ENCYCLOPEDIA OF FOOD TECHNOLOGY AND FOOD SCIENCE SERIES • VOLUME 2

Encyclopedia of Food Technology

ARNOLD H. JOHNSON

MARTIN S. PETERSON

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THE AVI PUBLISHING COMPANY, INC.
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1974

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Foreword

The field of Food Science and Technology is a new one insofar as scientific disciplines are concerned—and, in fact, even the scientific treatment of foods.

Prior to World War I, the handling, treatment, and consideration of foods were more in the terms of an art rather than a science. Some changes, therefore, even took place during that war, but they were few indeed. The greatest advances in the field of food science have occurred since World War II.

During World War II, there was great emphasis on the development of highly acceptable rations that could be used easily, were high in nutritive value, and could be stored for a considerable period of time with a minimal loss of eating quality and nutritional value. Furthermore it was essential that they be foods that were safe and remained safe. These needs of the armed forces resulted in the development of a large and effective food laboratory by the Quartermaster in Chicago. As a result of this, there developed the philosophy of considering needs and wants of the consumer and especially with respect to acceptability, utility, or ease of use, stability or shelf-life, nutritive value and safety. This was important to the consumer of those days (the soldier) but it is more important to the peacetime consumer—all of us.

As a result of the continuation of this development, specialists have evolved who think scientifically in terms of foods. There has evolved a real need for these specialists. Consequently, universities have developed curricula and laboratories concerned with Food Science and Technology and, of course, more and more people trained in the field have been moving into industry and other teaching institutions.

The food industries have accepted the new philosophy in terms of consumer needs and desires, and this has been a motivating force. In addition to the factors already mentioned, it has been necessary to consider the economics of food production and distribution to the consumer. Curricula and interests have broadened and the field advanced over a period of years to a point where a number of universities are granting the Ph.D. degree in Food Science and Technology.

Prior to World War II there were relatively few books in the field, but since that time, many have appeared covering the field in general, popular books, textbooks, highly specialized and technical books, and even a review series concerned with advances in Food Science and Technology. Several journals have appeared, not only in the United States, but in a number of countries throughout the world.

All this resulted in a new outlook or point-of-view and, one might say, too, a whole new language, old words with new meanings as well as new words and terms.

The field, therefore, has reached the point where a treatise on the meaning of these terms is not only in order, but is direly needed, as a useful tool for students and scientists in the field, teachers, other scientists, writers, and laymen in general.

This new compendium by Arnold H. Johnson and Martin S. Peterson

serves well to fill this need—the Encyclopedia of Food Technology. It fits well into the advance of the new and dynamic field of food science.

Drs. Johnson and Peterson have been heavily involved in food science, intensively and extensively for many years. They are the logical ones to prepare a comprehensive summary of knowledge, or in other words an *Encyclopedia of Food Technology*—a first in this field. It will indeed be a useful source of information.

Johnson and Peterson must be congratulated for undertaking this astronomical task and in so doing for helping to advance the field of Food Science and Technology toward full maturity and establishing it as an extremely important field of science in these days when food is foremost in the minds of so many throughout the world.

EMIL M. MRAK
Chancellor Emeritus
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July 1974

Preface

From "Acidulants" to "Zero Milk," the *Encyclopedia of Food Technology* contains more than 1000 pages on 275 subjects pertinent to food technology plus biographical coverage of men and women of historical importance in this field, awards to individuals in recognition of achievement in food technology, and information which the editors felt would be of general interest to all.

Over two years were spent in planning and amassing contributions from 235 individuals outstanding in the many fields and disciplines in and related to food technology: agriculture, chemistry, microbiology, engineering, quality control, processing and preservation, crops and animal products, fabricated foods, space foods, food service, nutrition and nutritional labeling, sensory evaluation, the ecology of waste handling and disposal . . . to name a portion of the topics covered in this work.

