**FOOD 5040 – Food Chemistry**

Table of content

Module One: Introduction to FOOD5040

M1-1: Welcome

M1-2: Food Chemistry – Overview

M1-3: Food Systems

URL: Course Outline

URL: Course Schedule

M1-4: Know Your Instructor

Quiz 1

**Module Two: Reaction Rate and Reaction Order**

**M2-1: Reaction Rate and Reaction Order**

**M2-2-1: Arrhenius Equation**

**M2-2-2: Enzyme Kinetics**

**Quiz 2**

**Module Three: Water**

**M3-1: Water in Food Systems**

**M3-2: Structure of Water**

**M3-3: Structure of Ice**

**M3-4: Water and Solutes**

**M3-5: Water Activity**

**Quiz 3**

**Midterm -1**

**Module Four: Proteins**

**M4-1: Proteins**

**Quiz 4**

**Module Five: Enzymes**

**M5-1: Enzymes**

**Quiz 5**

**Module Six: Carbohydrates**

**M6-1: Carbohydrates**

**Quiz 6**

**Midterm 2**

**Module Seven: Lipids**

**M7-1: Lipids**

**Quiz 7**

**Module Eight: Food Additives**

**M8-1: Colours**

**M8-2: Vitamins & Minerals in Foods**

**M8-3: Preservatives**

**M8-4: pH Adjusting / Acid reacting & Water reacting chemicals**

**M8-5: Sequestering agents**

**M8-6: Ingredients used in Health Food Products & Sports Nutrition**

**Quiz 8**

**Summary**

**Final Exam**

Module One: Introduction to FOOD5040

M1-2: Food Chemistry - Overview

<H1> Food Chemistry - Overview

Food Science is an integrated body of scientific knowledge that looks at the nature of food systems, from the microscopic to the macroscopic levels. At the microscopic level, the structural (and microstructural) as well as molecular and organoleptic properties of food systems are examined. The interfacial dynamics between the bio-environment and food systems and how they behave are also considered. Lastly, the sequential process steps in the manufacture and preservation of food systems are studied.

Food Technology is the practice of food science. Thus, a food technologist deals with the design and development of new products and processes, strategies for quality assurance and food safety, and process management in a food plant. Activities of the food technologist center for the most part on the principles of food science, yet knowledge from other fields, such as economics, marketing, accounting, engineering, and operations management is also required.

Food Chemistry deals with the chemical constituents in foods, the alteration of those constituents during process and storage, the molecular basis for sensory perception, the chemistry of nutrients and toxicants in foods, and the chemical basis for the behaviour of food ingredients and food additives.

Alterations of food components may be brought about by:

* increasing the temperature during processing, which will bring about chemical changes
* a decrease in temperature with the formation of ice (causing physical in addition to chemical changes)
* reduction in water content by dehydration (flavor changes)
* introduction of ionizing radiation (ϒ-rays) or non-ionizing radiant energy
* introduction of oxygen into food systems to cause oxidation (resulting in rancidity of fat through oxidation)
* the addition of food additives to control or minimize some of the above listed changes

As a result, the specialty of food chemistry also includes food toxicology, nutritional chemistry, and the bioassays for the assessment of nutritive value of foods as well as toxicants. Principles of taste and odour perception involving chemical-receptor associations can also be included in food chemistry.

M1-3: Food Systems

**<h1> Food Systems**

There are two main categories into which food systems can be divided: edible tissues and food dispersions. Examples of the first would be fish fillets, apple slices, and diced vegetables. In other words, these are intact tissue systems consisting of cells interconnected by membranes (connective tissue in meat) or adhesive substances (pectic substances in plants). Shearing those tissues by mechanical means or alteration of those adhesive substances can result in the formation of complex food dispersions, such as meat emulsions, fruit and vegetable juices, or purees.

By definition, food dispersions consist of one or more dispersed or discontinuous phases in a continuous phase. In most cases the continuous phase is either water or edible oil. A sugar solution or protein solution are examples of simple dispersions. Mayonnaise is an example of a more complex food dispersion in which oil is dispersed (or mixed) into water (in the form of vinegar) as the continuous phase. Thermodynamically such a system is unstable and will separate (as an oil and water salad dressing does). To overcome this, egg yolk is added as an emulsifier to stabilize the system. The types of dispersed particles can include crystals, amorphous solids, cell fragments, cells, liquid droplets, and gas bubbles.

The classification of dispersions can be done on the basis of size or the physical state of the particles. Colloidal dispersions contain particles ranging from 1 nm to 0.5 µm in size. Coarse dispersions have particles with dimensions greater than 0.5 µm. A solution (molecular dispersion) is a one-phase system with the molecules having dimensions below 1 nm. This contrasts with colloidal and coarse dispersions, which consist of two or more phases. Systems with two phases (diphase) can be categorized into eight different combinations of phases—solid (S), liquid (L) or gaseous (G)—but only five are of importance in food science. The most common diphase food systems are sols (S/L), emulsions (L/L), and foams (G/L).

Many foods consist of two or three dispersed phases in a continuous phase. For example, whipped cream is a tetraphase: aggregated protein particles and gas bubbles are the dispersed phase, and water is the continuous phase. Tetraphase systems can be symbolized by L-S-G/L, with the letters before the slash indicating dispersed phases and the letter after denoting the continuous phase. An alternative is to describe the system as an emulso-sol-foam.

The stability of a food dispersion is dependent on the interfacial characteristics, particle size distribution, viscosity of the continuous phase, phase-volume ratio, and density difference between the phases. Any alteration in the above mentioned properties can lead to destabilization and either result in the formation of aggregates (clumping) and if liquid in nature, coalesce to form a second bulk phase (e.g., an oil layer).

**Module Two: Reaction Rate and Reaction Order**

**M2-1: Reaction Rate and Reaction Order**

**<H1> Reaction Rate and Reaction Order**

Given that food is composed of chemicals and those chemicals and their properties are manipulated by the various processes or additions made to those chemicals, then an understanding of reaction rates and reaction order is necessary. The resulting changes to nutritional content or extension of shelf-life (in the case of destruction of micro-organisms) must also be understood.

The knowledge of kinetics supports what common sense tells us. No food is going to last forever. The use of predictive modeling or accelerated shelf life testing can only be done with an understanding of the appropriate kinetics. Time and temperature are the most significant factors affecting food quality and food safety. A mathematical understanding of how a specific reaction proceeds allows for predictions to be carried out, even though the actual mechanics of the reaction may not be well understood.

The following YouTube.com video provides an excellent review:

<http://www.youtube.com/watch?v=tSI8vcM-9Kw&feature=related>

Here are additional web based resources for reaction rates:

<http://www.chemguide.co.uk/physical/basicrates/orders.html#top>

The rate at which a reaction proceeds depends on the condition (temperature, presence of catalyst or inhibitors, pH, etc.) that must be incorporated into the rate questions. The Arrhenius equation allows for extensions that take into account conditions that vary from when the initial measurements have been made.

**M2-2-1: Arrhenius Equation**

**<h1> Arrhenius Equation**

The Arrhenius Equation is present in the form:

k = ko exp(-Ea/RT)

where k is the rate constant at absolute temperature T, Ea is the activation energy of the reaction (and how much quicker the reaction goes with heat), R is the gas constant (8.3 J/(K mol) and ko is the rate constant (at reference temperature). From the equation presented, it can be seen that as T increases the term in the bracket decreases. The effect is that as temperature increases, the reaction rate increases. Again, this makes intuitive sense.

The following site provides a good overview of the Arrhenius Equation:

<http://www.chemguide.co.uk/physical/basicrates/arrhenius.html>

What is the purpose of reviewing reaction rate, reaction order, and the Arrhenius Equation with respect to Food Chemistry? The answer is that many food preservation techniques seek to limit the effects of food deterioration. For example, lipid oxidation that results in rancidity will occur at a specific rate. Microbial destruction kinetics generally evidence a first-order reaction rate. Furthermore, reduced temperature and its effect on slowing reaction rates and thus extending shelf life is also an important consideration. The addition of stabilizers may bring into question the rate of gel formation: for example, the use of a slow-set versus rapid-set pectin in jam making. The answer to all of these considerations is to what extent does the reaction take place and how quickly, based on temperature consideration? In summary then, an understanding of reaction kinetics, and the relationship between time and temperature lead to an understanding of the resulting effects on food quality.

**M2-2-2: Enzyme Kinetics**

**<h1> Enzyme Kinetics**

Proteins that catalyze biological reactions are called enzymes. These remarkable biomolecules demonstrate extraordinary specificity and catalytic power - far greater than those of man-made catalysts.

Enzymes are named by adding the suffix –ase to the name of the substrate (the molecule upon which the enzymes exerts if catalytic action). For example, lactase is an enzyme that hydrolyzes lactose. This nomenclature is not always practical and some enzymes have been given chemically uninformative names (such as trypsin, catalase and pepsin). A systematic classification system that identifies six major classes and subclasses of enzymes has been adopted by the Enzyme Commission (EC) in order to deal with this ambiguity.

As an example, creatine kinase is the recommended name that catalyzes the reaction below:

ATP + creatine ⮀ ADP + phosphocreatine

The systematic name based on the reaction catalyzed is ATP: creatine phosphotransferase. Its classification number is EC 2.7.3.2 where EC stands for Enzyme Commission, the first digit (2) for class name (transferases), the second digit (7) for the subclass phosphotransferases), the third digit (3) for the subclass phosphotransferases with a nitrogenous group as acceptor, and the fourth digit (2) designates creatine kinase.

The discussion on enzyme kinetics follows very similarly the discussion on chemical kinetics in that the number of molecules taking part can vary (monomolecular, bimolecular and termolecular in which one, two or three molecules respectively, undergo reaction). Similarly reaction order also comes into play. The following presentation explains enzyme kinetics and the Michaelis-Menten Equation.

http://www.wiley.com/college/pratt/0471393878/student/animations/enzyme\_kinetics/index.html

**Module Three: Water**

**M3-1: Water in Food Systems**

**<H1> Water in Food Systems**

**<reading icon> Reading Reference:**

**Food Chemistry, Fennema, 4th ed., Chapter 2:**

* **Physical-Chemical properties of water p. 18-27**

In the majority of food products, water is near the top of the list of ingredients. Not only is water essential from the standpoint of nutrition and the need to keep the body hydrated, water may be added in for the form of syrups and brines for various foods prior to canning or for the purpose of creating sauces. Even if water has not been added to the product, it may be required to reconstitute the final product or clean the raw product before further processing. Note that the quality of the water directly relates to the final quality of the product. Pure water (distilled) has no flavor. It is the impurities that give water its flavor. For example, the high mineral content of “hard” water used for making India Pale Ale beers contributes to their characteristic flavor.

