Food Science Sourcebook

Second Edition

Part 2

HERBERT W. OCKERMAN

Food Science Sourcebook

Second Edition

Part 2

Food Composition, Properties, and General Data

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An avi Book
Published by Van Nostrand Reinhold
New York

Dedicated to Frances

An AVI Book
(AVI is an imprint of Van Nostrand Reinhold)

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Library of Congress Catalog Card Number 90-21740
ISBN 0-442-23388-4
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Manufactured in the United States of America

Published by Van Nostrand Reinhold
115 Fifth Avenue
New York, New York 10003

Chapman and Hall
2-6 Boundary Row
London, SE1 8HN

Thomas Nelson Australia
102 Dodds Street
South Melbourne 3205
Victoria, Australia

Nelson Canada
1120 Birchmount Road
Scarborough, Ontario M1K 5G4, Canada

16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

Library of Congress Cataloging-in-Publication Data
Ockerman, Herbert W.
Food science sourcebook/Herbert W. Ockerman.—2nd ed.
p. cm.
Rev. ed. of: Source book for food scientists. ©1978.
"An AVI book."
ISBN 0-442-23388-4
1. Food—Dictionaries. 2. Food—Composition—Tables.
I. Ockerman, Herbert W. Sourcebook for food scientists.
II. Title.

TX349.03 1991 90-21740
664'.003—dc20 CIP

Preface to second edition, titled *Food Science Sourcebook*

It was realized, even prior to the printing of the first edition, that a book of this magnitude would never be complete and that at some point a line must be drawn and data currently available must be organized. This was done to get the first edition into print. However, prior to its printing, revisions and new data were becoming available for inclusion in the second edition (now titled *Food Science Sourcebook*), which includes most of the information in the first edition plus twelve additional years of collecting data.

The author wants to thank the many readers, colleagues, and students who have made suggestions on how the manuscript could become more useful. Most of the suggestions have been incorporated into this edition. Like the first edition, the second edition is certainly also not complete, and the author would certainly appreciate communications from readers and colleagues for suggestions and recommendations on how additional editions might be improved.

HERBERT W. OCKERMAN
Columbus, Ohio

Preface to first edition, titled *Source Book for Food Scientists*

The *Source Book for Food Scientists* materialized as the result of accumulating current data and relevant facts in the field of food science and technology. Since reference sources are often scattered, there has been a need for a one-volume data book of this type. A number of my colleagues have urged me to make my data bank available to others, hence this volume.

Such a book could be organized as follows: a dictionary interpretation of terms used in food science and technology; tabular material giving detailed information on food composition and properties; chemical formulas and structures; uses of foodstuffs; harvesting; slaughtering and related information concerning the meat industry . . . , in fact, almost any and every type of subject one might encounter dealing with food.

I have organized the material in two parts. Part 1 covers what I call my "personal dictionary" of pertinent information. Part 2 contains the tabular and general information that broadens the base of Part 1 with factual data.

I have found it invaluable. My earnest desire, now that the material is to be published, is that it will equally serve other food scientists and technologists working in various capacities in industry, government, and the academic community.

I wish to acknowledge the encouragement given me by Dr. Donald K. Tressler, President, AVI Publishing Company, and to express my appreciation for his belief and support in this project.

It is also a special pleasure for me to acknowledge the editorial assistance provided by Mrs. Lucy Long, Senior Editor at AVI, and to Mr. Gessner Hawley, Editor of the *Condensed Chemical Dictionary* and Co-editor of the *Encyclopedia of Chemistry*. It was their collaboration and assistance that transformed a very rough draft into a publishable manuscript. However, errors of omission or commission are mine alone to bear.

I would also like to thank the scores of publishers and authors who have granted me permission to reprint their copyrighted materials. Thanks are also extended to the many authors and contributors to government publications for information obtained from those sources. Specific acknowledgement is noted for each source as it appears in this book.

I also wish to extend grateful thanks to my wife, Frances, for her assistance in typing and proofreading. Her patience and help contributed much to the completion of this book.

This is the First Edition of the *Source Book* and I would greatly appreciate communications from readers for suggestions or recommendations on how to improve it and also to call to my attention errors that may be corrected in the next printing.

