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PREVENTION AND CONTROL OF FOODBORNE SALMONELLOSIS THROUGH THE APPLICATION OF THE HAZARD ANALYSIS CRITICAL CONTROL POINT SYSTEM

Report of an International Commission on Microbiological Specifications for Foods (ICMSF) *ad hoc* Committee

(Copenhagen, 29-31 October 1984 and La Jolla, 25-28 October 1985)

NOTE TO READERS

This document has been prepared by the International Commission on Microbiological Specifications for Foods (ICMSF) of the International Union of Microbiological Societies (IUMS) - a non-governmental organization. The issue of the report by WHO does not necessarily imply the Organization's endorsement of the content. The World Health Organization is grateful for the result of this fruitful collaboration.

This document contains detailed advice on critical events and measures for salmonellosis prevention and control in the manufacturing of foodstuffs. The document supplements the WHO Guidelines on Prevention and Control of Salmonellosis (VPH/83.42) and other relevant literature such as the report of a WHO/ICMSF Meeting on Hazard Analysis: Critical Control Point System in Food Hygiene (VPH/82.37).

The Guidelines on Prevention and Control of Salmonellosis describe many of the critical points and measures to be taken in the preparation of animals for slaughter and their transport, as well as in subsequent phases of the feed-animal-food chain which are not included in detail in the present document.

Salmonellosis prevention and control may be implemented at the level of animal feed provision (e.g. sterilization of animal protein concentrates, fish meal, etc.). Many preventive measures are components of farming practice (e.g. general hygiene and pest animal control, specific pathogen-free production under quarantine conditions, or shellfish harvesting in licensed waters), or are applied as specific veterinary interventions (e.g. vaccination). Environmental measures are important at the farm level (e.g. safe disposal and recycling of wastes), for processing establishments, restaurants and households. Even pet animals are part of the cycles of transmission (e.g. turtle associated outbreaks of human salmonellosis).

In many cultures of the world, people often eat raw animal products or food which is improperly heated or not treated for decontamination. It cannot be expected that such food habits will change rapidly. On the contrary, there is a rising demand for raw food, including animal products (milk, meat, fish) in many developed countries. Under these conditions, the HACCP system so far applied to food processing needs to be extended to other parts of the feed-animal-food chain with its roots in environment and agriculture.

The Veterinary Public Health Unit of WHO would welcome comments and suggestions from the readers for any improvement of the present HACCP document based on practical experience. In particular, suggestions are sought on the use and extension of the HACCP concept to other areas in the feed-animal-food chain which are not covered in this paper. This collaboration will help us to further develop the strategies and methodologies for the prevention and control of salmonellosis.

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SUMMARY

For the practical implementation of the guidelines prepared by the World Health Organization (1983) on prevention and control of salmonellosis, the ad hoc Committee selected a number of food categories known to have been implicated in salmonellosis. The Committee chose the more hazardous foods amongst them, identified the critical control points during their processing, and described the monitoring of these points.

PREFACE

The need to control zoonoses and foodborne diseases was reconfirmed by the Thirty-First World Health Assembly held in May, 1978. A response to this was the production through Veterinary Public Health, Division of Communicable Diseases, WHO, of the "Guidelines on Prevention and Control of Salmonellosis" (WHO, 1983). Subsequently, meetings of an ad hoc Committee of the International Commission on Microbiological Specifications for Foods (ICMSF), supported in part by WHO, were held in Copenhagen (1984) and La Jolla (1985) to consider the application of the Hazard Analysis Critical Control Point (HACCP) System to the control of foodborne salmonellosis. This report of those meetings is, therefore, an expansion of the more general discussion of the HACCP by a previous ad hoc Committee (WHO/ICMSF, 1982).

This document discusses critical control points (CCP) in relation to salmonellosis. The HACCP system is also applicable to the prevention of other foodborne diseases, especially those of enteric origin. Such diseases are also of concern to both WHO and the International Commission on Microbiological Specifications for Foods (ICMSF).

I. INTRODUCTION

Salmonellosis is a major zoonotic disease causing foodborne illness in man. It occurs world-wide and is, therefore, of concern in all countries. Its epidemiology and the ecology of Salmonella have been reviewed (WHO, 1983).

a) The organism

Control of Salmonella in foods may involve (1) selection of uncontaminated raw materials, (2) destruction of Salmonella, (3) prevention of contamination, and/or (4) prevention of multiplication. The application of HACCP provides the most effective use of control resources by emphasizing monitoring of the CCP rather than concentrating on analyses of end-product.

Responses of Salmonella to the environment are important in determining CCP. Growth of these bacteria may occur, especially in foods of animal origin, under otherwise optimal conditions, at temperatures from about 7°C to 47°C, at water activities above 0.94 or in the approximate pH range 4-8. In practice, the combined effects of these factors must be taken into account.

Inactivation occurs rapidly at most pasteurization temperatures in foods with water activities greater than 0.95. At lower water activities, heat resistance increases. Thus, for a moist product such as liquid whole egg a heat treatment to eliminate Salmonella of 3.5 minutes at 61.1°C is used. For drier foods, processes such as 30 minutes at 80°C (e.g. shredded coconut) and 14 days at 52-55°C (spray dried egg albumin) have been recommended. Values below pH 4 are lethal to Salmonella but the effect depends greatly upon both temperature and the nature of the acids present. Salmonella is relatively sensitive to low doses of ionizing radiation.

The procedures discussed in this report emphasize the control of Salmonella. Application of the HACCP concept must also take into account the control of other agents identified as important in the particular food which are not addressed in this document (e.g. Clostridium perfringens in cooked meat or poultry, Vibrio parahaemolyticus in oysters, Listeria monocytogenes in certain cheeses, Trichinella in fermented pork sausages). Control of Salmonella will not assure control of all those agents.

b) HACCP*

The HACCP system consists of (a) an analysis of hazards and assessments of their severity, (b) identification of CCP, and (c) monitoring of these points and taking whatever corrective action is necessary (WHO/ICMSF, 1982). Hazard analysis considers hazards associated with growing, harvesting, processing, distributing, marketing, preparing, and using a given raw material or food product. It may, however, concentrate on hazardous raw ingredients or animals entering a plant and on operations that affect contamination, survival, or multiplication of pathogens (Salmonella in this report) or spoilage organisms in an establishment. In some products control by HACCP is so effective that microbiological monitoring can be reduced to a minimum. In others microbiological monitoring of the environment and of the end-product remains essential to verify that the HACCP programme has been effective.

i) Analysis of hazards: the hazard analysis with reference to Salmonella should address the nature of a product including its formulation, processing, and the conditions of intended distribution and use by answering such questions as:

With respect to formulation:

1) What raw materials or ingredients are used?
2) Is Salmonella likely to be present in these materials or introduced as a result of the process?
3) What is the pH?
4) What is the water activity?
5) Are preservatives used and, if so, what are they?

With respect to processing:

1) Will Salmonella be killed during processing?
2) Could Salmonella contamination occur during or after processing?
3) Could Salmonella multiply during processing or storage?
4) How does the packaging influence survival and/or growth of Salmonella?

With respect to the intended product use:

1) Is the product expected to be distributed warm, chilled or frozen?
2) Is the product expected to be stored warm, chilled or frozen?
3) What times and temperatures will be used for cooking and holding the product before consumption?
4) If held after cooking, will it be reheated or served cold?
5) Will it be handled after cooking?
6) What other mishandling can be expected during transportation, storage, marketing, or final preparation for consumption?

ii) Identification of CCP: Hazards might exist at one operation or more of a process or stage(s) of the food chain. Once these hazards have been identified they can be wholly or partially eliminated at certain points along the processing line or food chain. These points are referred to as critical control points. Therefore, a CCP is a location, practice, procedure or process which, if controlled, could prevent or minimize contamination with foodborne pathogens (e.g. Salmonella) or spoilage microorganisms, or to their survival or unacceptable growth. This definition has been altered from that given in WHO/ICMSF (1982) to accentuate the positive consequences of controlling a CCP rather than the negative effects of failing to control it. The emphasis of this document will be to describe the use of CCP in the control of salmonellosis.

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* For the purpose of this text "Hazard" means the unacceptable contamination, survival or growth of Salmonella. A CCP1 is a location, practice, procedure or process that will assure the control of a hazard, and a CCP2 is a location, practice, procedure or process that will minimize, but cannot assure the control of a hazard.

iii) Monitoring of CCP: CCP must be monitored to ensure that these processes and practices are under control. This monitoring might be done either continuously or periodically, as appropriate for the situation and process. Monitoring might involve making observations, taking measurements (e.g. temperature, pH, aw, concentrations of disinfectants), collecting samples and performing appropriate analyses. The type of monitoring depends upon the nature of the CCP under consideration (see WHO/ICMSF, 1982, for a more detailed discussion of the principles and applications of the HACCP system).

When monitoring results indicate failure of control at a CCP, the reason for the failure should be determined immediately and corrective action taken (e.g. by adjustment of temperature or timing controls, removal of a source of contamination). At the same time, the stringency of end-product testing for Salmonella should be increased. Salmonella testing of the environment and end-product may be essential to verify monitoring procedures. If Salmonella is detected in a product when the monitoring programme shows that all CCP are under control it is important to review whether all the hazards and CCP have been properly identified. Should epidemiological data indicate a hazard from a product when all CCP are under control, it is conceivable that the product is being used in a manner which was not anticipated in the hazard analysis. In such situations the hazard analysis should be re-evaluated, but it might be concluded that certain hazards are inherent in particular products if they are abused. In many such cases, informing the public of the risk is the only appropriate positive action, (e.g. salmonellosis as a result of reconstituting infant formula with contaminated water).

c) Categories of foods

Various foods have been vehicles identified in salmonellosis or are occasionally contaminated with Salmonella. For the purposes of this report, these foods are grouped as follows:

1. High moisture foods - no processing step destroys Salmonella:

   e.g. raw meat, raw poultry, and molluscan shellfish.

2. High moisture foods - thermal process can destroy Salmonella:

   e.g. pasteurized milk, pasteurized liquid eggs, canned meat, cooked beef, cooked turkey, and cooked, cured meat.

3. Low moisture foods or feeds - ingredients may contain Salmonella:

   (a) moist ingredients: thermal process can destroy Salmonella:

   e.g. dried eggs and dried egg products, dried milk, dessicated coconut, fish meal*, and animal feeds*

   (b) dry ingredients: initial thermal process can destroy Salmonella:

   e.g. chocolate, peanut butter, and dried pet food.

   (c) dry ingredients: blended with no thermal process that destroys Salmonella:

   e.g. corn-soy-milk, dry blended infant formulas, and soup mixes.

   (d) wet blended with no thermal process:

   e.g. pasta

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* As a source of Salmonella infecting animals, which after slaughter are used as foods for humans.

4. Fermented foods of animal origin:

e.g. certain types of cheese, and certain types of fermented sausage.

5. Acidified foods:

e.g. mayonnaise, and salad dressing.

In the discussions that follow, selected foods from each of these five categories will be discussed in detail with reference to CCP and their monitoring, and they will be illustrated in flow charts, indicating major and possible sources of contamination together with CCP1 and CCP2. Brief mention will be made of other foods in the five categories where either a CCP or its monitoring differs from that of the example given.

II. APPLICATION OF HACCP

1. High moisture foods - no processing step destroys Salmonella:

1.1 Raw meat

At farms:

As meat is an important source of Salmonella in man, the prevention and elimination of this infection in animals are of paramount importance. Salmonella infections in animals are not always manifest as clinical symptoms, therefore some farmers fail to appreciate the public health problems caused by Salmonella. Animals that have subclinical infections of Salmonella defy detection at both ante- and post-mortem inspections.