In food systems, the physical state of water has a direct relationship to the organoleptic (sensory) as well as rheological (flow characteristics) properties of the food. The organoleptic properties are those of sight, smell, taste, and aroma. The rheological properties are the result of measuring stress (force) and strain (deformation). The table below summarizes some of these properties.

**Table 3-1: Relationship of the physical state of water in food systems to organoleptic attributes and rheological properties (Powrie, 1988).**

|  |  |  |  |
| --- | --- | --- | --- |
| **Physical State of Water in Food Systems** | **Typical Foods** | **Organoleptic Attributes** | **Rheological Properties** |
| 1. Continuous aqueous phase in dispersions and solutions 2. Crystal dispersions 3. Solutions and dispersions | Fondants (sucrose crystals, ice cream (ice crystals)  Syrups, chocolate milk | Plasticity, chewiness, stickiness  Fluid, viscous | Plasticity (yield value)  Viscosity |
| 1. Water entrapment in 3-dimensional continuous polymer network (2 continuous phases) 2. Gel systems | Wieners,  gelatin dessert,  fruit jelly | Resiliency,  resistance-to-bite  chewiness, gumminess | Elasticity,  Resistance to shear  (semisolid) |
| 1. Water entrapment within cells 2. Plant parenchyma tissue with high cell turgidity 3. Animal fiber tissue with capillary immobilization of free water | Lettuce, apples  Muscle | Crispness (auditory),  Resistance-to-bite,  Juiciness  Juiciness,  Resistance-to-bite | Resistance to shear  (semisolid)  Resistance to shear  (semisolid) |
| 1. Strong water attraction to hydrophilic compounds. 2. Dehydrated and low-moisture foods | Corn flakes,  Hard candy,  Crackers | Crunchiness,  Hardness,  Brittleness | Resistance to shear |

Apples, for example, contain 85% water. The water is trapped within the cell walls of the parenchyma cells. If the cell wall is ruptured, the water will leak out. However, in the presence of 10% sugar, osmotic pressure (turgidity) results inside the cell (on to the order of 9 atm pressure) and when the teeth come into contact with the cell, it pops (giving rise to “crunchiness”) as the osmotic pressure is released. Conversely, as the apple ages, water evaporates and the turgidity decreases.

In the case of animal cells, micro-channels within the muscle fibre hold water. When pressure is applied, the fluid (sarcoplasm) comes out. The fluid, with its mix of protein and water, is responsible for the juiciness of meat. Any change in the size of the micro-channels will increase or decrease the amount of that exudate. For example, the freezing of meat will increase the amount of exudate as micro-channels are enlarged due to ice crystals.

Bound water is the one or two layers of water molecules bound to the product onto polar groups (proteins and sugars for example). Cornflakes, for example, have a moisture content of 2–3%. This gives rise to its crunchiness. As the corn flakes become hydrated, (in the presence of milk), they lose their crunchiness and become soggy.

**M3-2: Structure of Water**

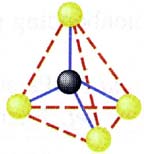
**<H1> Structure of Water**

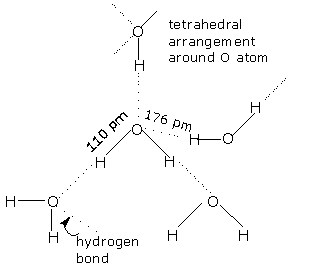
Dr. Stephen Lower (retired faculty member of the Dept. of Chemistry, Simon Fraser University, Canada) provides a very through overview of the structure and chemistry of water on this website:

<http://www.chem1.com/acad/sci/aboutwater.html>

Water, with its V-shaped molecular structure and a bond angle of 104o 31’, comprises a portion of a tetrahedron, with two positive and two negative corners.

This results in the molecule having a net negative charge on the oxygen end and a net positive charge on the hydrogen end.

**** **IMAGE SOURCE: "Chemistry and Life", 4th Edition, John W. Hill, Dorothy M. Feigl, and Stuart J. Baum, Macmillan Publishing Company, New York, 1993**



The oxygen atom has a great affinity for the electrons of the hydrogen atoms, resulting in a net charge of minus two for the oxygen atom. The hydrogen atoms, as a result, possess a positive charge (proton). This arrangement of a charge distribution means that the water molecule can be regarded as a dipole. Each of the four charged areas of a water molecule can attract another water molecule, with the formation of a hydrogen bond. One water molecule can then attract a maximum of four water molecules. It is this formation of hydrogen bonding that is responsible for the outstanding physical features of water and ice.

**M3-3: Structure of Ice**

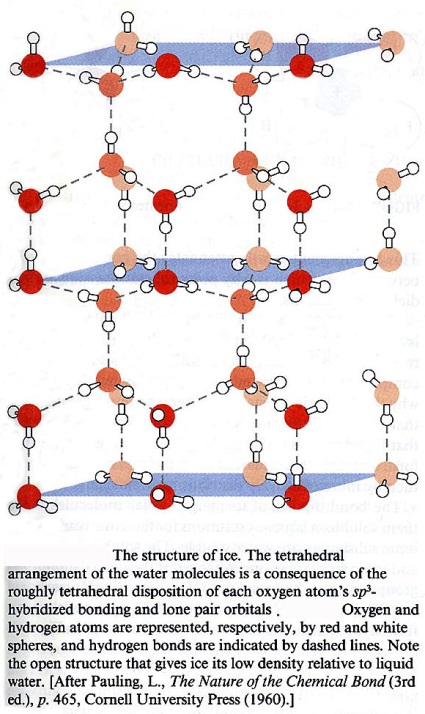
**<h1> Structure of Ice**

**<icon> Reading Reference:**

**Food Chemistry, Fennema, 4th ed., Chapter 2:**

* **Physical properties of ice p. 28-29**

Water molecules in ice are arranged as a network of puckered six-membered rings, as shown below. As would be expected with such an open structure, ice density (0.9164 g/cm3) at 0oC is considerably lower than water density (0.9999 g/cm3) at 0oC.



At the present time, ten polymorphs of ice have been reported, plus an amorphous or vitreous state of largely non-crystalline structure, making for 11 structures in total. Ice-Ih , formed under atmospheric pressure, is the only polymorph of practical importance.

In ice, the O atom of a water molecule is surrounded tetrahedrally by four other O atoms or, in other words, each water molecule is at the centre of a regular tetrahedron with four molecules at the vertical. According to Heslop and Robinson (1960), the temperature of ice must be lowered to –180oC before every water molecule is associated with four others through hydrogen bonding.

As the temperature is increased from –180oC to 0oC, the thermal agitation of the molecule becomes sufficient to stretch, bend, and ultimately break some hydrogen bonds. As suggested, the degree of hydrogen bonding is temperature dependent. Ice at 0oC has a coordination number (nearest neighbour molecules) of 4.0, with the nearest neighbour at a distance of 2.76 anstroms (A). With the input of the latent heat of melting, H-bonds are broken (increasing the distance between neighbours) and other hydrogen bonds become strained as water molecules assume a fluid state with more compact (on average) associations. As the temperature is raised, the coordination number increases from 4.0 for that of ice at 0oC to 4.4 for water at 1.50oC, then to 4.9 at 83oC. This presents several characteristics of ice water transformation. As the distance between neighbours increases, there is a resulting decrease in density. However, an increase in the average number of nearest neighbours indicates a density increase. It is that predominates during the phase change to yield the net increase in density associated with melting. This reaches a maximum at 3.98oC, then gradually declines. The effect of increasing distance between nearest neighbour (due to thermal expansion) is predominant above 3.98oC. To demonstrate: at 0oC, 52.8% of H-bonds are intact, while at 100oC, only 32.5% are intact.

**M3-4: Water and Solutes**

**<h1> Water and Solutes**

**<icon> Reading Reference:**

**Food Chemistry, Fennema, 4th ed., Chapter 2:**

* **Water-solute Interactions p. 31–40**

Water and solutes are present in all food systems and their interaction occurs at both the molecular and macroscopic level. At the molecular level, there is an alteration of the properties of both components compared to when they are not mixed. The molecular interactions between water and the specific solute present will determine the nature of the change.

Ions or charged groups interact with water primarily through electrostatic forces, which of course may enhance or interfere with the normal orientation of water molecules. For example, salt mixed into water will result in a hydration of the ionic surfaces of the sodium and chloride atoms. The first layer of water molecules will result in a very strong electrostatic interaction. The interaction of the second layer is less strong, the third layer even less strong, and the subsequent layers having no interaction and take on the characteristics of liquid water (bulk phase).

Water interaction with hydrophilic solutes produces interactions that are weaker than those above and are similar to water-water interactions. The result is that there may or may not be a reduced mobility or change of properties of the first layer water as compared to the bulk phase water. The distribution and orientation of the hydrogen bonding sites and how that relates to the orientations and spacings of the hydrogen bonding structures of water will determine if the solute is disruptive or not. Eligible groups for hydrogen bonding of water are hydroxyl, amino, carbonyl, amide, imino groups, etc. As a result, water bridges can be formed, whereby one water molecule “bridges” or interacts between two functional groups found in a protein.

H

│

─ N ─ H · · · O ─ H · · · O = C <

│

In the case of non-polar solutes (such as hydrocarbons, rare gases, and the apolar groups of fatty acids, proteins, and amino acids) such water bridging is thermodynamically unfavourable. The result is that the water structure will adjust to minimize contact with apolar groups. Similarly, the apolar groups will move closer together to lessen the water-apolar interfacial area.

Application of molecular-modeling techniques to the effects of solutes in the solvation process tend to confirm that the hydrogen-bonding associations of water are important. This indicates that the modulation of the hydrogen-bonding associations by the solutes is a primary effect that occurs within pure water. In particular, the changes caused mirror those induced in pure water by changes in temperature and pressure.

The above description outlines some of the properties of water as well as aqueous solutions. This also provides a good foundation for the role water has in food systems as well as its influence on the chemistry and microbiology of food.

**M3-5: Water Activity**

**<h1> Water Activity**

**<icon> Reading Reference:**

**Food Chemistry, Fennema, 4th ed., Chapter 2:**

* **Water Activity Concepts p. 41–53**
* **Moisture Sorption Concepts p. 65–77**

It has been recognized since ancient times that foods with higher moisture contents spoiled faster. Thus, the oldest form of food processing is dehydration. The strategy is to prevent or slow down deterioration or spoilage, particularly from a microbial point of view, which is the first and most rapid form of spoilage.

