HACCP in the chocolate industry

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Over the last 20 years chocolate products have been at the origin of several salmonellosis outbreaks involving mainly children. One of the main characteristics are the very low levels of Salmonella *normally found in such contaminated products. Due to the low water activity, the pathogens are not able to grow but these conditions provide a good protection leading to increased heat resistance and survival. It is therefore necessary to take preventive measures during processing to avoid recontamination of the product after the roasting step which represents the only barrier for* Salmonella. *The particular aspects of the HACCP system for chocolate are described and outlined.*

Keywords: HACCP, chocolate, *Salmonella*

MICROBIOLOGICAL HAZARDS

Introduction

Chocolate and confectionery products have a good safety record. Most products, because of their low water activity, can be kept at ambient temperatures (in temperate climates) for several months or even one or two years. They are not especially susceptible to physical hazards, although occasionally stones or other hard objects can pose a problem in products containing raisins or nuts. Potential chemical hazards are quite limited, depending on agricultural, storage and distribution practices. Mycotoxins do not seem to pose a problem because mycotoxinogenic moulds do not grow or produce toxins inside the beans.

On the other hand, there are a number of microbiological hazards related to these products. Some of these are a source of serious concern. This paper, therefore, deals with microbiological safety exclusively.

Studies on the microbiological aspects of cocoa published up to the late 1960s examined only the fermentation of raw cocoa beans, because of the importance of the process in obtaining beans of a high quality. The microorganisms involved in the different steps were studied extensively to identify them and to define their role and the influence of their metabolism on biochemical changes occurring in the beans.

Certain microbiological problems were found not to be of concern to public health. Spoilage of certain types of confectionery products with an increased water activity by osmophilic yeasts is a phenomenon known to occur periodically (Windisch *et al.*, 1978). However, due to the low water activity ($a_w = 0.4–0.5$) in chocolate, which completely inhibits bacterial growth, this is not even a quality problem. *Listeria monocytogenes* is not a hazard in factories where dry cleaning procedures are applied (Cox *et al.*, 1989).

For a long time, the only measures taken to avoid deviations affecting the quality of chocolate-based products were those related to the organoleptic and physicochemical characteristics. In the mid-1960s, however, several chocolate manufacturers were forced to recall their products after *Salmonella cubana* was detected in a pink summer coating. In response to this, the Food and Drug Administration in the USA began to look at salmonellae in confectionery products and issued the first minimum sanitation requirements, as well as some studies of the behaviour of salmonellae in chocolate products.

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Outbreaks

The real problem of *Salmonella*, however, was not recognized until 1970–1973, after two outbreaks which were clearly linked to the consumption of contaminated chocolate. In Sweden, cocoa powder contaminated with *Salmonella durham* and used in confectionery products caused an outbreak affecting 110 people (Gästrin *et al.*, 1972). In Canada and the USA,

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chocolate candy containing *Salmonella eastbourne* was at the origin of an outbreak involving 200 people, mostly children (Craven *et al.*, 1975; D'Aoust *et al.*, 1975).

In 1982/1983 an outbreak in the UK affecting 245 people, mostly young children, was traced to chocolate bars contaminated with *Salmonella napoli* and which were imported from Italy (Gill *et al.*, 1983). Two outbreaks of salmonellosis linked with chocolate were registered in 1986. Some cases due to *Salmonella nima* reported in Canada were traced back to chocolate coins manufactured in Belgium (Hockin *et al.*, 1989). In Norway, more than 300 children were affected after the consumption of chocolate contaminated with *Salmonella typhimurium* (Kapperud *et al.*, 1989).

These outbreaks over the last 20 years have demonstrated that *Salmonella* represents a real hazard in chocolate and it is still a source of concern. There is little data on the economic impact of most outbreaks, but figures compiled by Todd (1985) and Roberts *et al.* (1989) show that they can have disastrous consequences for the companies involved. Therefore, constant efforts must be made to eliminate or minimize the risks of contamination with *Salmonella* during chocolate production by introducing preventive measures based on the HACCP system and by adherence to good manufacturing practices. Detailed documents on the HACCP system in chocolate manufacturing have been issued by the International Commission on the Microbiological Safety of Foods (ICMSF, 1988) and by the International Office of Cocoa, Chocolate and Confectionery Products (IOCCC, 1991) with a complementary document on good manufacturing practice (IOCCC, 1993).

Several factors which are specific to chocolate products have contributed to the outbreaks linked to them and have to be kept in mind when establishing preventive measure.

