Salmonella in low-moisture foods and environments: challenges and control strategies

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Introduction: Food safety
- The ability of pathogenic microorganism to gain entry into food supply systems remains a major public health challenge & concern.
- Each year, foodborne illness outbreaks affect millions of people and kill thousands.
- Tainted food has cost the food industry billions of dollars in recalls, lost sales and legal expenses.
- Additionally, these outbreaks undermine consumer confidence in affected products, and diminish market demand.

Challenges in low moisture foods and environments:
- Low water activity ($a_w$) processing environments present altogether a different food safety challenges than those found in higher $a_w$
- Introduction of water can:
  - Cause microbes to multiply fast and contaminate the food products and environments
  - Reduce the shelf life of the finished products
- Food processing equipment and nonfood-contact surfaces must be cleaned before sanitation
- Dry sanitation technique need to be implemented
- Care should be taken to design new processing equipment or retrofitting may be employed in case of old equipment

Common misconception
Low moisture foods (including some bakery products) and environments are considered to be safe, as they do not support the growth of microorganisms including harmful pathogens.

Facts and reality
Research clearly indicates that pathogens, including Salmonella can survive in adverse conditions such as low moisture environment for a long time (Hiramatsu et al. 2005; Janning et al. 1994; Juven et al. 1984).

Why Salmonella?
- Leading human foodborne pathogen in the U.S. & around the world
- Responsible for more deaths than any other known human foodborne pathogen
- An estimated 1.2 million cases occur annually in the US
- Salmonella form biofilms on contact surfaces such as glass, stainless steel, glazed tile, plastic, and are very resistant to cleaning & sanitation practices (Corcoran et al. 2013)

Factors contributing *Salmonella* survival:
- The factors that can cause *Salmonella* contamination in low-moisture foods are (but are not limited to):
  - poor building and equipment design
  - poor quality ingredients
  - poor cleaning and sanitation practices
  - poor pest management practices
  - lack of validation etc.
- *Salmonella* can adapt to extreme environmental conditions such as low water activity, pH (can survive at pH 3.8 and 9.5 (optimal 6.5 to 7.5)) and varied temperature conditions (2-54°C (optimal 35-37°C)).

Factors affecting *Salmonella* survival in food:
- As the water activity ($a_w$) of the products becomes limited, the probability of *Salmonella* growth is reduced; however, the ability of the remaining *Salmonella* survival is greatly increased.
- The survival is affected by nutritional composition of the products:
  - *Eg:* *Salmonella* showed highest resistance in low water activity and high fat foods.
- The location (internal vs external) of *Salmonella* cells in a product is also critical for its long term survival.
- The storage conditions, the strain and serotypes also play an important role in *Salmonella* survival for long period in low-moisture foods and in environments.

Sources of *Salmonella* in a bakery
- Many of these products are often ingredients in bakery and can consequently drive further recalls of those products.

FDA’s food safety concerns:
- *Salmonella* cannot grow in low moisture foods & environments but, it can survive.
- Survival can occur for long periods of time
- Longer shelf life of low moisture foods
- Increased heat resistance at low moisture conditions
- Low numbers of *Salmonella* can cause illness
- If low-moisture ingredients or foods are rehydrated during manufacturing or preparation, then bacteria grows fast thus increasing the health risk to consumers

*Salmonella* in bakery products
- The U.S. baking industry (approx. ~$30 billion market value per year) traditionally had a very safe record for the production of shelf stable processed foods
- Pathogens such as *Salmonella* spp. can be introduced into bakery products through a wide range of ingredients such as egg (Board 1969; FSIS 1998), milk products (El-Gazzar et al. 1992; Ahmad et al. 2000), flour (Richter et al. 1993; Dack 1961), milk chocolate (D’Aoust 1977), coconut (Goepfert 1980), peanut butter (Scheil et al. 1998), fruit (Golden et al. 1993), spices (Hara-Kudo et al. 2000) and yeast flavorings (Joseph et al. 1991)
- The presence of *Salmonella* spp. in bakery products could create a public health risk if the product is improperly baked

The need:
- Reducing risks from foodborne pathogens is an essential part of every food manufacturer's responsibility to protect both its customers and its business.
- U.S. regulatory agencies instituted ZERO tolerance standards for pathogens such as *Salmonella*, *E. coli* O157:H7, and *Listeria monocytogenes* in ready-to-eat products.
- Since *Salmonella* are able to persist in low-water activity foods & processing environments it is vital to employ mitigation strategies to control *Salmonella* occurrence.
How to control *Salmonella* in low moisture foods and environments?

