Extent of Implementing the Hazard Analysis Critical Control Point (HACCP) system in Sudanese Beef Industry.

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B.Sc. (Agric.) Honors
University of Sudan, 2002

A Thesis submitted to the University of Khartoum in Partial Fulfillment of the Degree of Master of Food Science and Technology.

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September, 2007
DEDICATION

To whom who stood with me through the ups and downs

My dear father

With love and respect

Eiman.
Acknowledgements

First all my thanks go to Allah who helps me in all my life. I wish to express my deepest, sincerest and gratitude for my have to thank my supervisor, Prof. Abdel Halim Rahama Ahmed for his valuable guidance, assistance and keen supervision throughout this work.

Appreciation is extended to Prof. Hamza Abu-groon for cooperation of this study.

I deeply thanks to Prof. EL Rakha B. Babiker for his assistance in microbiological writing.

Iam gratefully, indebted to Dr. Inaam A. Ismael and Dr. El.Dirdiri M. Osman, Fruit and Vegetables Department, Food Research Center, shambat who followed this work with a great attention.

Special thanks to Dr. Al-Nour Abd almageed for his unlimited help.

Iam especially grateful to Mr. Al,Tag, Microbiological section , University of Khartoum, for his assistance in microbial test.

Iam greatly indebted to all my friends for their encouragement.
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Abstract

An attempt was made to assess extent of implementing the hazard analysis and critical point (HACCP) system in the Sudanese beef processing factories. Six meat plants scattered in Khartoum State were surveyed for data in HACCP requirements using the recommend HACP checklist.

Outside the scope of the HACCP, all these meat plants adopt company policy on product safety with documentation of quality and safety management, address product hygiene and acceptance of raw materials, and also adopt knowledge and understanding of policy at all levels of the organization.

Looking into the specific requirements of the HACCP elements, almost none of these plants have documentation of risks to which the product is exposed from the raw materials until distribution, on flow diagram describing the production process, no validation of process engineering sheets, never conducted any assessment for potential risks in all production steps, and none of these plants actually address any aspects of the production process.

More critical is that all of the six meat plants investigated, seemed not to be concerned about corrective or preventive measures adopted to eliminate or reduce risks to an acceptable level, or possession of HACCP decision tree, or execution of risk assessment and management, or establishment of any specification regarding critical limits of each step, beside total absence of critical documentation associated with all these HACCP elements.

Such extremely poor food safety monitoring is reflected in high level of total viable count of bacteria in beef products (3.7\times 10^4-7.0\times 10^5 CFU/G), with other microbial features of *E.coli* (7-120MPN/G), *staphylococci* (3.9\times 10^2 -8.0\times 10^3 CFU/G) and *Salmonella* in few sausage samples.

Worth mentioning, the effort carried out by half of these meat plants on product description, process control charts relevant to legislation standards with required documentation, and company assurance on safety and quality of end products. Only one third of these factories (2 out of 6) seemed to be concerned about personnel facilities and locker rooms, calibration of instruments, beside implementation of preventive measures for risks already identified.
ملخص البحث

تمت محاولة تقييم مدى تطبيق نظام تحليل المخاطر ومراقبة النقاط الحرجة في مصانع تصنيع لحوم الأبقار السودانية. تم مسح وجمع البيانات من ستة مصانع منتشرة بولاية الخرطوم حول متطلبات الهسب المستخدمة في ذلك قائمة مراجعة الهسب الموسي بها.

وجدت الدراسة وخارج نظام الهسب، أن كل المصانع التي تم مسحها تتبني في سياسة الشركة سلامة المنتج مع توثيق الجودة وإدارة السلامة وتخطيط صحة المنتج في قبول المواد الخام المستخدمة في التصنيع وكذلك تتبني سياسة المعرفة والتفاهم على مصطلحات المؤسسة وذلك خارج نظام الهسب.

وبالنظر للمتطلبات الخاصة لعوامل نظام الهسب فقد انعدمت في جميع المصانع اللحوم التي تم مسحها عملية توثيق المخاطر التي قد يتعرض لها المنتج اعتباراً من مرحلة المادة الخام وحتى التوزيع كما لا يوجد المخطط الإنسبيا ولا يوجد ما يعرف بمراجعة صلاحية صحاحيه هندسه التصنيع ولم يتم إجراء عملية تقييم المخاطر المحتملة وبالتالي لم يكن يوجد بين تلك المصانع من يتعامل أي من مواضيع عملية الإنتاج.

يبدو أن الأجرام من ذلك عدم وجود أي اهتمام من كل المصانع التي تم مسحها حول الاجراءات الوقائية أو التشريحيه الواجب تبنيها بإزالة التقليل للمخاطر للمستوى المطلوب وكذلك لا تملك ما يعرف بمفهوم شجرة اتخاذ القرار أو اتخاذ تحليل إدارة المخاطر أو تأسيس مواصفات متعلقة بالحدود لكل خطوة من خطوات الإنتاج بجانب الغياب الكامل لعملية التوثيق المرتبطة بأي من عوامل الهسب وقد انعكس هذا الأسلوب الضعيف من مراقبة سلامة الأغذية من مصانع اللحوم في المستوى المقبول من العد الميكروبي في منتجات لحوم الأبقار (3.710 ^4 - 7.010 ^5 CFU/G) بجانب الميكروبات من فصيلة بكتريا القولون بالسالمونيلا ببعض منتجات النقانق (السج). مما يستحق ذكره في نهاية الدراسة هو الجهد المبذول بواسطة 50% من تلك المصانع في متطلبات وصف المنتج وخط مراقبة التصنيع الخاطية بالمعايير التشريعية للموافقة مع عملية توثيقها واهتمام المنشأة بتأكيد السلامة والجودة للمنتجات النهائيه.

تلاحظ أن ثلاثة تلك المصانع لديها اهتمام بمتطلبات العماله وغرف تبديل الملابس بجانب معايير المعدات وتطبيق بعض الإجراءات الوقائية على الأقل للمخاطر التي تم اكتشافها أو تحديها.
CHAPTER ONE
INTRODUCTION

Hazard Analysis Critical Control Point (HACCP) is a preventive system of food control which aims at food safety assurance. The HACCP is a documented and verifiable approach to the identification of hazards, preventive measures and critical control points (CCPs) and the implementation of a monitoring system.

The HACCP has become an internationally recognized tool for managing the safety aspects of the production, processing, preparation and distribution, of food. HACCP in relation to microbiological food safety and born pathogens, the concept is recommended as the best insurance policy against undesirable microorganisms.

The traditional approach to food safety assurance is based on applying codes of Good Hygiene Practice (GHP) and Good Manufacturing Practice (GMP) in food processing where confirmation of safety and identification of potential problems are obtained by end – product testing and the check for compliance with the codes by sampling the foods for laboratory analysis.

In Sudan, the meat industry is one of the food processing sectors that are in the process of implementing certain hygienic measures to assure safety requirements, the objective of this study:

a- To evaluate and assess the good manufacturing practices (GMP) in Khartoum state beef industries with the aim of future implementation of HACCP system.

b- To examine safety level in beef products through monitoring their microbial load.
CHAPTER TWO
LITRETURE REVIEW

2. The Hazard Analysis and Critical Control Point (HACCP) System
2.1 Development and adoption of the Hazard Analysis and Critical Control Point (HACCP) System

The Pillsbury Company first developed the concept of Hazard Analysis and Critical Control Point (HACCP) in the early 1960's. This firm worked cooperatively with NAS (National Academy of Sciences) to develop this new system to ensure safety of the food consumed by the astronauts. At that time, most safety systems were based on end product testing. This approach would not be feasible because the entire product would be required. At the 1971 National Conference on Food Protection, the HACCP system was first presented. This new approach to food safety gained interest among food processors. Furthermore, the FDA even began using HACCP for investigation activities. However, after the initial excitement of the new system, interest in HACCP began to fade. According to Stevenson (1990), only a few large companies continued to apply HACCP. During the 1980s, some of the government protection agencies asked NAS/NRC (National Academy of Sciences/National Research Council) to form a committee that would generate some general principles for the application of microbial criteria in foods. This committee proposed the implementation of HACCP in food protection programs. Mortimore and Wallace (2000) mentioned that many food industries have implemented HACCP since its inception. The meat and poultry industry fell under the HACCP mandate in 1998.
Small and very small plants followed in 1999 and 2000, respectively. The smaller plants were given more time to develop their HACCP plans due to fewer resources and personnel.