It has been noticed, however, that foods with the same moisture content can have varying rates of spoilage. Therefore the water content alone is not sufficient to explain or reliably indicate perishability. Thinking back to the above discussion on water and the effect of solutes, one could conclude that water engaged in strong interactions with solutes would be less available for processes such as microbial growth or hydrolytic chemical reactions. Weak interactions would increase the availability of water. The indication of that intensity is termed “water activity”, aW.

Natural products such as grain and honey are stable over a long period of time, due to having a low aW. Traditional food products such as jerky, pasta, salted meats, and jams have had solutes added to affect tie up or bind water, reducing the water activity. Modern food products whereby aW has been reduced include breakfast cereals and skim milk powder.

Moisture Content (percentage), can be calculated on either a wet basis:

Weight of water

% Moisture (wet basis, w.b.) = ──────────────── x 100

Total food weight

(i.e., wt. of water + wt. of solids)

Or a dry basis:

Weight of water

% Moisture (dry basis, d.b.) = ──────────────── x 100

Dry weight of food

(i.e., wt. solids only)

<icon> Example:

If a 1 kilogram pineapple has a moisture content of 95% (and therefore 5% solids), then on a wet basis, the % moisture content is:

950g

───── x 100 = 95%

1000g

On a dry basis, the % moisture content is:

950g

───── x 100 = 1900%

50g

Moisture content, wet basis (w.b.) is used for comparison; moisture content, d.b. is used for calculations.

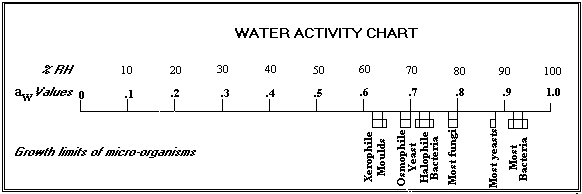
But where does that leave the discussion of water activity? From the discussions on thermodynamic theory, the concept of “activity” was derived. The application to food was pioneered by Scott (1953, 1957) as a measure of fugacity. Fugacity is the measure of the tendency of solvent molecules to escape a solution. Therefore:

aW = ( ƒ/ ƒo)T

where ƒ is measure of the fugacity of the escaping tendency of the solvent from the solution and ƒo is the fugacity of the pure solvent (solution) at some defined standard state. The subscript T refers to the measurement being made at standard temperature. At low pressures (such as ambient) the difference between fugacity and partial pressure is less than 1%, so the definition in terms of partial pressures, now becomes:

aW = ( p/ po)T

p represents the partial pressure of water in the food and po is the partial [pressure of pure water. Obviously the maximum value of aW is 1.0 (that of pure water) and all food products will fall between 0 and 1.0.



The assumption of thermodynamic equilibrium is often violated in foods and so the above expression better serves as an approximation. The expression generally used is:

aW ≈ ( p/ po)T

This expression of aW is better referred to as the Relative Vapour Pressure (RVP), as mentioned by Reid and Fennema (2008). It is this expression that gives rise to some of the lack of accuracy of aW as a totally reliable predictor. However, the correlation with microbial growth and many other degradative changes makes it a very useful indicator of microbial safety and potential product stability. The regulations of many jurisdictions around the globe dealing with food safety and good manufacturing practices specify aW as an important parameter in meeting those regulations.

The distinction is that p/po is a readily measured term and has come to be referred to as aW. From a Food Science perspective, it is more correct to use ( p/ po)T. The lack of understanding of the distinction between the two terms is what leads to the failure of aW-RVP being a perfect estimator of food stability. The key distinction is that the proper definition of aW refers to the relationship at thermodynamic equilibrium. RVP, then refers to the approximation.

One also needs to consider the effect of the specific solute, particularly in the case of using RVP or aW as a tool for determining product safety and stability. Chirife (1994) provides a good example relating to the minimum RVP for *Staphylococcus aureus*.

Thinking back to the concept of fugacity, the RVP, being an intrinsic property of the food sample, also then relates to the surrounding product environment through the percent equilibrium relative humidity (%ERH):

aW ≈ RVP = ( p/ po)T = %ERH/100

I have included the aW term here to alleviate any confusion resulting from the above discussion.

The %ERH is a property of the atmosphere once it has reached steady state equilibrium with the sample. Waiting for equilibrium to be reached can be a time consuming process. Reid and Fennema (2008) suggest using the term Steady State Relative Humidity (SSRH):

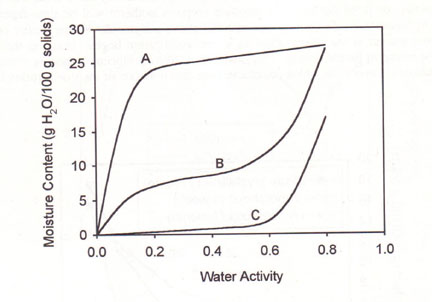
aW ≈ RVP = ( p/ po)T ≈ %ssRH/100

Many measurement techniques exist to then measure RVP and thereby provide a method of determination of RVP and product stability and safety.

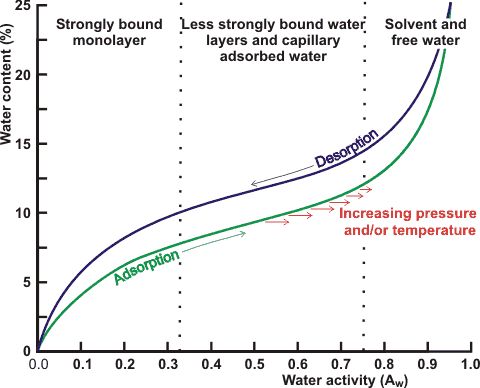
In returning to our discussion on moisture content, how does this relate to water activity? Clearly the water activity gives a more accurate explanation of food stability than moisture content, but can the two be related in some fashion? The answer is yes: a Moisture Sorption Isotherm (MSI). The MSI describes the relationship between moisture content in a food and the aW of that food at a specific temperature.

The application of an MSI for a specific food is that from the MSI, the ERH can be determined from the moisture content. As a result, the relative humidity of a warehouse can be set such that there is no gain or loss of moisture in their food products. In other words, there will be no moisture migration. Another way to control moisture migration is through packaging. Formulation can also be carried out to ensure food mixtures do not transfer moisture by determining what moisture content will prevent microbial growth or chemical changes within the food product.

In general terms, there are three zones to an MSI, although it should be noted that MSIs can be very different between food products and not all will exhibit the same shape.



The above graph shows three very different shapes. The more generalized shape is shown with line B; line A is the MSI for anti-caking agents and line C the MSI for crystalline solids such as sucrose. Line A shows that anti-caking agents are able to adsorb significant amounts of moisture before there is a major change in water activity. This makes sense in reality as products such as cake mixes are able to remain as a “free-flowing” powder form even when the surrounding relative humidity is high. Crystalline solids however will adsorb water quite readily but show also a rapid change in water activity. This relates in all cases to the nature of how the water is bound in the food.



Zone I water is found between aW (RVP) values of 0 and ~ 0.35 and represents tightly bound water that forms a monolayer adjacent to charged or polar groups on the food surface. This water is almost immobile, doesn’t act as a solvent, does not plasticize (contribute texture) to the food, is unfreezable, and is not available for microbial use or chemical interactions. It does, however, help protect against oxidation reactions since it forms over oxidizable groups.

Zone 2 water is less tightly bound water and forms additional layers of water over the monolayer. This is in the range of aW ~ 0.35 to ~ 0.60. This water is mostly unfreezable at –40oC, may have a very slight texture effect, and is not really available as a solvent.

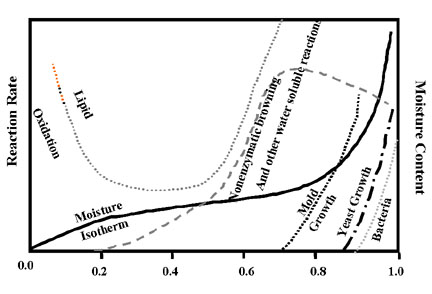
Zone 3 water (aW between ~ 0.6 and 1.0) is “bulk” water and is the least strongly bound and therefore the most mobile. This water is freezable and acts like water in solution. It is available for chemical and microbial processes and included capillary water, water in gel matrices, etc. It also has a major impact on texture. It is this most mobile fraction that governs the stability of the food product.

The above curve also shows two lines: one for dehydration (or desorption), the other rehydration (adsorption). The difference between the two curves is referred to as hysteresis. Even within the same food, depending on how the drying has proceeded (i.e., environmental factors) there may be greater or lesser hysteresis upon rehydration. Generally, hysteresis is more pronounced at temperatures lower than 80oC.

The reason for hysteresis is that the drying or hydration processes change the nature of the food in a somewhat irreversible manner. Two possibilities arise. One can be referred to as the “ink bottle” analogy. Water serves to plug the capillary so that the water does not flow down and in. In other words, a higher water vapor pressure is needed to fill the capillaries than is needed to remove the water. This becomes a suitable explanation for plant and animal tissues which have a porous structure.

In the second possibility, the drying process now allows contact between surfaces which had previously been separated by the solvent. This allows for chemical interactions to take place between those surfaces, either through covalent or non-covalent bonding. The water now cannot move between those surfaces and therefore rehydration does not take place.

The final aspect of water activity is the effect not only on micro-organisms, but also on chemical interactions.



Generally reactions will decrease with decreasing water activity, as the reactants are progressively less able to come into contact with each other due to the loss of the solvent properties of the water being removed. However, one reaction shows a decline, followed by an increase at lower aW values. When this occurs in some foods, it is thought to be from the removal of the protective water solvation layer that surrounds lipid hydroperoxides (Chen et. al, 1992).

**Module 4: Proteins**

**M4-1: Proteins**

**<h1> Proteins**

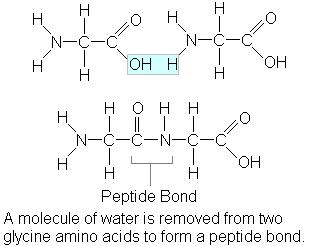
**<icon> Reference Reading:**

**Food Chemistry, Fennema, 4th ed., Chapter 5.**

* **Amino acid structure/classification p. 219–224**
* **Structure and bonding p. 231–245**
* **Nutritional/safety factors p. 296–299**
* **Carbonyl-amine reactions p. 412–413**
* **Protein-protein interactions p. 312**
* **Denaturation p. 249–257**
* **Functional properties p. 269–289**
* **Milk protein structure-function p. 889, 899, 909, 917**

Protein comprises a basic component of the cells of living matter. Constituting 50% or more of the cell’s dry weight, they are the most abundant organic molecules in cells. Therefore, they are found in both plants and animals and are fundamental to cell structure and function. Plants have the ability to synthesize protein from inorganic nitrogen, water, and carbon dioxide while animals depend on both plant and animal sources for protein.