The editors are indeed grateful to these contributors who are acknowledged in the previous pages. A cursory examination of this roster of prominent people will show their high standing in their respective fields of endeavor and the international character of their activity in food technology.

It is on the basis of this expert knowledge that the detailed compilation of "A to Z" articles will be invaluable to students and professors alike in food technology and related fields, and professional people and others engaged in the food industry including those in production, marketing, and merchandising. The editors also trust that the work will be useful to the non-professional, and be available in public and general libraries in the United States and throughout the world.

The *Encyclopedia of Food Technology* represents Volume 2 in The AVI Publishing Company's Encyclopedia of Food Technology and Food Science Series. The *Encyclopedia of Food Engineering* (Hall, Farrall and Rippen) was published in 1971 as Volume 1 and has had wide success. Your editors have already started work on Volume 3 in this series: *Encyclopedia of Food Science.*

It has been a rewarding personal experience to the editors to deal worldwide with so many contributors and to have their good wishes and encouraging comments in the course of the enterprise. Also, thanks are overdue to many others who helped in the various stages of preparation of the *Encyclopedia of Food Technology* and without whom this job could never have been completed.

ARNOLD H. JOHNSON
MARTIN S. PETERSON

October 1973

A

ACIDULANTS

The modern supermarket is a living tribute to the progress of food technology. This technology involves the use of many food additives which ensure the safety and palatability of the vast array of processed foods available today. Among these food additives, the acidulants play a very important role.

Functions

Food acidulants serve many functions. They aid in sterilization, in food preservation, and in chelation. They are important adjuncts in product standardization, in modifying sweetness, in enhancement of flavors, as well as other functions.

Sterilization.—Probably the major contribution of the acidulants to processed food products is as an aid in sterilization. Sterilization of canned food products, in particular, depends on the thermal kill efficiency of the heat applied in retorts and other processing equipment. Many bacteria are highly resistant to heat and in some instances revert to a spore form which can survive high temperatures for a long period of time. Incomplete sterilization can result in instances of botulism or food spoilage. This is a serious public health hazard. Fortunately, bacteria and other deleterious microorganisms are more susceptible to thermal kill in a low pH environment. Therefore, acidification to lower the pH to a safe level is necessary. Many food products, which formerly could not have been adequately sterilized, are now safely processed and maintained for long periods of time through the technique of acidification. Governmental agencies have recognized this need and have promulgated regulations and guidelines on this subject in order to ensure the availability of food products which are safe for general consumption.

Preservation.—In addition to ensuring a more efficient bactericidal effect in the heat sterilization of foods, the acidulant also performs a bacteriostatic function in processed foods such as salad dressings and syrups, among others. The reproduction and growth of bacteria and other microorganisms are inhibited in an acidified medium. This helps improve the shelflife of foods which otherwise would have spoiled in a short period of time. In addition to the acidulants' ability to retard spoilage, they are frequently used as a fixative for flavors.

Chelation.—Certain acidulants have the ability to chelate stray metal ions, especially iron and copper, and thus can be used to retard and inhibit undesirable chemical reactions, such as rancidity in lipids and the browning of fruit. The objectionable metal ion, which could catalyze these reactions, is effectively tied up by the acidulant. Ascorbic acid is frequently used in conjunction with other acidulants such as citric or malic acid in these applications. Partially through their chelating function, the acidulants are also useful in retarding the enzymatic browning of fruits and vegetables.

Product Standardization.—A century ago, most food was consumed in the area in which it grew. Today, modern transportation methods plus large-scale buying practices of major supermarkets have brought about change. Agricultural products may be grown in the south, the midwest, the far west, or elsewhere and, following canning, are transported long distances before they reach the consumer. There are variations in the acid content of fruits and vegetables grown in different parts of the country. In addition, there are annual variations in the acid content of produce grown in the same area; and there is a variation in acid content between early and late crops.