2.2 HACCP PRINCIPLES

There are seven principles for implementation of HACCP system which include assembling HACCP team, conduct a hazard analysis, determine the critical control points (CCP), establish the critical limits, establish corrective actions, establish verification procedures, establish record-keeping and documentation procedure (Huss, 2004).

2.2.1 Conduct a hazard analysis

Hazard analysis is the process of identification and listing of all the food hazards that are reasonably likely to occur during the production of a product and of the preventive measures needed to control the hazards (Rodehamel, 1992). Mayes (1994) reported hazards are likely to occur in raw materials such as meat (e.g. chilled beef carcass, trimmings) and non meat ingredients (e.g. spices, vegetables, food additives). Hazards need to be specifically defined e.g. *Clostridium botulinum* or may be identified as a class, based on their characteristics, when this is appropriate e.g. enteric pathogens, spore forming organisms, metal objects. Also, to identify any biological, chemical or physical hazards resulting from a process step requirement not being met (e.g. metal from equipment). Process step hazards may be controlled under effective prerequisite programs and/or dealt with at CCPs in the HACCP plan (Bernard, 1994). Equally important is to identify any hazards that are likely to occur in association with other inputs at each process step (e.g. packaging processing aids). Generally, these hazards will be addressed by appropriate programs (e.g. supplier quality assurance SQA” program, and food contact materials).
2.2.2 Identification of critical control points

A critical control point (CCP) is a point on the process, a step, or procedure where control can be applied and a food safety hazard can be prevented, eliminated, or reduced to acceptable levels. Critical control points are identified by asking a series of questions about all of the hazards for example, raw meat is a known source of pathogens identified during the hazards analysis. Such questions should address the preventative measures that eliminate or reduce the occurrence of the hazard to an acceptable level, contamination that occur or increase to greater than acceptable level, and whether subsequent steps in production eliminate the hazard or reduce it to acceptable level. A decision tree for identifying critical control points is illustrated in Figure 2.

2.2.3 Establishing critical limits

A critical limit is the maximum or minimum value to which a variable must be controlled at a critical control point to prevent, eliminate, or reduce to an acceptable level a food safety hazard (Huss, 2004). Critical limits could be established for variables such as temperature, time, humidity, moisture level, water activity, pH, salt concentration, preservative, or survival of pathogens (Fries, 1993). For example, internal temperature of fresh meat should be less than 4°C and the meat is kept at that temperature less than three days from fabrication or according to age specifications for product as set by the plant (Anderson and Dormedy, 1999). Establishing critical limit based on food safety and inspection service (FSIS) regulations, scientific and technical data, experimental studies, or the recommendations of recognized experts. Critical limits must be established for every critical control point (Mulder, 1996).
Q1. Do preventive measures exist for the hazard?

Modify step, process or product

Yes        No

Is control at this point Necessary for safety?

No → Not a critical Control point → Stop

Q2. Will the preventive measure eliminate or reduce The occurrence of the hazard to an acceptable level? yes

No

Q3. Could contamination occur or increase to greater than acceptable levels?

Yes           No  Not a critical control point → stop

Q4. Will subsequent steps in production eliminate the hazard or reduce it to acceptable levels? No → critical control point

Yes → not a critical control point → stop

Fig.1. Decision tree for identifying critical control points.

(ICMCF, 2002).
2.2.4 Monitoring critical control points

Monitoring is an integral part of HACCP. It consists of observations and measurements to insure that the critical control point is within the critical limits (Mulder, 1996). Responsibility for monitoring must be assigned and personnel must be adequately trained to record results and initiate corrective action immediately if critical limits are exceeded (Alli, 1992). Most monitoring procedures need to be rapid because they are related to on-line processes. For example, monitoring activities include: visual observations and measurement of temperature, time, pH, and moisture level (Baumgart, 1997). Anderson and Dormedy, (1999) reported that temperature of each
combo of fresh meat will be checked by the receiving clerk using a calibrated thermometer. Product organoleptic evaluation will be recorded.

2.2.5 Establishing corrective actions

HACCP plans must define the corrective actions that will be taken when there is a deviation from a critical limit (Huss, 2004). Corrective actions should define what will be done to bring the process back within the critical limits and the disposition of potentially unsafe products or those that do not meet standards (Huss, 2004). For example, fresh meat must be examined by the quality assurance officer for internal meat temperature. If it does not meet the critical required temperature, the corrective action is the rejection of the meat product (Anderson and Dormedy, 1999).

2.2.6 Verification of the system

Verification is defined as those activities, other than monitoring, that determine the validity of the HACCP plan and that the system is operating according to the plan (Hogg, 1995). Verification is the initial validation of HACCP plan to determine that the plan is scientifically and technically sound, that all hazards have been identified and that if the HACCP plan is properly implemented such that these hazards will be effectively under controlled (Hechelmann, 1993). For example, validation of the cooking process for beef patties should include the scientific justification of the heating time and temperatures needed to obtain an appropriate destruction of pathogenic microorganisms and studies to confirm that the conditions of cooking will deliver that required time and temperature to each beef patty (Humphrey, 1996).

2.2.7 Establishing effective record keeping

Record keeping procedures that document the entire HACCP process must be developed and maintained. Example of establishing record keeping is that
for receiving lots of fresh meat that includes the date, carcass, slaughter house, date of production, temperature of meat and organoleptic observations. Mayes, (1994) reported that in the smoking of frankfurter in the smoke house, the internal temperature of the product must be recorded.

2.3 HACCP programs in meat slaughter operations

Raw meat is expected to carry pathogenic microorganisms to a certain extent depending on their origin. Part of this contamination will continue to exist on slaughter carcass meat subsequently entering the processing plant when unprocessed raw materials are used as food ingredients. The main emphasis of HACCP in slaughter operations is to minimize the potential for contamination of the finished raw products (Untermann, 1993). Two fundamental concepts must be considered during the slaughtering process. The first one is related to the use of procedures which will minimize the degree of contamination on carcass, such as training workers, providing adequate work space and time, providing a plant layout that favours microbial control, and selecting equipment. For this purpose, cost-effective technology is needed (Mackey and Roberts, 1993). The second concept is to include procedures which can reduce or destroy pathogens which inadvertently contaminate the carcass during slaughtering (Tompkin, 1994). The flow diagram for the production of raw meat is shown in figure 1. The construction of a flow chart is very useful in order to describe the process, locate the identified hazard at the appropriate points on the chart, identify the steps where control can be gained, and provide an estimation of the expected control (Harting, 1994). The primary goal of farmers is to achieve efficient feed conversion and sufficient disease control to maintain a favorable health status and maximize the growth rate of animals (Tompkin, 1994). Good farming practice is the major mean of controlling diseases on the farm. The
risks are usually minimized with pasture farming but can be increased with more intensive production. Farmers' attention should be drawn to the quality of water, the use of *Salmonella* free feeds, and proper waste disposal practices (Fries, 1993). The receiving and holding of the animals in the farm, their-transportation to the processing plant, the holding time, and conditions before slaughtering seem to include the spreading of organisms, resulting in higher contamination and a continued carrier state of the animals (Mulder, 1996). The widespread occurrence of pathogenic bacteria at high level suggests that control at this stage is rather difficult. Scalding is a critical control point (CCP) because the hazard for microbial contamination of skin is high and may contain various pathogens. The critical operations for the spread of pathogenic bacteria to carcass are circumcising of the rectum and removal of the intestinal tract and the pluck set (Franco *et al.*, 1991). Removal of the head contributes to the spread of pathogenic bacteria since some of the tissues that surround the tonsils and the tongue may remain.

```
BREEDING & Rearing       CCP
    ↓
Receiving / holding       CCP
    ↓
Restrainting/stunning
    ↓
(Cattle, sheep, goats, horses)
    ↓
Hoof removal/skinning
    ↓
Head removal       CCP
    ↓
Trimming & washing       CCP
    ↓
```
Furthermore, inadequately cleaned surfaces, the cutting equipment and the flow of personnel may contribute to contamination of the carcass (Snijders et al., 1984; Reuter, 1992). Chilling of carcasses can be effective for preventing the multiplication of pathogens when properly controlled. The contamination through chilled carcasses should be limited by the use of an effective HACCP/GMP plan, where appropriate cleaning and disinfection routines should limit the contamination from the environment in the chilling chambers (Untermann, 1993). The carcass surface must be cooled down to 7°C or below. Cooling must be completed rapidly before rigor mortis can result in cold-induced toughness. The combined effects of temperature,
airflow, and relative humidity (R.H) will determine whether condensation occurs in chillers (Neuber, 1993). Moisture from condensation facilitates microbial growth on meat and on premises, walls, floors, and equipment (ICMSF, 2002). After chilling, the transport of meat to other plants for further processing requires refrigeration and protection from condensation and contamination. Packaging also protects meat from further contamination and prevents moisture loss (Church, 1993).

