NUVONIC

formerly Aquionics, Berson, Hanovia and Orca GmbH

UV Water Disinfection – Technology & Dosing

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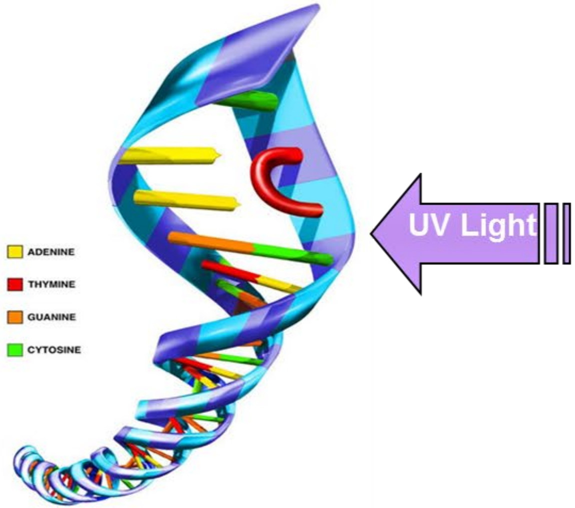
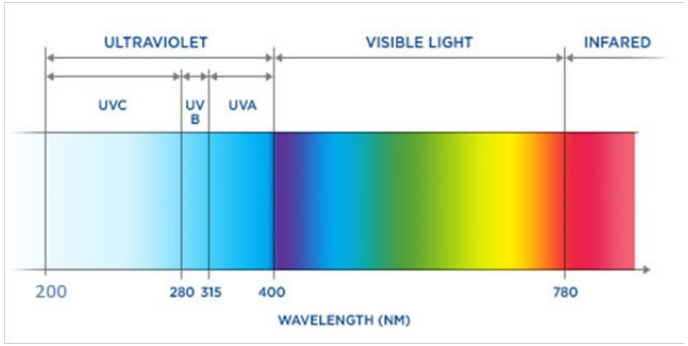
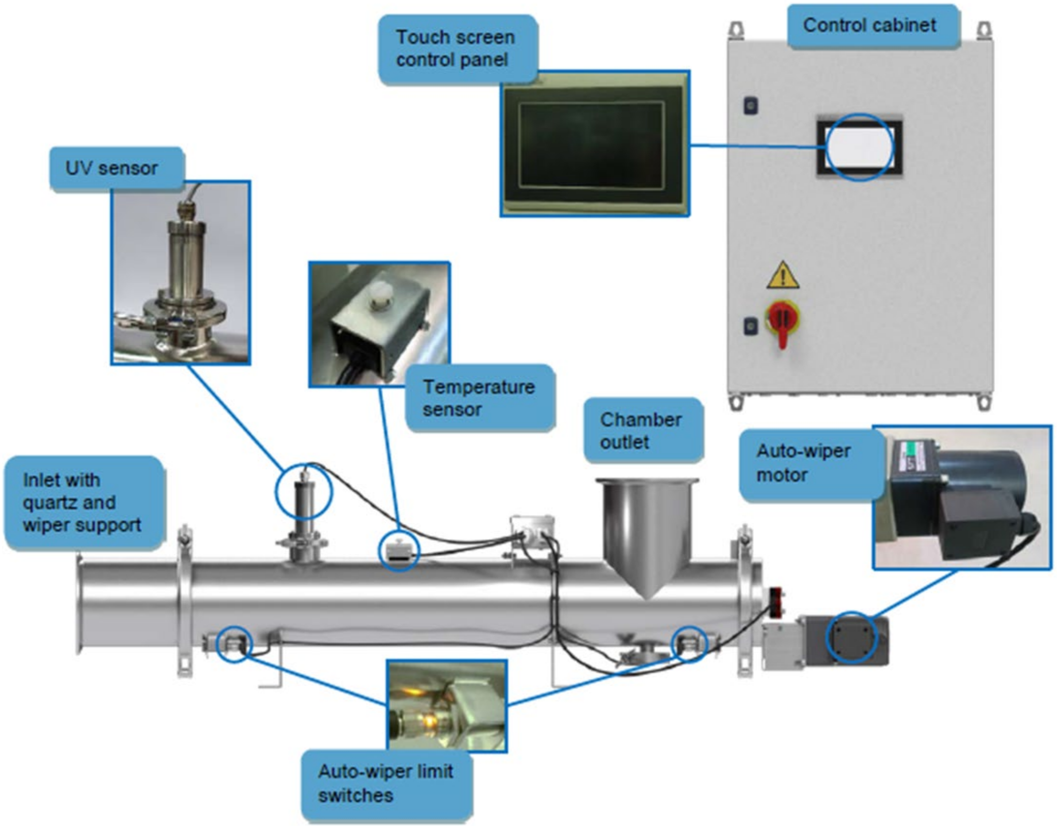
What is UV Disinfection?

