PATHOGENS

QUESTION:

What procedures are followed to minimize the risk that food ingredients from the corn wet-milling industry will contain microbial pathogens that might pose a significant health risk in food products?

Summary

The Corn Refiners Association, Inc. (CRA) member companies manufacture a variety of dry and liquid food ingredients. Use of corn wet-milling ingredients in the preparation of foods and beverages has not been shown to be a contributing factor for food-borne illness from pathogenic microorganisms. Implementation of Good Manufacturing Practices (GMP) and quality management systems in CRA member company plants are designed to work synergistically with the natural physical and functional properties of corn syrups and sweeteners, starches and acidulents to provide a deterrent to the growth of pathogenic microorganisms:

- CRA member companies continue to seek ways to reduce the likelihood of incidental product contamination by implementing GMP and quality management systems to complement existing finished product testing.
- An inhospitable environment for microbial pathogens is created by low product pH, low water activity, high percentage dry substance and high processing temperature.
- There is convincing experimental data to demonstrate not only the growth inhibitory (bacteristatic) effect of liquid and dry corn syrups, sweeteners, starches and acidulents, but also the ability of these products to destroy (bactericidal) contaminating pathogens, should any be present, during transportation and storage.

1. Microbial Causes of Food-Borne Illness

The FDA's *Center for Food Safety & Applied Nutrition* publishes a "Bad Bug Book"[1] that lists common food-borne pathogens. A list of selected pathogens of greatest interest to the general public is presented in Table 1, along with information about pathogen origin and transmission.

Pathogens on the list range from the relatively rare (*B. cereus*, *Clostridium botulinum*, *E. coli*, *Streptococcus* spp. and *V. cholerae*) to the more common (*Campylobacter jejuni*, *Clostridium perfringens*, *L. monocytogenes*, *Salmonella* and *Shigella* spp. and *Y. enterocolitica*).

Most food pathogens are of soil or intestinal origin, and are transmitted through poor food preparation, personal hygiene or public sanitation practices. It is significant that as of 2000, no documented pathogen outbreaks have ever been related to corn wet-milled products.

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Table 1: Examples of food-borne pathogens—origin and transmission.

Pathogen	Origin	Transmission
Bacillus cereus		Meats, milk, vegetables and fish; starchy products like rice, potato & pasta; cheese products; sauces, puddings, soups, casseroles, pastries and salads
Campylobacter jejuni	Found in intestinal tracts of animals & birds, raw milk, untreated water and sewage sludge	Transmitted by contaminated water, raw milk, and raw or undercooked meat, poultry or shellfish
Clostridium botulinum	Widely distributed in nature: in soil & water & honey, on plants and in intestinal tracts of animals & fish	Transmitted by inadequately processed canned foods, garlic in oil, vacuum-packed & tightly-wrapped food, commercial sausages & meat products, canned vegetables and seafood products
Clostridium perfringens	Found in soil, dust, sewage and intestinal tracts of animals & humans; grows only in low oxygen	Cafeteria germ: transmitted via meats, meat products & gravy left for long periods in steam tables or at room temperature
Escherichia coli	Found in intestinal tracts of some mammals, raw milk & unchlorinated water; several strains can cause human illness	Transmitted via water contaminated with human sewage; infected food handlers; semi-soft cheeses
Listeria monocytogenes	Found in intestinal tracts of humans & animals, milk, soil, leafy vegetables & processed foods; grows slowly at refrigerator temperatures	Transmitted via raw milk, soft cheese, improperly processed ice cream, raw leafy vegetables, fermented raw-meat sausages, raw & cooked poultry, raw meats, and raw & smoked fish
Salmonella spp.	Found in intestinal tracts & feces of animals; some spp. found in raw shellfish	Transmitted via raw and undercooked meats, poultry, & eggs; raw milk and dairy products; seafood; and food handlers
Shigella spp.	Found in the human intestinal tract; rarely found in animals	Transmitted person-to-person by fecally contaminated water and unsanitary food handling; most outbreaks result from food prepared & handled by workers using poor personal hygiene
Staphylococcus aureus	Found in humans: on skin and in infected cuts, pimples, noses & throats	Transmitted person-to-person through improper food handling
Streptococcus spp.	Found in humans	Introduced to foods through poor hygiene, ill food handlers or use of unpasteurized milk; foods allowed to stand at room temperature between preparation and consumption: milk, ice cream, eggs, steamed lobster, ground ham, potato salad, egg salad, custard, rice pudding and shrimp salad
Vibrio cholerae spp.		Spread by poor sanitation resulting in contaminated water supplies; nearly eradicated due to excellent sanitation facilities in US
Yersinia enterocolitica		Meats, oyster, fish and raw milk

2. Conditions Permitting the Growth of Pathogenic Microorganisms

While most foods and ingredients contain sufficient nutrients to support microbial growth, some present more hospitable environments than others. Predicting whether or how fast microorganisms will grow is complicated by the rather complex chemical matrices found in foods and ingredients. The most important factors to encourage, limit or prevent the growth of microorganisms in foods and ingredients are water activity (a_w), pH and temperature.