2.4 Application of HACCP principles in meat industry

The primary purpose of every HACCP program is the prevention of potential problems that could contribute or cause any threat to public health or food safety (Schimitzek, 1994). Identifying potential hazards and devising which means to control them is the basis for developing a HACCP plan (Hogg, 1995). All predictable biological, chemical, and physical hazards that can affect the safety of a food must be identified (Hogg, 1995). Risk analysis and HACCP must be implemented through the entire chain to provide consumers with the safest food supply. After the completion of hazard analysis, CCPs should be identified (Harris et al., 1995). Intervention included as CCPs in a HACCP plan must be based on scientific premise and knowledge and may be applied in live animal production, slaughter and processing, distribution, retail, food service, and by the consumer as well (Hechelmann, 1993).

2.5 Microbiology of Meat

The microorganisms on carcass meat originate from two main sources; those derived from the slaughter environment, i.e., the contamination on skin / hide and on slaughter and cutting equipment, and organisms from the intestinal tract which is occasionally punctured during evisceration (Mulder, 1996).
2.5.1 The presence of *Salmonella* spp in meat

*Salmonella* are the most commonly reported etiology of infection, although the relative importance of other agents varied (Hogg, 1995). The Hazard Analysis Critical Control Point (HACCP) concept provides a systematic approach to improve the preparation and handling of meat products, to reduce significantly food-borne illness (Tompkin, 1994). *Salmonella* infection is spread among animals through the use of contaminated feed and the incidence tends to repack a peak where intensive stock raising is practiced (Crossland, 1997). To eliminate the presence of *Salmonella* in meat is necessary to maintain strict hygiene regimes that implement the HACCP concept (Fraco et al, 1991). To monitor the effect of these measures, it is necessary to screen raw material, products, and in process for the presence of the pathogen.

2.5.2 The presence of *Escherichia coli* in meat

*Escherichia coli* are found in the intestine of farm and domestic animals, in the intestine of poultry and in farm wastes. The presence of *E.coli* in meat products indicates fecal contamination of the meat (Harris, *et al.*, 1995). Chilling of meat can cause a reduction in number (Shapon and Shapon, 1994).

2.5.3 The presence Staphylococci in meat

Staphylococcus is an important cause of food intoxication and may be found on humans and animals (Franco *et al*, 1991). *S. aureus* may be used as an indicator of general hygiene (Harris *et al*, 1995). Workers hands, equipment, and environmental conditions may harbor the bacterium (Shapon and Shapon, 1994).
CHAPTER THREE
MATERIALS AND METHODS

3.1 Materials and tools used
Documents containing HACCP checklists were adopted as an instrument for assessment of implementing HACCP plan system (Appendix No.1) in six meat factories in Khartoum province. Factories assessed included Lolli, AL-Arabi, Maxim, EL-Momaiaz, EL–Goussi and Agwat.

3.2 Methods
3.2.1 Survey
Six factories for processing of meat scattered in Khartoum state, were surveyed for data on HACCP requirements using HACCP checklist. Upon arrival at each plant, there was a meeting with representatives from quality control and plant management. The latter provided information and discussed what type of food safety system they follow. This provided a general idea on how the employees follow sanitation guidelines and they familiarize the reviewer with the processing operations to facilitate a more effective HACCP plan assessment.

3.2.1.1 HACCP checklist
A checklist of HACCP (Appendix No.1), recommended by SGS (1997) was used to investigate the following HACCP features

3.2.1.1.1 Company information
3.2.1.1.1.1 Process control
Six factories were investigated concerning availability of process control, documentation system covering safety assurance and product quality and coverage of process control flow charts for all aspects relevant, yet pertinent to the applicable legislation.
3.2.1.1.2 Responsibilities for the product safety
The same companies were surveyed regarding company policy on product safety, documentation of management for the quality/safety policy, address of policy and its related objectives for hygiene and acceptance of raw materials and/or food production, documentation of HACCP system and knowledge and understanding of policy at (all) levels of the organization.

3.2.1.1.3 HACCP team
The surveyed companies were investigated concerning identification and operation of HACCP team for maintaining the HACCP process control system, presentation of sufficient expertise in the various fields of HACCP system, establishment of criteria for membership of HACCP teams and nomination of a coordinator with responsibility for establishing HACCP process control system involving process and maintenance.

3.2.1.1.2 Product information
3.2.1.1.2.1 Product description
The six companies were surveyed regarding availability of the product description, documentation of the risks to which the product is exposed from the raw materials until distribution, and availability of the end product documentation.

3.2.1.1.2.2 Identification of intended use
The survey included statement and documentation of the target consumers for the product destination, reference to the international legislation, and definitions of other properties concerning consumption such as specific regulations.

3.2.1.1.3 Process information
3.2.1.1.3.1 Flow diagram
These factories were investigated on issues concerning description of
production process and engineering flow set by the company, validation process engineering sheets by HACCP team, and product safety in process/engineering flow sheets.

3.2.1.1.3.2 On site verification of the flow diagram
The same companies were surveyed concerning updating the systematic process flow/engineering diagram which represents all the production units. This should take place at least on a yearly basis so as to allow evaluation of product safety risk and quality assurance aspects.

3.2.1.1.3.3 Facility lay-out
All of the companies were investigated on issues concerning seeing the locker rooms and personnel facilities are shown applicable, the regulatory requirements concerning facilities designs are being met and possibilities of cross contamination between raw materials and processing aids, intermediate products, end products and personnel waste.

3.2.1.1.4 Dangers, risk and preventive measures
3.2.1.1.4.1 Assessment
These companies were investigated on assessment of all potential risks in all production steps which are made by HACCP team and addressing all aspects of the production processes which can negatively influence the product safety.

3.2.1.1.4.2 Preventive measures
The six factories were investigated also on identification and implementation of preventive measures which address assessment of risks, elimination or reduction of the risks to an acceptable level by preventive measures, and the question of expression of preventive measures in specifications (raw materials, processing aids, process tolerance), instructions, procedures, purchasing plants, hygiene plants, maintenance and cleaning plan,
disinfections practices, training programmes etc.

3.2.1.1.5 HACCP decision tree application to each step

3.2.1.1.5.1 Assessment application of HACCP decision tree
The food companies were surveyed on points concerning assessment of every process step by an experimented HACCP team.

3.2.1.1.5.2 Risk assessment
The meat processing factories were investigated for whether their HACCP teams have executed a risk analysis and assessment or not. If yes, were the results of assessment documented and so the rationale. The questions also covered establishment of acceptable risk levels in a accordance of regulations, and taking into account information based upon practical experience, literature, etc.

3.2.1.1.6 Monitoring of critical process parameters
All the companies were surveyed on parameters concerning establishment of the appropriate monitoring system for all CCP, documentation of monitoring system of each CCP, proper calibration of instruments used and accuracy of the appropriate measuring method in each case.

3.2.1.1.7 Limits and tolerances
The factories were also investigated for issues concerning establishment and specification of the critical limits for each process step with tolerance and also for documentation.

3.2.1.1.8. Corrective action
These factories were investigated for issues regarding definition of every CCPs that may need corrective actions, definition and responsibilities of authorities for corrective actions in place, of recall procedures and evaluation of the efficiency and efficacy of the corrective measures.
3.2.1.9 Verification procedures
The companies were surveyed as well for issues concerning seeing a review of the HACCP system when the processes are subjected to change, seeing a regular review in order to verify that the system is properly applied, and is still satisfactory or needs amending.