- Mercury vapor lamps produce UV-C light at a wavelength of 253.7nm
- DNA of many common bacteria & virus have a peak absorption around 260-265nm
- Exposure to UV-C destructs part of the DNA, preventing reproduction
- UV-C is the only effective treatment for many chlorine resistant organisms such as cryptosporidium and giardia



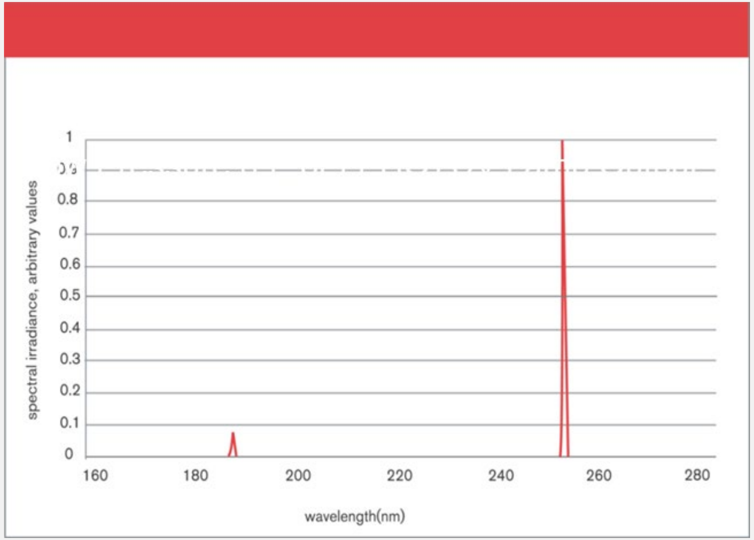


UV System Components

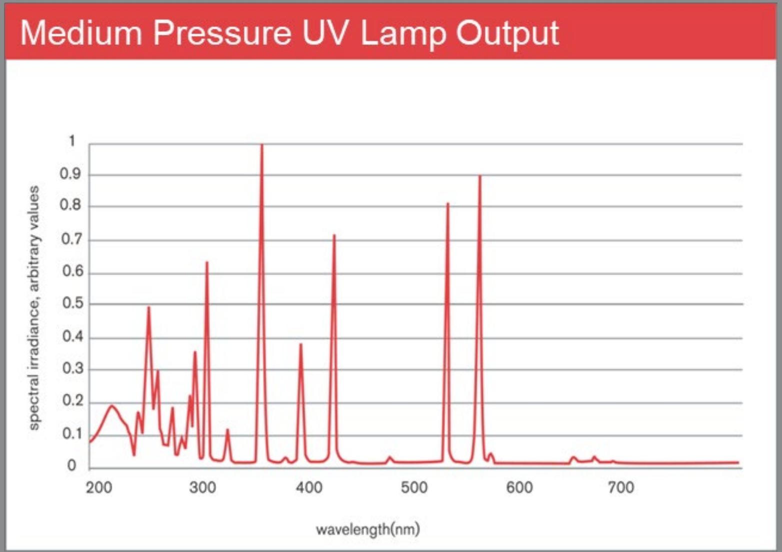


UV Lamp Technology Comparison

Low Pressure (LP) or Low Pressure Amalgam (LPHO) lamps are called monochromatic, as they emit only one wavelength. LP lamps are usually longer, and more are required to treat the same amount of flow as a MP lamp, however they consume less energy and typically last longer.



Medium Pressure (MP) lamps are also called polychromatic lamps, as they emit multiple wavelengths. MP lamps provide a higher output, but for usually a shorter amount of time, allowing for a smaller footprint and less lamps.