As a result of these variations in product acid, coupled with block buying, warehousing, and large-scale distribution of products, it may be possible to have two cans of "Brand A" tomatoes on a supermarket shelf that have completely different origins. To cite an extreme example, one can could be packed with an early crop of midwestern tomatoes and the other can packed with a late crop of California tomatoes. Thus, seasonal and geographic differences in acid content could make

TABLE A-1

PROPERTIES OF SOME COMMON FOOD ACIDULANTS

Property	POMALUS® Malic Acid	Fumaric Acid	Adipic Acid	Succinic Acid	Succinic Anhydride	Citric Acid	Tartaric Acid
							
Appearance	White crystal. powder	White crystal. powder	White crystal. powder	White crystal. powder	White crystals	White crystals	White crystals
Crystal system	Triclinic crystal	Monoclinic prisms	Monoclinic prisms	Monoclinic prisms	Ortho-rhombic prisms	Monoclinic holohedra	Monoclinic sphenoidal prisms
Taste	Smooth tart	Tart	Tart	Tart	Burning tart	Tart	Bitter tart
Empirical formula	$C_4H_6O_5$	$C_4H_4O_4$	$C_6H_{10}O_4$	$C_4H_6O_4$	$C_4H_4O_3$	$C_6H_8O_7$	$C_4H_6O_6$
Melting point, °C	130°–132°	286°–287°	153°	188°	118.3°–119°[1]	153°	168°–170°
Specific gravity	1.601 (20°/4°)	1.635 (20°/4°)	1.380 (25°/4°)	1.564 (15°/4°)	1.503 (20°/4°)	1.542 (18°/4°)	1.7598 (20°/4°)
Bulk density, lb/ft³	57.3	32.6	40.5	55.0	47.2	56.2	50.2
Solubility in ethanol gm/100 ml @ 25°C	39.16	4.3	16.10	9.0	2.56	58.9	19.6
Solubility in ether gm/100 ml @ 25°C	1.41	0.56	0.92	0.66	0.64	1.84	0.59
Solubility in chloroform gm/100 ml @ 25°C	0.04	0.02	<0.01	0.02	0.87	<0.01	0.04
Ionization constant K_1	4×10^{-4}	1×10^{-3}	3.7×10^{-5}	6.5×10^{-5}	(See	8.2×10^{-4}	1.04×10^{-3}
K_2	9×10^{-6}	3×10^{-5}	2.4×10^{-6}	2.3×10^{-6}	succinic	1.8×10^{-5}	4.55×10^{-5}
K_3	—	—		—	acid)	3.9×10^{-6}	—
Heat of combustion, kcal/mole, 20°C	-320.1	-320.0	-669.0	-357.1	-369.6	-474.5	-257.1
Heat of solution, kcal/mole solute	4.9	—	—	—	—	3.9	3.3
Viscosity 50% aqueous solutions, cps, @ 25°C	6.5	[2]	[2]	[2]	[2]	6.5	6.5
Standard free energy of anion formation, ΔF°_f, kcal, @ 25°C, aqueous solutions	-201.98	-144.41	—	-164.97	—	-278.8	—
Sp gr saturated aqueous solutions, @ 5°	1.210	1.000	1.002	1.012	(See succinic acid)	1.24	1.26
25°	1.250	1.000	1.005	1.024	"	1.28	1.27
75°	1.310	0.989	1.032	1.076	"	1.31	1.31

[1] Solidification point.
[2] Solubility too limited.

these two cans of "Brand A" tomatoes taste different to the consumer. In order to preclude this situation the industry is depending, more and more, upon standardization of products wherein acidulants are added to optimize processing safety and uniform taste acceptability.

In that manner, a late crop California tomato or an early crop Indiana tomato will contain an equivalent amount of acidity and be equally acceptable from a taste standpoint. The influences of origin and differential harvesting time are then nullified and the consumer can purchase a product which is uniform in taste, regardless of origin or time of harvesting. Thus, the acidification of tomatoes and other canned vegetable products helps ensure the availability of food products which have been safely processed and are consistently good.

