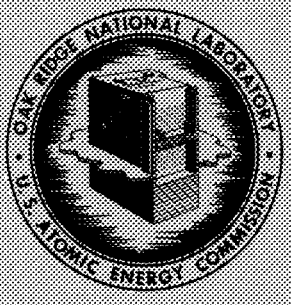

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DATE - Nov. 6, 1967

PRESENT COSTS OF AMINO ACIDS AND A PROPOSAL FOR THEIR PRODUCTION IN AN AGRO-INDUSTRIAL COMPLEX

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ABSTRACT

Of the 20 amino acids that are essential to, or usable in, human nourishment, all can be made by wholly-chemical methods that are described in the literature. Present costs and production rates of these acids are summarized. At present, arginine, glutamic acid, histidine, and tryptophan are usually produced from biologically-derived materials, such as gelatin, wheat gluten, blood proteins, and casein, respectively. It is suggested that the manufacture of all amino acids, essential and nonessential, should be examined as a unit of Agro-Industrial Complexes associated with dual-purpose power-desalination reactors.

COSTS AND PRODUCTION RATES OF AMINO ACIDS

Many amino acids can now be purchased in quantities ranging from 25 g to 10,000 kg (Table 1 and Fig. 1), generally as materials of rather high purity. Some of these acids are derived from biological materials, for example, glutamic acid from wheat gluten,[1] histidine from blood proteins,[2] and tryptophan from casein.[3] Most of the other available amino acids are made from relatively common, synthetic organic and inorganic chemicals such as HCl, NH_3, Na, KOH, CH_3OH, C_2H_5OH, Br_2, Cl_2, H_2SO_4, $MgSO_4$, cyanamide, P, Hg, $Pb(OH)_2$, etc.

Although the data show considerable scatter, Fig. 1 suggests that, when these amino acids are sold in quantities of 10,000 to 100,000 lb, the cost will be only about $1.00/lb. The cost would probably be reduced further, to a few tenths of a dollar per pound if sales volumes were on the order of 500 tons or more. Available data are not adequate to express this cost in terms of, for example, tons/day production rates.

CHEMICAL MANUFACTURE OF AMINO ACIDS

Most of the amino acids are already being made by methods involving wholly-chemical materials and reactions, as contrasted with methods based on biologically-derived materials, such as wheat gluten, or biochemical reactions, such as fermentation (Table 2). It is probable that the expansion of present manufacturing rates by two to six orders of magnitude will be more readily achieved if the manufacturing processes are entirely chemical. Chemical methods are available even for those amino acids that are currently being made from biologically-derived materials. For example, glutamic acid could be manufactured according to the flow diagram shown in Fig. 2. In view of the world population explosion[4] and the accompanying need for expanding food production,[5,6] and in view of the existence of limitations on the extent to which orthodox methods of food production can be expanded,[7] it is evident that a large-scale expansion of the manufacture of amino acids will be

necessary in the next 50 years. It is suggested that this expansion will ultimately have to be based on manufacturing processes that are independent of any biologically-derived materials or of biochemical reactions. Since many of the basic chemicals for such processes can be produced from seawater, and since others, for example, NH_3, are already being studied in terms of an Agro-Industrial Complex associated with a large nuclear desalination reactor, it is suggested that the manufacture of amino acids should be made an integral part of such a complex.

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Table 1. Information on Amino Acid Manufacture, Including Costs for the First Half of 1967

