Food borne microorganisms are the most significant cause of food illnesses among the public. The food industry is charged with the legal and commercial obligation to ensure the risks associated with these hazards are maintained at an acceptable level.

In order to do this a solid understanding of the nature and character of food microorganisms is essential. This whitepaper covers the basic knowledge required to understand these hazards and in turn support more effective hazard identification and risk assessment for food safety controls.
1 INTRODUCTION

Microbiological hazards are the single greatest cause of foodborne illnesses. They are also some of the most difficult hazards to risk assess given their diversity and dynamic nature. New and emerging microbial hazards present a particular threat to public health and the food industry must continually take account of this in the development of control programs both at an international, national and plant level.

Most food safety managers will find themselves at some point developing HACCP plans which require them to identify and profile a range of hazards including microbiological hazards. Unless the manager has studied the field in some detail it can often be difficult to identify and characterise the risks posed. A basic understanding of food microbiology is essential to produce robust and effective HACCP plans. Consulting a food microbiologist is always recommended for validating HACCP plans; however, it is still important to understand and correctly interpret the information provided from such sources.

In order to assist our customers we have produced a series of three whitepapers focusing on food microbiology and how it relates practically to food safety and its management in a food production environment. The three papers are:

- Basic Food Microbiology for Food Safety Managers
- Treatment and Preservation Methods in Food Production
- Microbiological Hazards in Food Safety

This first Whitepaper has been developed to provide food safety managers responsible for food safety systems in a processing plant acquire a basic knowledge of food microbiology and to underscore the learning of those who have previously covered it during their education. It is not intended to be a complete representation of the subject which is vast and constantly changing. Nor should it replace detailed examination of pathogenic hazards required as part of HACCP studies. This whitepaper should be read in conjunction with our whitepaper on Microbiological Risk Assessment.

2 MICROBIOLOGY AND FOOD SAFETY

Microbiology is the science that studies living organisms that cannot be seen with the naked eye. A microscope is the only way to view the millions of tiny creatures living in our environment. While they often play a beneficial role in human health and food production they can also cause disease (pathogens). Whether the microorganism is harmful or beneficial, it needs favorable conditions to grow. Conditions vary with the type of microbe:

- Temperature
- pH (acidity versus alkalinity)
- Food
- Moisture
- Oxygen (for certain bacteria)
There are three main categories of microorganism concerned in food safety. These are *bacteria, viruses* and yeasts / moulds. All are potentially transmissible through foods and water and their survival times can vary from hours to years in some cases. For the majority of foods we consume, it is not possible to guarantee they are free from microbiological pathogens. The target is to ensure the level of hazards and the risk is known and reduced to a level that is acceptable. Bacteria are usually classified according to their reaction to a Gram stain, cell shape, serotyping and/or phagetypeing. The main categories of microorganisms may be summarised as follows:

### Table 1: Microorganisms in Food Safety

<table>
<thead>
<tr>
<th>Microorganism</th>
<th>Details</th>
<th>Picture</th>
</tr>
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<tbody>
<tr>
<td><strong>Bacteria</strong></td>
<td>Single-celled classified by shape and arrangement</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Can be categorized according to how arranged; arrangement is a way to identify exact species</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Some are:</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cocci – round</td>
<td>Strep</td>
</tr>
<tr>
<td></td>
<td>Streptococci – chains</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Staphlococci – in groups or clusters</td>
<td>Staph</td>
</tr>
<tr>
<td></td>
<td>Diplococci – in pairs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Microccoci</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Some are:</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rod-shaped – bacilli</td>
<td></td>
</tr>
<tr>
<td></td>
<td>In pairs, single or in chains</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flagella – tail</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Some are:</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spiral, or corkscrew-shaped – spirilla</td>
<td>Salmonella spp</td>
</tr>
<tr>
<td></td>
<td>Bacteria replicate by</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Binary fission</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grow in Food</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Endospore formation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Toxin production in food</td>
<td></td>
</tr>
<tr>
<td><strong>Viruses</strong></td>
<td>Parasitism of host cell</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Do not grow in food</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Transmission by foods and water</td>
<td></td>
</tr>
<tr>
<td><strong>Fungi</strong></td>
<td>Fitness</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Budding, spore formation, mycelial growth</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grow in Food</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Toxin production (mycotoxins) in food</td>
<td></td>
</tr>
<tr>
<td><strong>Yeasts and Moulds</strong></td>
<td></td>
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</tr>
</tbody>
</table>
Sources - the chief sources of microbial food contamination depend on the food product, method of production and processing, and the hygiene standards employed in their manufacture. Sources include:

- Soil
- Water
- Intestinal tract of humans and animals
- Food handlers
- Food utensils and equipment
- Animal feeds
- Animal hides
- Air and dust

3 MICROBIAL GROWTH CURVE

The growth of microbes in a system or food matrix follows a number of phases:

- Lag phase – when microbes are adapting to the new environment and have not yet produced enzymes to breakdown food. One of the objectives of food preservation is to extend the Lag phase.
- Exponential phase – a large increase in microbe numbers is observed and depends on the food matrix and other conditions.
- Stationary phase – in this phase food supply starts to run out or chemical inhibitors are being produced, limiting growth.
- Death phase – when a decline in the viable number of microorganisms is observed due to food supply, inhibitors and competition.

The microbiology growth curve is more relevant for long-term growth and food spoilage than for pure food safety considerations. The Generation Time (or the time for a microbial population to double in numbers) is usually 20 minutes. Populations of microorganism are rarely distributed uniformly in a food product.
Figure 1: Microbial Growth Curve

**Food Preservation** – Delay or prevention of microbial growth (thereby extending shelf-life) while maintaining the wholesomeness of the food is an important field of food science and technology. However, its effects on pathogens and therefore food safety is not necessarily a direct relationship. It is important to consider:

- Destruction of spoilage micro-organisms does not mean destruction of pathogens
- Food may appear edible yet contain pathogens
- Damage of microbial cells may be sub-lethal

## 4 FACTORS AFFECTING MICROBIAL GROWTH IN FOOD

There are a number of factors which affect the growth of microbes in food. These include:

- Extrinsic factors – external environmental influences which can be controlled in many cases
- Intrinsic factors – physical, chemical and structural properties of food

<table>
<thead>
<tr>
<th>Factor</th>
<th>Details</th>
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</table>
| **1. Temperature During Storage** | - Recommended storage of perishable foods <5ºC  
- Microbial enzyme reaction rates and cell membrane permeability affected  
- Psychrotrophs include several food pathogens, e.g. Listeria monocytogenes, Clostridium botulinum Type E, Yersinia spp, Vibrio spp, Aermonas spp.  
  **Psychrotrophs** [cold tolerant]:  
  Opt >15ºC; Max >25ºC; Min ≥0ºC  
  **Psychrophiles** [adapted for cold temp]:  
  Opt <15ºC; Max 25ºC; Min ≤0ºC  
  - Prolonged storage at low temperature or gradual decrease in storage temperature may reduce minimum growth temperature. |
| **2. Relative Humidity (R.H.) of Environment During Storage** | - Generally the lower the temperature the higher the RH  
- Refrigerator units usually have a higher RH  
- RH interacts with moisture content in foods  
- Packaging impacts depending on permeability |
- CO2 – ‘Controlled atmosphere’ (CA) storage; Modified atmosphere packaging (MAP)  
- O3 – Ozone can sterilize but difficulties regarding high lipid foods [oxidizing agent]  
- Most food poisoning microorganisms are facultative aerobes |
### 4.1 Extrinsic Factors

