improve their processes and perhaps reduce cost in the long term and produce hamburgers which are safer for consumption.

5. Conclusion

This study concurs that there are health issues regarding the consumption of processed food of animal origin based on the variation in the fat content in hamburgers. Fast food particularly hamburgers are very popular with children and teenagers. These foods are known to be high sources of unsaturated fatty acids which may lead to obesity and cardiovascular disease on excessive consumption. This may be detrimental to health particularly of the younger generation. This study showed that generally hamburgers prepared in restaurants are not standardized in terms of the application of the oil content in the preparation of individual hamburgers. This contributes to the variation in the fat content in individual hamburgers for consumption. Thus, awareness as to the effects of high consumption of processed foods of animal origin is necessary to caution the customers of the dangers of frequent consumption of these foods. With regards to this, efficient consumer response to the fat content in hamburgers in the supply chain management may help in determining the quality of the raw material to the finished product in terms of the delivery and the effective storage of the inventory. Based on the findings of this study, monitoring the supply chain and the control of the overall processing activities in the preparation of hamburgers seems necessary in order to improve the quality of the fast food and improve the efficiency and productivity of the process. Thus, compliance issues are important in order to improve the quality of processed foods of animal origin. This may contribute to an increase in their marketability as well to address health issues.

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