3.2.1.10 Record keeping and documentation
All the companies were investigated on matters related to documentation of the HACCP system in a handbook, keeping up to date, and coverage of the HACCP system in documentation, description and implementing of ISO

3.1.2 The microbial tests
3.1.2.1 Collection of samples
The samples of meat products (sausage, burger and meat balls) were collected from different factories: namely, Lolli, AL Arabi, Maxim, EL Momaiaz and EL Goussi. The samples were kept in sterile containers in ice and transferred immediately to the laboratory freezer.

3.1.2.2 Sterilization of glassware
Glassware was washed thoroughly and left to dry, then they were sterilized in a hot air oven at 160°C for at least 3 hours (Harrigan and McCane, 1976). Instruments such as loops, needles, forceps, spoons and knives were sterilized by flaming directly after dipping in spirit.

3.1.2.3 Culture media used
3.1.2.3.1 Nutrient agar (oxoid)
The nutrient agar was used for cultivation of bacteria. Twenty – eight grams of dehydrated nutrient agar were suspended in a liter of distilled water, steamed to dissolve completely, the pH was adjusted to 7.4 and then the medium was sterilized by autoclaving at 121°C for 15 minutes (Harrigan and McCane, 1976).
3.1.2.3.2 Plate count agar (oxoid)
The plate count agar medium was used to determine total bacterial count. Seventeen and half grams of this media were suspended in a liter of distilled water, dissolved by bringing to boiling with frequent stirring, mixed and distributed into conical flasks sterilized by autoclaving at 121°C for 15 minutes (Harrigan and McCane, 1976).

3.1.2.3.3 MacConkey broth (oxoid)
The MacConkey broth medium was used for the primary isolation of coliform bacteria. Forty grams of this media were suspended in a litre of distilled water, the medium was distributed in test tubes with inverted Durham tubes, the pH was adjusted to 7.0 and then the medium was sterilized by autoclaving at 121°C for 15 minutes. (Harrigan and McCane, 1976).

3.1.2.3.4 Brilliant green bile lactose broth (oxoid)
The Brilliant green bile lactose broth medium was used to confirm the presence of coliform bacteria by multiple tube technique. Forty grams of dehydrated media were suspended in a litre of distilled water, the pH was adjusted to pH 7.4, distributed in the test tubes with inverted Durham tubes and then the medium was sterilized by autoclaving at 121°C for 15 minutes (Harrigan and McCane, 1976).

3.1.2.3.5 Eosin methylene blue agar (oxoid)
The Eosin methylene blue agar medium was used for the differentiation of *Escherichia coli* and *Aerobacter aerogenes*. Thirty seven and half grams of dehydrated Eosin methylene blue agar were suspended in a litre of distilled water, steamed to dissolve completely, the pH was adjusted to 6.8 and then the medium sterilized by autoclaving at 121°C for 15 minutes (Harrigan and McCane, 1976).
3.1.2.3.6 *Staphylococcus medium No.110 (oxoid)*

A selective *Staphylococcus* medium No.110 was used for isolation and differentiation of pathogenic *Staphylococci*. One hundred and fifty gram of this media were suspended in a litre of distilled water, steamed to dissolve completely, the pH was adjusted to 7.0 and then the medium was sterilized by autoclaving at 121°C for 15 minutes (Harrigan and McCane, 1976).

3.1.2.3.7 *Nutrient broth (oxoid)*

The nutrient broth medium was used for the cultivation of microorganisms which are exacting in their food requirements. Thirteen grams of dehydrated nutrient broth were suspended in a litre of distilled water, mixed well, the pH was adjusted to 7.4 and then the medium was sterilized by autoclaving at 121°C for 15 minutes (Harrigan and McCane, 1976).

3.1.2.3.8 *Selenite broth*

The Selenite broth medium was used as an enrichment medium for the isolation of *Salmonella*. Nineteen grams of dehydrated Selenite broth were suspended in one liter distilled water which 4 grams of sodium biselenite has been added, and then the medium was sterilized by boiling in a water bath at 100°C for 10 minutes (Harrigan and McCane, 1976).

3.1.2.3.9 *Bismuth sulphite agar*

The Bismuth sulphite agar medium was used for the isolation and preliminary identification of *Salmonella*. Fifty two grams of dehydrated Bismuth sulphite agar were suspended in a litre of distilled water, steamed to dissolve completely, the pH was adjusted to 7.0 and then the medium sterilized by boiling in a water bath at 100°C for 10 minutes (Harrigan and McCane, 1976).
3.1.2.3.10 Triple sugar iron agar
The triple sugar iron agar medium was used for the different of Enterobacteriaceae according to their ability to fermentation lactose, sucrose, dextrose, and to produce hydrogen sulphide. Sixty five grams of dehydrated triple sugar iron agar were suspended in a litre of distilled water, steamed to dissolve completely and then the medium was sterilized by autoclaving at 121°C for 15 minutes (Harrigan and McCane, 1976).

3.2.2 Microbial analysis
3.2.2.1 Preparation of serial dilutions
Thirty grams from each type of processed meat (sausage, burger, meat balls) were weighted aseptically in a sterile bottle and then blended with 270 ml sterile distilled water by using an electric blender (Homogenizer MSE). The emulsion was blended for 3 minutes to give 1/10 dilution as described by Harrigan and McCane (1976).

3.2.2.2 Microbial parameters studies
Total viable count for bacteria was carried out using the standard plate count method as described by Harrigan and McCane (1976). One ml from the suitable dilution was transferred aseptically into sterile Petri dishes. To each dilution 10-15 ml of (melted and cooled to 45°C) plate count agar were added. The inoculum was mixed with medium and allowed to solidify. The plates were then incubated at 37°C for 48 hours. A colony counter (Quebec Colony Counter and Hand Tally) was used to count the viable bacteria.

3.2.2.3 Determination of coliform bacteria
3.2.2.3.1 Presumptive coliform test
Five tubes each containing nine ml of MacConkey broth (enrichment medium), fitted with Durham tubes, were incubated with 0.1 ml from suitable dilutions of meat products samples at 37 °C for 48 hrs. Growth and
gas production after 24 and 28 hrs were recorded. Gas production constituted a positive test (Harrigan and McCane, 1976).

**3.2.2.3.2 Confirmed coliform test**

All fermentation tubes from the presumptive test showing gas with 48 hrs at 37 °C were utilized in the confirmation test. The medium used in this test was Brilliant Green Bile (BGB). Each tube contained 10 ml of medium fitted with Durham tubes. Presumptive test tubes were transferred to each (BGB) tubes, and then incubated at 37 °C for 48 hours. Fecal coliforms were calculated from the most probable number (MPN) via (MPN) tables (FAO, 1992 b).

**3.2.2.3.3 Isolation of E.coli**

For further confirmation of faecal coliform in tubes giving positive reaction on *Escherichia coli* media EC at 44.5°C for 28 hours were streaked on Eosin Methylene Blue (EMB). Colonies with green metallic shine gave a positive test (Harrigan and McCane, 1976).

**3.2.2.4 Staphylococcus**

From suitable dilutions of meat products samples, one ml was aseptically transferred into asterile Petri dish. Fifteen ml of Staphylococcus medium No.110 were added. The incoulm was mixed with medium and allowed to solidify. Plates were then incubated at 37 °C for 48 hours and count was expressed as Colony Forming Units (CFU) for gram.

**3.2.2.5 Presence of Salmonella**

Twenty – five grams of meat products sample were aseptically weighed and mixed well with 250 ml sterile nutrient broth, then incubated at 37°C for 24 hours. Then 10 ml were aseptically drawn and added to 100 ml selenite broth. The broth was incubated at 37°C for 24 hours. Using a loop full, streaking was carried out into solidified Bismuth sulphite agar plates. The
plates were incubated at 37°C for 72 hours. Black metallic shine discrete colonies indicated the presence of *Salmonella*. A confirmatory test was carried out by taking a discrete black sheen colonies and subculturing it in triple sugar iron agar tubes (Harrigan and McCane, 1976).
CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 HACCP Checklist

4.1.1 Company Information of processed beef plants

Table 1 shows company information of beef processing plants in Khartoum state. The below mentioned plants included: Lolli, AL – Arabi, Maxim, Al – Momaize, Al – Gousi, Agwat. The products processed by these plants included sausage, Burger, meat balls, martidella, ground beef, frankfurter, basturma.