Understanding UV Dose

- There are many items that can affect the ability of a UV system to perform, however the chart below show the main water quality items that are taken into consideration when sizing a UV system.

Parameter	Influence / Effect	Typical Range
UV Transmittance (UV-T)	Measure of UV absorption Effects system sizing requirements	50 – 70 % - WW 85 – 90 % - DW
Turbidity	Measure of light scattering Effects disinfection performance	< 5 NTU recommended
Minerals (Coagulants)	Can cause scaling on quartz sleeves Effects UV transmission	Fe < 0.1 mg/l Mn <0.1 mg/l
Suspended Solids	Absorbs UV light & shields bacteria Effects disinfection performance	< 30mg/l recommended

Understanding UV Dose

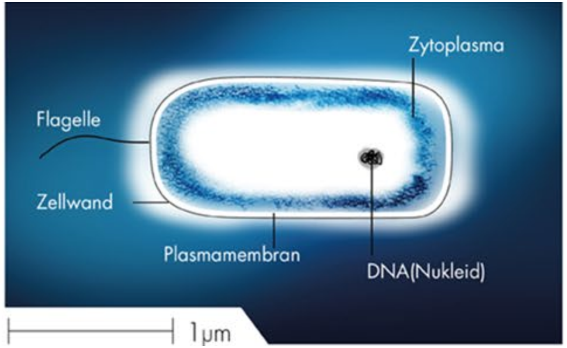
- While there is some regulation that drives the level of DOSE required, many facilities look to UV manufacturers to make recommendations.

- Studies have been conducted to prove the DOSE require for most common bacteria, protozoa, molds & spores and virus.

Organism	UV DOSE (mJ/cm2) for a given Log Reduction							Reference
	1	2	3	4	5	6	7	
Legionella pneumophila (ATCC 43660)	3.1	5	6.9	9.4				Wilson et al. 1992
Salmonella spp.	<2	2	3.5	7	15	29		Yaun et al. 2003
Streptococcus faecalis)ATCC29212)	6.6	8.8	9.9	11.2				Chang et al. 1985
Cryptosporidium hominis	3	5.8						Johnson et al. 2005
Giardia lamblia	<2	<2	<4					Mofidi et al. 2002
Adenovirus (type 15)	40	80	122	165	210			Thompson et al. 2005
Bacillus subtilis (ATCC6633)	36	48.6	61	78				Chang et al. 1985

Disinfection Dose

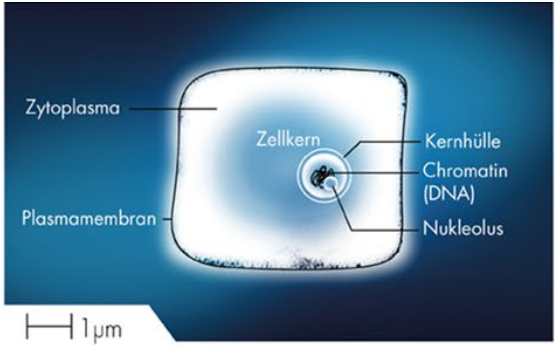
Bacterium
(prokaryotic cell)



- DNA hardly protected
- small cells
- Simple cell without core
- → low LD_{90} doses:

1 - 6 mJ/cm²

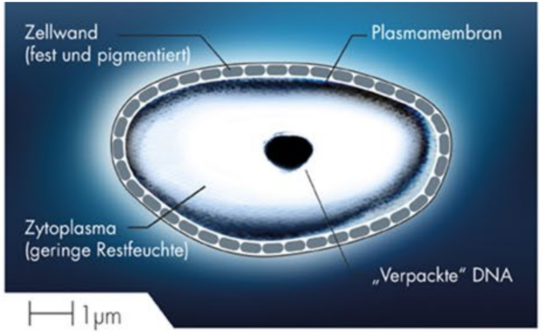
Yeasts, Vegetative Fungal Cell
(eukaryotic cell)



- DNA as chromosomes
- Large cell with organelles
- Complex cell with nucleus
- → medium LD_{90} doses:

4 - 10 mJ/cm²

Fungal Spores
as a survival stage

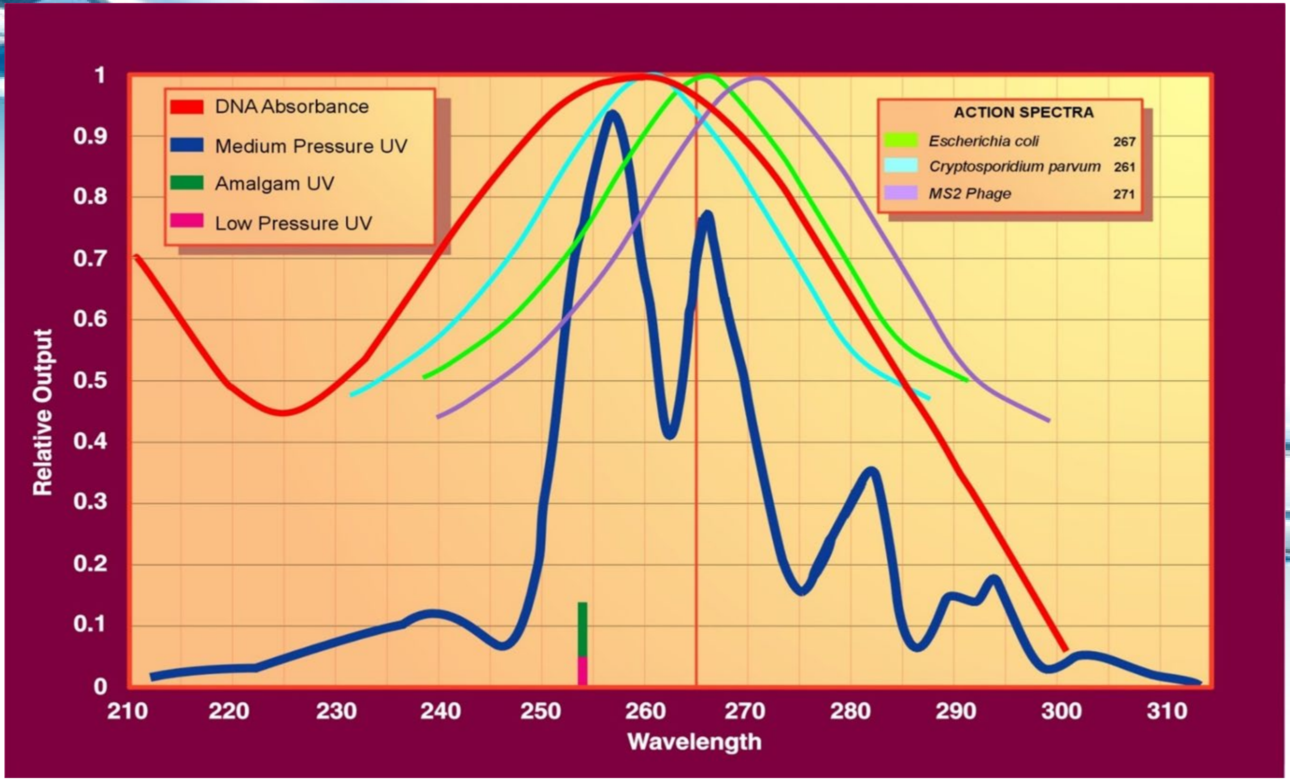


- DNA complexly packaged
- dense cell volume
- Thick cell wall (partly pigments)
- high LD_{90} doses:

8 - 100 mJ/cm²

Typical LD_{90} doses (90% kill) for different groups of organisms

Lamp Output and Action Spectra



UV in the FDA PMO

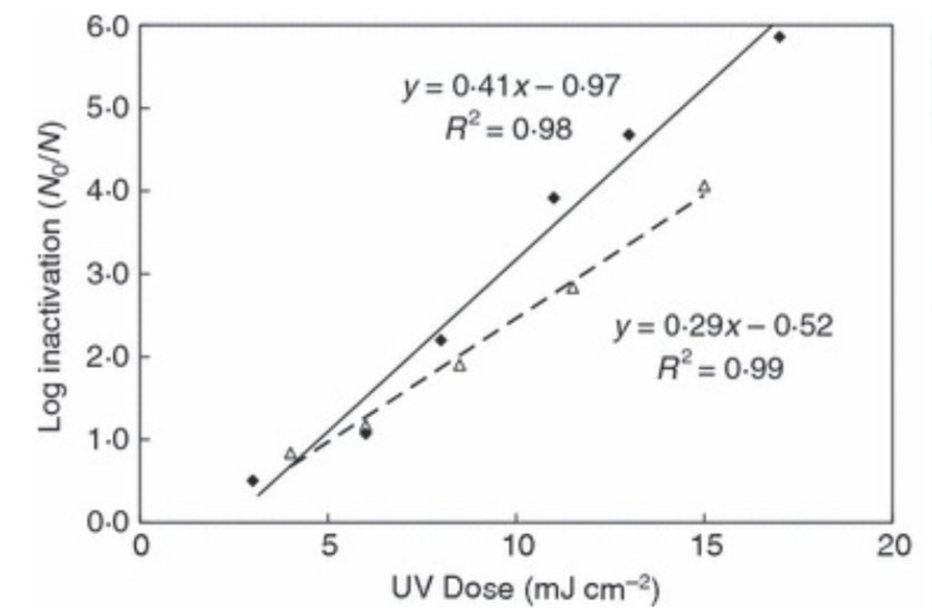
- The PMO speaks to the use of UV in two areas:
  - Appendix D: Continuous Water Disinfection
  - Appendix H: Creation of “Pasteurized Equivalent Water”

- Historical focus on Adenovirus (known “challenge organism” for UV)
- 4 log virus inactivation dose (120mJ/cm2 MP, 186mJ/cm LP)
- Upcoming PMO shifts focus to enteric pathogens thereby reducing the dose down to 40mJ/cm2
- Opens the door for LP systems to be practical

But what are we now missing moving forward?

Comparing UV to Pasteurization

HTST pasteurization is well known to provide a 5 log reduction of organisms.
What is FDA PMO UV "pasteurized equivalent water" providing?



UV doses (D10) for thermotolerant organisms commonly found in dairies:

Organism	UV Dose mJ/cm2 (D10)
Listeria	8
Pseudomonas	6
Clostridium	12
Corynebacterium	4
Micrococcus	7
Streptococcus	6

Incoming Municipal Water

- What is the right dose based on what organisms are being found?
  - Incoming from municipal supply

Rank	Genus	2000 - 2014: Number detected (Percentage of total, n=504)	UV dose required (4 log reduction)
1	*Pseudomonas*	121 (24%)	17mJ/cm2
2	*Brevundimonas*	70 (14%)	
3	*Sphingomonas*	50 (9%)	
	Bacillus	37 (7%)	>80mJ/cm2 depending on species
4	*Moraxella*	34 (7%)	
	Micrococcus	33 (7%)	>20mJ/cm2 (1 log reduction)
5	*Ralstonia*	31 (6%)	Assumed to be similar to Pseudomonas
6	*Stenotrophomonas*	22 (4%)	10mJ/cm2 (2 log reduction)
7	*Burkholderia*	18 (4%)	50mJ/cm2 (1 log reduction)
8	*Methylobacterium*	10 (2%)	

https://symbiosisonlinepublishing.com/microbiology-infectiousdiseases/microbiology-infectiousdiseases33.php

Food for Thought

- With roughly 700 water main breaks daily across the US, how are you proactively monitoring and responding to this threat for microbiological intrusion?
- Is backwashing your carbon bed periodically good enough?
- How does commensalism play a role in pathogen exposure (biofilms, Pseudomonas, Listeria)?

UV Water Disinfection Applications in the Cheese Making Process

Norman LaVigne
Valcour Process Technologies
October 28, 2021

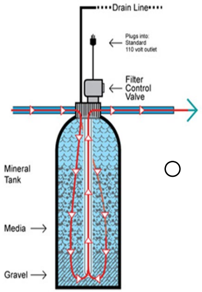
UV Technology in Cheese Production

Valcour PROCESS TECHNOLOGIES

- UV Technology has proven to be an effective way to reduce counts of both spoilage organisms and other house bugs of concern in food production.
- Reduced spoilage organism counts help make a safer product, improved shelf life, and fewer defects in cheese produced.
- UV is utilized in a number of ways in the Dairy and Cheese Market including:
  - Water - Incoming, Process, Source, CIP, etc.
  - Product – UV Conveyor
  - Air – For Production, Packaging, or Converting Rooms
  - Product Containers – As an option on a filler or packaging equipment, cap sterilization.
- While UV is a mature technology it has benefited from dramatic adjacent innovations in other enabling technologies – lamps, electronics, computerized flow modeling, sensors, etc.
- UV provides instantaneous disinfection of water borne organisms but not residual disinfection.