There are several possible sources of Salmonella on farms, but the most important are pastures and streams which have been contaminated with untreated manure or sewage, other animals harbouring Salmonella, and animal feeds (see Figure 1). It is unrealistic to try to control Salmonella in streams and pastures. Other sources of Salmonella on the farm include incoming stock, pets and wildlife, particularly birds and rodents. While it is impossible to control all these sources of Salmonella on the farm, experience has shown that the provision of Salmonella-free animal feeds can be a CCP.

At the slaughterhouse:

The holding pen/lairage area should be cleaned and disinfected frequently to prevent contamination of successive groups of animals. Residence time in the lairage area should be minimal, consistent with the need for rest after transportation. The longer animals remain in lairage the greater the likelihood of cross-infection and cross-contamination.

Processing and storage areas for meat should be kept separate from the slaughtering area. Monitoring is performed by visual inspection and may be supplemented by microbiological checks of surfaces which may come into contact with the meat.

The CCP at the slaughterhouse are skinning or scalding/dehairing processes, evisceration and chilling. Removal of hides, as in beef and lamb dressing, should be performed to avoid contact between the outside of the skin and the carcass. This CCP should be monitored visually.

For pigs the scalding/dehairing process can be a serious contamination site. To inactivate Salmonella transmitted to the scald water, the temperature should be maintained between 60 and 62°C and should be monitored. However, commonly applied methods of dehairing may recontaminate the scalded carcass. Singeing also reduces number of Salmonella but the subsequent polishing commonly recontaminates the carcass.

If carried out improperly, evisceration can transfer Salmonella from intestine to the carcass. Disinfection of knives in water at 80°C is used in an attempt to minimize cross-contamination. Carcass chilling is also a CCP and should be monitored.

Control afforded by the above CCP is essential to minimize the Salmonella hazard in red meat. Nevertheless, existing technology, including controlling these CCP, does not ensure that red meat will be free from Salmonella. This can only be accomplished by appropriate further processing or cooking (see Section 2).

1.2 Poultry

Breeders and Layers: Salmonella from poultry is a major cause of human illness and sometimes of mortality in fowl. Eradication programmes for S. pullorum and S. gallinarum in chickens have been successful in the developed countries. Similar programmes for S. typhimurium in turkeys and ducks have met with less success. These programmes are based on testing the blood of birds for specific Salmonella antibodies. Reactors are eliminated from breeder flocks. There are no programmes aimed at eliminating other Salmonella serovars. New stock should come from sources known to be disease-free and should be quarantined before being mixed with other birds.

Figure 2 illustrates poultry husbandry and associated CCP.

Layer farms: Egg collection, sorting, fumigation and disinfection of certain pieces of equipment are CCP in layer farms. Eggs should be collected frequently, preferably from roll away nests with automatic pick-up to minimize faecal contamination. Cracked or dirty eggs should not be used for hatching. Eggs should be fumigated with formaldehyde soon after collection and egg trays washed and disinfected after use. Monitoring is by observing that these practices are carried out with properly designed, operated, and cleaned equipment, and by checking concentrations of chemicals used.

Hatching: A CCP in hatching operations is to fumigate eggs upon arrival at the hatchery before entering the hatching area. Fluff is sampled after hatching and tested for Salmonella.

Farms: Numerous attempts are made to minimize infection of fowls and contamination of their feet or feathers with Salmonella. These include obtaining Salmonella-free breeding and supply stock, using Salmonella-free feed, providing rodent- and bird-proof housing, providing protective clothing for workers, disinfecting footwear, frequent cleaning of water troughs, removing sick or dead fowls, removing droppings and litter and cleaning with subsequent decontamination of houses after removal of flocks.

Despite these actions live poultry presented to the processing plant will frequently harbour Salmonella. However, experience has shown that obtaining feed free of Salmonella and protecting it from contamination and moisture is a CCP. Significant reduction of the Salmonella problems has been achieved in Nordic countries by obtaining Salmonella-free freedstuffs including heat-processing ingredients (e.g. fish meal) from regions known to have contaminated products. Use of pelletted feed (70°C for 70 sec. and a 4% rise in moisture level) significantly reduces the level of Salmonella in feeds.

Processing: Salmonella enter processing plants on or in incoming live animals. Figure 3 illustrates typical operations in poultry processing. No process other than ionizing irradiation will eliminate Salmonella from carcasses and retain the characteristics of raw poultry. Certain measures, however, are critical in reducing contamination of carcasses during processing. Scalding in water at a temperature of 60°C or higher significantly decreases microbial counts of many groups of organisms, including Salmonella, on poultry carcasses. This is not always achieved when carcasses are scalded at 55°C or less. Water temperature should be continuously monitored. The feather-picking operation is a major point of spread of Salmonella. Spray washing of carcasses after picking and at other stages during processing can partially remove the microbial flora, including some Salmonella, from poultry surfaces. The reduction of Salmonella can be enhanced by using efficient spray patterns and appropriate water volume and pressure.

Chilling is a CCP. There are two methods of chilling poultry carcasses - water and air. Chlorination of chill water kills detached Salmonella and minimizes cross-contamination between carcasses. The chlorine concentration and water volume should be monitored. Continuous and liberal replenishment of cooling water aids in cleaning skin, and counter-flow immersion chilling decreases bacterial counts and minimizes cross-contamination.

Periodical cleaning and disinfecting of equipment can prevent microbial build-up during shut-down time and reduce transfer of organisms at the start of operations, but transfer readily occurs following the processing of a few carcasses.

1.3 Molluscan shellfish

Molluscan shellfish consumed raw have frequently been implicated in human enteric illness. Figure 4 indicates the steps in the harvesting and handling of raw molluscan shellfish.

Control of the microbiological quality of waters in which molluscan shellfish are grown has greatly reduced the hazard of typhoid fever and other salmonelloses, and is recognized as an effective CCP. This CCP consists of intercepting sewage and treating it in such a manner that pathogens are killed, removed or substantially reduced in number before the effluent flows into estuaries or coastal waters from which molluscan shellfish are harvested. These waters need to be surveyed for sewage discharges and monitored by bacteriological sampling to determine the degree of contamination. Molluscan shellfish are not monitored for Salmonella because there is also concern about other pathogens (e.g. enteric viruses). It is more prudent to test for the best possible indicator of faecal pollution (e.g. Escherichia coli, faecal coliforms). Criteria for growing waters exist in many countries (e.g. USA).

Harvesting of molluscan shellfish from unapproved waters is somtimes permitted provided the shellfish are subsequently transferred to clean waters and held for two or more weeks (relaying). Alternatively, molluscan shellfish may be held for an appropriate period in tanks through which is circulated water that has been treated with ozone or chlorine (depuration). Both relaying and depuration are CCP.

2. High moisture foods - thermal process can destroy Salmonella

2.1 Fluid milk

Figure 5 indicates the steps in treatment of fluid milk. Contamination of raw milk by Salmonella occurs from time to time. Prompt chilling to below 7°C prevents multiplication of Salmonella. Fluid milk is subjected to a heat treatment to destroy Salmonella and other vegetative pathogens. Time-temperature relationships other than those indicated in Figure 5 are also used (ICMSF 1980, p. 480). The first CCP is the pasteurization process. Since other pathogens having greater heat resistance than Salmonella are also of concern, the accepted pasteurization processes provide a considerable margin of safety with respect to Salmonella destruction. High-temperature short-time (HTST) pasteurizers are fitted with flow diversion valves to ensure that in the event of failure to achieve the required pasteurizing conditions the milk is recirculated. The temperature of pasteurization should be measured and recorded. In HTST processing, the time to achieve pasteurization is determined by the temperature, physical dimensions of the holding tube and the flow rate.

The second CCP is preventing recontamination in the subsequent processing steps (e.g. cooling, holding, packaging). Equipment and materials must be clean and sanitary. This CCP can be controlled by visual monitoring of the pipelines for conveying the milk and observing that the processing and cleaning instructions are being correctly followed. It is not normally necessary to analyze for the presence of Salmonella.

2.2 Cooked beef

It must be assumed that Salmonella may be present in or on the raw beef. The first CCP (see figure 6) is the cooking process. Times and temperatures necessary to assure the destruction of Salmonella havebeen specified for this product (USDA, 1983). Monitoring this CCP consists of measuring temperature and time. Further CCP are a) providing prompt rapid chilling of the cooked product through the temperature range over which pathogens are able to multiply; b) thorough chilling to below 4.4°C; c) preventing recontamination, particularly during further processing such as slicing and packing and d) refrigerated storage. A properly designed commercial facility can provide a product flow which assures separation of the cooked product from the raw meat. In the home and food service establishments this is more difficult to achieve.

Education of personnel is essential to assure the awareness and the alertness required to prevent cross-contamination and to observe temperatures and times specified for cooking, cooling and storage. Thus, personnel (and equipment) should not be interchanged between the raw and the post-cooking areas. This CCP is monitored by observing procedures during handling raw and cooked meat. Microbiological monitoring of the cooked product and of surfaces in contact with cooked product can be used to supplement visual control of CCP. It is advisable to monitor for Salmonella as a direct assessment of hazard and E. coli as a monitor of post-cooking contamination.

2.3 Cooked turkey in homes and food service operations

Turkeys have frequently been implicated as vehicles in outbreaks of salmonellosis. Figure 7 illustrates typical operations associated with preparation of whole turkeys in institutional kitchens, food service establishments and homes. CCP are cooking, hot holding, cooling, reheating, handling cooked product, and cleaning up after raw product is handled.

Thawing:

Improper thawing at elevated temperatures and subsequent storage at these temperatures for extended time may result in increased numbers of Salmonella posing a greater potential for cross-contamination. Salmonella will not multiply during thawing in refrigerators. Thawing is faster in ($<$ 20°C) cold running water than in air, but microbial counts can become high if the thawed turkeys are not removed from the water. Cross-contamination can be intensified when the thawing water is splashed around as carcasses are removed from the water-bath and transferred to tables for the next step in preparation. Microwave thawing results in considerable differences in temperatures in different regions of a carcass and, if carcasses are not tempered before cooking, over- or under-cooking of certain regions can result. Thawing as part of a cooking process, of course, can be done safely if given enough time at sufficiently high temperatures, but several failures are on record when cooking time was insufficient and outbreaks of salmonellosis followed. Incomplete thawing prior to cooking is also a serious hazard because the consequent undercooking may result in survival of Salmonella. Monitoring is by observing and feeling whether turkeys are thawed before cooking.

Cooking:

The cooking process is a CCP. Turkeys, and other raw, non-cured poultry products, should be cooked to at least 74°C. The extent of cooking can be monitored continuously during the process (not often practicable), at the time foods are removed from the heat source, or during the post-heat temperature rise period, by measuring temperatures (usually in the centre of the breast).

Hot-holding:

If cooked turkey meat is held hot, hot holding is a CCP. The temperature should be maintained at or above 55°C. Although the maximum temperature for growth of Salmonella is ca. 46°C and holding above this temperature will prevent multiplication of any Salmonella present, holding at or above 55°C is recommended to prevent growth of C. perfringens.

Cooling:

Cooling of cooked turkey is a CCP. It is important to cool rapidly through the temperature range within which Salmonella can multiply. Complete monitoring of cooling rates while a food cools in a refrigerator is desirable but not usually practicable. Therefore, monitoring usually involves different considerations: the depth of the turkey meat in containers (preferably 9 cm or less); the cross section and height of the containers (e.g. wide and long pans not higher than 10 cm); avoiding containers stacked on top of each other; maintaining adequate spacing between shelves, walls and containers; and whether or not some form of rapid cooling (e.g. ice baths, water baths) is used prior to refrigeration.

