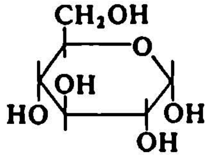
All of these areas, and a great many more referred to in subsequent chapters, provide daily problems for food scientists. Together they help convey a better understanding of the term food science than can any simple definition.

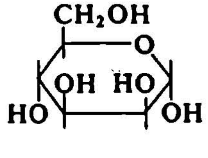
References

Altschul, A.M. 1993. Low-Calorie Food Handbook. Marcel Dekker, New York.
Bauernfeind, J.C. and Lachance, P.A. 1991. Nutrient Additions to Food: Nutritional, Technological and Regulatory Aspects. Food & Nutrition Press, Trumbull, CT.
Catsberg, C.M.E. and Kempen-Van Dommelin, G.J.M. 1989. Food Handbook. E. Halsted Press, New York.
Charalambous, G. 1992. Food Science and Human Nutrition. Elsevier, Amsterdam.
Hall, R.L. 1992. Global Challenges for Food Science Students. Food Technol. *46*(9), 92, 94, 96.
Harlander, S. 1989. Introduction to Biotechnology. Food Technol. *43*(7), 44, 46, 48.
Hood, L.F. 1988. The Role of Food Science and Technology in the Food and Agriculture System. Food Technol. *42*(9), 130–132, 134.
Hui, Y.H. 1992. Encyclopedia of Food Science and Technology. Wiley, New York.
Institute of Food Technologists. 1992. IFT Undergraduate Curriculum Minimum Standards for Degrees in Food Science 1992 Revision. Institute of Food Technologists, Chicago.
Levine, A.S. 1990. Food Systems: The Relationship Between Health and Food Science/Technology. E.H.P. Environ. Health Perspect. *86*, 233–238.
Morton, I.D. and Lenges, J. 1992. Education and Training in Food Science. A Changing Scene. E. Horwood, New York.
O'Brien, J. 1991. An Overview of Online Information Resources for Food Research. Trends Food Sci. Technol. *2*(11), 301–304.
Ockerman, H.W. 1991. Food Science Sourcebook. 2nd ed. Chapman & Hall, London, New York.
Patlak, M. 1991. Looking Ahead to the Promises of Food Science in the Future. News Rep. *61*(2), 13–15.
Rayner, L. 1990. Dictionary of Foods and Food Processes. Food Science Publishers, Kenley, Surrey, England.
Ronsivalli, L.J. and Vieira, E.R., 1992. Elementary Food Science. 3rd ed. Chapman & Hall, London, New York.
Shewfelt, R.L. and Prussia, S.E. 1993. Postharvest Handling: A Systems Approach. Academic Press, San Diego, CA.

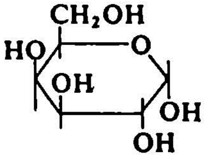
Simple carbohydrates are called sugars. One of the simplest carbohydrates is the six-carbon sugar glucose. Glucose and other simple sugars form ring structures of the following form:



α-D-glucose



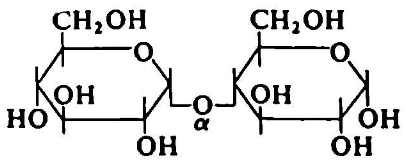
α-D-mannose



α-D-galactose

These simple sugars each contain 6 carbon atoms, 12 hydrogen atoms, and 6 oxygen atoms [$C_x(H_2O)_y$ where $x=6$; $y=6$]. They differ in the positions of oxygen and hydrogen around the ring. These differences in the arrangement of the elements result in differences in the solubility, sweetness, rates of fermentation by microorganisms, and other properties of these sugars.

Two glucose units may be linked together with the splitting out of a molecule of water. The result is the formation of a molecule of a disaccharide, in this case maltose:



Common disaccharides formed in similar fashion are sucrose (e.g., cane or beet sugar) made from glucose and fructose (a five-membered ring), maltose or malt sugar from two molecules of glucose, and lactose or milk sugar from glucose and galactose. These disaccharides also differ from one another in solubility, sweetness, susceptibility to fermentation, and other properties.

A larger number of glucose units may be linked together in polymer fashion to form polysaccharides (i.e., "many sugars"). One such polysaccharide is amylose, an important component of plant starches (Fig. 3.1). A chain of glucose units linked together in a slightly different way forms cellulose.

Thus, the simple sugars are the building blocks of the more complex polysaccharides, the disaccharides and trisaccharides, the dextrins, which are intermediate in chain length, on up to the starches, celluloses, and hemicelluloses; molecules of these latter substances may contain several hundred or more simple sugar units. Chemical derivatives of the simple sugars linked together in long chains likewise yield the pectins and carbohydrate gums.

The disaccharides, dextrins, starches, celluloses, hemicelluloses, pectins, and carbohydrate gums are composed of simple sugars, or their derivatives. Therefore, they can be broken down or hydrolyzed into smaller units, including their simple sugars. Such breakdown in the case of amylose, a straight chain fraction of starch, or amylopectin, a branched chain fraction (Fig. 3.1), yields dextrins of varying intermediate chain length, the disaccharide maltose, and the monosaccharide glucose. This breakdown or digestion can be accomplished with acid or by specific enzymes, which are biological catalysts. Microorganisms, germinating grain, and animals including humans possess various such enzymes.