4.1.1.1 Process control

Table 2 shows results concerning the process control of processed beef plants investigated. The results revealed that about 50% of these factories do have documented process control system describing how the company assures safety and quality of product, and possess process control flow charts which cover aspects relevant to international standards. The remaining factories lack such control facilities which are expected to lead to a negative impact on the product safety. Process control facilities are the tool and key for the enhancement of food safety (Bernard et al, 1994). It is clear that almost one out of two beef processing plants lack tools for enhanced product safety.

4.1.1.2 Responsibilities for product safety

Table 3 shows results of responsibilities for the product safety. Almost all these food plants adopted company policy system which includes the product safety, documentation of management for the quality/safety policy, addressing product hygiene and acceptance of raw materials or food production, knowledge and understanding of policy at all levels of the organization. These results are similar with the results reported by Wilkinson
<table>
<thead>
<tr>
<th>Name of plants</th>
<th>Location of the factories</th>
<th>The products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lolli</td>
<td>Khartoum state</td>
<td>Sausage, burger, meat balls, Martidella, ground beef, frankfurter, basturma.</td>
</tr>
<tr>
<td>AL-Arabi</td>
<td>Khartoum state</td>
<td>Sausage, burger, meat balls, Martidella, ground beef, frankfurter, basturma.</td>
</tr>
<tr>
<td>Maxim</td>
<td>Khartoum state</td>
<td>sausage, burger ,meat balls, Martidella, ground beef, frankfurter, basturma</td>
</tr>
<tr>
<td>EL-Momaiaz</td>
<td>Khartoum state</td>
<td>Sausage, burger, meat balls, martidella, ground beef, frankfurter, basturma.</td>
</tr>
<tr>
<td>EL –Goussi</td>
<td>Khartoum state</td>
<td>Sausage, burger, meat balls, martidella, ground beef, frankfurter, basturma.</td>
</tr>
<tr>
<td>Agwat</td>
<td>Khartoum state</td>
<td>Sausage, burger, meat balls, martidella, ground beef, frankfurter.</td>
</tr>
</tbody>
</table>
Table 2. Process control feature in meat factories

<table>
<thead>
<tr>
<th>Process control</th>
<th>Number of factories</th>
<th>OK</th>
<th>%</th>
<th>Nok</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Availability of process control documentation system (covering safety assurance and product quality).</td>
<td>6</td>
<td>3</td>
<td>50</td>
<td>3</td>
<td>50</td>
</tr>
<tr>
<td>Coverage of process control flow charts for all aspects relevant, yet pertinent to the applicable legislation.</td>
<td>6</td>
<td>3</td>
<td>50</td>
<td>3</td>
<td>50</td>
</tr>
</tbody>
</table>

*Nok : Not Ok.*
Table 3. Responsibilities for product safety feature in meat factories

<table>
<thead>
<tr>
<th>Responsibilities for product safety.</th>
<th>Number of factories</th>
<th>OK</th>
<th>Nok</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company policy on product safety.</td>
<td>6</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Documentation of management for the quality/safety policy.</td>
<td>6</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Address of policy and its related objectives for hygiene and acceptance of raw materials and/or food production.</td>
<td>6</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Documentation of HACCP system.</td>
<td>6</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Knowledge and understanding of policy at (all) levels of the organization.</td>
<td>6</td>
<td>6</td>
<td>0</td>
</tr>
</tbody>
</table>

*Nok: Not Ok.*
And Wheelock (2004) of a study conducted in Northern Ireland and the Republic of Ireland plants, who found that 95% of those companies have a formally documented food safety policy. The same situation was also reported by Anderson and Dormedy (1999) who reported a 94% adoption in American plants.

4.1.1.3 HACCP Team

Table 4 shows results concerning HACCP team in the surveyed factories. The results indicated that all the plants have no HACCP element. It is clear that the absence of the HACCP features would suggest absence of the whole HACCP concept unlike the reported 93% in Irish plants (Wilkinson and Wheelock, 2004), and 95% in Canadian ones (Hathaway, 1993). It is also obvious that emerging food safety concepts such as HACCP are of no interest or access to this important and sensitive sector of food industry.

4.1.2 Product information features in beef processing factories

4.1.2.1 Information on beef products

Table 5 shows product information features in beef processing factories. The results indicated that half of these plants have end product description available and possess end product documentation. Anderson and Dormedy (1999) found that most of the American beef plants which practiced product description and end product documentation were available at a lower level. For the documentation of risks to which the product is exposed to from the raw material until distribution, all plants have no document of the risks. This situation has a significant effect on the product quality. Hathaway (1993) found that more of the Canadian processing beef plants documented raw materials risks. These variations between Sudanese beef plants and Canadian beef plants could be attributed to the lack in quality concepts awareness.
<table>
<thead>
<tr>
<th>HACCP team</th>
<th>Number of factories</th>
<th>OK</th>
<th>Nok</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification and operation of HACCP team for maintaining the HACCP process control system.</td>
<td>6</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Presentation of sufficient expertise in the various fields of HACCP system.</td>
<td>6</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Establishment of criteria for membership of HACCP teams.</td>
<td>6</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Nomination of a coordinator with responsibility for establishing HACCP process control system involving progress and maintenance.</td>
<td>6</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 5. Product information features in beef processing factories

<table>
<thead>
<tr>
<th>Product information</th>
<th>Number of factors</th>
<th>OK</th>
<th>%</th>
<th>Not OK</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Availability of the product description.</td>
<td>6</td>
<td>3</td>
<td>50</td>
<td>3</td>
<td>50</td>
</tr>
<tr>
<td>Documentation of the risks to which the product is exposed from the raw materials until distribution.</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>100</td>
</tr>
<tr>
<td>Availability of the end product documentation.</td>
<td>6</td>
<td>3</td>
<td>50</td>
<td>3</td>
<td>50</td>
</tr>
</tbody>
</table>
4.1.2.2 Identification of intended use of beef products

Table 6 shows identification of intended use of products in beef processing factories. Regarding statement and documentation of the target consumers for the product destination, all these plants did not adopt this parameter. Ababouch (2002) reported that the intended use of beef products should be based on expected use by the consumer. Also, Fries (1993) mentioned that the intended consumers may be the general public or a particular sector of the population e.g. infants and elderly. For the second feature in Table 6, none of the factories has applied this specification. Anderson and Dormedy (1999) found that most all the American beef plants which practiced identification of intended use of products referring to the relevant legislation. This trend in the Sudanese beef plants could be due to some carelessness or most likely unawareness of such quality concepts. It is clear from Table 6, that all the beef processing factories have practiced the definition of other properties concerning consumption, such as various information and instructions for use on the labels. A similar behavior was reported by Mulder (1996) for European beef plants.

4.1.3 Process information features in beef processing factories

4.1.3.1 Flow diagram in beef processing factories

Table 7 presents the flow diagram features of beef processing factories. The results indicated that these plants have no flow diagram which is used to describe the production process. Hartig (1994) mentioned that the construction of a flow diagram chart is very useful in order to describe the products and locate the identification of the hazard at appropriate points on the chart. Also, Hathaway (1993) found that most of the Canadian beef beef plants possess a flow diagram. For the second feature which is pointed out in Table 7, all the plants under investigation lack the validation of process
Table 6. Identification of intended use of products in beef processing factories

<table>
<thead>
<tr>
<th>Identification of intended use of products</th>
<th>Number of factories</th>
<th>OK</th>
<th>Nok</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Statement and documentation of the target consumers for the product destination.</td>
<td>6</td>
<td>0</td>
<td>6</td>
<td>100</td>
</tr>
<tr>
<td>Referring to the relevant legislation.</td>
<td>6</td>
<td>0</td>
<td>6</td>
<td>100</td>
</tr>
<tr>
<td>Definitions of other properties concerning consumption such as various informations and instructions for use on the labels.</td>
<td>6</td>
<td>6</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>
### Table 7. Flow diagrams feature in beef processing factories

<table>
<thead>
<tr>
<th>Flow diagrams feature</th>
<th>Number of factories</th>
<th>OK</th>
<th>Nok</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description of production process and engineering flow sheets by the company.</td>
<td>6</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Validation process engineering sheets by HACCP team.</td>
<td>6</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Product safety in process/engineering flow sheets.</td>
<td>6</td>
<td>0</td>
<td>6</td>
</tr>
</tbody>
</table>
engineering sheets. This might be attributed to the absence of HACCP team in Sudanese beef processing plants. According to Mortimore and Wallace (2000) a HACCP team members need to be provided with the ability to draw a flow diagram. Consequently, product safety in process engineering flow sheets were absent in these plants. This poor situation in Sudanese beef processing factories did not cope with HACCP requirements. Hartig (1994) reported that identification of hazards in process engineering flow sheets is very important for highlighting critical control points (CCP) in beef processing factories.