Reheating:

Reheating leftover turkey meat is a CCP. The temperature of cooked turkey which is reheated should attain 74°C or higher. Monitoring at this stage of processing is at least as important as during initial cooking, because if contamination and/or poor storage practices prevailed, large numbers of microorganisms must be killed.

Environment:

The environment in which the cooked turkey is held and prepared for serving as a CCP. The handling of turkey after cooking can be monitored visually. Observations can be made to determine whether there was opportunity for cross-contamination from raw foods to food handlers' hands to cooked foods, from raw foods to equipment to cooked foods processed on the same equipment, or from cloths used to wipe up areas where raw and then cooked foods are handled. Observations can also be made to determine whether cooked foods are touched or whether improperly cleaned equipment is used to either handle or hold the cooked foods. Managers of food service establishments should develop a sanitary maintenance schedule that specifies what should be cleaned, recommended cleaning and disinfection procedures, when equipment should be cleaned, who should clean specific items of equipment, and who should monitor the effectiveness of cleaning and the manner by which this is done. Education of the public and training of personnel in the food service industry are important in the prevention of foodborne diseases attributable to this product.

3. Low moisture foods - ingredients may contain Salmonella

3.1 Moist ingredients: thermal process can destroy Salmonella

3.1.1 Dried milk

The range of dried milks and milk products that are available includes those used as ingredients for further processing and those for direct consumption following reconstitution. Salmonella has been the pathogen of concern in a number of them. A flow diagram illustrating the processing of non-fat dried milk with an indication of the CCP is given in Figure 8.

Contamination of raw milk by Salmonella occurs from time to time. The processes involved in the production of dried milks must therefore include steps which will destroy this bacterium. Promptly chilling the raw milk to below 7°C will prevent multiplication of Salmonella.

The subsequent procedures include several heat processes which vary in intensity with the nature of the raw material and the desired product. Each may have some effect on the survival of Salmonella. The temperature of the drying process cannot be depended upon to destroy these organisms. The decisive destructive step is pasteurization. This will generally be a high-temperature, short-time (HTST) process, which is the first CCP. The temperature and time must be monitored by indicators, recording thermometers and speed controlled pumps to ensure that all milk receives the intended treatment. HTST pasteurizers should be fitted with flow diversion valves to ensure that in the event of failure to achieve the required pasteurizing conditions the milk is recirculated.

The second CCP is the environment. This CCP must be monitored visually to observe, for example, the source and movement of air throughout the environment, the presence of standing water and the condition of the air filters. Observations such as these must be supplemented by the use of microbiological tests for Salmonella. Due to the time required to obtain results, Salmonella assays do not permit ongoing control of this CCP (i.e. environment) during processing. The results determine whether the visual monitoring is effective. In the case of a positive sample the visual monitoring programme must be re-evaluated.

If supplemental microbiological tests are to be performed, appropriate environmental sampling sites are air filters to the drier and conveyor, vacuum systems, sifter tailings and floor sweepings. Of these, the tailings may be the most important as they most closely represent the packaged product but with greater opportunities for contamination. The same considerations apply to a variety of food products, e.g. dried eggs, dried infant formulas, peanut butter, confectionery products. If any of the environmental samples contain Salmonella, the source of contamination must be sought immediately and controlled. As in any plant producing a dry food, wet cleaning should be avoided unless essential, in which case all moisture must be removed as rapidly and completely as possible.

Finished product should be tested for Salmonella according to an appropriate sampling plan. In response to an occasional positive environmental sample, it may be adequate merely to increase the stringency of the end-product sampling plan to increase confidence that the product is free of Salmonella while eliminating the source of contamination. On the other hand, widespread contamination of the environment would justify closing the plant for thorough cleaning.

Other dried foods for which the raw materials may be assumed to contain Salmonella include dried whole egg and dried egg albumin. Although not foods for human consumption, fish meal and other meals destined as animal feeds also fall into this category.

3.1.2 Dessicated coconut

Coconuts are dropped or fall to the ground where they are frequently contaminated with infected animal and human excreta and hence with Salmonella. The manual processes of husking, shelling, paring and cracking may transfer contaminating organisms to the milk and the meat of coconuts. Wash water may also be a source of Salmonella. The meat is ground or shredded and finally dried. A drying process sufficient to destroy all Salmonella present on the shredded coconut will cause discoloration and unacceptable quality loss in the final product. Therefore, a pasteurization step is introduced prior to shredding, in which the cracked meat is subjected to a temperature of 80°C in water for 5-10 minutes. This time-temperature treatment should be carefully monitored as it is the CCP where Salmonella is eliminated. The accepted drying process (93°C-121°C; 30 minutes) cannot, in spite of the relatively high air temperature, be relied upon to destroy Salmonella because of evaporative cooling effects and the progressive reduction in water activity. A flow diagram for dessicated coconut is shown in Figure 9.

Preventing recontamination from the environment is a CCP. Thorough sanitation of grinding equipment is required to prevent recontamination. Separation of post-pasteurizing from pre-pasteurizing processes is essential. The post-pasteurizing environment must be monitored visually to assess the cleanliness of the equipment and processing environment, and the movement of and handling by personnel to maintain separation of raw and processed product.

3.2 Dry ingredients: initial thermal process can destroy Salmonella

3.2.1 Milk chocolate

Milk chocolate is a product of sufficiently low aw (0.37-0.50) to preclude microbial growth. It may be consumed as such or be used as an ingredient in various confectionery products. If milk chocolate is contaminated with Salmonella, decontamination by heat treatment is impracticable, because their heat resistance is substantially increased at such low aw.

Confectionery products in which chocolate is incorporated as an ingredient are likewise of low aw. Thus, contamination in chocolate can be carried into products in which Salmonella is not eliminated by the manufacturing process and which pose a health risk to consumers. The flow diagram for processing milk chocolate is shown in Figure 10.

One of the raw materials for production of milk chocolate is cocoa beans. These are frequently contaminated with Salmonella. The roasting step (heating from 15 min. to 2 hr. at 105°C-150°C) kills viable Salmonella. Roasting is thus a CCP which is best monitored by time and temperature checks.

No processing step beyond the roaster can be depended upon to destroy Salmonella, even though high temperatures are encountered during subsequent processing and handling, (e.g. grinding, milling, storage and conching). The water content of roasted beans is 1-2%, and under these conditions Salmonella is not readily destroyed by heat. The environment of the roasted bean processing area is a CCP that should be monitored constantly by visual observation. The environment of the roasted bean processing area is a CCP that should be monitored constantly by visual observation. The environment in which raw beans are handled is likely to be contaminated. Therefore, this area must be physically separated from the area in which the roasted beans are further processed. Personnel from the raw bean area should be excluded from the area of further processing, and air movement should be from the further processing to the raw bean area, never in the opposite direction. The movement of personnel and air can be monitored visually.

Moisture must be controlled in the post-roasting environment (see Figure 10). Condensation on or over the chocolate mass is a source of moisture. Wet cleaning should not be done as a routine. However, if equipment or areas become contaminated, wet cleaning and sanitizing may become necessary. In this event, provision must be made for prompt and complete drying. Any accumulation of water must be avoided.

Hot water jacketed pipes, for example, used for transporting and maintaining chocolate in the liquid state, pumps and holding tanks may pose problems. Also, if pipe connexions are not tight or if holes (e.g. from improper welding or from corrosion) exist in the pipes carrying the liquors, water can leak from the outer pipe into the liquor. If microholes occur, microorganisms may grow in the heating water and be carried into the chocolate mass.

Supplemental Salmonella tests of environmental samples could include samples of air, floor sweepings, dust collector contents and static material collecting on equipment. These environmental samples should be free from Salmonella. If not, the source must be determined and eliminated and the visual monitoring programme re-evaluated.

Milk, condensed or dehydrated, is an ingredient of milk chocolate. Dehydrated milk products used include non-fat dry milk, dry whole milk and dried whey. These dry dairy ingredients are a CCP to the producer of milk chocolate. This CCP must be monitored for Salmonella using an appropriate sampling plan, as contamination will be carried into the finished product and survive the process. These ingredients must not be used unless the results of the monitoring tests for the presence of Salmonella are negative.

The finished milk chocolate must likewise be tested for Salmonella, using an appropriate sampling plan (ICMSF, 1986). If there is any evidence of environmental contamination, however, more stringent sampling plans for finished product are indicated.

3.2.2 Peanut butter

Peanut butter (and other nut butters) and certain dry pet foods present problems analogous to those encountered with chocolate and confectionery. A roasting step eliminates Salmonella in raw peanuts. Mixing with steam and extrusion under pressure destroys Salmonella in the ingredients of pet foods. Thereafter, environmental control measures and CCP are similar to those described for the production of milk chocolate.

3.3 Dry ingredients: blended with no thermal process

3.3.1 Dried infant formulas

Consumers of these products are highly susceptible to infection by Salmonella. The formulas require reconstitution with water and may be held rehydrated at temperatures that permit multiplication of any contaminating microorganisms, including Salmonella. Freedom from contamination of the dried product is thus of the utmost importance, as is the use of potable water for reconstitution.

Infant formulas are either wet blended, pasteurized and dried, or compounded from several dry ingredients. They are based on proteins of milk or vegetable origin which could be contaminated with Salmonella. Heat treatment of the dry blended formula to destroy Salmonella is not appropriate because of the heat sensitivity of some ingredients and the enhanced heat resistance of Salmonella in dry foods.

A simple flow diagram for the production of dry-blended infant formulas is shown in Figure 11. In this example, the first CCP to ensure freedom from Salmonella in the dry blend procedure is the selection of dry ingredients that have been carefully examined microbiologically and shown to be Salmonella-negative by the most stringent sampling plan (ICMSF, 1986). The risk of blending Salmonella-contaminated dry ingredients can be reduced if the ingredients are obtained from suppliers who have an effective HACCP programme in place. It is then essential that the acceptable ingredients be blended and packaged under conditions that prevent contamination by Salmonella.

The second CCP is the environment in which the product is blended and packaged. Monitoring by visual observation is important but must be supplemented by extensive microbiological surveillance to ensure that the processing and packaging environment is free from Salmonella. Particularly useful in assessing the status of the environment are material from dust collectors and static material which has accumulated on packaging equipment.

If several types of dry blended products are prepared in the same plant, it is important that ALL raw materials introduced into the processing area be free of Salmonella to prevent contamination of the more sensitive foods (e.g. infant food formulas). The microbiological surveillance programme is a check that this is the case.

Because infants are highly susceptible to salmonellosis, it is necessary to apply a stringent sampling plan for Salmonella to the final packaged product to verify that the HACCP system has been effective.

3.3.2 Corn-soy-milk and dried soup mixes are other products in this category. Corn-soy-milk is manufactured primarily for use in non-industrialized countries where hygienic conditions during and after reconstitution may magnify any health hazards in the children and infants that normally consume the product. In contrast, dried soups are normally reconstituted in hot water or in cold water with subsequent heating, and are less likely to be eaten by susceptible persons. They are therefore substantially less hazardous than foods intended for infants and children.

3.4 Wet blended with no thermal process

3.4.1 Pastas fall into this group of products. They are made by mixing water with wheat, farina and semolina flours. Noodles are prepared from doughs containing whole egg or egg yolk; whereas other pastas do not contain added egg products. In any case, the dough (aw 0.95-0.98) is thereafter extruded and dried. The drying temperatures vary over a wide range, depending on the product and the equipment used. If the dough contains Salmonella, a reduction in the numbers occurs during drying. Survivors are to be expected, however, especially if high numbers are present in the dough.

The most important source of Salmonella in these products is the egg ingredients. These may be frozen or reconstituted dried egg products. Therefore, a CCP is the raw materials. Eggs are particularly important when used in the manufacture of pasta because the drying process cannot be depended upon to eliminate Salmonella. Furthermore, improper handling of the eggs may result in extensive growth of Salmonella prior to their use. Eggs should be pre-tested for Salmonella using an appropriate sampling plan.