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| **1. Moisture Content of the Food [Water Activity, aw]** | - Water activity (aw) is the amount of available water which can be used by microbes for growth.  
- It is the ratio of water vapour pressure of the food [P] to that of pure water [Pw] at the same temperature.  
- In terms of this ratio we can define the aw growth ranges of various microorganisms  
  - 0.99–0.91 Fungi and bacteria can grow  
  - 0.91–0.80 Moulds, halophiles, S. aureus only  
  - 0.80–0.60 Halophilic bacteria and moulds only  
  - <0.60 No microbial growth  
- Most spoilage bacteria do not grow below 0.91  
- Most pathogens require 0.95 – 0.99, except S. aureus [0.86]  
- All microorganisms require water to grow but not to survive. The absence of moisture causes the cessation of growth while survival varies.  
- A reduction in aw can be brought about by dehydration, the addition of salt and addition of sugar. In some cases a reduction in aw can increase heat resistance. |
| **2. pH of the Food** | - The pH of the food product can affect the growth and survival of various microorganisms.  
- For growth the pH ranges are as follows:  
  - Moulds – Min 0-1; Opt 4.5-5.5  
  - Yeasts – Min 3-10; Opt 4.5-5.5  
  - Bacteria – 4-9; Opt 6.5-7.5  
- Many metabolic reactions in microorganisms are pH dependent. If the pH is unsuitable it will result in a longer Lag phase.  
- Foods can be categorized according to the pH  
  - Low acid foods > 5.3 [Protein foods]  
  - Medium acid foods 5.3-4.5 [Cheese, canned meats]  
  - Acid foods 4.5-3.7 [Tomatoes, yogurt]  
  - High acid foods < 3.7 [Citrus fruits]  
- Acid foods are generally spoiled by yeasts and moulds and certain bacteria such as lactic acid bacteria  
- Certain foods have a buffering power and resist changes in pH, e.g. protein  
- Pre-exposure to low pH reduces microbial heat resistance in foods that will be heat treated subsequently |
<table>
<thead>
<tr>
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</table>
| 3. Oxidation - Reduction Potential of the Food | • This factor goes by many names including O/R, Eh, Redox potential or Oxygen potential of food and is a measure of the ease at which food is oxidized  
  • It depends on a number of factors including O/R of the food itself; capacity of food to resist a change in O/R; Oxygen tension of atmosphere around the food; access which the atmosphere has to the food  
  • Oxygen in the air is a powerful oxidizing agent  
  • Microorganisms can be categorized according to their requirements for oxygen:  
    Obligate aerobes:  
    require oxidized conditions; high Eh +400mv  
    Obligate anaerobes:  
    require reduced conditions; low Eh -200mv  
    Microaerophiles:  
    require slightly reduced conditions 4-10% oxygen  
    Facultative aerobes/anaerobes:  
    grow in either condition  
  • Reducing agents can be used to maintain a low Eh such as proteins and ascorbic acid  
  • Microbial growth in the food also reduces the Eh |
| 4. Nutrient Content of the Food              | • Nutrients are required for microbial growth, e.g. carbon, nutrient and growth factors  
  Carbon:  
  sugars, alcohol, amino acids, complex carbohydrates, fats  
  Nitrogen:  
  amino acids, proteins, inorganic nitrogen  
  Growth factors:  
  B vitamins  
  • Some microorganisms require simple nutrients, e.g. gram-negative bacterial, moulds. Others require more complex ones, e.g. Gram positive |
| 5. Antimicrobial Substances in the Food      | • These are naturally present in the food and include essential oils, bacteriocins, lysozymes, benzoic and other strong acids  
  • They can also be produced by other microorganism [acids and alcohols] or during processing  
  • They can be added intentionally as part of the recipe or maliciously [additives or adulterants] |
| 6. Physical and Biological Structure of the Food | • Some foods have a natural protective outer layer [skin, rind, shell, waxy coating]  
  • Changes in structure during processing [slicing, dicing, grinding, cutting, mincing, etc.] increases surface area with a greater opportunity for contamination, higher Eh. |
Product Benefits

- Easily record and manage all elements of your food safety system including HACCP and CCP monitoring, PRPs, management systems and documents
- Eliminate paper using the 30 integrated modules that come as standard
- Access and work with your system from any location at anytime
- Stay up to date and fully compliant with software that updates automatically in line with changes to global food standards
- Improve compliance and audit outcomes through the action driven features of the software
- Accelerate compliance with all of the international food safety standards including the BRC, SQF, IFS & FSSC 22000.
- Spend less time managing your food safety system and more on value adding activities

Product Features

- Dashboards & KPI's
- 100's of reports as standard
- Notifications
- Multi-site management & oversight
- Real-time legal and alert updates to dashboard
- Roles & security
- Actions management
- Safe and secure web based solution
- No internal IT support or data back-up required
- Unlimited Users
- 24/7 world class customer support
- Covers in complete detail the requirements of the SQF, BRC, IFS, FSSC 22000, retailer standards and legislation
- FDA 21 CFR Part 11 –Technical Compliance
- Automatic audit log
- One click data export