4.1.3.2 Facility lay – out in beef processing factories

Table 8 shows facility lay – out feature in the beef processing factories. One third of these plants have personal facilities and locker rooms. The Sudanese beef processing factories are not similar to Anderson and Dormedy (1999) who found that most of the American beef plants have personal facilities and locker rooms. For the second feature, two thirds of the factories plants have the possibility of cross contamination between raw materials and processing aids, intermediate products and end products, personnel and waste, while the risks of cross contamination does not exist in only one third of the beef processing factories. It is established that process facilities are the tool and key for the enhancement of food safety (Bernard et al, 1994). It is clear from the previous observation that the possibility of cross contamination, which will certainly lead to deterioration of products quality, is very high.
Table 8. Facility lay – out features in beef processing factories

<table>
<thead>
<tr>
<th>Facility lay – out</th>
<th>Number of factories</th>
<th>OK</th>
<th></th>
<th>Not OK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seeing the locker rooms and personal facilities.</td>
<td>6</td>
<td>2</td>
<td>33.33%</td>
<td>4</td>
</tr>
<tr>
<td>Possibility of cross contamination between raw materials and processing aids, intermediate products and end products, personnel and waste.</td>
<td>6</td>
<td>4</td>
<td>66.66%</td>
<td>2</td>
</tr>
</tbody>
</table>
4.1.3.3 On site verification of the flow diagram in beef processing factories

Table 9 represents on site verification of the flow diagram in beef processing factories. The results revealed that all of the plants did not adopt the updating of the systematic process flow/engineering diagram and consequently, updating was not done on a yearly basis. It is clear that the absence of the flow diagram will certainly lead to absence of verification. This situation did not meet the requirement stated by Huss (2004) who pointed out the importance of a constructed flow diagram and its on-site verification and inspection during all hours (night shifts, weekend) for accuracy. These Sudanese beef processing factories did not cope with Troller (2003) who found that most of the British plants have scheduled verification on place.

4.1.4 Risks and preventive measures features in beef processing factories

4.1.4.1 Hazard assessment in beef processing factories

Table 10 shows the hazard assessment in beef processing factories. Almost all the plants have not conducted any assessment of any potential risks in all production steps, which must be carried out by the HACCP team in beef processing factories. Rhodehamel (1992) stated that the risk step in food processing is the assessment of hazards associated with all aspects of food production from production to consumption. Also, Harris et al (1995) assured the importance of implementing hazard assessment through the entire chain of processing to provide the consumer with the safest food supply. Most probably, the absence of hazard assessment in Sudanese beef processing factories is due to the lack of understanding the implementation of HACCP principles. For the second point in Table 10, none of the factories
Table 9. On site verification of the flow diagram features in beef Processing factories

<table>
<thead>
<tr>
<th>On site verification of the flow diagram</th>
<th>Number of factories</th>
<th>OK</th>
<th>Nok</th>
</tr>
</thead>
<tbody>
<tr>
<td>Updating the systematic process flow / engineering diagram to keep these as built. Taking place at least on a yearly basis so as to allow for evaluation of product safety, risk and quality assurance aspects.</td>
<td>6</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>0</td>
<td>6</td>
</tr>
</tbody>
</table>

*Nok: Not Ok.*
### Table 10. Hazard assessment features in beef processing factories

<table>
<thead>
<tr>
<th>Hazard assessment</th>
<th>Number of factories</th>
<th>OK</th>
<th>%</th>
<th>Nok</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assessment of all the potential risks in every step of production which is usually done by HACCP team.</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Addressing all aspects of the production processes which can negatively influence the product safety.</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>100</td>
</tr>
</tbody>
</table>

*Nok: Not Ok.*
surveyed have adopted this parameter concerning whether hazard assessment has addressed all processing aspects. It may be concluded that if no hazard assessment is practiced in any of these factories, it means that none of the aspects of the production process are addressed. This situation is very serious compared with elsewhere (British Beef Plants) where all production processes which can negatively influence the product safety were addressed (Troller, 2003). It is clear that the Sudanese beef products industry is far beyond the international beef industry as far as quality and safety of products are concerned.

4.1.4.2 Preventive measures in beef processing factories

Table 11 shows preventive measures in beef processing factories. Almost only one third of the plants under the study have adopted identification and implementation of preventive measures for risks which should have been assessed. This situation looks bad compared to the findings of international investigators; Anderson and Dormedy (1999) found that most of American plants have implemented this parameter. Unfortunately, all the plants assured that preventive measures adopted in the beef plants are not sufficient for elimination or reduction of risks to an acceptable level. This result is not coping with what has been stated by Mulder (1996) who reported that almost all of the European beef plants have preventive measures implemented in away that eliminate or reduce food hazards to an acceptable level. Hartig (1994), also suggested that HACCP teams must decide whether CCPs can be eliminated by design improvement or by preventive measures. This poor situation in Sudanese beef processing factories lead to deterioration of the product quality and safety.
Table 11. The Preventive measures feature in beef processing factories

<table>
<thead>
<tr>
<th>Preventive measures</th>
<th>Number of factories</th>
<th>OK</th>
<th>Nok</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>Identification and implementation of preventive measures which address assessment of risks.</td>
<td>6</td>
<td>2</td>
<td>33.33</td>
</tr>
<tr>
<td>Elimination or reduction of the risks to an acceptable level by preventive measures.</td>
<td>6</td>
<td>2</td>
<td>33.33</td>
</tr>
</tbody>
</table>

*Nok: Not Ok.*
4.1.5 HACCP decision tree application to each step in beef processing factories

4.1.5.1 Assessment of application of HACCP decision tree in beef processing factories

Table 12 shows results of checking the application of HACCP decision tree in beef processing factories. The results indicated that all of the plants surveyed do not possess HACCP decision tree to assess every process step which should be based upon the experience. This situation means that all of the plants did not use the HACCP decision tree to control hazards threatening beef products safety. Hathaway (1993) found that most of the Canadian plants surveyed used the codex decision tree to control their critical control points (CCPs) also, Bernard (1994) reported that a decision tree should be used for identifying CCPs in beef industry.

4.1.5.2 Risk assessment in beef processing factories

The risk assessment in beef processing factories is shown in Table 13. The results revealed that none of these plants execute risk analysis and assessment, and consequently, no documentation of risks could be available. Adms (1994) reported that most of the American beef processing plants maintained records for the assessment of risks. Huss (2004) stated that documentation of risks associated with all aspects of food production from the raw material until consumption is required. Only one plant adopted the establishment of acceptable risk level for part of the processing line steps. This bad situation may be due to the lack of understanding on how to
implement risk assessment protocol.

Table 12. HACCP decision tree features in beef processing factories

<table>
<thead>
<tr>
<th>Assessment of application of HACCP decision tree</th>
<th>Number of factories</th>
<th>OK</th>
<th>Nok</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assessment of HACCP decision tree application for every process step by HACCP team.</td>
<td>6</td>
<td>0 0</td>
<td>6 100</td>
</tr>
<tr>
<td>Presence of the experience in the assessment.</td>
<td>6</td>
<td>0 0</td>
<td>6 100</td>
</tr>
</tbody>
</table>
Table 13. Risk assessment features in beef processing factories

<table>
<thead>
<tr>
<th>Risk assessment</th>
<th>Number of factories</th>
<th>OK</th>
<th>Nok</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk analysis and assessment executed by the HACCP team.</td>
<td>6</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Documentation the results of the risks.</td>
<td>6</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Establishment of acceptable risk levels in accordance of regulations.</td>
<td>6</td>
<td>1</td>
<td>16.66</td>
</tr>
</tbody>
</table>
4.1.6 Features of critical limits and tolerances in beef processing factories

Table 14 shows features of critical limits and tolerances in Sudanese beef processing factories. All beef factories have not established any specifications of the critical limits of each step; therefore, there wasn’t any documentation for this feature. Such situation was not similar to the observation reported by Adms (1994) who found that most of the American beef plants had established critical limits for each process step, and accordingly documented specifications as should be. Mulder (1996) mentioned that critical limits must be established for each critical control point in beef processing plants.