Thawing of frozen eggs is another CCP. Often, this is done at ambient temperature under conditions where the periphery of the egg mass reaches temperatures where growth of Salmonella occurs or the thawed eggs are left at ambient temperatures for some time. Thawing should be carried out either under refrigeration or under cold running water. The subsequent holding temperature of the eggs is a CCP. The eggs should be held below 7°C to preclude Salmonella growth. Thawing time and temperature and subsequent storage should be monitored. In some operations, dried egg is added directly to the mixer, thus obviating problems associated with thawing and holding frozen eggs and holding of reconstituted dry egg.

Time-temperature abuse of either thawed eggs or reconstituted dried eggs may result in growth of Salmonella in the holding tanks feeding the mixer. In addition, if wet spots develop in the mixer, this will also permit growth. Therefore, the control of moisture in the mixer is a CCP. Development of pockets of dough having high moisture in the mixer must be monitored by visual inspection. This hazard can be avoided by scraping down the sides of the mixer with a rubber spatula.

The environment is a CCP and is monitored visually. Collecting and testing appropriate environmental samples for Salmonella is indicated.

4. Fermented foods of animal origin

4.1 Cheese

As already mentioned, raw milk is sometimes contaminated with Salmonella. The first CCP (see Figure 12) in the manufacture of cheese is destroying Salmonella in the raw milk. Pasteurizing is the most reliable method if it is acceptable for the type of cheese being produced. Conventional pasteurization (e.g. HTST at 71.1°C for 15 seconds) assures the destruction of non-sporeforming milkborne pathogens, including Salmonella. An alternative heat treatment involves sub-pasteurization (e.g. 64-70°C for 15-20 seconds), which will also kill Salmonella in raw milk (ICMSF, 1980, p. 501). For cheeses made with raw milk, Salmonella control is dependent solely upon the subsequent steps in the processing.

The second CCP consists of a controlled fermentation. Vats of milk which are slow in developing acid or in which poor acid production occurs pose the greatest risk of Salmonella reaching higher numbers and surviving in the cheese during aging. For the fermentation to proceed normally and attain the desired level of acid in the cheese, the milk must not contain antibiotics, there must not be excessive residual sanitizers in or on the equipment, and infection of the starter culture with bacteriophages must be prevented. The temperature of the milk must be within the range of optimum activity for the starter culture(s), and the type and amount of starter culture must promote an effective fermentation. The means of monitoring include measuring the temperature of the milk and the rate of increase in titratable acidity.

The third CCP is destruction of Salmonella during storage and aging of the cheese. The destruction is a function of time and temperature of storage. This relationship will differ for different cheeses and is dependent upon the microbial and chemical composition (e.g. pH, type and concentration of organic acids, moisture and salt content) of the cheese. Information on Salmonella destruction in cheese is available (ICMSF 1980, p. 507). Existing recommendations for the aging of some cheeses have proved inadequate to destroy Salmonella and are being reviewed.

4.2 Fermented sausages

It must be assumed that the raw meat used in the formulation of these products may contain Salmonella. By comparison, the prevalence of Salmonella in the other ingredients is inconsequential.

The first CCP (see Figure 13) for Salmonella control is the fermentation process. A proper fermentation process which is capable of controlling the growth of Salmonella includes decrease of pH, decrease of aw, and build-up of a microbial flora that is competitive with, or inhibitory to, Salmonella. These three changes occur simultaneously rather than sequentially. If one is partly, or entirely, missing (e.g. decrease of aw) others must be enhanced (e.g. by formation of higher acid concentration by addition of glucono-delta-lactone, use of starter cultures or inclusion of fermentable carbohydrates). During this stage in processing organic acids are produced as a result of microbial metabolic activity. To minimize the growth of Salmonella in the product during fermentation, and active population of acid-producing bacteria must be present.

Several methods can be used to provide this population. In method 1, sausages are moved directly from the stuffing room to the fermentation room. In method 2, blended meat or stuffed sausages are held at refrigeration temperatures (e.g. 10°C) for one or more days before transferring to the fermentation room. In method 3, a portion of fermented unheated product from a previous production lot is added to the sausage formulation. In method 4, pure cultures are added to the sausage formulation. Each method has some degree of risk which will be influenced by the temperature of the fermentation room. In general, the more rapidly the fermentation proceeds, the greater the assurance that growth of Salmonella will be prevented.

The choice of method is influenced by tradition and the type of product being produced. Method 1 carries the highest risk of Salmonella growth, particularly if the product is fermented at elevated temperatures (e.g. $>$ 25°C). Time is required for a natural lactic flora to develop and produce sufficiently high concentrations of acids. Method 2 reduces the risk associated with method 1 by allowing for a phase of adjustment and selection of a natural lactic microflora before the product is transferred to the fermentation room. Method 3 further reduces the risk if adequate controls are placed upon the inoculum material. If properly controlled, method 3 compares favourably with method 4 in ensuring a prompt, dependable fermentation.

The rate of fermentation can be influenced by several factors (e.g. concentration of fermentable carbohydrates, salt concentration and temperature). The most common method of monitoring this CCP is to observe the appearance and the firmness of the product, and to test for pH. For any given product a normal fermentation pattern will result in a product with pH $<$ 5.5 within a specified time. Guidelines with time-temperature indications have been suggested (AMI, 1982). Deviations for the normal fermentation pattern (e.g. unusually long fermentation times and/or product having pH $>$ 5.5) increase the possibility that Salmonella may multiply.

Following fermentation some fermented sausages may be rinsed with water. Excessive rinsing can remove salt from the surface and lead to a secondary fermentation at the surface of the product during which high levels of Enterobacteriaceae can develop.

The intent of a controlled fermentation is to yield a product of uniform acceptable quality. If properly controlled, the population of Salmonella will not increase and may even decline. Subsequent processing can assure the destruction of Salmonella in the product by the time it is released for distribution.

The second CCP for Salmonella control involves holding the product under such conditions of time and temperature that Salmonella declines to below levels of detection.

Some fermented sausages are heated after fermentation (e.g. to kill Trichinella). The time-temperature of heating, the combined effect of salt and acid, and size of the product influence the destruction of Salmonella. Considering the variety of products involved, it is not possible to specify minimum internal temperature to which these products must be heated.

Some fermented sausages are held at reduced temperatures for drying and aging. The intent is to permit full development of flavour and texture. Where illness has occurred it appears that faulty fermentation contributed to the survival of Salmonella. The combination of a faulty fermentation which provides insufficient acid (e.g. pH $>$ 5.5 and reliance upon the drying/aging process for destruction of Salmonella is where the risk lies. It is not possible to specify the combination of minimal times and temperatures for holding, product pH, and aw for the wide variety of fermented sausages produced throughout the world. Thus, each manufacturer should preferably develop this information to assure safety of the process that is being used. This can be accomplished only by bacteriological evaluation of the product during processing.

5. Acidified foods

5.1 Mayonnaise, salad dressings and related products

These products are emulsions in which water is the continuous phase and fat is the discontinuous phase. The growth rate and/or fate of microorganisms is not affected by the water dispersion as it is in butter and margarine; only the chemical composition of the water phase plays a role.

Manufacture of these products is generally carried out in small batches using tanks with high-speed beaters. Commonly, a pre-mix of ingredients such as salted egg blend, spices, sugar, vinegar, cooked starch paste (in salad dressing) and vegetables (in speciality dressings) is prepared. Then oil is gradually added. The ingredients are coarsely emulsified and then homogenized in a colloid mill before packaging.

Egg yolk is an ingredient of both mayonnaise and salad dressing and is the principal source of Salmonella among the various raw materials used. However, if the pH of mayonnaise and salad dressings is $<$ 4.1 and the concentration of acetic acid is 0.25% or greater, Salmonella will die in these products (Smittle, 1977). A few outbreaks of salmonellosis traced to mayonnaise in Europe have been reported (see ICMSF, 1980, pp. 757-8). In these instances the mayonnaise did not contain sufficient acetic acid and the pH exceeded 4.1.

The CCP in the production of mayonnaise and salad dressings is pH and acetic acid concentration. These may be monitored by determination of pH and by proper formulation.

III. RECOMMENDATIONS

The ICMSF ad hoc Committee recommends:

1. that this document be used as a guideline to implement the recommendations of the WHO/ICMSF (1982) document for applying the HACCP approach to control of salmonellosis in developing countries using, as an example, an appropriate food considered in this document;

2. that this document be consulted, together with WHO/ICMSF (1982), whenever codes and ordinances that relate to food hygiene are reviewed, to ensure that they cover and properly emphasize critical control points and appropriate monitoring procedures;

3. that this document, together with WHO/ICMSF (1982), be used as guidelines for WHO- and national-sponsored training programmes in food hygiene for public health, food regulatory and industry quality control personnel. WHO should stimulate the development of such training by demonstration courses for key personnel in WHO regions.

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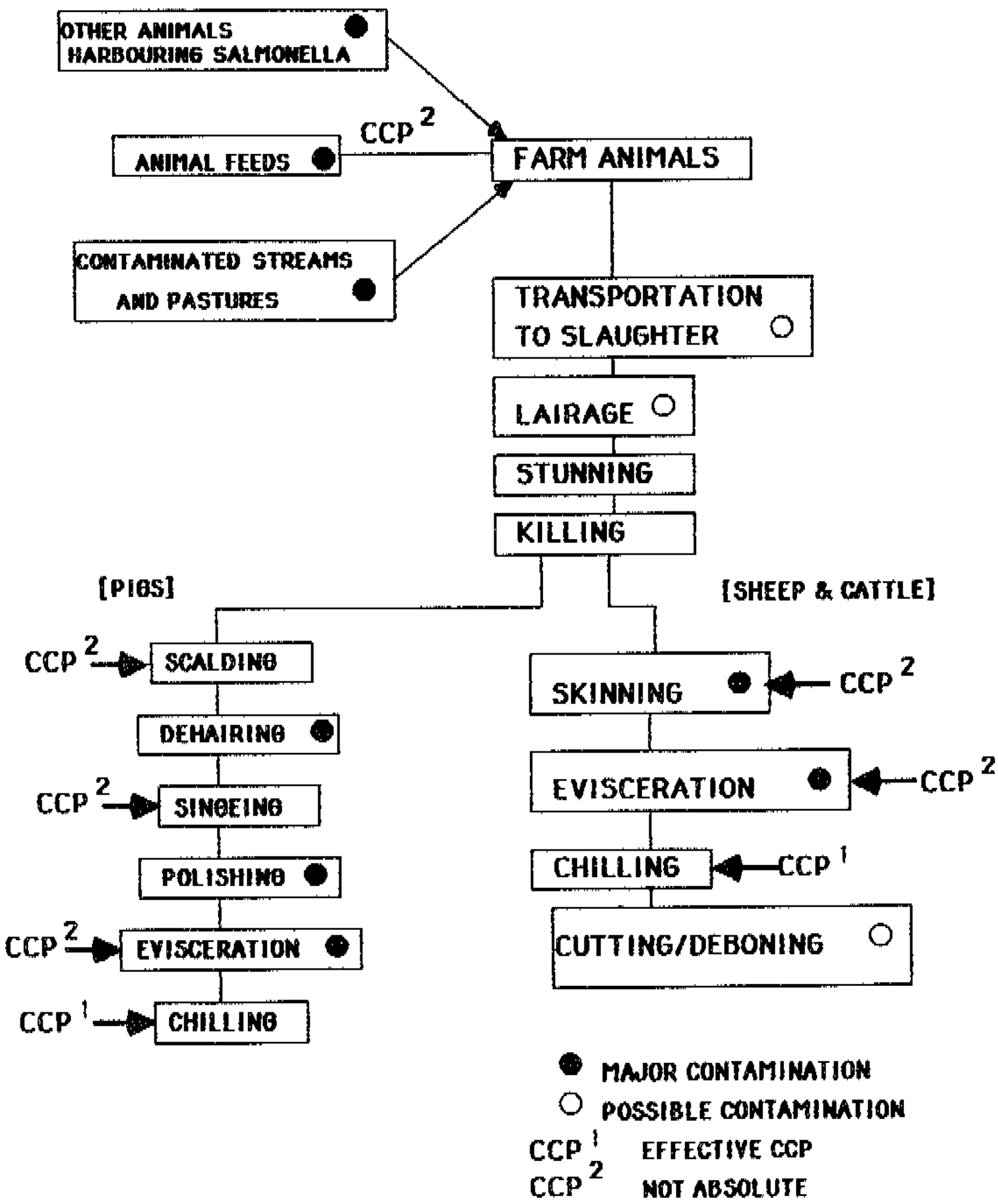