In this case, the fatty acids reacting with glycerol from top to bottom are lauric acid, stearic acid, and oleic acid, with carbon chain lengths of 12, 18, and 18, respectively. Stearic and oleic acids, although of similar length, differ with respect to the number of hydrogen atoms in their chains. Stearic acid is said to be saturated with respect to hydrogen. Oleic acid with two fewer hydrogen atoms is said to be unsaturated. Another 18-carbon unsaturated fatty acid with four fewer hydrogen atoms and two points of unsaturation is linoleic acid. This unsaturated fatty acid is a dietary essential for health. The degree of unsaturation also affects the physical properties, such as melting temperature, of fats.

Fat molecules can differ with respect to the lengths of their fatty acids, the degree of unsaturation of their fatty acids, the position of specific fatty acids with respect to the three carbon atoms of glycerol, orientation in the chains of unsaturated fatty acids to produce spatial variations within these chains, and in still other ways.

Fat molecules need not have all three hydroxyl groups of glycerol reacted with fatty acids as in a triglyceride. When two are reacted, the molecule is known as a diglyceride; when glycerol combines with only one fatty acid molecule, the resulting fat is a monoglyceride. Diglycerides and monoglycerides have special emulsifying properties.

Natural fats are not made up of one type of fat molecule but are mixtures of many types, which may vary in any of the ways previously described. This complexity of fat chemistry today is well understood to the point where fats of very special properties are custom-produced and blended for specific food uses.

The chemical variations in fats lead to widely different functional, nutritional, and keeping-quality properties. The melting points of different fats are an example of this functional variation. The longer fatty acids yield harder fats, and the shorter fatty acids contribute to softer fats. Unsaturation of the fatty acids also contributes to softer fats. An oil is simply a fat that is liquid at room temperature. This is the basis of making solid fats from liquid oils. Hydrogen is added to saturate highly unsaturated fatty acids, a process known as hydrogenation. More will be said about changes in fat consistency in the chapter on fats and oils (Chapter 16).

Some additional properties of fats important in food technology are the following:

- They gradually soften on heating, that is, they do not have a sharp melting point. Since fats can be heated substantially above the boiling point of water, they can brown the surfaces of foods.
- When heated further, they first begin to smoke, then they flash, and then burn. The temperatures at which these occur are known as the smoke point, the flash point, and the fire point, respectively. This is important in commercial frying operations.
- Fats may become rancid when they react with oxygen or when the fatty acids are liberated from glycerol by enzymes.
- Fats form emulsions with water and air. Fat globules may be suspended in a large amount of water as in milk or cream, or water droplets may be suspended in a large amount of fat as in butter. Air may be trapped as an emulsion in fat as in buttercream icing or in whipped butter.
- Fat is a lubricant in foods; that is, butter makes the swallowing of bread easier.
- Fat has shortening power; that is, it interlaces between protein and starch structures and makes them tear apart easily and short rather than allow them to stretch long. In this way, fat tenderizes meat as well as baked goods.
- Fats contribute characteristic flavors to foods and in small amounts produce a feeling of satiety or loss of hunger.

inhibitors and hemagglutinins of beans, avidin of egg white, and thiaminase of fish. Water soaking and fermentation also remove some cyanogenic compounds. Removal of gonads, skin, and parts of certain fish eliminates toxins concentrated in these tissues. Breeding and selection also have lowered concentrations of toxicants in certain plant foods. Further, in the course of evolution, man has developed physiological mechanisms to detoxify low levels of many potentially dangerous substances and has learned to exclude clearly toxic species as food sources.

Although much more remains to be learned, a varied diet of the conventional foods of a region or culture pose small risk from natural toxicants to normally healthy individuals. Departures from conventional food sources and time-honored processes without adequate testing, microbial toxins, and harmful levels of industrial chemicals generally present greater dangers. With respect to all substances that may be normal constituents of food or become part of a food, it is important to recognize that such substances are not harmless or harmful per se but only so in terms of their concentrations.

Water

Water is present in most natural foods to the extent of 70% of their weight or greater. Fruits and vegetables may contain 90% or even 95% water. Cooked meat from which some of the water has been driven off still contains about 60% water. Water greatly affects the texture of foods—a raisin is a dehydrated grape, and a prune, a dried plum. The form in which water occurs in foods to a large extent dictates the physical properties of the food. For example, fluid milk and apples contain approximately the same amount of water but have different physical structures.

Water greatly affects the keeping qualities of food, which is one reason for removing it from foods, either partially as in evaporation and concentration, or nearly completely as in true food dehydration. When foods are frozen, water as such also is removed, since water is most active in foods in its liquid form. As a liquid in foods, it is the solvent for numerous food chemicals and thus promotes chemical reactions between the dissolved constituents. It also is necessary for microbial growth.

The other reason for removing water from food (in addition to preservation) is to reduce the weight and bulk of the food and thus save on packaging and shipping costs.

A great deal of food science and food technology can be described in terms of the manipulation of the water content of foods: its removal, its freezing, its emulsification, and its addition in the case of dissolving or reconstituting dehydrated foods.

Water exists in foods in various ways—as free water in the case of tomato juice, as droplets of emulsified water in the case of butter, as water tied up in colloidal gels in gelatin desserts, as a thin layer of adsorbed water on the surface of solids often contributing to caking as in dried milk, and as chemically bound water of hydration as in some sugar crystals.

Some of these bound water forms are extremely difficult to remove from foods even by drying, and many dehydrated foods with as little as 2–3% residual water have their storage stability markedly shortened.

Close control of final water content is essential in the production of numerous foods: as little as 1–2% of excess water can result in such common defects as molding of wheat, bread crusts becoming tough and rubbery, soggy potato chips, and caking of salt and sugar. Many skills in food processing involve the removal of these slight excesses of water without simultaneously damaging the other food constituents. On