Important characteristics of *Salmonella*

The infective dose of *Salmonella* is normally relatively high but is influenced by many factors such as the serotype or strain, the susceptibility of the consumer as determined by age, health and immune status, the number of pathogens able to reach the intestine and to multiply, as well as the type of food consumed.

Remarkably low infective doses have been determined for chocolate: an average of 1.6 cells/g was found for *Salmonella napoli* (Greenwood and Hooper, 1983); of 0.2–1.0 cells/g for *Salmonella eastbourne* (D'Aoust and Pivnick, 1976) and as low as 0.005–0.025 cells/g for *Salmonella nima* (Hockin *et al.*, 1989). These very low infective doses may be linked to the short intragastric residence and the high percentage of fat in chocolate, which serves as a protection from gastric acids (Tamminga *et al.*, 1976: D'Aoust, 1977).

Another important characteristic is the persistence of the pathogens in naturally contaminated chocolate; periods of several years have been reported (Rieschel and Schenkel, 1971; Dockstäder and Groomes, 1971; Tamminga, 1979). Furthermore, the pathogens show a strongly increased heat resistance in chocolate, which may be due to the low water activity and the protective effect of fat. This means that the temperatures of 70–80°C reached during milling, refining and conching do not destroy the pathogens (Goepfert and Biggie, 1968). Trials performed with small numbers of *Salmonella senftenberg* showed that even overheating ($\geq$100°C) the product does not guarantee complete destruction.

RAW MATERIALS

The production of cocoa powder, chocolate and part of the confectionery products is a dry operation which does not destroy *Salmonella* or other vegetative organisms. Therefore, the quality of the raw materials used during manufacturing is very important and will determine the quality of finished products.

Simple visual checks at reception are useful tools to guarantee raw materials of good quality. Presence of condensation in containers or of spoiled packaging material represents a risk.

Hygienic conditions at the reception area of bulk materials, such as liquid chocolate masses or sugar, are important; pipes and valves as well as air-intake of pneumatic transport systems should be controlled. Containers such as tanks for chocolate masses can be CCPs requiring precise cleaning procedures.

Correct handling of raw materials is an important part of the preventive system. Therefore strict separation of high-risk from low-risk raw materials is necessary during reception, handling and storage to avoid cross-contamination.

Raw materials of agricultural origin

Raw materials such as raw milk, untreated raw cocoa beans or nuts may become contaminated with *Salmonella* if they are produced under unhygienic conditions. These raw materials, however, are not CCPs because these organisms are destroyed further along the line.

For such raw materials, the heat treatments must be carefully monitored (CCP1; see below under heat treatment) and strict measures applied (CCP2; see below under environment) to prevent cross-contamination or recontamination with untreated raw materials.

Processed raw materials

Certain processed raw materials such as dairy products, cocoa liquor or powder, crumbs or cocoa butter, gelatine, egg products, flours and starches, lecithin and coconut represent an important potential risk (CCP2). These raw materials should be chosen carefully and purchased from suppliers working according to good manufacturing practices (GMP) and applying an effective HACCP system which can be verified by discussions and audits. When this cannot be done, analysis for *Salmonella* must be carried out. Analyses for coliforms or Enterobacteriaceae and for aerobic mesophilic counts can provide additional information on the hygienic status of the materials. However, *Salmonella* analysis has certain limitations due to statistical and methodological aspects; thus, prevention should, in principle, not be based on analyses and certificates.

Low-risk processed raw materials, such as sugar, flavours, roasted nuts or processed cereals, should be treated in the same way but the number of analyses can be reduced. For new ingredients, risk can be estimated and adequate preventive measures applied only if their characteristics, such as origin, conditions of processing and analytical data, are known.

Rework

Rework should be handled as a high risk raw material. It should be clearly identified and strictly separated from waste. Preventive measures taken during collecting, handling and storage can be monitored visually, and microbiological analyses performed for confirmation.

Water

Water, although normally not in direct contact with the product, is an important raw material used in large quantities during processing. It should be of good microbiological quality to avoid the risk of contamination through micro leaks in double-walled systems: pipes, tanks and equipment. Closed or protected systems should be used to avoid ingress of nutrients favouring microbial growth. Furthermore, systems should be checked for leaks and if possible fitted with biocide dosing systems. Regular microbiological checks should be performed.

Air

Air directly introduced in the product or in zones where the product is exposed must be filtered to ensure safety of the product. Monitoring is best done by regular microbiological analyses of filters and water traps and by visual checks ensuring their integrity and function.

PROCESSING

Heat treatment

The occurrence of basic biochemical reactions at the roasting step makes it the most important step in the development of chocolate flavour (Zak, 1988). Even though manufacturers accept certain general principles of roasting, many of them apply their own specific conditions, mainly based on experience, to obtain the desired effect (Martin, 1987).