HERBERT W. OCKERMAN
Columbus, Ohio

Jan. 1, 1978

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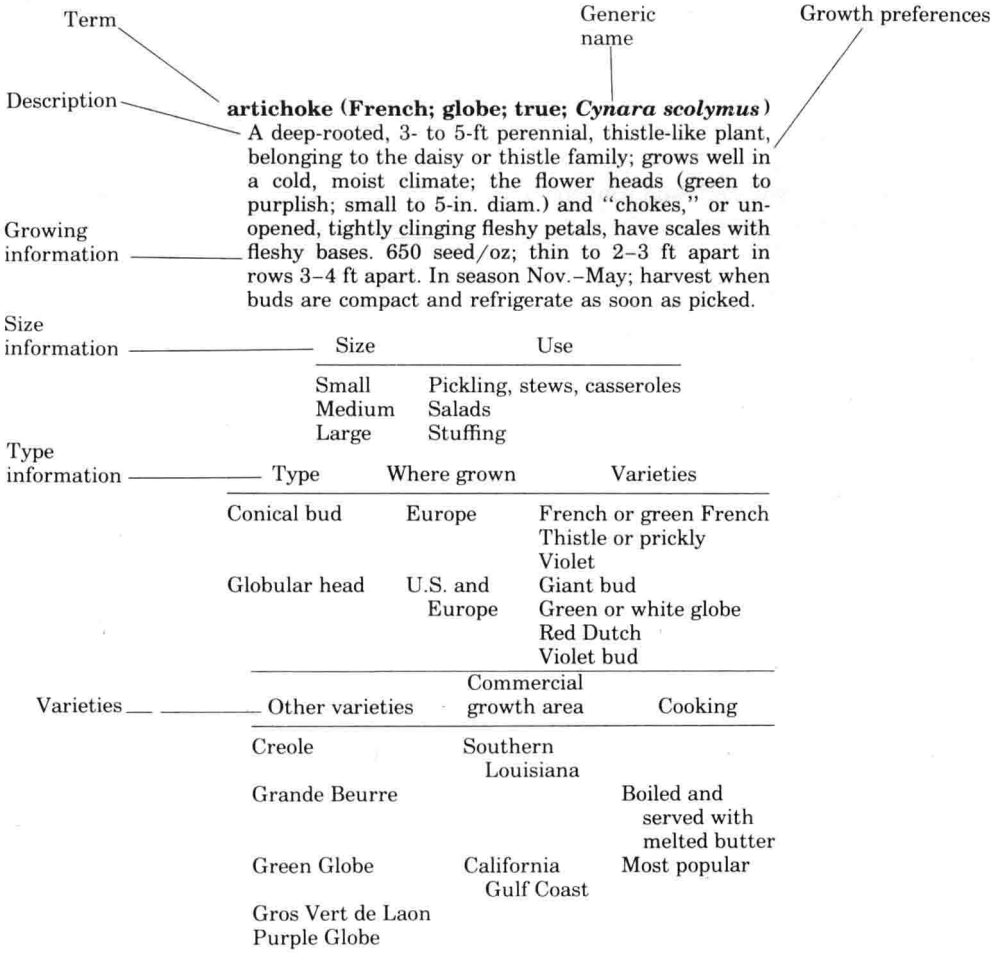
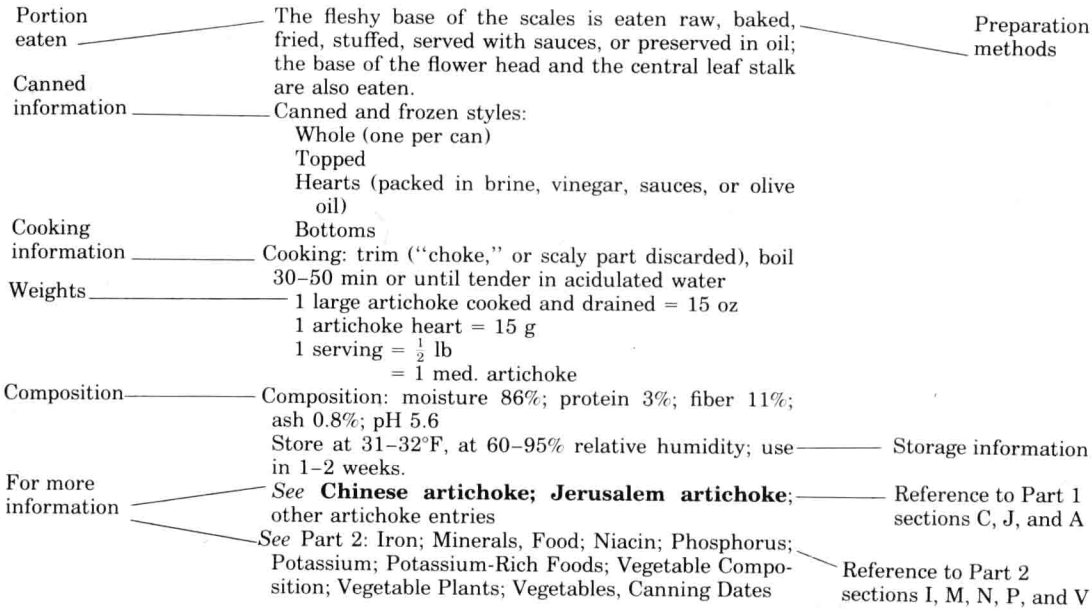
How to Use The *Food Science Sourcebook*
(important to obtain maximum utilization of this book!)