Proteins are generally of high molecular weight and are composed of amino acids joined in a peptide bond.



The amino acid composition affects the biological function of the protein as well as degrees of hydrophobicity, and primary, secondary and tertiary structure. From a food processing point of view, rheological properties, flavour production, colouration, emulsification, gel formation, and foamability are also affected. In addition, most of the genetic information is expressed by proteins. However, while a detailed discussion of the nature of the relationship between DNA and protein structure, as well as the effect of mutations in DNA on protein structure are outside the realm of this course, the following YouTube videos explain the process for both transcription (DNA to RNA) and translation (RNA to protein).

<http://www.youtube.com/watch?v=TSv-Rq5C3K8>

Two classes of proteins exist in nature: simple and conjugated. Modification of these classes by a chemical, physical, or enzymatic agent produces a third class known as derived proteins.

Simple proteins consist only of amino acid groups. Examples are:

* Albumins (egg white): water soluble and coagulated by heat
* Glutelins (wheat): insoluble in water or neutral salt solutions
* Globulins (blood serum): insoluble in water, soluble in dilute salt solutions
* Prolamines (corn zien): soluble in 70% to 80% alcohol, due to a high concentration of hydrophobic groups. The ratio of hydrophilic to hydrophiobic groups determines the solubility of the protein.
* Protamines: soluble in water, not coagulated by heat, low molecular weight, and strongly basic
* Histones (thymus gland): soluble in water, insoluble in dilute ammonium hydroxide, basic in nature
* Albuminoids (scleroproteins such as hair, skin, or horn): insoluble in all solvents. This is due to the high level of disulfide linkages between the proteins.

Conjugated proteins consist of amino acids combined with other chemical groups. Examples of the more common conjugated proteins are:

* Chromoproteins (blood hemoglobin, chlorophyll): containing a coloured group
* Phosphoproteins (milk casein): containing a phosphorous group. These will interact with Ca2+ in serum and result in cross-linking with other molecules through electrostatic bonds, producing a gel (i.e., curd).
* Nucleoproteins (cellular nuclein): contains nucleic acids
* Glycoproteins (saliva mucin): contain a carbohydrate group
* Lipoproteins: contain a lipid group (e.g., if a diglyceride had a choline protein attached to the third “vacant” position, the result is the lipoprotein lecithin)

The derived proteins result from denaturation or hydrolysis of an original protein. These derivatives differ in solubilities and other properties, in addition to how they are produced. Primary derivatives include the coagulated proteins, proteans, and metaproteins. The secondary derivatives include proteoses, peptones, and peptides. Depending on the specific protein, denaturation may be either reversible or irreversible.

Many of the processes common in the food processing industry, such as heat, light, drying, mechanical forces, organic solvents, or exposure to other reagents can bring about these changes.

More often, Food Scientists and Food Technologists are concerned more with the source and functionality than with the specific groupings. Commonly used food proteins are:

* Casein (from milk and whey): supply emulsification, coagulation, and adhesion properties
* Glutin (from cereals): for adhesion, foaming, elasticity properties
* Albumin (egg white): foaming, binding, coagulation
* Myosin (muscle, blood): emulsification, gelling, adhesion
* Collagen (muscle, fish): gelling, foaming

**Module 5:** **Enzymes**

**M5-1: Enzymes**

**<icon> Reference Reading:**

**Food Chemistry, Fennema, 4th ed., Chapter 6.**

* **Proteases p. 277, 377**
* **Enzymatic browning p. 407**
* **Lipooxygenase activity p. 388, 415**
* **Ascorbic acid oxidase p. 469**

Enzymes are used in applications where chemical changes to raw materials are desired. They function as catalysts to specific biological reactions.

In fermentation, it may be desirable to convert certain types of carbohydrates into forms that can be used as a nutrient by the fermenting organism: e.g., amylase, pectinase, glucoamylase, cellulase, pentosanase.

In cheese, enzymes may be used to precipitate or coagulate proteins, (rennet, milk coagulating enzyme) or to convert fats into fractions for the purpose of flavour development (lipases).

In meat processing, proteases are used to tenderize meat by breaking down the protein structure (e.g., bromelain, ficin, papain).

In sweetener production, invertase is used to convert liquid sugar to invert sugar.

For a review of enzyme kinetics, the following YouTube video from module 1 describes enzyme kinetics:

<http://www.youtube.com/watch?v=6cGdWi_DSGk>

**Module 6: Carbohydrates**

**M6-1: Carbohydrates**

**<h1> Carbohydrates**

**<icon> Reference Reading:**

**Food Chemistry, Fennema, 4th ed., Chapter 3.**

* **Monosaccharide chemistry p. 84–90**
* **Oxidation, reduction reactions p. 92–93**
* **Non-enzymatic browning p. 96–101**
* **Sweetness chemistry/sweeteners p. 643–645**
* **Caramelization (see reader) p. 100**
* **Oligosaccharide chemistry p. 103–105**
* **Polysaccharide chemistry p. 108–113**
* **Starch, cellulose chemistry p. 120–135**
* **Starch granule morphology p. 123**
* **Gelatinization and pasting p. 126**
* **Retrogradation and Staling p. 127**
* **Hydrolysis reactions p. 128**
* **Modified starches p. 130–135**
* **Pectins p. 146**

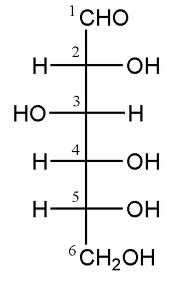
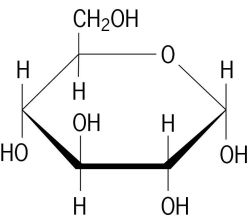
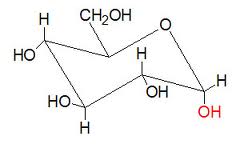
Carbohydrates represent the majority of the caloric intake of humankind. The most abundant source of carbohydrate is cellulose: the major structural component of plants. The main food ingredient consumed by humans is starch, providing on average 75–80% of the total caloric intake.

Carbohydrates, derived from the French *hydrate de carbone*, have a general composition of Cn(H2O)n,

signifying a composition containing carbon along with hydrogen and oxygen in the same ration as in water. As chemical methods evolved, this early elemental composition was replaced by more visual representations of spatial or steric structure.

As an example, D-glucose, the fundamental metabolic sugar of most living organisms, has the empirical formula C6H12O6. Originally the structure was depicted as an open chain as in the lower left of the diagram below. Later it was shown as a stable hemiacetal in ring form (lower right2 of diagram); presently it is shown more with its most thermodynamically stable ring conformation.

Figure 6-1: Visual structures of D-glucose: open chain, hemiacetal, and thermodynamically stable ring

[](http://www.google.ca/imgres?q=D-glucose&hl=en&sa=G&biw=1280&bih=528&tbm=isch&prmd=imvns&tbnid=0YAmhO7kxAjc6M:&imgrefurl=http://www.uspto.gov/web/patents/classification/uspc536/defs536.htm&docid=v2IHf2aSIpz9EM&imgurl=http://www.uspto.gov/web/patents/classification/uspc536/c536s1-11-2.gif&w=312&h=539&ei=tX1sUI_EEu33igL4wIDwCA&zoom=1&iact=hc&vpx=261&vpy=132&dur=1311&hovh=295&hovw=171&tx=93&ty=153&sig=100059819286919668438&page=1&tbnh=153&tbnw=78&start=0&ndsp=13&ved=1t:429,r:1,s:0,i:127)[](http://www.google.ca/imgres?q=D-glucose&hl=en&sa=G&biw=1280&bih=528&tbm=isch&prmd=imvns&tbnid=yQe17RYCDdFmOM:&imgrefurl=http://themedicalbiochemistrypage.org/carbohydrates.php&docid=DAguasYyJOPBsM&imgurl=http://themedicalbiochemistrypage.org/images/chairglucose.jpg&w=300&h=180&ei=tX1sUI_EEu33igL4wIDwCA&zoom=1&iact=hc&vpx=890&vpy=168&dur=390&hovh=144&hovw=240&tx=111&ty=68&sig=100059819286919668438&page=3&tbnh=121&tbnw=201&start=29&ndsp=18&ved=1t:429,r:16,s:29,i:272)

Carbohydrates are comprised of:

1. Monosaccharides (single sugars, S1). E.g., D-glucose, D-galactose, L-galactose, D-mannose and the two riboses D-xylose and L-arabinose as well as the two found in small levels in nucleic acids (D-ribose and 2-deoxy-D-ribose). Galactose is almost exclusively found in dairy products (particularly those which have been hydrolyzed). The riboses are found in fish and beef muscle.
2. Disaccharides (S1 + S2 → S3). E.g., sucrose, maltose and lactose.
3. Oligosaccharides: Two – 10 monosaccharide units joined together.
4. Polysaccharides: Polymers containing more than 10 saccharides, but most have 100 to several thousand sugar units. The primary sugar in polysaccharides is glucose, which in a (1→4)-β-D-linkage constitutes cellulose. D-glucose, joined by a (1→4)-α-D-linkages form starches. D-glucose combined with other saccharides containing six carbon atoms (hexoses) and those containing five carbon atoms (pentoses) are sugar units commonly found in other polysaccharides other than cellulose and starch.

Beyond the nutritional aspect, carbohydrates are important in the food industry from the standpoint of being:

1. Sweetening agents

These can take the form of either caloric or non-caloric sweeteners. The choice of which to use depends on calories as well as a need for “bulk” in the finished product. For example, in diet soft drinks aspartame is used to reduce caloric loading while providing the desired level of sweetness. However, in products such as ice cream or confectionary/baked products, sugars provide textural and bulking abilities that the non-caloric sweeteners cannot, since the non-caloric sweeteners are used at levels of 50–500 times less than sugar, due to their higher levels of sweetness versus sugar.

1. Thickening agents

There is an increasing viscosity of foods as carbohydrate viscosity increases (due to water binding capacity).

This is the function of flours, starches, and gums (hydrocolloids). Starches are flours in which proteins and lipids have been removed. The hydrocolloids have properties of thickening or gelling.