From a microbiological point of view, roasting of beans, nibs or liquor is the only step common to all processing lines having a lethal effect on *Salmonella* and other vegetative germs. Depending on the parameters, destruction of certain *Bacillus* spores can also be achieved. Other processing steps applied in manufacturing cocoa and chocolate-based products have the same lethal effect: pasteurization and sterilization of beans or liquor; alkalization (dutching); bleaching, dry or oil roasting of nutmeats; cooking of fillings and baking of biscuits.

All these steps have to be considered as CCP1 according to the HACCP terminology.

New systems, particularly those offered to pasteurize or sterilize beans, nibs or liquor, must be evaluated. Once validated, the critical parameters such as time, temperature or humidity conditions need monitoring.

Due to the characteristics of the product, i.e. a high proportion of fat and a low water activity, the manufacturing steps such as grinding, milling or conching following roasting or other heat treatment mentioned above have no lethal effect on *Salmonella* or other vegetative organisms in case of prior recontamination. Decontamination procedures involving the addition of small amounts of water as described by Barrile and Cone (1970) should be carefully validated (microbiological and organoleptical parameters).

Environment and layout

Preventive measures to avoid recontamination during further processing are very important in this industry because of the low infective doses of *Salmonella* in chocolate products. In this respect the environmental aspects, buildings, premises, equipment as well as personnel, play an important role (CCP2). It is important to realize that these measures increase, but do not guarantee, product safety.

The location of a new factory can be chosen to minimize risks. For existing factories, however, the location and climatic conditions are already determined. Microbiological analyses for monitoring are of limited use but potential risks should be analysed.

Elimination of residues and maintenance of external installations and premises in the immediate environment of production zones are necessary to avoid attracting birds, rodents and insects known to be vectors for microbial contaminants. Monitoring involves regular visual inspections of surroundings, and of the status of walls, roofs, windows and doors which represent barriers towards external zones.

Internal zones may be subdivided into unclean and clean zones. Certain internal unclean zones, such as storage rooms, cleaning rooms or zones where untreated raw materials of agricultural origin are handled, are likely to be contaminated with *Salmonella*. Therefore, these zones must be physically separated from other clean processing areas to avoid cross-contamination or recontamination of processed products. Visual inspections should be used to monitor these zones; analyses of environmental samples for *Salmonella* or indicator organisms provide information of only limited value.

Zones located after the barrier represented by roasting or other heat treatments are clean zones which must be physically separated to prevent recontamination. A linear and logical layout of production lines favours the establishment of such physical barriers. Walls and openings in direct contact to external or unclean zones must be controlled or blocked. Potential bypasses, such as air conditioning and transport systems, must be kept under control.

In the case of personnel, application of the usual good hygienic practices is necessary but must be accompanied by a strict control of movements. If necessary, adequate measures such as hygienic junctions between clean and unclean zones, (requiring shoe changes, for example), should be installed to maintain an efficient separation. Vehicles such as forklift trucks, or tools such as vacuum cleaners, must also be confined to defined zones, clean or unclean.

Since production of chocolate, cocoa powder and certain confectionery products are considered to be dry operations, it is important to separate dry and wet zones. Installations and rooms used to clean equipment must be separated from dry zones. In these dry zones it is necessary to avoid wet cleaning as much as possible. If unavoidable, water residues must be eliminated and wet spots dried immediately to eliminate the risk of microbial development.

Condensation is another potential source of microbial growth. Appropriate design of rooms and adequate insulation of pipes or equipment are important to minimize the risks.

Microbiological analyses (*Salmonella* and Enterobacteriaceae) of samples taken at critical points can be performed to confirm the effectiveness of the system (Cox *et al.*, 1988). Particular attention should be paid to access points from external zones, to weak points in the separations and to residues.

Corrective measures should be taken in response to critical situations such as positive *Salmonella* results or increases in the counts of Enterobacteriaceae: cleaning and disinfection, modification of the separation measures, increased sampling of environmental and product samples. Verification of the effectiveness of these measures is necessary.

The hygienic status of equipment must be confirmed by appropriate samples such as product, swabs or contact plates. A particular attention must be paid in case of work or modifications performed by technical services coming from unclean zones and representing an increased risk.

FINISHED PRODUCTS

If a proper HACCP system is applied, analyses of finished products are performed only for verification. The frequency of sampling must take into account the general conditions described above as well as to the specific features of the factory and the line. When results indicate that the line is not under control, the HACCP plan should be reviewed.

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