Summary of UV Water Disinfection Applications in Cheese Making

- **Incoming Plant Process Water**
  - Water “Firewall” Applications to deactivate organisms in Plant Water
    →Mitigates the risk from upstream contamination of the municipal water supply from main breaks, aging infrastructure, low/varying chlorine levels, etc.
    →Solution for known well water organism deactivation



  - Disinfection step after Charcoal Beds, Filters, Membrane Systems, etc.
    →Deactivates residual biofilms coming out of process water treatment equipment. Prevents their spread downstream to seed new colonies.
  - Replacement of Charcoal Beds for Chlorine Destruction
    →UV requires a much smaller footprint while providing both de-chlorination and disinfection with a single device.
    →Charcoal Beds are typically only backwashed and therefore act as a seed source for biofilms and others to move downstream into the process.

Summary of UV Water Disinfection Applications in Cheese Making

- **Process Applications**
  - Cow Water Recovery
    - After Reverse Osmosis -Polishers for Class 1 water use (PEW)
  - Pasteurized Water Use Applications
    - Unburdening of the Pasteurizer for more production time
    - UV is much more effective against psychrotrophic organisms
  - Sterilized Water Applications
    - Culture Room Water
    - Replacement of Steam Sterilizers & Filtration Skids for Equivalent Log Reduction
  - Product Contact Applications
    - Washed Curd Cheese & Cottage Cheese
    - Fresh Mozzarella Cooling & Packing
    - Water used to make & make-up Brine
  - Product Ingredient Hydration Applications
    - Addition of Hydrated Powders for American and Pizza Cheese
  - Evaporation Process Water Reuse

Summary of UV Water Disinfection Applications in Cheese Making

- **Wastewater Treatment Applications**
  - Final Treatment before Discharge into Rivers, Lakes, etc.
  - UV provides a lower cost solution for disinfection to meet NPDES permit levels

In Summary

- UV Water Disinfection Systems have come a long way in the past 10 years and their use in Dairy and Cheese Applications is widespread and diverse.

- Applications are customer and process specific since the dose and disinfection objectives can be quite different even in similar applications.

- UV Technology when properly applied can provide a number of benefits to Cheese Producers. Improved shelf life and product quality are the primary benefits of using this technology to mitigate the risk of water borne house bugs and cheese with fewer defects.

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House Bugs

“Flora de Maison” in Dairy and Cheese Manufacturing

by Steve Funk | National Accounts Manager | Nelson-Jameson

What are “house bugs”?

Definition(s):

1. Organisms that enter plants through means of raw milk, water, air, supplies, ingredients, and other commercial sources that can cause both attributes and problems in Dairy and Cheese Manufacturing.

2. "Native" organisms in a plant environment that can establish "residence" and cause issues in manufactured products.

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Sources of Contaminant Microorganisms in Milk

- **Human:** Coliforms, Salmonella, Enterococcus, Staphylococcus
- **Air:** Streptococci, Micrococci, Coryneforms, Bacillus, Yeast and Molds
- **Feed:** Clostridium, Listeria, Bacillus, Lactic Acid bacteria
- **Soil:** Clostridium, Bacillus, Pseudomonas, Mycobacterium, Yeast and Molds
- **Bedding:** Clostridium, Bacillus, Klebsiella
- **Milking Machine:** Micrococcus, Streptococci, Bacillus, Coliforms
- **Inside Udder:** Streptococcus, Micrococcus, Corynebacterium
- **Outside Udder:** Micrococcus, Staphylococcus, Enterococcus, Bacillus
- **Feces:** E.coli, Staphylococcus, Listeria, Mycobacterium, Salmonella