FIGURE 1. FLOW DIAGRAM FOR FARM ANIMALS AND RAW MEAT IN SLAUGHTERHOUSE

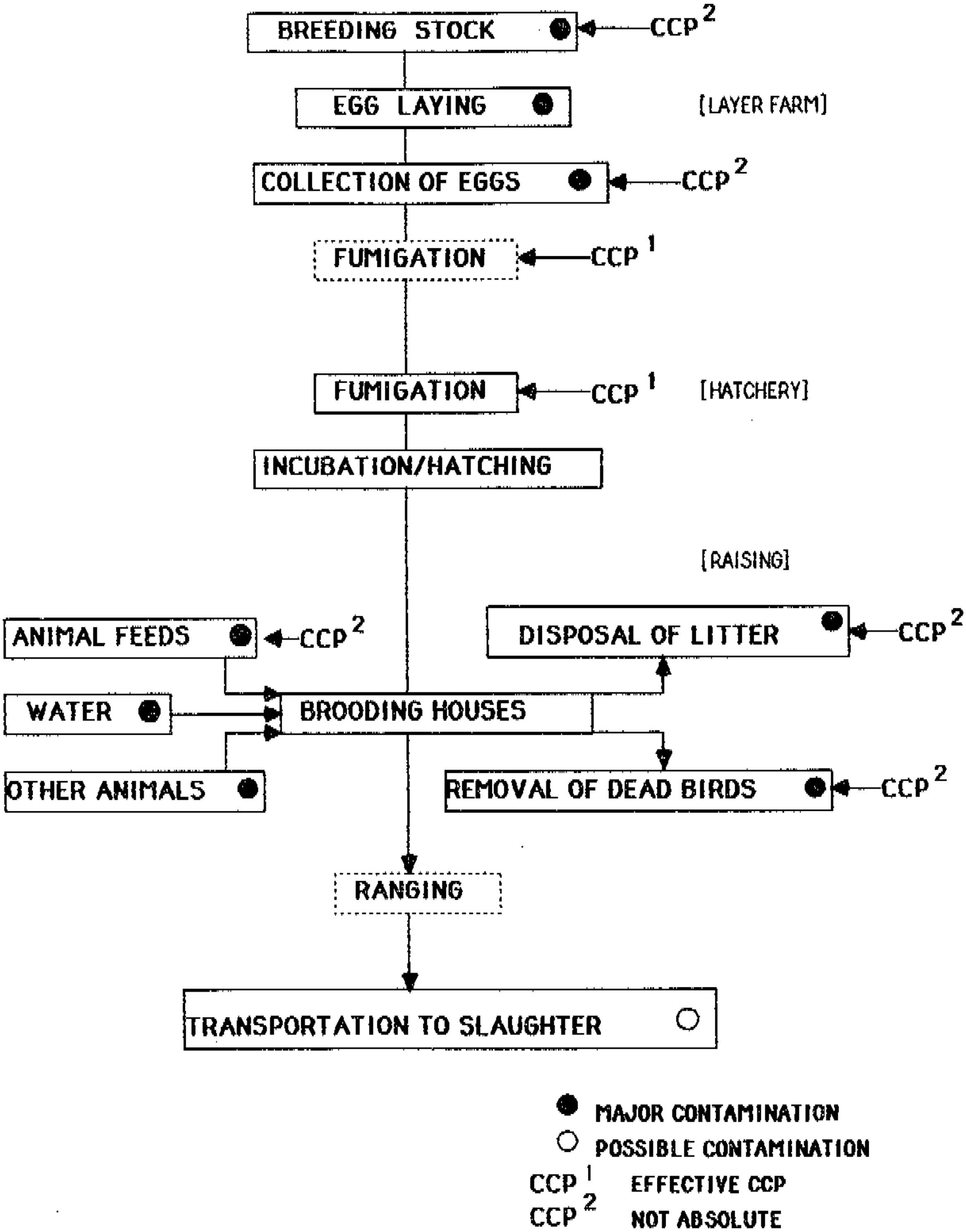

FIGURE 2. FLOW DIAGRAM SHOWING SOURCES OFCONTAMINATION OR CCP IN POULTRY HUSBANDRY.

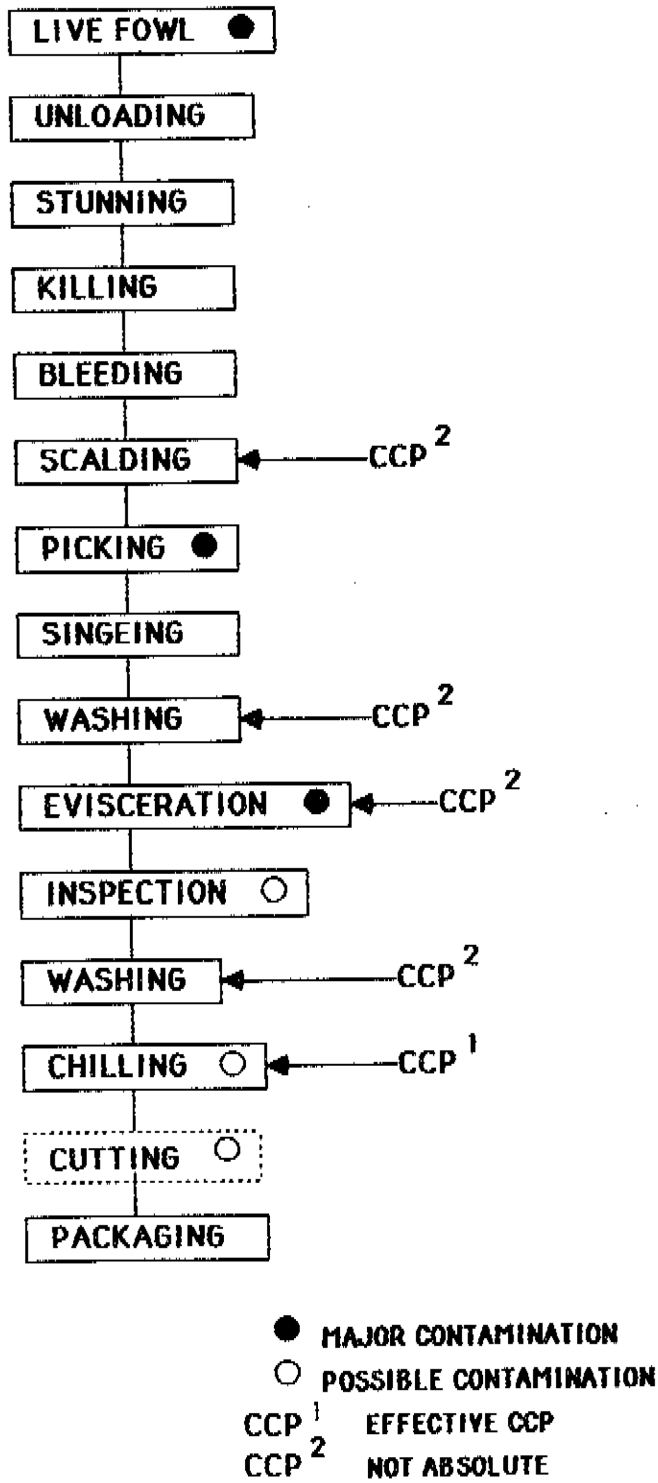

FIGURE 3. FLOW DIAGRAM FOR SLAUGHTERING AND PROCESSING OF POULTRY MEAT.

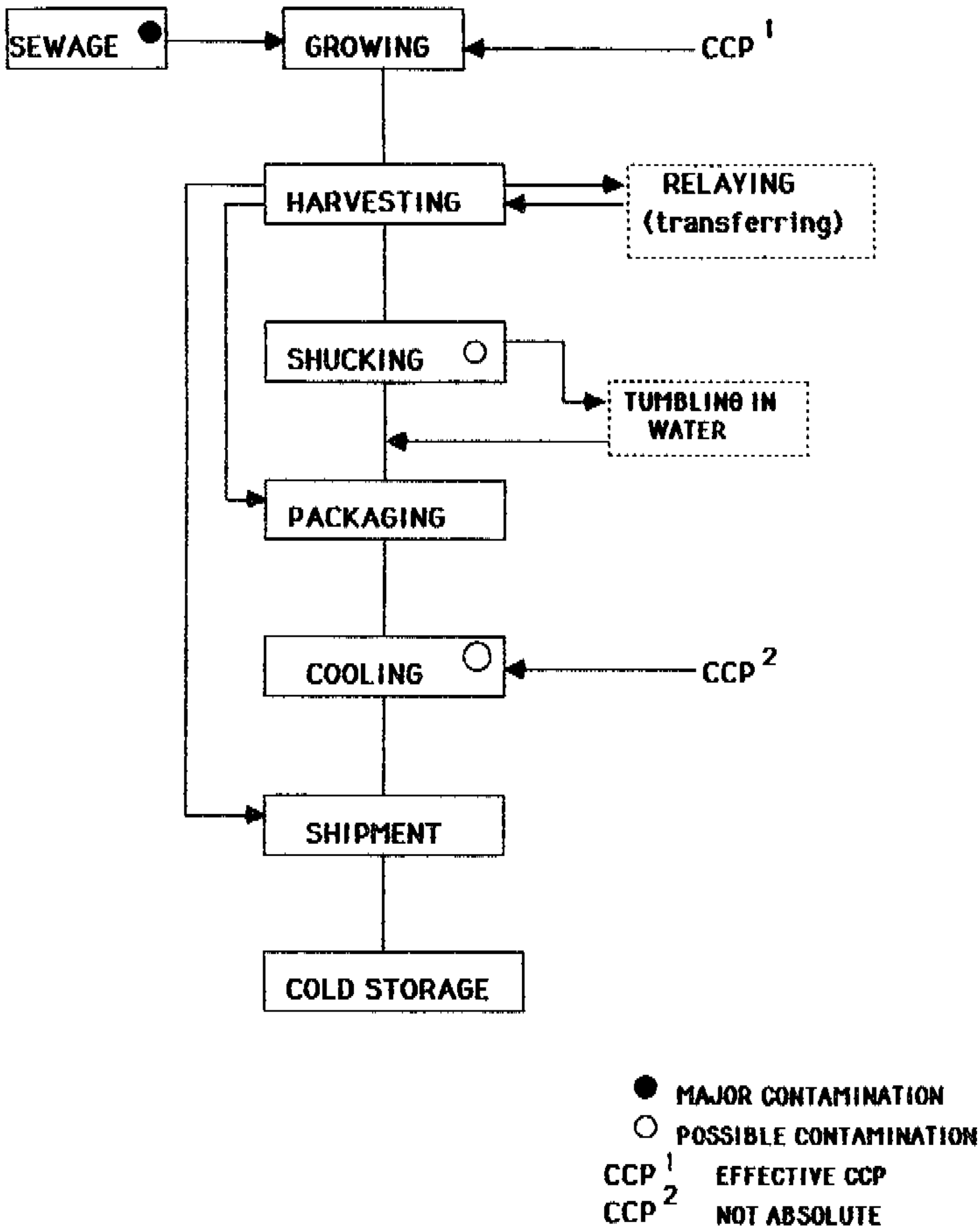

FIGURE 4. FLOW DIAGRAM FOR MOLLUSCAN SHELLFISH.