1. Cryoprotective agents–i.e., protecting food commodities at frozen temperatures

For example, milk concentrated to 33% solids then frozen will produce a precipitate (or gel) upon thawing. This is due to the attraction of caseinate micelles to each other. If sugar is added, the sugar will block the interactions of the micelles, as the sugars will become physically adsorbed onto the micelle. This effect is lost if the sugars are not solubilized. For example, the 5% lactose in milk is insoluble in water, as there are two forms of lactose that exist: β and α lactose (at a ratio of β/α = 1.68 at 20oC (Nickerson, 1965). The α anomer crystallizes under ordinary conditions. This causes problems in frozen products due to the formation of large crystals of α-lactose and is a common defect in ice cream, known as sandiness. If the milk is concentrated to 20% lactose, such that the lactose precipitates out, the cryoprotective effect is lost. The answer is to increase the solubility of lactose by adding lactase (an enzyme to cleave lactose into glucose and galactose). These sugars are both more soluble than lactose and therefore restore the cryoprotective effect.

1. Tenderizing agents

In cakes, due to the high concentration of sugar, the sugar coats the gluten strands of the flour such that a stringy, elastic cohesive mass is not formed as it is in bread. The –OH groups of the sugars react with the hydrophilic groups on the gluten proteins to prevent that interaction.

1. Development of flavour (odour)

baking

Glucose + bread dough −────→ odor and colour

This is due to non-enzymatic browning, by which both colour and odour are produced. If there is no glucose or other reducing sugars, then there is no browning. The addition of milk to dough will add lactose, which is able to interact with the proteins present in flour to produce the baked bread odour. However, lactose cannot be used by yeast to produce CO2. Lactose can provide a reserve for non-enzymatic browning as the glucose is used by the yeast and will decrease rapidly on concentration.

**Module 7: Lipids**

**M7-1: Lipids**

**<h1> Lipids**

**Reference Reading:**

**Food Chemistry, Fennema, 4th ed., Chapter 4:**

* **Classification/Metabolic pathways p. 157–164; 210–211**
* **Polymorphism p. 176–77**
* **Fatty acid oxidation (auto-oxidation) p. 186–198**
* **Sterols & sterol oxidation p. 198-207**
* **Lipid oxidation measurements p. 207–209**
* **Chemistry of fat/oil processing p. 179**
* **Hydrogenation p. 180, 210**
* **Interesterification p. 182, 211**

Fats and oils in foods are grouped together in a category called lipids, which are those components that are soluble in non-polar solvents such as ether. They normally occur as glycerides, which consist of a glycerol backbone condensed with a fatty acid to form mono-, di- and trigylcerides. The triglycerides are the majority of fats used in the diet. Mono- and diglycerides are used as emulsifiers.

Figure 7-1 Triglyceride synthesis

O







O H2C-OH O H2C-OCR

3 RC OH + OH-CH RCO CH-O + 3 H2O

H2C-OH H2C OCR

fatty

acid glycerol triglyceride



Despite the negative connotations associated with fats, they are essential to our diet, and to a large extent indispensable to food processors. Fats are categorized into several classes. First we will look at the origin.

Animal-derived fats include those found in various meats, such as: beef, pork, poultry, and seafood; those found in dairy products (butterfat); and those found in eggs. Fats found in eggs are rarely isolated and used as ingredients. They are only found in the yolk, and generally bound to lecithin, a natural emulsifier.

Plant-derived fats include: canola, sunflower, safflower, corn, soy bean, cottonseed, flax, hemp, wheat germ, olive, lemon, orange, coconut, cocoa, peanut, and grape seed oil, to name a few.

Fats found in animal tissue are mostly saturated, with the exception of certain fish oils. Saturation refers to the level of hydrogenation (bound hydrogen atoms) found in the fat. The higher the level of saturation, the higher the melting point of the fat. Fats in plants, seeds, and fruits are generally unsaturated, with the notable exception of cocoa butter and coconut oil.

Figure 7-2 Saturation of Fatty Acid Chains

H H H H H H H H

C C C C C C C C

H H H H H H H

Saturated Monounsaturated

H H H H H

C C C C C





H

Polyunsaturated



H H H

C C C C









H

cis trans

The human diet requires fats, but the body can manufacture fats from a variety of sources. Fats are generally stored as glycogen—the energy source for the liver—where glycogen is converted to glucose.

Figue 7-3. Omega 6 and Omega 3 fatty acid utilization





There are two types of essential oils (those that cannot be manufactured by the body) in humans: alpha-linolenic acid (an omega-3 fatty acid) and linoleic acid (an omega-6 fatty acid).[

Common sources of omega-3 fatty acids include: flax, salmon, and hemp.

Common sources of omega-6 fatty acids include: sunflower, safflower, and canola.

Unsaturated fatty acids are more susceptible to oxidative rancidity, particularly those high in the omega-3 and omega-6 fatty acids. Oxidative rancidity occurs more rapidly when fats are exposed to heat. As a result, these oils must be treated with special care when they are used in foods. Because the conversion of one form of fatty acid to another does not occur with 100% efficiency, omega-3 and omega-6 fatty acids may be supplemented in a variety of forms.

The various forms include:

* n-6 : Linoleic (LA), Dihomo gamma linolenic (DHA) and arachadonic
* n-3: Linolenic ; EPA and DHA

Fats serve a wide range of functions:

* nutritive
* structural/textural
* processing (frying, dehydration)
* lubrication
* release agents
* flavor enhancement

Fats are extracted from plant products using hydraulic presses or chemical (petroleum ether) extraction. They may be further purified by steam distillation and treatment with calcium hydroxide or calcium carbonate to precipitate any impurities. Finally, fats may be deodorized by filtration through activated filters. Animal fats are generally rendered, by means of boiling animal remains and allowing the fats to float. They may then be processed like vegetable fats, in order to purify them.

For specific applications, certain unsaturated fats are treated with hydrogen in the presence of catalysts to increase the level or saturation (hydrogenation). This will result in oils that are more stable, particularly when fats will be exposed to elevated temperatures (such as in baking or during frying). It is also done to increase the melting point, to produce fats that are ‘plastic’ or semi-solid at room temperatures (such as in margarine). Such chemical hydrogenation, however, does result in the production of ‘trans’ fatty acids. Saturated fats can occur in the ‘cis’ form, which the body can break down and digest. The ‘trans’ form is found in hydrogenated oils and the milk of ruminants. Excessive intake is thought to present a health hazard, and recently Health Canada has issued a maximum recommended daily intake for such trans fats. Manufacturers have responded by modifying their formulations to minimize the amount of trans fats their products contain.

Fats contribute and enhance flavor, mouth feel, and texture to food products. These characteristics have been difficult to mimic using alternative sources, such as carbohydrates (gums, starches) and proteins. Despite a wide trend to produce low-fat food products to take advantage of the increasing trend of health conscious consumers, manufacturers have found that consumers still prefer products that taste good over those that are good for them, when those two issues compete.

Nevertheless, the level of fat in food products has dropped. Future product development will no doubt focus on fats that are ‘healthy’ as opposed to absent.

**Module 8: Food Additives**

**M8-1: Colours**

**H1> Colours**

**<icon> Reference Reading:**

**Food Chemistry, Fennema, 4th ed., Chapter 4:**

* **Acid-base buffering p. 698, 707, 711**
* **Sequestering agents/phosphates p. 204, 527–529, 411**
* **Antioxidants p. 198–206, 463, 702–704**
* **Emulsifiers p. 270–275, 823–825**

**Colours**

Colours are found in a wide range of foods. The use of synthetic colours has decreased, however, and will continue to decrease, as alternatives are found.

Currently, the following synthetic food colours are legal for use (with limitations as to the amount) in Canada:

Amaranth (Not legal in US)

Allura Red (US: FD&C Red #40)

Tartrazine (US: FD&C Yellow #5)

Sunset Yellow (US: FD&C Yellow #6)

Erythrosine (US: FD&C Red #3)

Brilliant Blue (US: FD&C Blue #1)

Indigotine (US: FD&C Blue #2)

All these colours are water soluble dyes. All are available as oil soluble products (known as lakes). Lakes are manufactured by the treatment of the dyes with aluminum hydroxide, resulting in aluminum salts of these dyes. Generally, they are found in food products and are used at a levels from 10–400 ppm by eight.

Artificial colours are extremely concentrated and difficult to handle unless good clean-up and ventilation is available. Because of their extreme dustiness (particle sizes from 200–400 Mesh), the powder readily becomes airborne and can contaminate everything in a processing plant. Because of this, dye manufacturers now produce agglomerated powdered, pastes, and liquids to allow for cleaner handling.

Natural colours offer a great alternative to dyes, but with many shortcomings. Natural colours are as a rule not stable in air or light, change tint with pH, and are much more expensive to use. The notable exception to this rule is caramel colour, which is derived from sugar, and is both light and oxygen stable, and can be obtained for a variety of pH applications.

*Common natural colours include:*

* + Grape skin (purple - red)
  + Turmeric (yellow)
  + Beet (purple - red)
  + Annato (orange-red) - found in most cheddar cheese
  + Black Carrot extract (purple red)
  + Titanium dioxide ( a mineral - used as white colour or clouding agent )
  + Elderberry extract (red-purple)
  + Spinach Extract (green)
  + Canthaxanthin (pink)
  + Astaxanthin (pink)
  + Paprika (orange)
  + Cochineal (ground beetle shell)
  + Tomato (orange red)
  + Pomegranate juice

There is no natural blue colour commercially available at this point, making blue, some purple shades, and various green food colours impossible to manufacture naturally.

**M8-2: Vitamins & Minerals in Foods**

**<h1> Vitamins and Minerals in Foods**

Vitamins and minerals are regularly added to a variety of food products, although their use is heavily regulated by Health Canada. These essential nutrients occur naturally in many foods, but in certain instances fortification is required or desired. It is important to note, especially for those working in the health food product and fortification industry, that vitamins and minerals frequently work synergistically and have interactions that must be addressed when formulating foods.

Vitamins facilitate the absorption, regulation, and utilization of other vitamins, minerals, and metabolic intermediates in rather complex and involved manners, which need to be understood and incorporated during the design of a food product. The Food and Drug Act, which regulates what vitamins and minerals should be incorporated into foods, and at what levels, takes part of this complexity into account.

Foods that require fortification include: breakfast cereals, or food represented as breakfast foods; meal replacements; human milk replacements (infant formulae); milk and milk products; fruit-flavored juice; wheat flour, and by extension, bread and pasta products.

Food processors are faced with several challenges when adding vitamins and minerals to foods and nutritional supplements:

* First, many vitamins are heat labile and will not tolerate the extreme temperature or processing conditions required to stabilize a food product.
* Second, several oxidize readily and must be protected to conserve their activity in the food long enough for it to be consumed and provide a benefit to the consumer.
* Additionally, the levels that are allowed by food and drug regulations are closely controlled. The processor needs to have accurate data to ensure that only the required amount of fortification is added to ensure that the added nutrient does not exceed the tolerated level.