For ease of retrieval, this book has been organized into two parts. *Start your search in Part 1* and this, if necessary, will lead you to Part 2 by extensive cross-references. Part 1 consists of dictionary terms and descriptions wherein the definition usually contains detailed information on the subject and, where feasible, some data concerning its use or properties. With the majority of these *Sourcebook* terms and description in Part 1, there is a reference to Part 2, giving a list of subjects for further information. (See the breakdown of the **artichoke** entry below.)

Part 2 is composed of alphabetical sections containing food composition, properties, and general data designed as the basis for the initiation of a broader search for further information relevant to the dictionary term given in Part 1. Part 2 is, in truth, a "data book" of tables, figures, charts, formulas, etc.

Part 1 will lead the reader to a pertinent, appropriate section in Part 2, or one can refer to Part 2 independently of the Part 1 dictionary description because it is organized alphabetically; however, some information will be missed if the second approach is used.





Other ready-reference material that is to be found in the book:

Inside the front cover is a table for temperature conversion from Fahrenheit to Celsius or vice versa.

Inside the back cover will be found conversion factors for units of weight, units of liquid measure, oven temperatures, and units of volume.

And following is a list of the most-often-used abbreviations for quick reference.

Common Abbreviations

NOTE: Where the abbreviation denotes either the singular or plural, the spelled-out version of the abbreviation carries an asterisk (*).

A	ampere*
AAAS	American Association for the Advancement of Science
AOAC	Association of Official Analytical Chemists
apoth.	apothecary
approx.	approximately
atm	atmosphere
at. no.	atomic number
at. wt.	atomic weight
avg.	average
avdp.	avoirdupois
bp	boiling point
Brit.	British
Btu	British thermal units
bu	bushel*
cal	calorie*
°C	Centigrade or Celsius
ca.	circa or about
cc	cubic centimeter* (also cm^2)
CAMP	computer assisted menu planning
CFN	Council on Food and Nutrition of the American Medical Association
cg	centigram*
chem.	chemical or chemistry
cl	centiliter*
cm	centimeter*
CP	chemically pure
cps	cycles per second
cu.	cubic
cwt	hundredweight
d	density
dc	direct current
deg	degree*
df	degrees of freedom
dg	decigram*
diam.	diameter
dag	dekagram*
dal	dekaliter*
dl	deciliter*
dm	decimeter*
dwt	pennyweight
doz	dozen*
dr	dram*
e.g.	for example
EMF	electromotive force
equiv. wt.	equivalent weight
°F	Fahrenheit
FAO	Food and Agricultural Organization, United Nations
FDA	Food and Drug Administration
ffa	free fatty acid*
fl	fluid
FNS	Food and Nutrition Service, US Department of Agriculture
FNB	Food and Nutrition Board of the National Academy of Science–National Research Council
fp	freezing point
fpm	feet per minute
fps	feet per second
ft	foot*
g	gram*
gal	gallon*
gpm	gallon* per minute
gr	grain*
h	hectare*
hg	hectogram*
Hg	mercury
hhd	hogshead*
hp	horsepower
h	hour*
i.d.	inside dimension
i.e.	that is
imp	imperial
in.	inch*
IU	International Units