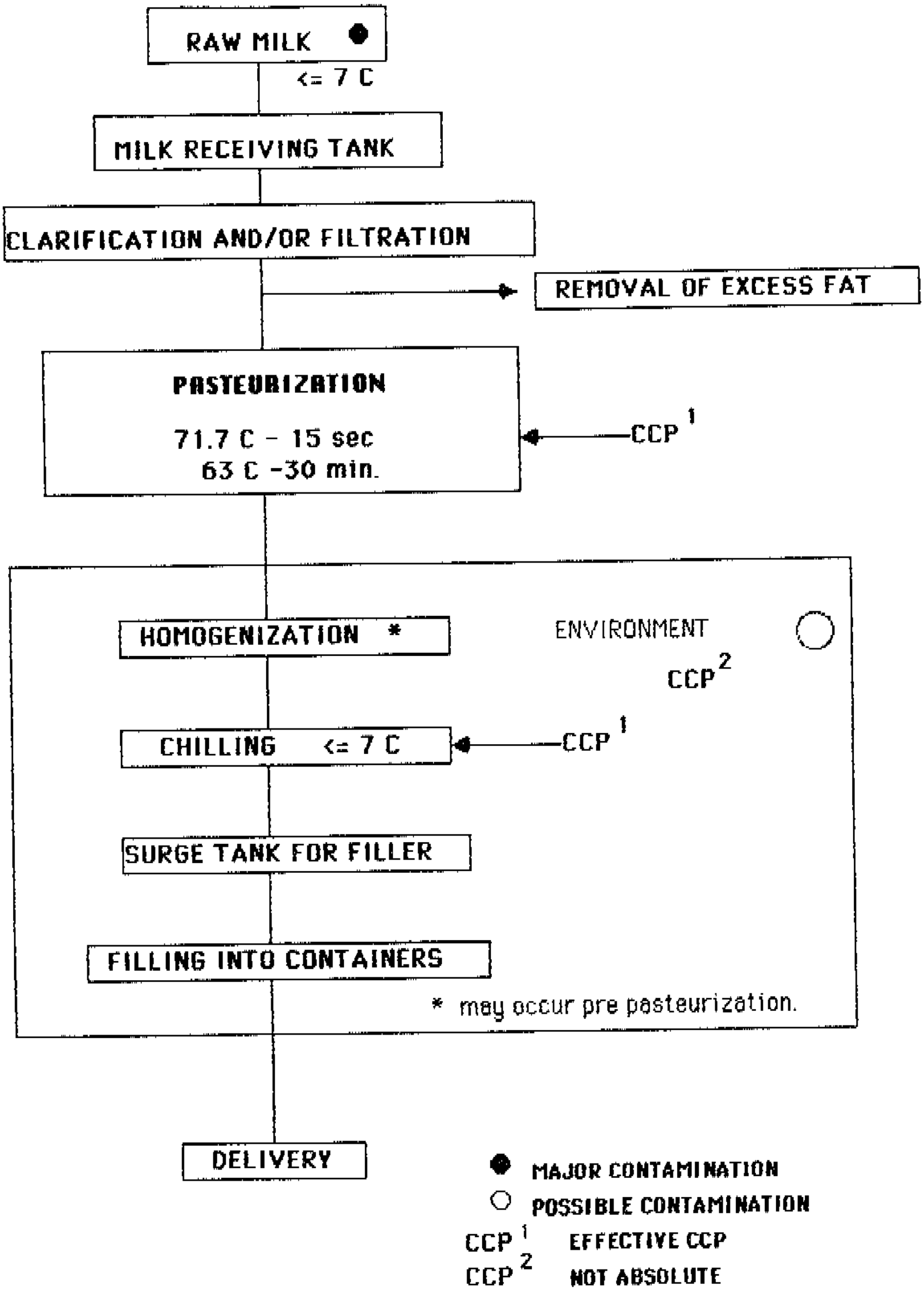

FIGURE 5. FLOW DIAGRAM FOR PASTEURIZED MILK.

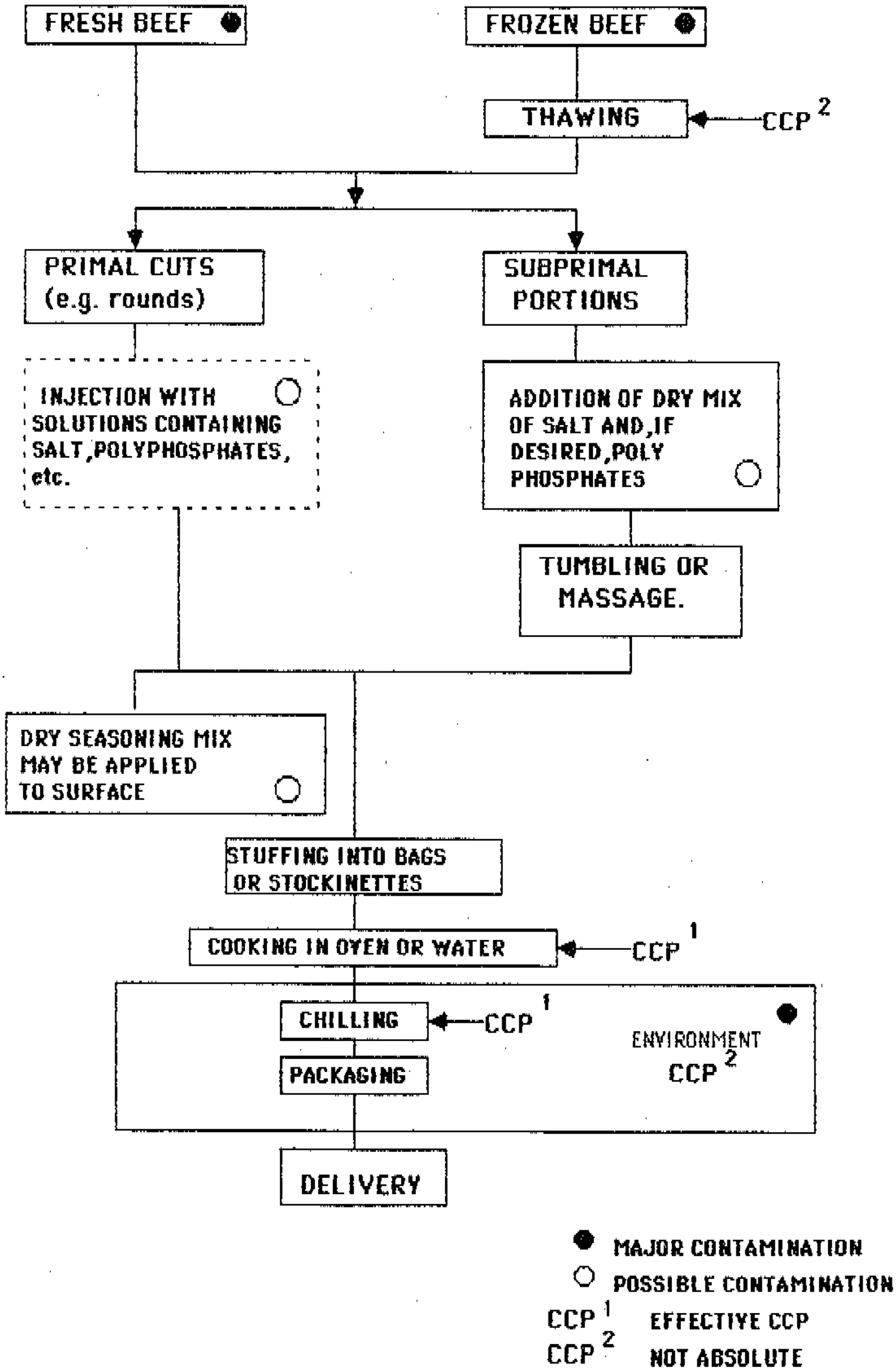

FIGURE 6. FLOW DIAGRAM FOR COOKED BEEF

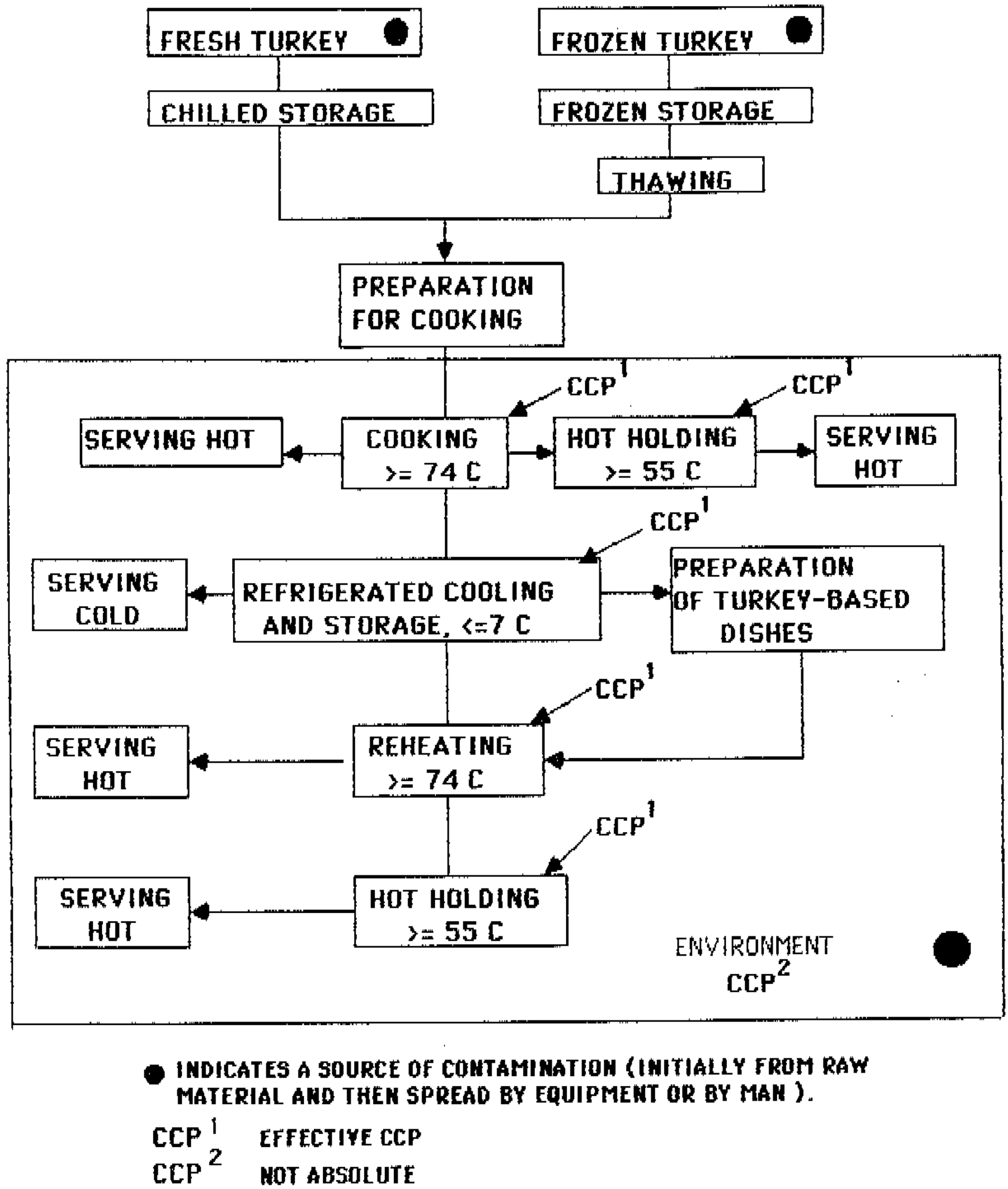

FIGURE 7. FLOW DIAGRAM FOR PREPARATION AND SERVING COOKED TURKEY IN FOOD SERVICE ESTABLISHMENTS OR HOMES.