<u>Note: Milk from a healthy animal and healthy udder should be sterile</u>

[1] *Source: Vasavada*

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Other Sources of “House Bugs”

- **Starter Cultures—**Starter cultures can “reside" in manufacturing plants simply because of their use in fermenting dairy products. Their residual presence can be enhanced by poor sanitation in vats, lines, tables, belts, curd knives, curd handling equipment, etc. which can lead to biofilms. Plants that manufacture different cheeses during the day, week, etc. using different genuses and species of organisms and cross-contaminate these "makes".
- **Adjunct Cultures—**There are many companies using adjunct cultures for flavor, body, and texture enhancement and attributes in dairy products. This was created to have controlled flavors and attributes, versus uncontrolled by inconsistent or "dirty" milk. Adjuncts come in a wide variety of genus and species and poor sanitation can lead to these establishing colonies on equipment and in plant environments.
- **Enzymes—**Proteases and lipases can carry over in vats, tables, belts, and *cook water,* for several vats after use.

Typical Types of Contaminant Organisms

Psychrotrophs:

- Micrococcus, Bacillus, Staphylococcus, Pseudomonas, Flavobacterium, Coliforms. These organisms prefer temperatures of < 7°C/45°F. Although preferring the lower temperatures and practically presumed to be destroyed by pasteurization, some can sometimes survive pasteurization, but more importantly if they are highly present in raw milk can produce heat stable enzymes that break down fat and protein. These can lead to off-flavors such as putrid, fruity, fermented, and bitter.
- Psychrotrophs can also produce EPS, (exopolysaccharides), which can enhance the ability to create biofilms, and cause issues such as ropiness in dairy products.

NOTE: *There is also a grouping called psychrophilic but these are usually associated with more "earthbound"/in the ground bacteria and liking temperatures of 10° to 20°C/50° to 68°F. Not to say they can't get introduced if other "dirt" prone bacteria are present.*

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Typical Types of Contaminant Organisms
continued

Thermodurics:

- Bacillus, Micrococcus, Streptococcus, Lactobacillus, Clostridium, Enterococcus, Staphylococcus, and Corynebacterium. These organisms prefer temperatures above 55°C/130°F and can survive pasteurization. These are probably the most common contaminants found in cheese manufacturing plants. They can be very heterofermentative, and can seed cheese milk causing many issues of acidification, off-flavors, gassing, breakdown, etc.
- The industry has seen more and more instances of thermoduric issues since plants have gotten larger and larger, running their equipment longer, cleaning in shorter time frames, and extending PM programs such as equipment breakdowns.
- A study at University of Cork(2) found that Aerobic, thermoduric spore-formers such as Sporosarcina, Paenisporosacina, Brevibacillus, Paenbacillus, Geobacillus, and other Bacillus fond that these can survive pasteurization, and produce biofilms, protecting themselves from "normal" sanitation methods.
- All these organisms can not only survive pasteurization, they can create colonies in dead-ends, corners, cracks, crevices, gaskets, valves, joints, milking machines, transportation devices, storage tanks, and processing equipment.

[2] *Gopal, Ross, Beresford, Fenelon, Cotter, @ Cork Ireland*

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Trouble in the Numbers

- Various studies(3), (4), (5) have shown that numbers as low as 10*3 can indicate serious sanitation problems and numbers of 10*6 or higher can cause serious product defects of all these types of "House bugs".
- In my industry experience this has been observed by taking samples of pasteurized uninoculated (by culture) cheese milk, and plating. Actually I have seen "runaway" acidification with numbers as low as 10*5. Other testing can be done by taking uninoculated milk off the pasteurizer and incubating at over 100°F for several hours. If the milk is "clean" the pH should not change. If the pH drops, there is an indication of problems.

[3]Johsnston/Bruce—1982, [4]Griffiths—1985, [5]Jay—2005

Solutions

- Know your milk.
- Know, as many as you can, of the "introduced by natural sources" organisms in your plant.
- Regular PM and quality checks of all equipment.
- Adding time and/or steps to the sanitation program. Consider UV or enzyme sanitizers.
- Know all the culture organisms you are using in your plant.
- Work with your suppliers, universities, and industry associations.

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Thank You

Questions?

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