J	joule*
K	kelvin
kcal	kilocalorie*
K_{eq}	equilibrium constant
kg	kilogram*
km	kilometer*
kW	kilowatt*
l	liter* (more often spelled out to avoid misinterpretation with numeral one)
lat	latitude
lb	pound*
m	meter*
M	Molal
max.	maximum
MDR	minimum daily requirement (no longer used; see RDA)
med.	medium
mg	milligram*
MHz	megahertz
mi	mile*
MID	Meat Inspection Division, US Department of Agriculture
min.	minimum
ml	milliliter*
mm	millimeter*
mo.	month*
mol. wt.	molecular weight
mp	melting point
mps	meters per second
mV	millivolt*
No.	number (when followed by numeral)
NFE	nitrogen free extract
NIH	National Institutes of Health
NMR	nuclear magnetic resonance
NPU	net protein utilization
NPV	net protein value
NRC	National Research Council
NSF	National Science Foundation
o.d.	outside dimension
opt.	optimum, optional
oz	ounce*
PER	protein efficiency ratio
pk	peck*
ppm	parts per million
ppt	precipitate; parts per trillion
prob.	probable
psf	pounds per square foot*
psi	pounds per square inch*
psia	pounds per square inch atmosphere*
pt	pint*
qt	quart*
r	correlation
R	Réaumur
rd	rod*
RDA	recommended daily allowance
RH	relative humidity
rpm	revolutions per minute
s	second*
sig.	significant
sp.	specific
sp. gr.	specific gravity
sq.	square
tbsp	tablespoon*
temp.	temperature
tsp	teaspoon*
USDA	United States Department of Agriculture
USP	*US Pharmocopeia*
vit.	vitamin (rarely used)
vol.	volume
wt.	weight
yd	yard*
yr	year*

Contents

Part 2

Food Composition, Properties, and General Data

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A

Acidulants

TABLE 2.A.1
Properties of some common food acidulants

Property	POMALUS® Malic Acid	Fumaric Acid	Adipic Acid	Succinic Acid	Succinic Anhydride	Citric Acid	Tartaric Acid
	HOCHCOOH CH_2COOH	HOOCCH HCCOOH	CH_2CH_2COOH CH_2CH_2COOH	CH_2COOH CH_2COOH	$CH_2C\,O$ O $CH_2C\,O$	CH_2COOH HOCCOOH CH_2COOH	HOCHCOOH HOCHCOOH
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 succinic acid)	8.2×10^{-4}	1.04×10^{-3}
K_2	9×10^{-6}	3×10^{-5}	2.4×10^{-6}	2.3×10^{-6}		1.8×10^{-5}	4.55×10^{-5}
K_3	—	—	—	—		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, $\Delta F°_f$, 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.

Source: Sausville, T. J. (1975). Acidulants. In *Encyclopedia of Food Technology*. A. H. Johnson and M. S. Peterson (editors). AVI Publishing Co., Westport, Connecticut.

Acre, Plants

TABLE 2.A.2
Number of plants per acre at given spacings

Inches	No. of Plants	Inches	No. of Plants	Inches	No. of Plants
12 x 1	522,720	24 x 6	43,560	40 x 30	5,227
12 x 3	174,240	24 x 9	29,040	40 x 36	4,356
12 x 4	130,680	24 x 12	21,780		
12 x 6	87,120	24 x 15	17,424	42 x 3	49,782
12 x 9	58,080	24 x 18	14,520	42 x 6	24,891
12 x 12	43,560	24 x 24	10,890	42 x 12	12,445
				42 x 18	8,297
15 x 1	418,176	30 x 3	69,696	42 x 24	6,223
15 x 3	139,382	30 x 4	52,272	42 x 30	4,978
15 x 4	104,544	30 x 6	34,848	42 x 36	4,148
15 x 6	69,696	30 x 9	23,232		
15 x 9	48,484	30 x 12	17,424	48 x 3	43,560
15 x 12	34,848	30 x 15	13,939	48 x 6	21,780
		30 x 18	11,616	48 x 12	10,890
18 x 1	348,390	30 x 24	8,712	48 x 18	7,260
18 x 3	116,160	30 x 30	6,969	48 x 24	5,445
18 x 4	87,120			48 x 30	4,356
18 x 6	58,080	36 x 3	58,080	48 x 36	3,630
18 x 9	38,720	36 x 4	43,560	48 x 42	3,111
18 x 12	29,040	36 x 6	29,040	48 x 48	2,722
18 x 15	23,232	36 x 9	19,360		
18 x 18	19,360	36 x 12	14,520	60 x 3	34,848
		36 x 15	11,616	60 x 6	17,424
20 x 3	104,544	36 x 18	9,680	60 x 12	8,712
20 x 4	78,408	36 x 24	7,260	60 x 18	5,808
20 x 6	52,272	36 x 30	5,808	60 x 24	4,356
20 x 9	34,848	36 x 36	4,840	60 x 30	3,484
20 x 12	26,136			60 x 36	2,904
20 x 15	20,909	40 x 3	52,272	60 x 42	2,489
20 x 18	17,426	40 x 6	26,136	60 x 48	2,178
		40 x 12	13,068	60 x 54	1,936
24 x 3	87,120	40 x 18	8,709	60 x 60	1,742
24 x 4	65,340	40 x 24	6,534		

Source: Mortensen, E., and Bullard, E. T. (1969). *Handbook of Tropical and Sub-Tropical Horticulture*. Agency for International Development, U.S. Department of State.