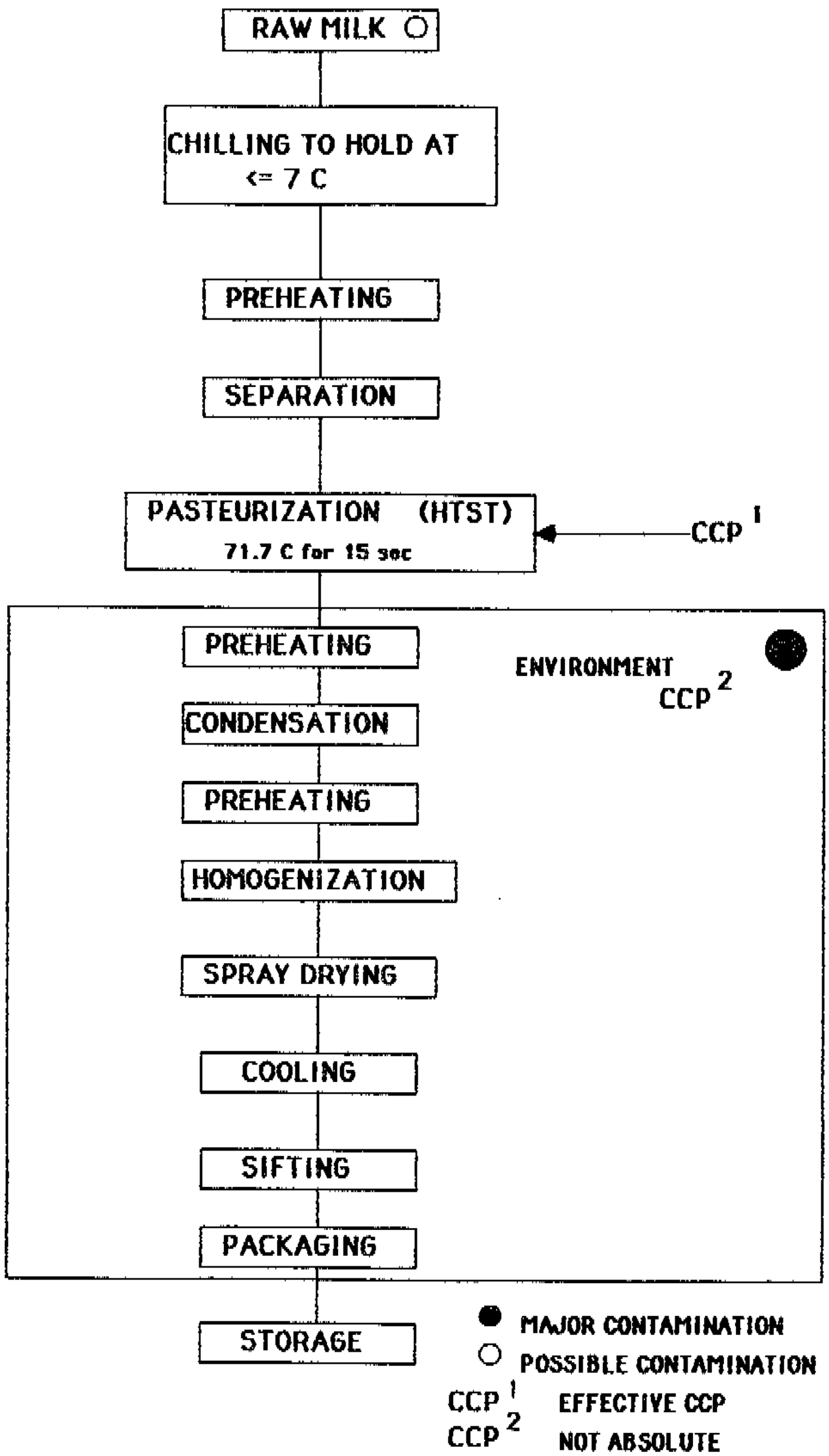

FIGURE 8. FLOW DIAGRAM FOR PRODUCTION OF NON FAT DRIED MILK.

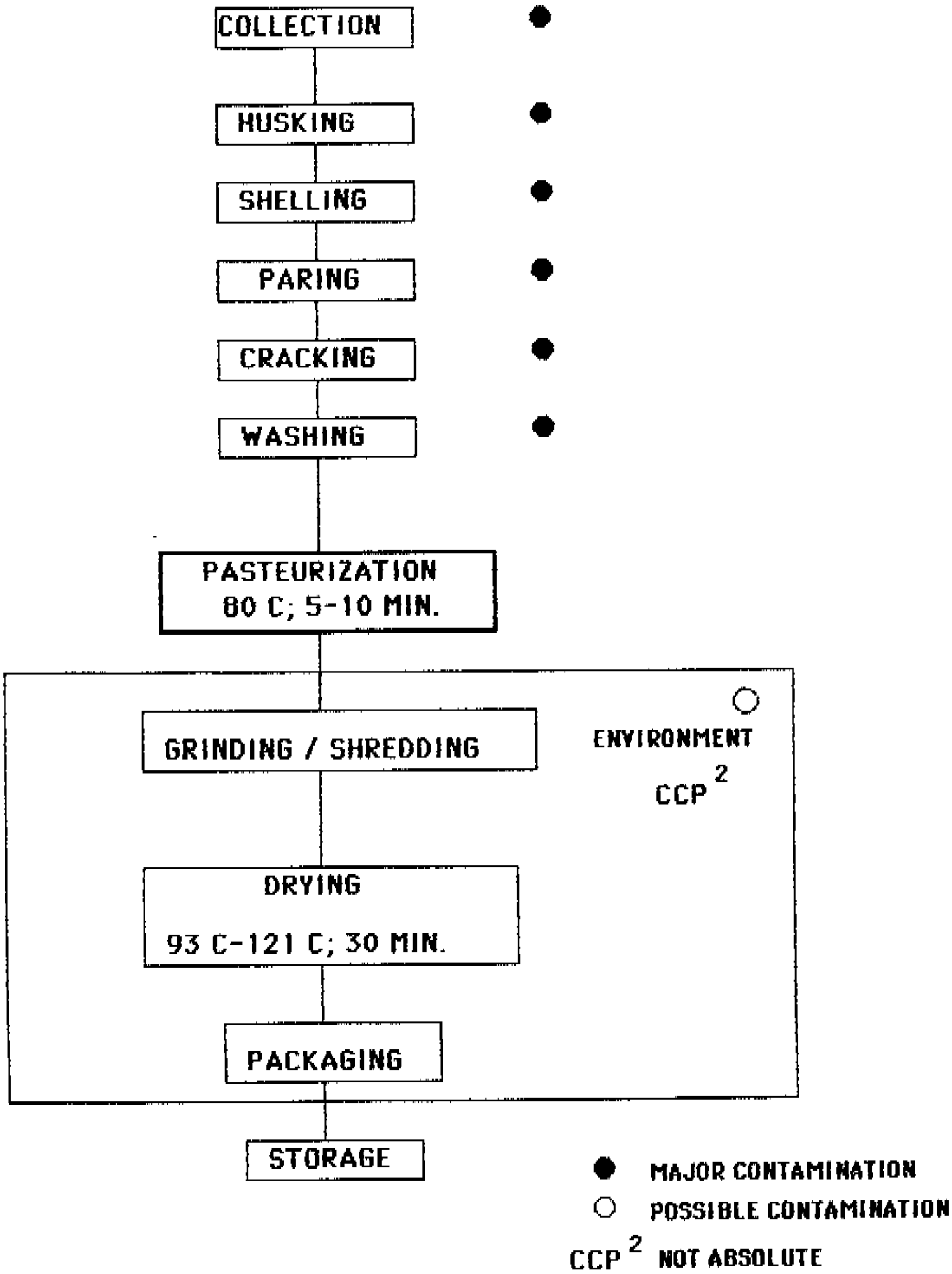

FIGURE 9. FLOW DIAGRAM FOR DESICCATED COCONUT.