Water Activity (a_w)

By themselves in pure solution, water molecules are loosely arranged and show great freedom of movement. By convention, a solution of pure water is said to have a water activity (a_w) of 1.00. When other molecules are added to the solution, water reorients itself about the molecules, the movement of water is restricted and the a_w falls below 1.00. This reorientation dramatically changes the properties of the solution. Some molecules—like the sugars in corn syrups and sweeteners—bind water molecules tightly, significantly lowering the a_w and limiting the availability of water to other constituents in the solution.

The concentration of non-aqueous molecules in solution—also called dry substance (% ds)—directly influences water activity: the higher the % dry substance, the more available water the molecules bind and the less available the water is for other constituents in solution. Thus, higher relative % dry substance also has the effect of lowering the water activity.

Microbial cells must successfully compete for available water with other molecules and constituents in solution in order to thrive. Other than *Staphylococcus aureus*, bacteria are rather poor competitors. Minimum a_w values required to sustain growth have been determined for many bacterial species. At a_w values below the minimum, bacterial growth is inhibited and cell death can occur.

pH

The pH range— relative acidity or alkalinity—within which a microorganism will thrive is defined by minimal (at the acidic end of the scale) and maximal values(at the alkaline or basic end of the scale). There is also a pH optimum for each microorganism at which growth is maximal. Moving away from the pH optimum in either direction slows microbial growth.

Temperature

The temperature range for permissible microbial growth, like pH range, has minimal, maximal, and optimal values. Microorganisms differ in their ability to grow at various temperatures and are classified in relation to temperature growth characteristics as either psychrotrophs, mesophiles, or thermophiles. Although mesophilic microorganisms grow well between 20°C and 45°C, with optima between 30°C and 40°C, various unit operations in the corn wet-milling process can exceed these temperatures considerably.

Pathogenic Microorganisms

Table 2 lists temperature, pH and water activity requirements for growth of selected pathogenic microorganisms in foods and ingredients, provided the proper nutrients are also present.

Table 2: Environmental conditions favoring pathogen growth[2]

Pathogen	Temperature (°c)	Optimum pH	Water Activity (a_w)
Bacillus cereus	5 – 50	4.4 – 9.3	>0.93
Campylobacter jejuni	27 - 45	4.9 - 9	>0.98
Clostridium botulinum (A&B)	10 - 50	4.7 - 9	>0.93
Clostridium perfringens	6 - 52	5.5 – 8	>0.93
Escherichia coli	8 - 43	4.4 - 9	>0.95
Listeria monocytogenes	0 - 44	4.6 - 9.2	>0.93

Table 2: Environmental conditions favoring pathogen growth – continued.

Pathogen	Temperature (°c)	Optimum pH	Water Activity (a_w)
Salmonella spp.	6 - 46	4 - 9.5	>0.94
Shigella spp.	7 - 46	4.9 - 9.3	>0.97
Staphylococcus aureus	7 - 48	4.2 - 9	>0.97
Vibrio cholerae O1	10 - 48	4.8 - 11	>0.96
Vibrio parahaemolyticus	10 - 44	4.8 - 11	>0.96
Yersinia enterocolitica	<2 - 45	4.6 - 9	**

With few exceptions, pathogenic microorganisms grow most favorably at temperatures below 50°C, within a pH range of 4.5 – 9.5 and at water activity values above 0.86.

3. Properties of Corn Products That Prevent the Growth of Pathogens

Liquid Products

Liquid corn syrups and sweeteners are manufactured to specifications that are typically outside the temperature, pH and water activity optima of most pathogenic bacteria (Table 3).

Table 3: Syrup processing and product properties deterring pathogen growth.

Product	Max Processing Temperature (°C)	% ds	pH	Water Activity (a_w)
42% HFCS	>60 ↓	71	3.8	0.76
55% HFCS		77	3.8	0.66
25 DE Corn Syrup		78	4.9	0.74
36 DE Corn Syrup		80	4.9	0.70
63 DE Corn Syrup		81	4.9	0.59
65% High Maltose Syrup		81	4.9	0.68

Finished product streams through corn wet-milling plants experience temperatures above 60°C that minimize microbial growth. High processing temperatures, high dry substance values, low final product pH and low water activity values combine to make corn syrups and sweeteners inhospitable hosts for growth of pathogenic microorganisms. It should be noted that any one of these variables below or above the optimum is sufficient to inhibit the growth of pathogenic bacteria.

In an experimental test of the theory that corn products do not sustain pathogen growth, Marceau[3] in 1968 demonstrated that *Salmonella* and *Escherichia coli* species were completely killed within two weeks of being inoculated into liquid sweeteners.