Acre, Trees

TABLE 2.A.3
Number of trees per acre at given spacings

Feet	No. of Plants	Feet	No. of Plants	Feet	No. of Plants
6 × 1	7,260	10 × 1	4,356	16 × 14	194
6 × 2	3,630	10 × 2	2,178	16 × 16	170
6 × 3	2,420	10 × 3	1,452		
6 × 4	1,815	10 × 4	1,089		
6 × 5	1,452	10 × 5	871	18 × 4	605
6 × 6	1,210	10 × 6	726	18 × 6	404
		10 × 7	622	18 × 8	303
7 × 1	6,223	10 × 8	544	18 × 10	242
7 × 2	3,111	10 × 9	484	18 × 12	202
7 × 3	2,074	10 × 10	435	18 × 14	173
7 × 4	1,556			18 × 16	152
7 × 5	1,244			18 × 18	132
7 × 6	1,037	12 × 2	1,815		
7 × 7	889	12 × 4	907		
		12 × 6	605	20 × 8	272
8 × 1	5,445	12 × 7	454	20 × 10	218
8 × 2	2,722	12 × 10	363	20 × 12	184
8 × 3	1,815	12 × 12	302	20 × 14	156
8 × 4	1,361			20 × 16	136
8 × 5	1,089	14 × 2	1,556	20 × 18	121
8 × 6	907	14 × 4	778	20 × 20	109
8 × 7	778	14 × 6	518		
8 × 8	680	14 × 8	389	24 × 12	151
		14 × 10	311	24 × 16	114
9 × 1	4,840	14 × 12	259	24 × 20	92
9 × 2	2,420	14 × 14	222	24 × 24	76
9 × 3	1,613				
9 × 4	1,210	16 × 2	1,361	30 × 20	72
9 × 5	968	16 × 4	680	30 × 30	48
9 × 6	807	16 × 6	454	30 × 40	36
9 × 7	691	16 × 8	340		
9 × 8	605	16 × 10	272		
9 × 9	528	16 × 12	227	40 × 40	27

Source: Mortensen, E., and Bullard, E. T. (1969). *Handbook of Tropical and Sub-Tropical Horticulture.* Agency for International Development, U.S. Department of State.

Alcoholic Solutions

TABLE 2.A.4
Various strengths of alcoholic solutions

Alcohol, Strength Desired Ml per Liter	Alcohol Required Grams	Ml
50	42.63	52.6
100	85.26	105.3
150	127.89	157.9
200	170.52	210.5
250	213.16	263.2
300	255.78	315.9
400	341.04	421.1
500	426.32 (proof)	526.3
700	596.84	736.8

NOTE: **Alcoholic solutions: Specification requires 95% C_2H_5OH by vol. Sp gr = 0.810 at 25°. Mix and dil. to 1 liter.**
Alcohol of any desired strength may be obtained by taking number of ml 95% alcohol equiv. to desired strength and dil. soln. to 95 ml. For example, to obtain soln. of 70% alcohol, take 70 ml 95% alcohol and dil. to 95 ml.

Source: Editorial Board, AOAC (1975). *Official Methods of Analysis of the Association of Official Analytical Chemists*, 12th Edition. Association of Official Analytical Chemists, Washington, D.C.

Altitude Adjustments For Baking

TABLE 2.A.5
Adjustments for high-altitude baking

	3000 ft	5000 ft	7000 ft
Reduce Baking Powder			
For each teaspoon, decrease	⅛ tsp	⅛-¼ tsp	¼-½ tsp
Reduce Sugar			
For each cup, decrease	no change	usually no change	1-2 tbsp
Reduce Lard			
For each cup, decrease	1-2 tbsp	2 tbsp	2-3 tbsp
Increase Liquid			
For each cup, add	1-2 tbsp	2-3 tbsp	3-4 tbsp
Increase Baking Temperature	6-10°F	10-15°F	15-25°F
Decrease Baking Time 5 to 10 minutes when recipes have been tested at sea level.			