Dispersion of micro-nutrients in food products presents an additional challenge. Some additives are used at levels as low as 1–2 ppm. To effectively disperse 1 or 2 grams of a nutrient in a 1000 kg batch of a food requires effective mixing methods.

Some nutrients are water soluble, whereas others (vitamin A, vitamin D, vitamin E) require a fat phase to dissolve. This means that in some cases, both phases must be present in order to assure proper dispersion.

Since micro-nutrients, specifically vitamins, degrade over time, these micro-nutrients must also be added in sufficient quantity to ensure that the product will provide the minimum stated level of all nutrients over the entire shelf-life of the product. In order to achieve this, certain tolerances for ‘overage’ are regulated.

Certain nutrients also provide a dual function in foods. Vitamin E, for example, is a highly effective stabilizer and antioxidant for fats. It may be added to certain fats to ensure a long shelf-life. But just because it is added as a preservative for fats, it may not necessarily be claimed as an added nutrient. Ascorbic acid serves a similar dual role. Certain minerals, such as calcium, in the form of tricalcium phosphate, function as an anticaking agent in powder blends. Tricalcium phosphate is also recognized as an approved fortification of calcium and phosphorus.

Minerals can also cause difficulties. Iron, for example, is fortified in a variety of formats, most of which are magnetic. Many food products use magnets to remove foreign ferrous or magnetic metal fragments from their products. In such a case, the mineral is added at one end and removed at the other end of the food processing line, thereby defeating the purpose of fortification.

Minerals can also pose problems in shelf life. Because many minerals are added in the form of ionic salts, the free metal ions can cause problems in the breakdown of the food product.

A thorough analysis of the entire process of the food production system will reduce the effert required in the product development stage. Additionally, an intimate knowledge and understanding of the laws and regulations pertaining to the fortification of food products in Canada and the US is required to ensure proper application of these nutrients in foods.

Following is a synopsis of the Vitamins, Minerals and (inter-)action of these micronutrients:

*<h2>* ***Vitamins***

1. Vitamin A (found in animal tissues, especially livers and fish oils – formed by conversion of carotenoids, especially Beta Carotene)
   1. Beta Carotene (pro Vitamin A) (found in plants and vegetables)

A fat soluble vitamin that plays a role in the maintenance of eyesight. Vitamin A can be toxic a high doses for prolonged periods.

1. Vitamin B1 (thiamine). The B Vitamins are best taken as a complex, as they act together in a host of functions. B1 functions in circulation, blood formation and as an antioxidant. Deficiency diseases: Beriberi, edema, constipation, hepatocephaly

Sources: brown rice, egg yolks, fish, legumes, bran (wheat, rice), whole grains. B1 is widely added to flour and grain based products.

1. Vitamin B2 (riboflavin). B2 is required for red blood cell formation. It assists in the absorption of Iron and B6. Required for the metabolism of tryptophan, which the body converts to B3 (niacin). Deficiencies include: Cracking of lips, oral & lingual lesions, dermatitis.

Sources: beef liver, broccoli, brewer’s yeast, carrots, cheese.

1. Vitamin B3 (niacin / niacinamide / nicotinamide) B3 is required for circulation, skin maintenance, nervous system function. Converted from the amino acid tryptophan with the aid of B2. Deficiencies of B3 manifest as: Pellagra, canker sores, dementia, depression, dizziness.
2. Vitamin B6 (pyridoxine) B6 is required in production of Hydrochloric acid (stomach), red blood cell formation, RNA & DNA sysnthesis,, immunity, enzyme activation, absorption of B12, regulation of homocysteine (which is responsible for deposition of fat around heart muscle)

Deficiency maladies include: anemia, convulsions, headaches, flaky skin and vomiting.

Found in: Brewer’s yeast, carrots, chicken, eggs, fish, meat, sunflower seeds, walnuts, most foods.

1. Vitamin B12 (cyanocobalamin). B12 aids the regulation of red blood cells with folic acid. Aids in cell formation, prevents nerve damage

Deficiency disorders: abnormal gait, chronic fatigue, constipation, depression, memory loss, tintinus,

Sources: Eggs, milk (especially whey proteins, fish, liver, clams

1. Vitamin C (ascorbic acid, sodium ascorbate, ascorbyl palmitate). A potent antioxidant that is required for tissue repair and growth, adrenal glands, required for metabolism of folic acid, tyrosine, and phenylalanine. It increases iron absorption, may reduce cholesterol levels.

Vitamin C is readily lost in the urine, and cannot be synthesized by the body, so dietary replacement is essential. Deficiencies include: scurvy, slow healing of injuries, edema and soft, bleeding gums.

It is found in berries, fruits, peppers, and most vegetables. In manufactured foods it is often added to fruit juices or fruit flavored frinks

1. The body through exposure to sunlight can synthesize Vitamin D. It is fat soluble, and required for the utilization of Calcium and the production of healthy bones and teeth. The sources delivered from foods are not fully active, and requires conversion by the liver in order to be functional. This explains why people with impaired liver function are susceptible to osteoporosis.

It is commonly added to milk and should be taken with Calcium. High doses can be toxic.

1. Vitamin E (d,l- α-tocopherol) is a powerful antioxidant. It protects against certain forms of cancer and is needed for tissue repair. It promotes normal blood clotting, reduces blood pressure, strengthens muscles. In order to properly utilize Vitamin E, the body requires zinc. Inorganic forms of iron (such as Sulphate, Oxide, etc.) oxidize Vitamin E, whereas organic (ferrous fumarate, ferrous gluconate) forms do not.

Sources : cold pressed oils, dark leafy green vegetables, legumes, seeds, nuts, grains, eggs, organ meats

1. Vitamin K (phyloquinone) is required for the production of prothrombin (blood clotting factor), bone & tissue repair, essential for bone repair & formation, calcium depositing on bones.

Sources include molasses, asparagus, Brussels sprouts, egg yolks, liver, oats. A majority of this vitamin is produced by the normal intestinal microflora.

1. Folic acid / Folate is used in RNA & DNA synthesis, protein metabolism, brain function, and helps prevent anemia. It is found to be especially useful in preventing birth defects including spina bifida, anencephaly and other neural tube defects. Works together with Vitamins C and B12.

Sources include barley, beef, bran, brown rice, cheese, chicken, leafy green vegetables

1. Pantothenic acid / Pantothenate
2. Biotin is needed in cell growth & fatty acid production and the utilization of B vitamins, metabolism of fats, proteins and carbohydrates. Deficiency in adults is rare (produced in the intestine, but can manifest as hair loss, depression, anemia, hyperglycemia

Found in brewer’s yeast, cooked egg yolks, meat, milk, poultry

1. Choline is used in nerve impulse transmission, gall bladder regulation and liver function. Deficiency can cause memory impairment & impaired brain function. It is found in egg yolks, lecithin, legumes, meat, milk and whole grain cereals

*<h2>* ***Minerals***

1. Calcium
2. Chloride
3. Chromium
4. Copper
5. Iodine
6. Iron
7. Magnesium
8. Manganese
9. Molybdenum
10. Phosphorus
11. Potassium
12. Selenium
13. Sodium
14. Vanadium
15. Zinc

**M8-3: Preservatives**

**<h1> Preservatives**

Preservatives have been used in the preparation of food products for centuries. Some uses were more inadvertent than planned. Most were likely developed by trial and error, which makes you wonder how many sensory scientists perished in food preservation techniques gone horribly wrong. Unfortunately, such techniques are still perpetuated. Many would-be food processors still believe that garlic is an excellent preservative and that sufficient quantities of grape seed extract are enough to kill whatever bacteria may be present or introduced during the commercial or kitchen preparation of foods.

It is unfortunate that people will believe such folk tales. It is also frightening that people will enter the commercial preparation of perishable food products with such ill-conceived notions. They expose hundreds or thousands of consumers to unnecessary risk.

The reason behind such notions lies in the belief that preservatives are dangerous, unnatural, and present long-term toxicity. This belief ignores the very real fact that food poisoning is a greater cause for sickness, disability, and death than preservative toxicity.

Ironically, many preservatives have their origin in natural products and methods.

Natural preservative methods include:

* cranberry juice treatment of salmon by West Coast natives (cranberries contain significant levels of benzoic acid)
* fermentation of dairy products to produce yogurt, cheese, buttermilk, and sour cream (lactic acid, a by-product of selected bacterial fermentation of dairy products, is a highly effective inhibitor of bacteria and yeasts)]
* treatment of fresh cut fruits with lemon/lime juice (both ascorbic and citric acids are present in citrus fruits, which provide both inhibition against enzymatic browning and bacterial degradation)
* pickling of fruits, vegetables, eggs, fish, and meats (acetic acid in vinegar is an excellent preservative)
* use of saltpeter in preservation of meat products (saltpeter is potassium nitrate, which is, along with other nitrate and nitrite salts, one of the few known antimicrobials effective against C. Botulinum)

Microbial cultures can also be effectively employed in food preservation. This is due to bacteriostatic chemicals produced by these organisms, such as propionic acid, lactic acid, acetic acid, etc., that preclude the growth of spoilage and pathogenic bacteria. Examples of cultures include lactobacillus cultures in dairy and meat products, micrococcus species in meats, and yeasts in beer and wine.

In the North American market, the time between harvest, processing, and consumption requires the use of certain preservatives to ensure that consumers enjoy safe and stable products. Few consumers are willing to accept food products that spoil within a day of purchase, or before.

There is a wide range of preservatives available to food processors. Some of these are intended to prevent microbial growth, others are intended to retard the natural breakdown of the food components. It is important to note that most preservatives do not kill micro-organisms, but inhibit their growth. If sufficient levels of micro-organisms are present in a food prior to the addition of a preservative, and no other methods are employed to reduce those micro-organisms, no amount of preservative will help the shelf life of the product.

The preservatives in Canada are broken down into four classes. The following listing provides a partial listing of these preservatives.

.The Class I preservatives include, but are not limited to:

* + Acetic acid
  + Ascorbic acid (vitamin C)
  + Calcium ascorbate (Calcium salt of ascorbic acid)
  + Erythorbic acid (iso-ascorbic acid)
  + Sodium Ascorbate (sodium salt of ascorbic acid)
  + Sodium erythorbate (sodium iso-ascorbate)
  + Sodium Nitrite
  + Wood Smoke

Essentially, all class I preservatives are allowed in certain processed meat products sold in Canada. As a rule, they are the only preservative permitted in meats.