- Consider points of entry for microorganism
- Understand the factors that influence the survival of *Salmonella* in low-moisture food and environments
- Building and equipment design
- Effective implementation of preventive controls, prerequisite programs (GMPs, HACCP)
- Inspection and auditing
- Effective corrective action
- Process validation or kill-step validation

Possible entry points of microorganism

- Raw materials/ingredients
- Air
- Water
- Personnel
- Contact materials/surfaces
- Pests

Control strategies: Raw materials/Ingredients

- In most cases ingredients are the primary source of contamination
- Ingredients are increasingly being tested by food processors and customers
- In most cases positive finished product tests have led to positive ingredient tests and recalls
- Ask for COAs and conduct testing where necessary

Control strategies: Pest management

- Pests (insects, birds, rodents etc.) can act as a potential source of contamination

Control strategies: Effective GMPs

- Personnel practices
- Building and equipment design
- Production and process controls
- Sanitation and cleaning practices
- Storage and distribution
- Environmental monitoring program (EMP)

Preventive control: Environmental Monitoring Program

Why do we need an Environmental Monitoring Program (EMP)?

- Microorganisms are generally introduced into the food processing environment through raw materials, pests, air, water, and employees.
- If contamination levels are high or sanitation procedures are inadequate, microorganisms may establish and can contaminate food products, leading to foodborne illness outbreaks.
- A substantial amount of foodborne illness outbreaks results from poor environmental controls and/or hygiene practices.
- Hence, it is critical to maintain and monitor the hygienic environment in the food processing facility.
Benefits of EMP

An effective EMP:
- Will measure the overall effectiveness of:
  - Sanitary design
  - Personnel practices
  - Operational methods
- EMP will verify that cleaning and sanitizing procedures are:
  - Keeping indicator organisms and any organisms of particular concern in check
- Will assess the risks posed by pathogen of concern
- Keep in mind that EMP does not make food safe.

EMP is not designed to validate the effectiveness of cleaning and sanitizing methods, but is more focused on validating cleaning and sanitizing frequencies, and all the programs of the Good Manufacturing Practices (21 CFR).

What is validation?

- As food safety management moves toward risk-based food management, food manufacturers will need to provide scientific evidence that their foods comply with current safety standards
- A preemptive scientific evaluation providing documentary evidence that a particular process is capable of consistently delivering a product, meeting its pre-determined specifications
- A collection of scientific evidence
- Often expressed as "log reduction".

What FDA FSMA says?

- What would constitute validation?
  (Proposed § 117.150(a)(2))
  The proposed rule would require that the validation of preventive controls include collecting and evaluating scientific and technical information or, when such information is not available or is insufficient, conducting studies to determine whether the preventive controls, when properly implemented, will effectively control the hazards that are reasonably likely to occur
- The owner, operator or agent in charge of a facility would need to conduct controlled scientific studies to establish that a preventive control measure is adequate to control the hazard

Scientific validation is the only way to confirm that a particular process is consistently delivering a desired lethal effect (heat in this case) to ensure the destruction of pathogenic microorganisms; often expressed as "log reduction".

Benefits of process or kill-step validation:

- Pathogen free bakery products assuring greatest safety possible
- Protects consumers, builds confidence and increases demand
- Helps in determining an effective treatment
- Demonstrate compliance with the FDA-FSMA act.
- Can save bakery industries millions of dollars by avoiding recalls and other legal penalties due to foodborne illness outbreaks
It's the responsibility of the food manufacturer to make the finished product safe. Salmonella can survive low moisture conditions, and may grow if the facility is unable to control the introduction of water. It is important to understand the factors that influence the survival of Salmonella in low-moisture food and environments. Effective implementation of preventive controls, GMPs, HACCP plan, and process validation or kill-step validation is vital to prevent, and to control Salmonella getting into the finished products.

References