NOTE: **When two amounts are given, try the smaller adjustment first; then if cake still needs improvement, use the larger adjustment the next time you make the cake.**

Source: Kitchen Classics. National Live Stock and Meat Board, Chicago.

Altitude Corrections For Boiling Water

TABLE 2.A.6

Altitude (feet)	Increase processing time if the time recommended is: 20 minutes or less	More than 20 minutes
1,000	1 minute	2 minutes
2,000	2 minutes	4 minutes
3,000	3 minutes	6 minutes
4,000	4 minutes	8 minutes
5,000	5 minutes	10 minutes
6,000	6 minutes	12 minutes
7,000	7 minutes	14 minutes
8,000	8 minutes	16 minutes
9,000	9 minutes	18 minutes
10,000	10 minutes	20 minutes

Source: USDA (1977). Canning, freezing, storing garden produce. USDA Agricultural Information Bull. *410*.

Amino Acids I

TABLE 2.A.7
Physical properties

	Amino Acid	Chemical Formula	Molecular Weight	Melting Point	Specific Rotation: Solvent	g/100 ml	Temp °C	Value	Isoelectric Point	Solubility g/100 ml solvent
1	L-Alanine	$C_3H_7NO_2$	89.09	297	1.0 *N* HCl	5.79	15	+14.7	6.11 [1]	sl.sol.alc.; insol.acet., eth.; 16.51, w.
2	β-Alanine	$C_3H_7NO_2$	89.09	196	.....	.....	.....	0	6.90	v.sol.w.; v.sl.sol.alc.; insol. eth.
3	L-α-Aminobutyric acid	$C_4H_9NO_2$	103.12	285	20% HCl	.....	20	+14.1	5.98	insol.eth.; 0.18, alc.; 28, w.
4	L-Anserine	$C_{10}H_{16}N_4O_3$	240.26	238-239	H_2O	5.0	20	+12.2	8.27	sol.me.alc., w.; sl.sol. alc.
5	L-Arginine	$C_6H_{14}N_4O_2$	174.20	238	6.0 *N* HCl	1.65	23	+26.9	10.76	v.sol.w.; insol.alc., eth.
6	L-Asparagine	$C_4H_8N_2O_3$	132.12	236	3.4 *N* HCl	2.24	20	+34.3	5.41	sol.dil.NH_4OH; v.sl.sol. alc.; insol.eth.; 2.46, w.
7	L-Aspartic acid	$C_4H_7NO_4$	133.10	269-271	6.0 *N* HCl	2.0	24	+24.6	2.98	sol.dil.HCl; v.sl.sol.alc.; insol.eth.; 0.50, w.
8	L-Canaline	$C_4H_{10}N_2O_3$	134.14	214	H_2O	1.6	21	−8.1	.....	sol.w.
9	L-Canavanine	$C_5H_{12}N_4O_3$	176.18	184	H_2O	3.2	20	+8.1	8.2	sol.w.
10	L-Carnosine	$C_9H_{14}N_4O_3$	226.23	246-250	H_2O	2.0	20	+20.5	8.17	sol.w.
11	L-Citrulline	$C_6H_{13}N_3O_3$	175.19	222	1.0 *N* HCl	2.0	27	+24.3	5.92	v.sl.sol.w.; insol.alc.
12	L-Cystathionine	$C_7H_{14}N_2O_4S$	222.26	270-312	1.0 *N* HCl	1.0	22	+23.7	.....	sol.HCl
13	L-Cysteic acid	$C_3H_7NO_5S$	169.17	289	H_2O	.....	.....	+8.7	1.6	sol.a., alk., w.; insol.alc.
14	L-Cysteine	$C_3H_7NO_2S$	121.16	175-178	H_2O	2.0	21	−10.1	5.07	v.sol.w.; sol.a., alk.
15	L-Cystine	$C_6H_{12}N_2O_4S_2$	240.30	258-261	1.0 *N* HCl	1.0	24	−214.4	5.02	sol.a. [2], NH_4OH; insol. alc., eth.; 0.011 w.
16	L-3,5-Dibromotyrosine	$C_9H_9NO_3Br_2$	338.99	245 [3]	0.3 *N* HCl	.....	20	−2.4	4.30	.....
17	L-3,4-Dihydroxyphenylalanine	$C_9H_{11}NO_4$	197.19	280	4% HCl	1.0	25	−12.0	.....	sol.a., alk.; insol.alc., eth.; 0.50, w.

(Continued)

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