The Class II preservatives include:

* + Benzoic acid
  + Methyl paraben
  + Potassium Bisulphite
  + Potassium Metabisulphite Antimycotic
  + Potassium sorbate broad range bacteriostatic
  + Propyl paraben
  + Sodium benzoate broad range bacteriostatic
  + Sodium bisulphite
  + Sodium Metabisulphite Used in vegetables & fruits to preserve colour
  + Sorbic Acid

The Class III preservatives include:

* + Calcium propionate mold rope inhibitor in breads and doughs
  + Natamycin Used on the surface of cheese to prevent mold growth
  + Potassium Sorbate
  + Propionic acid
  + Sodium Diacetate
  + Sorbic acid

Most of the above preservatives are those allowed in bread and dough products (except natamycin).

Class IV preservatives are intended for fats. They all function by inhibiting oxidative rancidity, as most fats are not susceptible to microbiological spoilage. They include:

* + Ascorbic acid
  + Ascorbyl palmitate
  + Ascorbyl stearate
  + Butylated Hydroxy Anisole (BHA)
  + Butylated Hydroxy Toluene (BHT)
  + Citric acid
  + l-Cysteine Hydrochloride
  + Lecithin
  + Lecithin Citrate
  + Monoglyceride citrate
  + Mono-isopropyl citrate
  + Propyl Gallate
  + Tartaric Acid
  + Tocopherols (mixed or alpha)
  + TBHQ (tertiary butylhydroxyquinone)

The water soluble preservatives (ascorbic acid, citric acid, tartaric acid) are used to chelate free metal ions that can contribute to rancidity. They are added to fats by means of specialized emulsions.

Note: Rosemary extract has also been successfully employed as an antioxidant for fats.

The regulations generally prescribe the maximum usage levels of preservatives. These usually exceed the required usage levels for most food products, and therefore are used at lower levels.

Aside from the preservatives, there is a range of chemicals that are used to accomplish certain processing challenges, provide for flavour profile, or other formulation difficulties

**M8-4: pH Adjusting / Acid reacting & Water reacting chemicals**

**<h1> pH Adjusting / Acid reacting and Water reacting chemicals**

pH adjusting chemicals are widely used as a means of food preservation. Acidification of food products is used to enhance their palatability and reduce the incidence of bacterial spoilage, as many spoilage bacteria are unable to proliferate in high acid conditions.

Alkali are used in various areas also. Phosphates are commonly used in meat products to enhance their tenderness and to counteract lactic acid formation, which leads to degradation of the muscle meats.

Alkali are also used in bakery applications, predominantly in the form of chemical leavening agents (sodium bicarbonate, ammonium bicarbonate).

Chemical leavening agents are used for the same purpose as yeasts: to produce carbon dioxide to increase the porousness of a dough, to form structure. Yeast, however, requires carbohydrates, and time to accomplish this task. It also contributes flavours, which is desirable in breads, but less so in other baked goods (cakes, pastry), Chemical leaveners provide a rapid and accurate method of introducing the right level of structure to a baked good in a consistent fashion.

Sodium bicarbonate has been the most widely used in the chemical leavening industry. It is regularly used together with a leavening acid to produce carbon dioxide, but will dissociate with heat:

Sodium bicarbonate dissociation

2 NaHCO3 + heat 2 NaCO3 + CO2 + H20

Due to the fact that this happens at rather high temperatures, during which time, in baked products, some irreversible changes take place (protein denaturation, starch swelling), it is desirable to accelerate this reaction with the use of an acid.

Acid neutralization of sodium bicarbonate

2 NaHCO3 + H+ Na+ + CO2 + H20

Sodium bicarbonate is readily soluble in water, so the rate of reaction is governed by the rate of dissolution/dissociation of the leavening acid. As the acid dissolves and dissociates, the hydrogen ions are released and become available for the reaction.

The neutralizing value (NV) measures the rate of dissolution of a leavening acid (and therefore its ability to neutralize sodium bicarbonate). NV is defined as the amount (in grams) of sodium bicarbonate neutralized by 100 g of the leavening acid.

Another measure employed to measure the effectiveness of a leavening acid, is the equivalence value (EV). EV is defined as the number of grams of leavening acid required to neutralize 1 gram of sodium bicarbonate. This establishes the relationship between NV and EV as follows:

EV = 100/NV

Table 8-1: Reactions of Leavening Acids

| **Reactions of Leavening Acids** | | |
| --- | --- | --- |
| **Leavening Acid** | NV | EV |
| **Monocalcium Phosphate (MCP)** | 80 | 1.25 |
| **Sodium Acid Pyrophosphate** | 72 | 1.39 |
| **Sodium Aluminum Phosphate** | 100 | 1.00 |
| **Sodium Aluminum Sulphate** | 104 | 0.96 |
| **Dicalcium Phosphate** | 35 | 2.86 |

In addition to the neutralizing/equivalence value, the rate of reaction of a leavening acid is important. The rate of reaction of a leavening acid is defined as the time required to achieve 60% of the total reaction with sodium bicarbonate (measured on a logarithmic scale).

The formulator's choice of leavening acid in a product will depend on the time and temperature of the baking/cooking of a product, the amount of moisture in the product, the preparation (mixing speed and time) and the holding time of the hydrated dough or batter.

Table 8-2:The Common Use of pH Adjusting / Acid reacting and Water reacting chemicals

**pH Adjusting / Acid reacting and**

**Water reacting chemicals Common Uses**

Acetic acid Pickling

Adipic acid Acidulant

Ammonium Bicarbonate Baking Powder (cookies)

Calcium Carbonate pH adjusting agent (alkali)

Calcium Chloride Water softening agent

Calcium Citrate Buffer / Calcium source

Calcium Hydroxide Lye Used to produce Masa from corn meal

Dicalcium Phosphate pH adjusting agent

Monocalcium Phosphate Baking powder formulations

Tricalcium Phosphate

Citric acid Acidulant

Cream of Tartar Baking

Fumaric Acid Acidulant

Glucono delta lactone Acidulant

Lactic acid Acidulant

Malic acid Acidulant

Phosphoric acid Acidulant (Cola beverages)

Potassium Acid Tartrate Baking Powder

Potassium Chloride Salt replacer

Potassium Citrate Buffer

Dipotassium Phosphate Coffee Creamer

Sodium Acid Pyrophosphate Baking Powder

Sodium Aluminum Phosphate Baking Powder

Sodium Aluminum Sulphate Baking Powder

Sodium Bicarbonate Baking Powder

Sodium Citrate Buffer

Sodium hexametaphosphate pH Adjuster (used with Sodium tripolyphosphate) - used in meat products

Sodium Lactate

Disodium Phosphate Cheese products / meat products

Monosodium Phosphate Cheese products

Sodium Potassium Tartrate Baking powder

Tetrasodium pyrophosphate Baking Powder

Sodium Tripolyphosphate pH Adjuster - meat products

Tartaric acid Acidulant

**M8-5: Sequestering agents**

**<h1> Sequestering agents**

Sequestering agents are used to scavenge free metal ions in liquid/plastic foods. Due to the oxidative effect of metal ions, they can contribute to spoilage by means of flavor degradation and oxidative rancidity.

Most of the sequestering agents are citrates and phosphates. The sodium salts of these products are commonly the most cost-effective and soluble, hence the most often used. Alternatives include the potassium and calcium salts. Potassium salts can have flavour problems (they are frequently bitter) and the calcium salts are not as readily soluble. In areas where excessive sodium is present in the food, they will often be employed. The magnesium salts are rarely used unless specific dietary requirements are to be achieved.

EDTA (ethylene diaminetetraacetate) is commonly used in salad dressings, where it is very effective in preventing oxidative rancidity of the fats by tying up mineral ions found in process water and other ingredients.

Sequestering agents also play an important role in the moisture retention in meat, where they act as moisture binders and inhibitors to ‘rigor’ of meats. As a result, they are extensively used in whole muscle-processed meat products such as roast beef, ham, bacon, and roasts.

To a lesser extent, and for somewhat different reasons, sequestering agents are used in emulsified meat products such as hot dogs, bologna, and other comminuted meats. Here, they provide the right pH conditions to allow the meat protein, water, and fats, to be mixed into a stable emulsion.

Following are the more common sequestering agents:

* + Sodium hexametaphosphate
  + Citric acid
  + Potassium citrate
  + Calcium citrate
  + EDTA (ethylene diaminetetraacetate)
  + Disodium phosphate
  + Sodium tripolyphosphate
  + Tetrasodium pyrophosphate
  + Tricalcium phosphate
  + Monocalcium phosphate
  + Sodium acid pyrophosphate
  + Tetrapotassium pyrophosphate
  + Dipotassium phosphate
  + Monocalcium phosphate
  + Dicalcium phosphate
  + Sodium Citrate

**M8-6: Ingredients used in Health Food Products & Sports Nutrition**

**<h1> Ingredients used in Health Food Products and Sports Nutrition**

With the soaring cost of health care and the renewed trend toward natural foods, there has also been a tremendous growth in the health food industry to produce foods with medical, and improved nutritive and preventative qualities. This is not new. The Assyrians, Babylonians, Egyptians, and Sumerians were known to use foods to heal medical conditions thousands of years ago. The Chinese have amassed centuries of knowledge relating to medical conditions and foods that heal them. Some are based on herbs, others use extracts, and yet others look for a variety of food groups that yield certain desirable reactions in the body.

Modern food processing does lend itself well to incorporating traditional herbal medicine into foods, but Canadian regulations simply do not permit the use of foods as medicine. That is, any product that makes a claim about treating, preventing, or healing a medical condition is classified as a drug and must meet all the requirements of drugs.

This explains why you will find many products with veiled references and trade names that subtly imply the medicinal or curative properties, but none that clearly state what they are intended for.

Due to the stringent regulations, a whole new method of communication, the modern age jungle drum, if you will, has developed to convey information from rudimentary research to consumers and vice versa.

The development of the Internet as an anonymous tool of mass communication has allowed this proliferation of information, sometimes to benefit, and at other times to great detriment.

Manufacturers may not make health-related claims about their products, neither on the label nor on any advertisement relating to the product. As a result, they are hampered by regulations to communicate the benefits and advantages to the consumers. Editorials, newsletters, and Internet chat areas through third parties, however, cannot be regulated the same way. These then become the areas where the information (and sometimes misinformation) flows freely.

Many herbs and related materials are recognized to have a positive or negative impact on health and sports performance. The usage levels and stringent medical data supporting their applications are generally lacking or poorly defined. As a result, current regulations allow for the use of a host of materials in various applications. The scientific data is lagging behind in substantiating the supposed and assumed safety and efficacy of the materials.