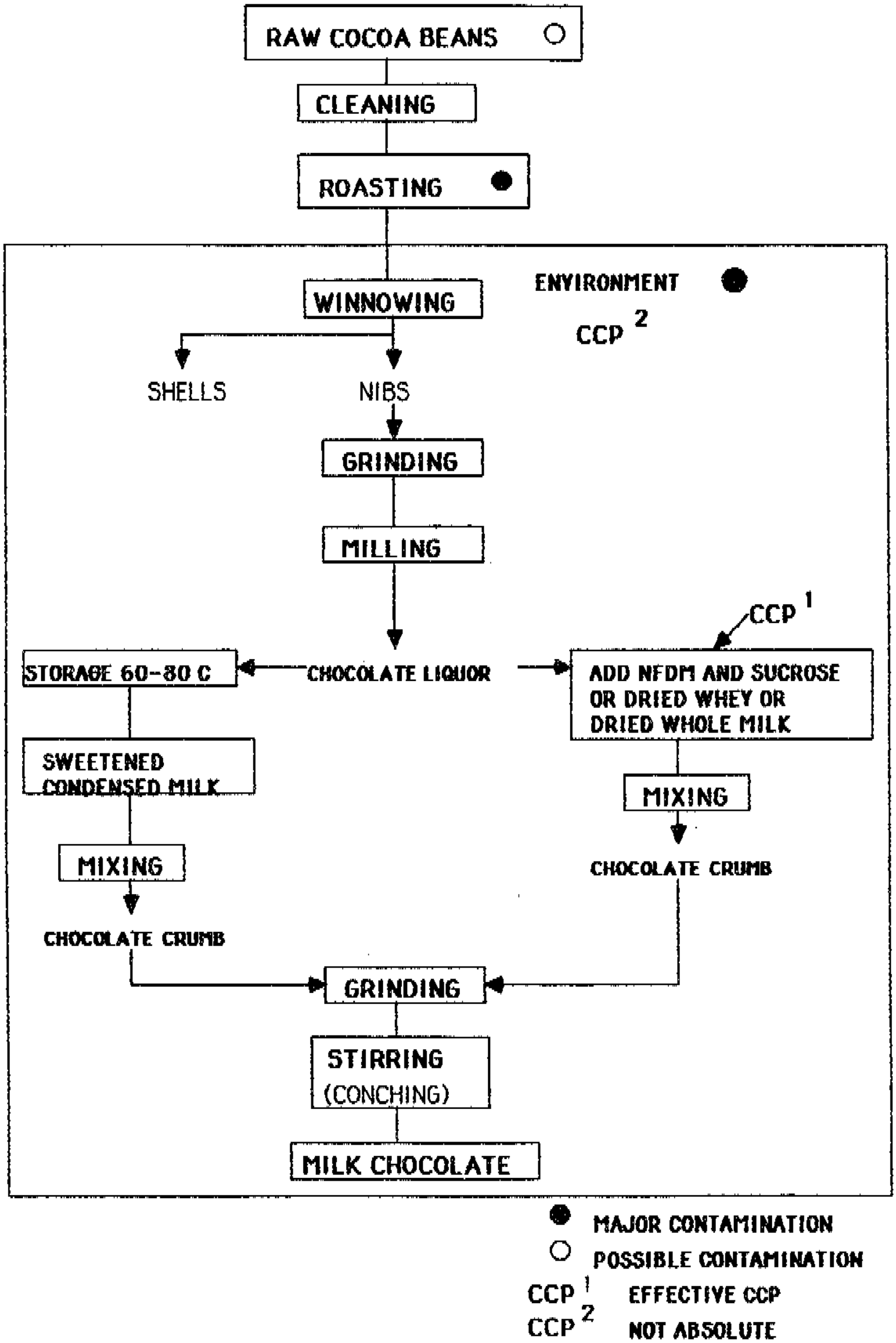

FIGURE 10. FLOW DIAGRAM FOR THE PRODUCTION OF MILK CHOCOLATE

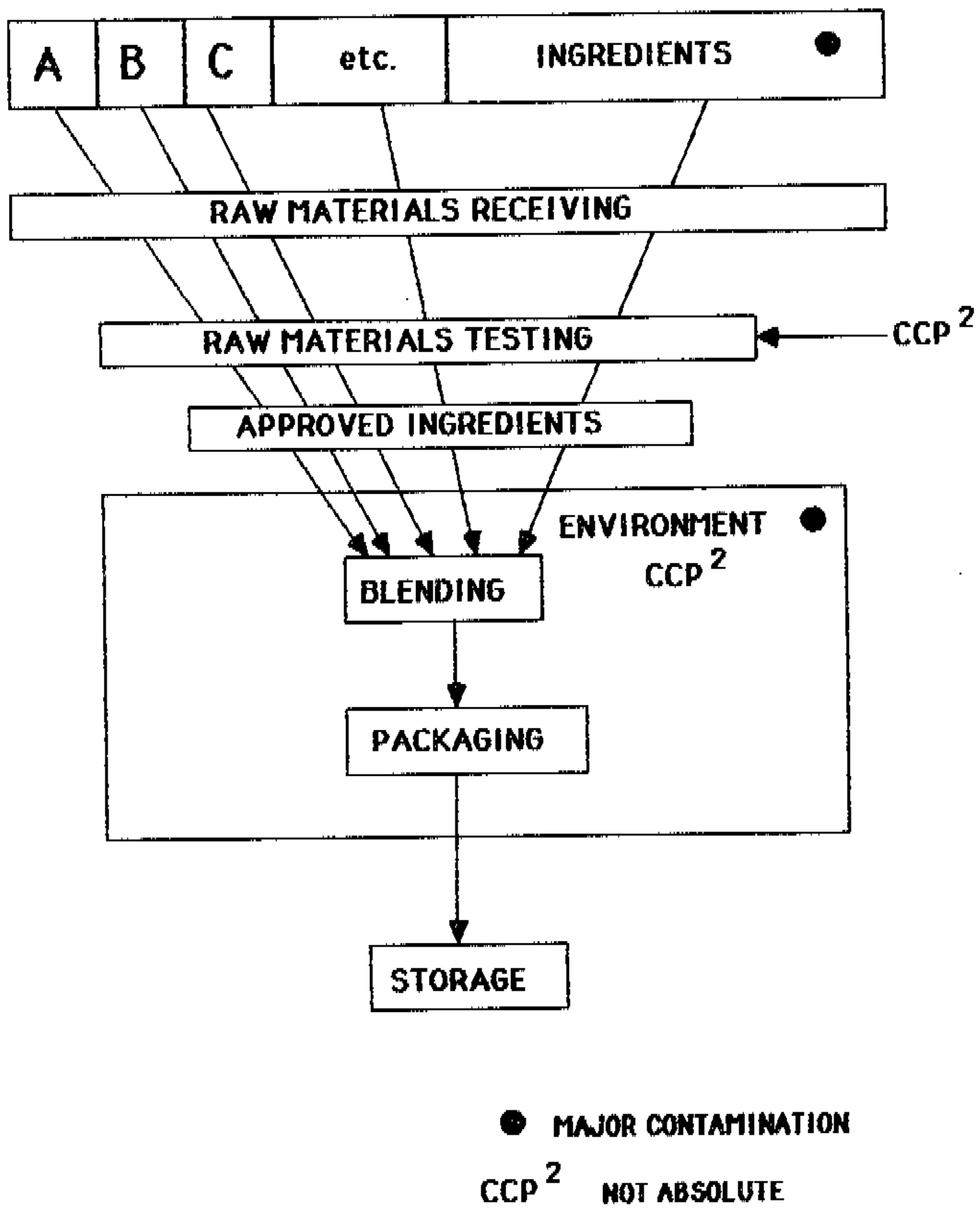

FIGURE 11. FLOW DIAGRAM FOR DRY INFANT FORMULA.

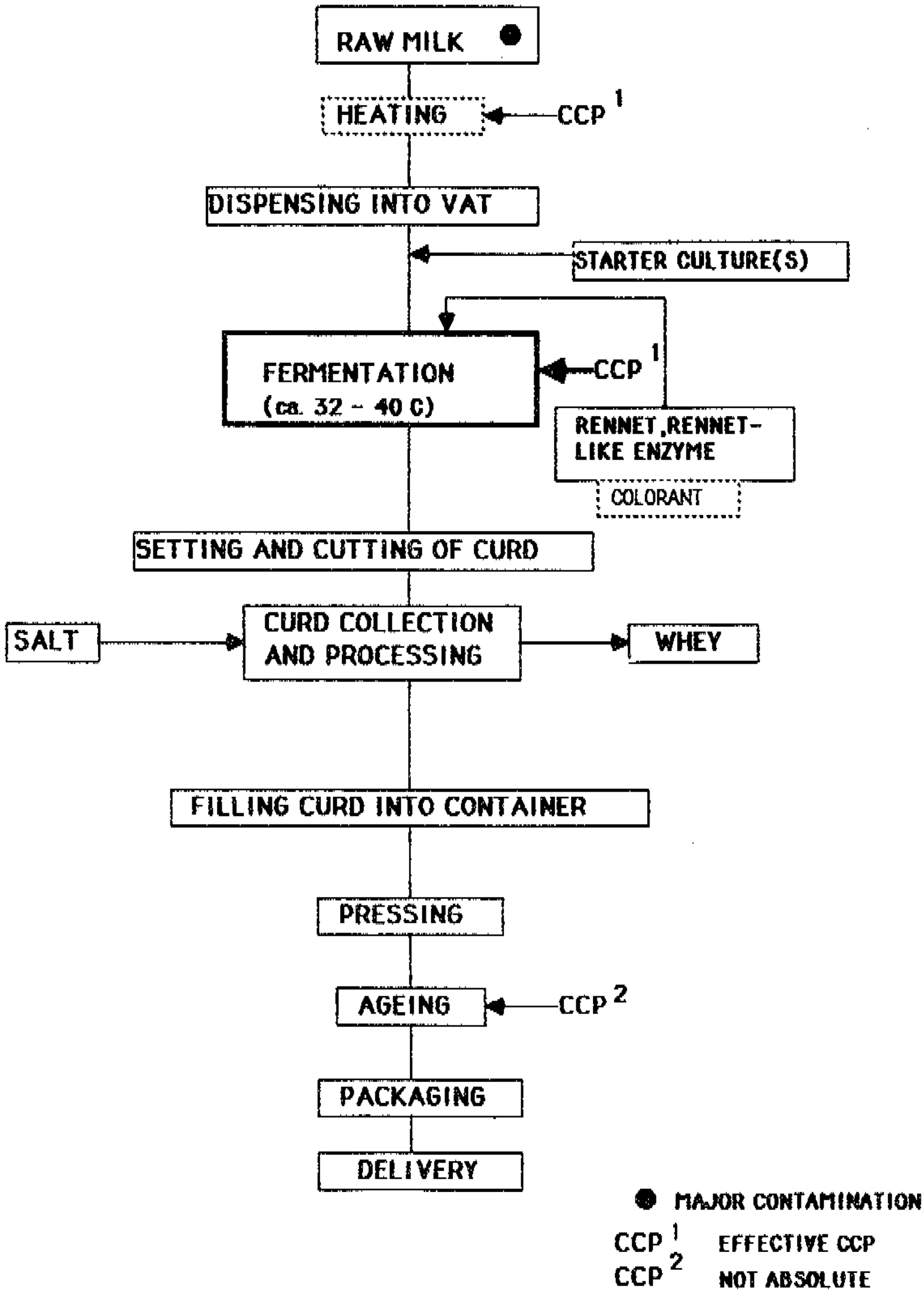

FIGURE 12. FLOW DIAGRAM FOR THE PRODUCTION OF CHEDDAR CHEESE.

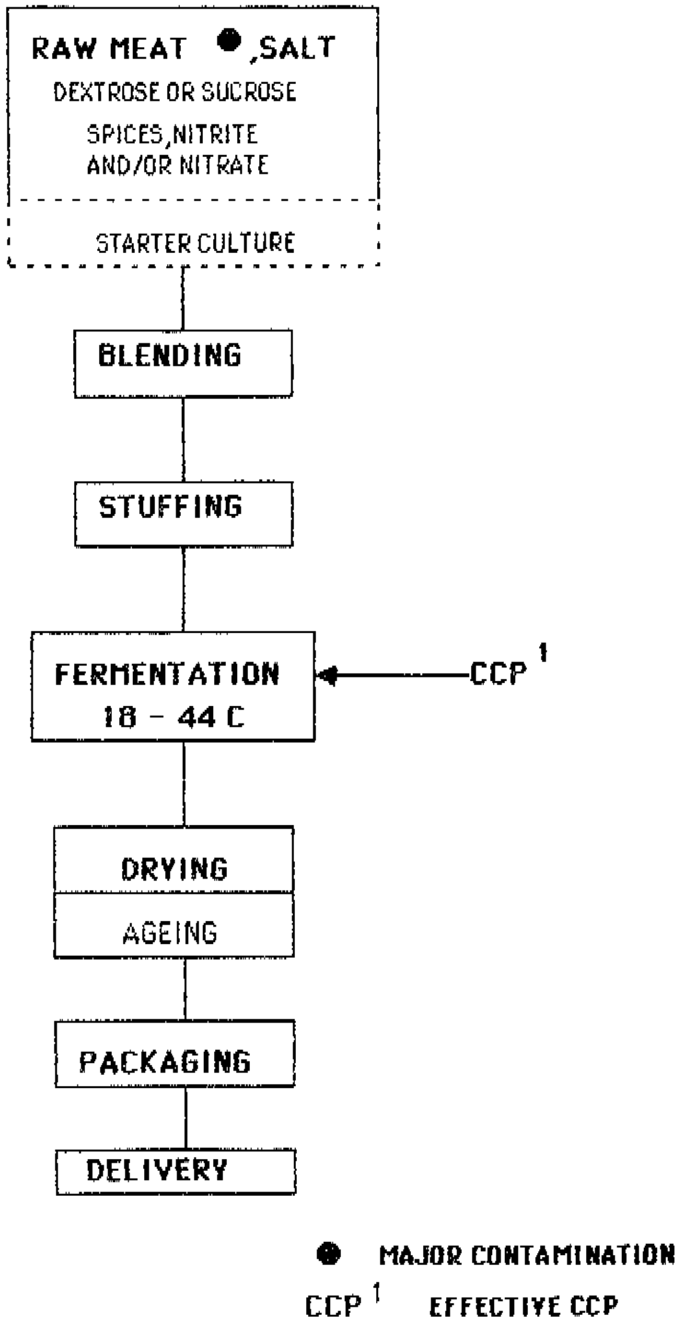

FIGURE 13. FLOW DIAGRAM FOR THE PRODUCTION OF FERMENTED SAUSAGES.

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