4.1.7 Monitoring critical process parameters in beef processing factories

Table 15 shows features of monitoring critical limits in the beef processing factories. It is clear that, all of the factories were not establishing the monitoring system for all CCPs. Food and Drug Administration (FDA, 1990) explained that monitoring is the scheduled testing or observation of the effectiveness of process control CCPs and their critical limits. This is furtherly supported by Mulder (1996) who pointed out that monitoring is an integral part of the HACCP system which consists of observations and measurements to insure that the critical points are within the critical limits. Similarly, only few plants are concerned with calibration of instruments which will have a negative effect on quality of the products. Hathaway (1993) found that this specification is practiced in Canadian plants at high level.
Table 14. Critical limits and tolerances features in beef processing factories

<table>
<thead>
<tr>
<th>Critical limits and tolerances</th>
<th>Number of factories</th>
<th>OK</th>
<th></th>
<th>Nok</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Establishment the critical limits for each process step with tolerance.</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>100</td>
</tr>
<tr>
<td>Specification the critical limits for each process step with tolerance.</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>100</td>
</tr>
<tr>
<td>Documentation the results of assessment.</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>100</td>
</tr>
</tbody>
</table>

*Nok: Not Ok.*
<table>
<thead>
<tr>
<th>Monitoring critical process</th>
<th>Number of factories</th>
<th>OK</th>
<th>%</th>
<th>Nok</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Establishment monitoring system for all CCPs.</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>100</td>
</tr>
<tr>
<td>Documentation monitoring system for each CCPs.</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>100</td>
</tr>
<tr>
<td>Calibration the instruments used.</td>
<td>6</td>
<td>2</td>
<td>33.33</td>
<td>4</td>
<td>66.66</td>
</tr>
</tbody>
</table>

*Nok : Not Ok.*
4.1.8. **Features of corrective actions in beef processing factories**

Table 16 shows features of corrective actions in beef processing factories. The result indicated that none of these plants have definition of every CCPs at which corrective actions need to be considered, hence, In consequence, the documentation of the corrective measures is absent. Huss (2004) reported that corrective actions should define what have to be done to bring back the process within the critical limits to avoid the occurrence of potentially unsafe and understand standard products. Adms (1994) reported that most of the American beef processing factories define all CCPs and their corrective actions when they deviate from their critical limits.

4.1.9 **Features of verification procedures in beef processing factories**

Table 17 shows verifying procedures in the beef processing factories concerning a review of the HACCP system when the process is subjected to a change. None of these factories has adopted this parameter. Anderson and Dormedy (1999) mentioned that most of the American beef plants have a verification schedule in place and a few of verification auditors were trained. For the second feature, all of the plants do not have a regular review in order to verify that the system is properly applied, and is still satisfactory and that the system needs amendment.

4.1.10 **Features of record keeping and documentation in beef processing factories**

The results of record keeping and documentation in beef processing factories are presented in Table 18. Almost all these plants did not implement record keeping and documentation. All these factories assured that there wasn’t any documentation of the HACCP system in a hand book, and hence no updating
of documents due to the absence of documentation of the HACCP system in a hand book. Canadian meat plants (Hathaway, 1993) and British meat plants (Troller, 2003) were found to have documentation performed at most factories inspected. Most of the plants British apply documentation performing the up dating of their documents. For the coverage of the documentation system all the HACCP step, unfortunately, none of the plants implement this step.
Table 16. Corrective actions features in beef processing factories

<table>
<thead>
<tr>
<th>Corrective actions</th>
<th>Number of factories</th>
<th>OK</th>
<th>Nok</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definition of every CCPs which corrective actions need to be taken at.</td>
<td>6</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Documentation for defining the corrective measure.</td>
<td>6</td>
<td>0</td>
<td>6</td>
</tr>
</tbody>
</table>

*Nok : Not Ok.*
Table 17. Verification procedures features in beef processing factories

<table>
<thead>
<tr>
<th>Verification procedures</th>
<th>Number of factories</th>
<th>OK</th>
<th>Nok</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>A review of the HACCP system when the processes are subjected to a change.</td>
<td>6</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Seeing a regular review in order to verify that the system is properly applied, and is still satisfactory or needs amending.</td>
<td>6</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

*Nok : Not Ok.
Table 18. Record keeping and documentation features in beef processing factories

<table>
<thead>
<tr>
<th>Record keeping and documentation</th>
<th>Number of factories</th>
<th>OK</th>
<th>Nok</th>
</tr>
</thead>
<tbody>
<tr>
<td>Documentation of the HACCP system in a hand book.</td>
<td>6</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Keeping the documentation up to date.</td>
<td>6</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Coverage of the HACCP system in documentation.</td>
<td>6</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

*Nok : Not Ok.*
4.2 Microbiological profile of beef products features quality

Meat is a highly perishable product and the microbiological safety therefore is an extremely important issue for both the consumer and the meat industry. Estimation of bacterial numbers in food is frequently used in the assessment of microbiological quality to assess the safety of foods. A number of microbiological tests are used by industry to check that the microbiological status is satisfactory. The purpose of these examinations is to detect pathogenic bacteria (*Salmonella, Staphylococcus, E.coli*), or for organisms which are possible indications of faecal contamination (*E.coli*) or other types of general contamination or poor manufacturing practices (coliform bacteria, aerobic plate count (APC)).

4.2.1 Total viable count of bacteria (TVC) in beef products

The total viable count (TVC) of bacteria in beef products are shown in Table 19. The results revealed that the samples under study carried different loads of bacteria ranging between $3.7 \times 10^4$ - $7.0 \times 10^5$ Colony Forming Units (CFU) per gram. This could be attributed to the different sanitary practices from plant to another. Mayes (1994) reported that TVC is the major indicator of microbiological contamination. However, FAO (2007) showed that total viable count (TVC) is of a very doubtful value in the examination of food products this is because kill or damage of the bacteria may have taken place during freezing and cold storage. A very low total count may therefore lead to false conclusions about the hygienic quality of the product. Tests for TVC may be useful for measuring the conditions of the raw materials, effective procedures (i.e. heat treatment) and hygienic conditions of equipment and utensils. This results are similar to these obtained by El –Roffai (2001).
4.2.2 *Escherichia coli* in beef products

The contamination of beef products with *Escherichia coli* is presented in Table 19. The contamination level ranged between 7 – 120 most probable number (MPN)/g. Harris (1995) mentioned that *Escherichia coli* is the best indictor of faecal contamination or state of hygiene. The natural habitat for this organism is the intestines of human and vertebrate animals. This organism is therefore particularly useful as an indicator of contamination (small numbers) or mishandling such as temperature abuse in product handing (large numbers). Contamination of food with *E. coli* implies a risk that one or more of enteric pathogens may have gained access to the food. However, failure to detect *E. coli* does not assure the absence of enteric pathogens (Mossil *et al.*, 1976).