Health Canada has established a new Office of Natural Health Products, and is developing new regulations to address this phenomenon. In the interim, products from Canada’s biggest trading partner, the USA, where products are not subject to the same laws and regulations, are finding their way to Canadian consumers, through mail order, Internet purchases or cross-border shopping. Until new laws have been developed to allow consumers and manufacturers to share products and information appropriately, many mistakes and violations will continue to be made.

Following ( Table 8-3) is a partial list of herbs, herbal extracts, animal extracts, and metabolic intermediates that have found their way into the food, sports nutrition, and the health food industry, with some of the claimed benefits associated with these products. This list of the ingredients is currently in use by food, health food and pharmaceutical manufacturers. These products may occur singly, or in combinations, and may be sold as supplements, or as part of a food or nutrition product.

Table 8-3. Health Food Ingredients

Ingredient Claimed Benefits / Nutritive Properties

|  |  |
| --- | --- |
| Acerola | Natural source of Vitamin C |
| Alfalfa Powder | Source of protein & vitamins |
| Alpha Lipoic Acid 99% | An antioxidant |
| Anise Seed Turkish Powder | Digestive aid |
| Apple Cider Vinegar Powder | Metabolic aid, weight loss |
| Apple Pectin Powder | A source of fiber |
| Astragalus powder | Lowering of blood pressure; diuretic |
| Atlantic Kelp | Source of iodine & trace minerals |
| Barley Whole Leaf Powder | Source of minerals & vitamins, rutin |
| Bee Pollen Powder | An immune aid |
| Beet Juice Concentrate | Digestive aid, source of minerals |
| Bilberry Extract | Improve eyesight, source of anthocyanins & antioxidants |
| Bioperine | Black pepper extract |
| Bladderwrack Powder (Fucos vesculosis) | Source of iodine, regulates thyroid function |
| Blue Cohosh Root Powder | antispasmodic, diuretic, anti-rheumatic |
| Borage Oil (Spray Dried) | Natural Source of Omega 3 fatty acids |
| Bromelain | Used to improve protein digestion |
| Buchu Leaf powder | Relieves bloating associated with PMS, diuretic |
| Burdock Root Powder | Anti-rheumatic, anti-arthritic |
| Butcher's Broom Powder | Vasoconstrictive, anti-inflammatory |
| Caffeine | Used to provide energy |
| Calcium Alpha Ketoglutarate | A Metabolic intermediate |
| Calcium Beta-Hydroxybeta-Methyl Butyrate | Increases strength & endurance |
| Calcium Pyruvate | Weight loss, increased endurance |
| Carrot Juice Concentrate | A source of provitamin A (beta carotene) |
| Carrot Powder | A source of provitamin A (beta carotene) |
| Cayenne Capsicum | An immune supplement |
| Celery Stalk Powder | Anti-rheumatic, anti-arthritic |
| Cetyl Myristoleate Powder | Used to combat joint pain / stiffness |
| Choline Bitartrate | A lipotropic facto, supports metabolism of fats & cholesterol |
| Citrus Aurantium Extract | Appetite suppressant, metabolic enhancer |
| Co-enzyme Q10 | Considered an essential nutrient in the maintenance of healthy skin |
| Coleus Forskohlii | Metabolic stimulant for fats |
| Corn Silk Powder | Urinary tract affectations |
| Cranberry Juice powder | Cures & prevents urinary tract infections |
| Creatine Monohydrate | Used to increase muscle volume, mass & strength |
| Cyanotis Vaga Root | Considered a plant steroid source |
| Dandelion Root Raw Powder | Regulates liver health |
| D-Ribose | Used to provide rapid energy |
| Echinacea Purpurea | An immune aid & used to fight colds & flues |
| Ephedra | A source of energy |
| Fennel Seed powder | Digestive aid |
| Fisetin | Antioxidant |
|  |  |
| Garcinia Cambogia (Citrus HCA) | Weight loss |
| Ginger Powder | Anti-inflammatory, digestive aid |
| Gingko Biloba | Enhances brain function, increases metabolic function |
| Glucomannan | A fiber |
| Glucosamine Sulfate K salt | An anti-arthritic |
| Glucosol (Lagestroemia Speciosa L. Ext) | Controls blood sugar / anti-diabetic |
| Glutamic Acid HCL | An amino acid |
| Glutamine Peptides | Used as a source of Glutamic Acid to increase muscle mass and strength |
| Glycine | An amino acid |
| Grape Seed Extract | A natural antioxidant |
| Green Tea Polyphenole | A natural antioxidant |
| Guarana Extract | A natural source of caffeine / energy |
| Guggul | Thought to control blood cholesterol |
| Gymnema Sylvestre | Considered to regulate blood glucose levels |
| Horny Goat Weed | Claimed as an Aphrodisiac |
| Horse Chestnut Extract | anti-inflammatory, circulatory aid |
| Horsetail Extract 4:1 | Used to reduce water retention (diuretic) |
| Huperizine A extract 5% | Thought to promote acetylcholine (nerve transmitter chemical) |
| Hydrangea Powder | Treatment of inflamed prostate |
| Inositol | An amino acid |
| Inulin HD | Used as a fiber and food source for probiotics |
| Inzitol (D-Pinitol) | Considered useful as an insulin activator |
| Ipriflavone | A source of isoflavones |
| Juniper Berry Powder | Diuretic |
| Kola Nut PE | A source of caffeine (energy) |
| Lactobacillus Acidophilus | A probiotic / intestinal aid |
| Lactobacillus Sporogenes | A probiotic / intestinal aid |
| LACTOFERRIN | An immune supplement |
| L-Carnitine | Thought to improve fat metabolism |
| Phosphatidyl Serine | An essential component in the maintenance of nerve cells |
| Licorice Root PE 25% | A digestive aid, source of fiber |
| Lipase | A digestive aid in the breakdown of fats |
| L-Lysine HCL | An amino acid |
| L-Tyrosine | An amino acid |
| Mucuna Pruriens Dry Extract | Increases testosterone levels, Aphrodisiac |
| Medium Chain Triglycerides | A fat source derived from fractionated coconut oil |
| Methoxy 7 Ipriflavone | Thought to increase bone density |
| Mexican yam powder | Source of DHEA, anti inflammatory, anti-arthritic |
| Milk Thistle extract | Antioxidant, restorative |
| Momordica Charantia Ext | (Bitter Melon) Used to treat diabetes & AIDS virus inhibition |
| MethylSulphonylMethane | Provides organic sulphur |
| Mucuna Ext (Dopa Bean) | Aphrodisiac |
|  |  |
|  |  |
| Muira Puama | Aphrodisiac |
| N- Acetyl Cysteine | A form of amino acid |
| Neopuntia | Thought to affect fat metabolism |
| Nettle Leaf Powder | Diuretic |
| Ipriflavone | A source of soy isoflavones |
| Oat Straw | A source of fiber |
| Parsley powder | Source of Vitamin C, Diuretic |
| Phytic Acid - Inositol Hexaphosphate | An amino acid |
| Pine Bark extract | An antioxidant |
| Psyllum Husk powder | A fiber source |
| Quercetin | A source of bioflavanoids |
| Red Clover Leaf Extract | Source of isoflavones, skin conditions |
| Rhodiola Rosea | Thought to be calming, anti-stress |
| Rice Protein Powder | A source of protein |
| RNA Powder | A source of ribonucleic acids |
| Rosemary Powder | An antioxidant |
| Royal Jelly | An immune aid |
| Rutin Flower | Bioflavanoid, antioxidant |
| Siberian Ginseng powder | An energy source, Aphrodisiac |
| Sida Cordifolia | Anti-inflammatory |
| Soy Fiber | A source of fiber |
| Soybean Oil | A source of Omega 6 fats |
| Spirulina | Source of Vitamin B12, amino acids, carotenoids & xanthophyll, immune stimulant |
| Stevia powder | A natural sweetener |
| Taurine JP 8 | An amino acid |
| Thyroid USP 23 | Bovine glandular extract - improvement of growth |
| Tomato Lycopene powder | A source of lycopenes |
| Tribulus Terrestris | Aphrodisiac, anti-inflammatory |
| Tulsi Extract | Digestive aid |
| Turmeric Extract Curcumin | A natural anti-inflammatory agent |
| Lecithin | Considered important in maintenance of nerve cells |
| Uva Ursi Leaf | Used in urinary tract infections |
| Wheat Germ | A source of fiber |
| White Willow Bark Powder | A source of acetylsalicylic acid - a pain reliever |

Formulation of encapsulated products or herbal supplements presents similar challenges as those with vitamins.

Considerations that must be addressed include:

* + Strength of the herb (extract or powder) or supplement
  + Declared amount of active ingredient on label
  + Capsule weight & capsule capacity
  + Bulk density of herb or supplement
  + Amount of wetting / anti-dusting agent added (varies with the bulk density of the supplement)
  + Amount of bulking agent added (varies with the strength of the herb or supplement)
  + Contra-indications of herbs, supplement when taken singly, in combination or with other medications.
  + Filling tolerances (acceptable limits)

**Summary**

Figure 8. Putting it all together (An example)

PH adjusting agents

Vitamins / Minerals Microbial Culture

Carbohydrates:

Moisture Sugars

Fibre / hydrocolloids

Starch

Bread

Flours

Humectants

Preservatives

(antioxidants) Fats & Oils

Proteins Emulsifiers

Preservatives (antimicrobials)

The above example demonstrates the functions of the various food ingredients and how they will be compiled into a food product:

* vitamins (B1, B3) are added to the flour
* minerals are naturally occurring in the flour; moisture is added in the form of water
* preservatives (antioxidants) are added in the form of ascorbic acid and sodium steroyl lactylate
* proteins are inherent in the flour, or may be added as wheat gluten, egg, or milk ingredients
* preservatives (antimicrobials) are added as proprionates
* emulsifiers are added as lecithin or mono- and diglycerides
* fats occur as shortenings, oils, or dairy fats
* carbohydrates are added as flour, sugar (yeast food), and possibly fiber (bran, hydrocolloids)
* microbial culture is added as lactic acid bacteria (sour dough) or yeast. pH adjusting ingredients may be added to ensure the proper pH of the process water

Food ingredients are versatile and powerful products in the food, nutrition, and health food industries. They perform a wide array of functions that allow formulators and food processors to produce wholesome and safe food products. The understanding of the functionality, safety, and legalities surrounding the use of food ingredients are of paramount importance to successful use of these tools.

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