Modifying Sweetness and Flavor Enhancement.—Another important role of food acidulants is the enhancement of food flavors. Without food acidulants, hard candies, gelatine desserts, carbonated and noncarbonated beverages, jellies, preserves, toppings and many other products would taste flat or sickeningly sweet. The acidulants add the tartness required to balance the excessive sweetness of these products. Until the proper balance of tartness and sweetness is achieved, the flavor cannot develop to its fullest potential. Even near the balance point, the ratio of sweetness to tartness can be fine-tuned to pronounce the primary flavor and enhance the secondary flavor notes which otherwise may be masked by excessive sweetness or tartness. The ratio of sweetness to tartness is commonly called the brix acid ratio. This ratio, contrary to some older beliefs, need not be a rigid rule applied arbitrarily across the board. In order to achieve the optimum of flavor enhancement, it can be varied to suit the product. For example, a lemonade should be more tart than a punch. A hard candy will require a higher level of acidification to compensate for the excessive sweetness of the product.

The effect of acidulants on flavor and taste can also vary, but none has a characteristic flavor per se. The taste of all acidulants is usually described as tart. However, each individual acidulant has a slightly different tartness. Among the organic acids, the tartness of citric has been described as clean; that of malic as smooth; fumaric as metallic; adipic as chalky; vinegar (acetic) as astringent; tartaric as sharp or bitter; and lactic as sour. Phosphoric, which is inorganic, tends to have a flat sourness.

The acidulants also vary in their effects on aftertaste. The acidic taste of some acids is retained and stimulates the taste buds for a longer period of time. The chalky character of adipic is retained for a while, as is the metallic note of fumaric. The proper selection of flavors and flavor ingredients can usually minimize and mask any undesirable aftertaste. Phosphoric tends to be retained in the taste buds, however. In the case of cola formulations, the resultant overall flavor rendition is highly desirable. Malic stimulates the taste buds for a long duration and the flavor of the product is also carried with it. This helps to disguise the undesirable aftertaste characteristics of artificial sweeteners and medicines. In addition to its ability to mask aftertaste, malic is also utilized to blend combination flavors such as orange/pineapple and apple/raspberry, wherein the end result is a harmonious blend rather than two distinct flavor sensations.

In view of the slightly different taste characteristics of the various acidulants it follows that some are more complementary to certain flavors than others. Moreover, a blend of acidulants, as frequently found in nature, will result in a superior

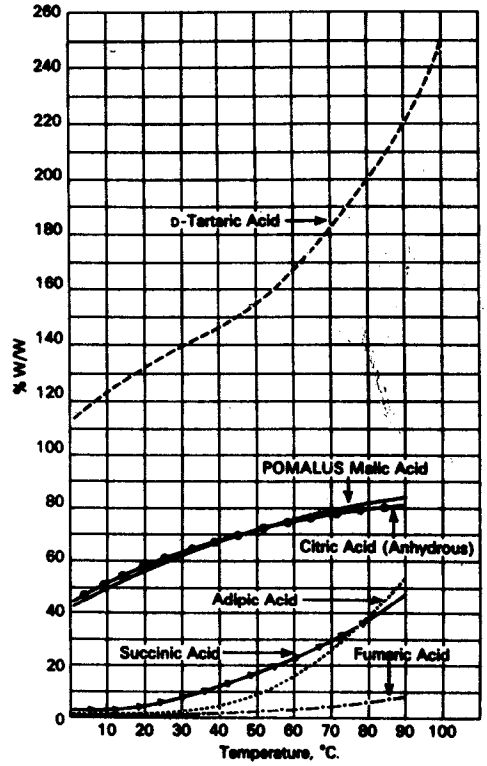

FIG. A-1. SOLUBILITIES IN WATER AT DIFFERENT TEMPERATURES