4.2.3 *Staphylococci* in beef products

The occurrence of *Staphylococci* in beef products is shown in Table 19. *Staphylococci* counts ranged between $3.9 \times 10^2$ - $8.0 \times 10^3$ (CFU)/gram. Workers, hands, equipment and environmental conditions may harbour the bacterium (Shapon and Shapon,1994 ). The FAO (1992) reported that the presence of *Staphylococci* in beef products indicated the contamination from skin, mouth and nose of the employees

4.2.4 *Salmonella* in beef products

The occurrence of *Salmonella* in beef products is presented in Table 19. With the exception of Agwat sausage results showed that *Salmonella* was not detected in all the samples under investigation. Presence of *Salmonella* in beef products is an indication that the plant's system for controlling contamination is not working Tompkin (1994) and Mossel *et al* (1976) mentioned that the presence of this organism indicates poor food preparation
and handling practices. Consideration may also be given investigating the health status of food handlers on the premises who may have been suffering from Salmonellosis or asymptomatic carriers of the organism. This results are similar to these obtained by Al – Amine (2004) who did not detect *Salmonella* in samples of Lolli, Maxim, and AL- Arabi.
Table 19. Microbial feature of beef products

<table>
<thead>
<tr>
<th>Meat product</th>
<th>plant</th>
<th>Total viable count (TVC/g)</th>
<th>Escherichia coli (MPN/g)</th>
<th>Staphylococcus (CFU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sausage</td>
<td>Lolli</td>
<td>$3.7 \times 10^4$</td>
<td>7</td>
<td>3.9 × 10^4</td>
</tr>
<tr>
<td>Meat balls</td>
<td>ALArabi</td>
<td>$4.9 \times 10^4$</td>
<td>14</td>
<td>6.6 × 10^4</td>
</tr>
<tr>
<td>Burger</td>
<td>Maxim</td>
<td>$5.6 \times 10^4$</td>
<td>21</td>
<td>7.3 × 10^4</td>
</tr>
<tr>
<td>Burger</td>
<td>EL-Momaiz</td>
<td>$4.2 \times 10^4$</td>
<td>15</td>
<td>6.9 × 10^4</td>
</tr>
<tr>
<td>Meat balls</td>
<td>EL–Goussi</td>
<td>$6.8 \times 10^5$</td>
<td>64</td>
<td>7.5 × 10^5</td>
</tr>
<tr>
<td>Sausage</td>
<td>Agwat</td>
<td>$7.0 \times 10^5$</td>
<td>120</td>
<td>8.0 × 10^5</td>
</tr>
</tbody>
</table>

TVC: Total viable count

MPN: Most probable number.

CFU: Colonies forming unit.
CHAPTER FIVE
Conclusions and Recommendations

5.1 Conclusions

From the outcome of the survey carried out for six meat plants manufacturing meat products in Khartoum State, the following conclusions relevant to HACCP system implementation in these plants, as follow:

*All these factories believe in company policy on product safety and product hygiene although none of them is willing to implement the HACCP system as a tool towards total quality assurance for their products.

*The limited monitoring means, these factories are adopting currently are reflected in acceptable level safety outcome shown by safe level of total viable count of bacteria in beef products, presence of *E.coli* and *Staphylococci*, and occurrence of *Salmonella* in few sausage samples.

*It seemed that it is still a long way to go for these meat plants to start implementing appropriate HACCP system which help them in market accessibility.

Recommendations

For meat factories, to start implementing food safety monitoring system such as HACCP, it is recommended to start first implementing food safety pre-requisite protocol such as good manufacturing practices (GMPs), and Sanitation Standard Operating Procedures (SSOP) which would obviously act as appropriate base for future implementation of the HACCP system.

Further efforts are needed for training the staff of these plants to help them on issues related to HACCP elements as well on other quality management requirements.
References


FAO (1992) Food and Agriculture organization. The use of HACCP
principles in food control, FAO Food and Nutrition Paper, 58.


Tompkin, R. B. (1994). HACCP in the meat and poultry industry, Food


APPENDIX (1)
HACCP Checklist

QUESTION ..... (OK)(NOK)

1. Company Information

1.1 General information
   a. Name
   b. Address of the site
   c. Production process

1.2 Process control
   1.2.1 Is a documented process control system available describing how the company assures safety and quality of the products?
   1.2.2 Are process control flow charts available covering all aspects which are relevant and which are pertinent to the application legislation?

1.3 Responsibilities for product safety ..... (OK) (NOK)
   1.3.1 Is product safety included in the company policy?
   1.3.2 Is it documented that the management is responsible for the quality/safety policy and its documentation, and commitment and employee motivation?
   1.3.3 Is the policy and its related objectives addressing product hygiene and acceptance of raw materials and/or food production?
   1.2.4 Is the documented HACCP system covering
      a. product, groups of products?
      b. production lines?
      c. sites?
1.2.5 Is the policy known and understood at (all) levels of the organization?

1.4 HACCP Teams: ...........................................(OK).(NOK)

1.4.1. Are HACCP teams identified and operational for maintaining the HACCP process control system?

1.4.2 Is sufficient expertise in the various fields present in these teams for setting up and maintaining HACCP system?

1.4.3 Are criteria established for membership of HACCP teams?

1.4.4 Has a coordinator been nominated with responsibility for establishing in a correct manner HACCP process control systems, their progress and maintenance?

1.5 Product Information: .................................................(OK).(NOK)

1.5.1 Product Information

1.5.1.1 Is a product description available which documents the risks to which the product is exposed from the raw materials until distribution?

1.5.1.2 Is it documented the risks to which the product is exposed from the raw materials until distribution.

1.5.1.3 Is end product documentation available?

1.5.2 Identification of intended use........... ............(OK).(NOK)

1.5.2.1 Is it stated and documented for which target consumers the product is destined for?

1.5.2.1 Is the relevant legislation referred to?

1.5.3 Are other properties concerning consumption defined?

1.6 Process Information ........... .(OK).(NOK)

1.6.1 Flow Diagrams

1.6.1.1 Does the company have a description of the production process in the format of process flow sheets and engineering flow sheets?
1.6.1.2. Are these process engineering sheets validated by the HACCP team?
1.6.1.3 Can it be seen in the process/engineering flow sheets how product safety processed?

1.6.2 On site verification of the flow diagram:
1.6.2.1 Is there a systematic updating of the process flow/engineering diagram so as to keep these as built?
1.6.2.2. Is this updating taking place at least on yearly basis, so as to allow to evaluate product safety risk and quality assurance aspects?

1.7. Dangers, Risks and Preventive ……………………………(OK).(NOK)

1.7.1 Hazard Assessment
1.7.1.1 Does the HACCP team make an assessment of all potential risk in all production steps?
1.7.1.2 Is the assessment addressing all aspects of the production processes which can negatively influence product safety?

1.7.2. Preventive measures
1.7.2.1 Are preventive measures identified and implemented which address risks which were assessed?
1.7.2.2 Do these preventive measures eliminate the risks or reduce them to an acceptable level?

1.8. HACCP Decision Tree Application to Each Step …….(OK) (NOK)

1.8.1 HACCP Decision Tree Application to Each Step
1.8.1.1 Has the HACCP team made an assessment of every process step?
1.8.1.2 Is the assessment based upon the expertise (s) present in the team and consulting of internal information?

1.8.2 Risk Assessment
1.8.2.1 Has the HACCP team executed a risk analysis and assessment?
1.8.2.2 Are the results of the assessment documented and the rationale is
equally documented?

1.8.3 Have acceptable risk levels been established in accordance with regulatory requirements?

1.9. **Limits and Tolerances** ……..(OK) (NOK)

1.9.1 Are for each process step the critical limits established with tolerances?
1.9.2 Are for each process step the specification and limits established?
1.9.3 Is it documented on what grounds the specifications are based on?

1.10. **Monitoring of critical process parameters** ………..(OK) (NOK)

1.10.1 Is for all CCPs an appropriate monitoring system established, Continually operational, recorded?
1.10.2 Is it documented what the rationale is to conceive the monitoring system of each CCPs?
1.12.3 Are efficiency used properly calibrated?

1.11 **Corrective Actions** ………………………………..(OK) (NOK)

1.11.1. Is for every CCP defined which corrective actions needs to be taken when an excursion beyond the limits occurs?
1.11.2 Is the rational for defining the corrective measure documented?

1.12. **Verification Procedures** ……………………………… ...(OK) (NOK)

1.12.1 Is a review of the HACCP system foreseen when the process is subjected to a change?
1.12.2 Is the review frequency defined, sufficient (min. 2 x per year) and appropriate?

1.13. **Record Keeping and Documentation** ………..(OK) (NOK)

1.13.1 Is the HACCP system documented in a (HACCP) handbook or integrated in an overall quality manual?
1.13.2 Is this document kept up to data?
1.13.3 Is this document completely covering the HACCP system?