More recently, Niroomand[4,5] and co-workers inoculated corn and sucrose ingredients and followed the number of viable colonies over time to test how a broad spectrum of bacterial pathogens would survive in liquid syrups and sweeteners. Pathogens tested included species of *Salmonella, Listeria, Staphylo-*

coccus, *Escherichia coli*, *Pseudomonas*, and the coliforms *Citrobacter*, *Enterobacter* and *Serratia*. Their data supported the following conclusions:

- The number of microorganisms fell below the detection limit in less than three days when syrups and sweeteners were stored at normal holding temperatures (32 – 46 °C).
- When products were stored at the lower temperature limit reached during transportation (27 °C), the reduction in number of microorganisms was still observed, but occurred at a slower rate.
- The fastest rates of reduction were observed in 42 and 55% HFCS and in 50% medium invert sucrose.
- The slowest rate of reduction was observed in liquid sucrose stored at the lower temperature, in which *S. aureus* survived up to one month.

The experiments of Marceau and Niroomand *et al* suggest that incidental contamination of corn syrups and sweeteners with pathogenic microorganisms does not present a public heath hazard. The authors attribute this to physical properties inherent in the manufacture of corn products, including high processing temperatures and % dry substance values, and low final product pH and water activity.

It is also worth noting that the work of Troller[6] and Chen & Strickler[7] supports the effectiveness of low water activity syrups and sweeteners in controlling yeasts and molds.

Dry Products

CRA member companies make a variety of dry ingredients for the food industry, including acidulents, corn syrup solids, dextrose and starches. Many of these products are characterized by low water activity (Table 4)—similar to the liquid corn wet-milling products discussed above.

Table 4: Dry product processing and properties deterring pathogen growth[7]

Product	Max Processing Temperature (°C)	pH	Water Activity (a_w)
Citric Acid	>60	1.8	0.15
Sodium/Potassium Citrate	↓	8.5-8.8	0.12-0.13
Corn Syrup Solids	↓	4.4-5.5	0.14-0.17
Dextrose	↓	4.2	0.12
Starches, various treatments	↓	4.6-5.7	0.28-0.46
Starch, pregelatinized with propylene oxide	↓	8.7	0.38

Processing temperatures above 60 °C, exceedingly low water activity, low product moisture (<1 to <10%) and moderate final product pH would appear to make dry corn wet-milling-based food ingredients inhospitable hosts for growth of pathogenic microorganisms as well. Whether these properties are sufficient deterrents to incidental microbial contamination has not been well-studied.

To shed some light on this area, Niroomand, Sperber, Lewandowski and Hobbs extended their work with liquid sweeteners to study the fate of microbial pathogenic inocula over time in dry sweeteners, starches and citrates[8]. Not surprisingly, they observed that dry products also exhibit bacteristatic and bactericidal properties against *Staphylococcus*, *Salmonella* and *Escherichia coli* inocula, though at a slower rate than liquid products. The precise rate appears to be governed by the water activity and pH of an individual dry product.

4. Pathogen Management by the Corn Wet-Milling Industry

Effective Product Sampling & Testing

For years, CRA member companies have had in place analytical procedures for detecting microbial levels in finished products. The 1999 Edition of *CRA Analytical & Microbiological Methods* contains the following microbiological methods[9]:

- Mesophilic Aerobic Bacteria
- Mesophilic Yeast and Mold
- Osmophilic Yeast, Mold and Bacteria
- Coliform Group of Bacteria
- *Salmonella* Species
- Thermophilic Spore-forming Bacteria
- Coagulase Positive *Staphylococci*
- Anaerobic Bacteria
- *Pseudomonas* Species
- *Bacillus cereus* Count
- Mesophilic Aerobic Spore-formers
- Rapid Microbiological Methods

Thorough microbial testing and rigorous specifications are designed to minimize the risk that product shipped to customers will present a microbial pathogen hazard.

GMP and Quality Management Systems

Recognizing that testing alone is not sufficient to ensure the absence of any organisms in the shipment of finished product, CRA member companies implement GMP and quality management systems. These systems are designed to eliminate the hazard of potential pathogen contamination through process controls and designs. Critical control points in the manufacturing process are identified, controlled and routinely monitored to restrict the growth of pathogenic microorganisms. Also, FDA's GMP regulations mandate adequate steps be taken to control the presence of any pathogenic organism in food production facilities.[10]

Thus, implementation of GMP and quality management systems in CRA member companies are designed to work synergistically with the natural physical and functional properties of corn syrups and sweeteners, starches and acidulents to provide deterrents to the growth of pathogenic microorganisms.

References

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4 Niroomand, F., W.H. Sperber, V.J. Lewandowski and L.J. Hobbs. Fate of bacterial pathogens and indicator organisms in liquid sweeteners. *J. Food Protection*. 61(3): 295-299. 1998.

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9 Corn Refiners Association, Inc, *CRA Analytical and Microbiological Methods*, 1999 Edition.

10 21 CFR 110.80.