Compound	Approximate Manufacturing Scale[a,b] or Available Form	Unit Cost for Largest Production Scale Listed (dollars per kilogram of compound listed in col. 1) Laboratory[b] Product	Technical[a] Product	Manufacturers[c]
α-Alanine (DL)[d] (dl-α-aminopropionic acid)	Kilograms	22.		AC, EC, GS, ICN, NB
--- (D) (l-α-aminopropionic acid)	Hundred grams	380.		AC, EC, GS, ICN, NB
Arginine (l)[d] (DL-2-amino-5-guanidopentanoic acid)	Tens of kilograms		60.	AC, EC, GS, ICN, NB
Asparagine (L)[d] (α-aminosuccinamic acid, Althein, asparamide)	Hundred grams	70.		AC, EC, GS, ICN, NB, PL, ROC
Aspartic Acid (DL)[d] (DL-aminosuccinic acid, DL-asparacemic acid)	500 grams	14.		
---- (L)	500 grams	36.		
Cysteine (l)[d] (L-β-mercaptoalanine)	Hundred grams, l-cysteine hydrochloride hydrate ($10.00/100 g)	145.		AC, BC, CS, EC, ICN
Glutamic Acid (L, +)[d]	Hundreds of pounds, 99-1/2% pure		3.97	---
Glutamine (L, +)[d] (α-aminoglutaramic acid)	Hundred grams	100.		AC, BC, GS, NB
Glycine[d] (aminoacetic acid)	Tons		1.87-2.09	AC, BC, BENP, CC, ICN, BLL, MCW, NB, OP, PL
Histidine (l)[d] (l-α-amino-β-imidazolepropionic acid)				NB
----	Hundred grams as l(+) histidine hydrochloridemonohydrate at $11.50/100 g	155.		AC, GS, ICN, NB
Isoleucine[e] (2-amino-3-methyl pentanoic acid)				AC, EC, ICN
Leucine (DL)[e] (DL-2-amino-4-methyl pentanoic acid, DL-α-aminoisocaproic acid)	Kilograms		50.	AC, EC, NB, RSA
Lysine (L)[e]	Hundreds of pounds, as l-lysine monohydrochloride		8.26	M, NB
---- (DL)	dl-lysine dihydrochloride			EC, ICN, NB
Methionine (DL)[e]	Lots of 30,000 lb or more. Hydroxy analog, 90% min (calcium salt), bags		2.72	BLL, D, NB, S, SBP
Phenylalanine (DL)[e] (dl-α-aminohydrocinnamic acid, dl-β-phenyl-α-aminopropionic acid)	Hundreds of kilograms as dl-phenylalanine		54.	AC, BC, EC, NB, W

Table 1. Information on Amino Acid Manufacture, Including Costs for the First Half of 1967 (Contd)

Compound	Approximate Manufacturing Scale[a,b] or Available Form	Unit Cost for Largest Production Scale Listed (dollars per kilogram of compound listed in col. 1) Laboratory[b] Product	Technical[a] Product	Manufacturers[c]
Proline (L)[d] (l-2-pyrrolidinecarboxylic acid)	Tens of grams $8.00/25 g (99+%)	320.		AC, GS, ICN, NB
Serine (DL)[d] (dl-2-amino-3-hydroxypropanoic acid, dl-β-hydroxyalanine)	dl-serine			EC, ECI, ICN, NB, RSA, W
---- (L)	Hundred grams as l-serine	560.		AC, EC, ICN, NB
Threonine (DL)[e] (DL-2-amino-3-hydroxybutyric acid)	Tens of kilograms		75.	AC, BC, GS, PL, W
Tryptophan (L)[e] (l-α-amino-β-indolepropionic acid)	Hundreds of grams	450.		AC, BC, GS, PL, W
Tyrosine (DL)[d] (dl-2-amino-3(4-hydroxyphenyl) propanoic acid, dl-β-p-hydroxyphenylalanine)	dl-tyrosine, synthetic			EC, ECI, ICN, NB
---- (L)	Kilograms, l-tyrosine, natural (99+%)	28.		AC, BC, EC, ICN, NB, PL
Valine (DL)[e] (dl-α-aminoisovaleric acid, dl-2-amino-3-methyl butanoic acid)	Kilograms		37.	AC, BC, EC, ICN, NB, ROC
Ascorbic acid (d) (Vitamin C)	Hundreds of kilograms		4.50	

[a] Oil, Paint, and Drug Reporter, May 29, 1967.

[b] Aldrich Chemicals.

[c] Chemical Week, October 15, 1966. Part 2. 1967 Buyer's Guide Issue-Chemicals.

[d] Nonessential amino acid.

[e] Essential amino acid.

Abbreviations are as follows:

AC	Aldrich Chem.	M	Merck Chem.
BC	Borden Chem.	MCW	Mallinckrodt Chem. Works
BENP	Benzol Products	NB	Nutritional Biochemicals
BFG	B. F. Goodrich Chem.	NC	Nopco Chem.
BLL	B. L. Lemke and Co.	OP	Octagon Process
CC	Chattem Chems.	PL	Pfanstiehl Labs.
CI	Croda, Inc.	RL	Roselle Labs.
D	Dow Chem.	ROC	Research Organic Chem.
EC	Eastern Chem.	RSA	RSA Corp.
ECI	Empire Chemical Industries	S	Shell Chem.
GS	Gallard-Schlesinger Chem. Mfg.	SBP	S. B. Penick and Co., NYQ Chem. Div.
HL	Hoffmon Labs.	W	Winthrop Labs.
ICN	International Chem. and Nuclear		

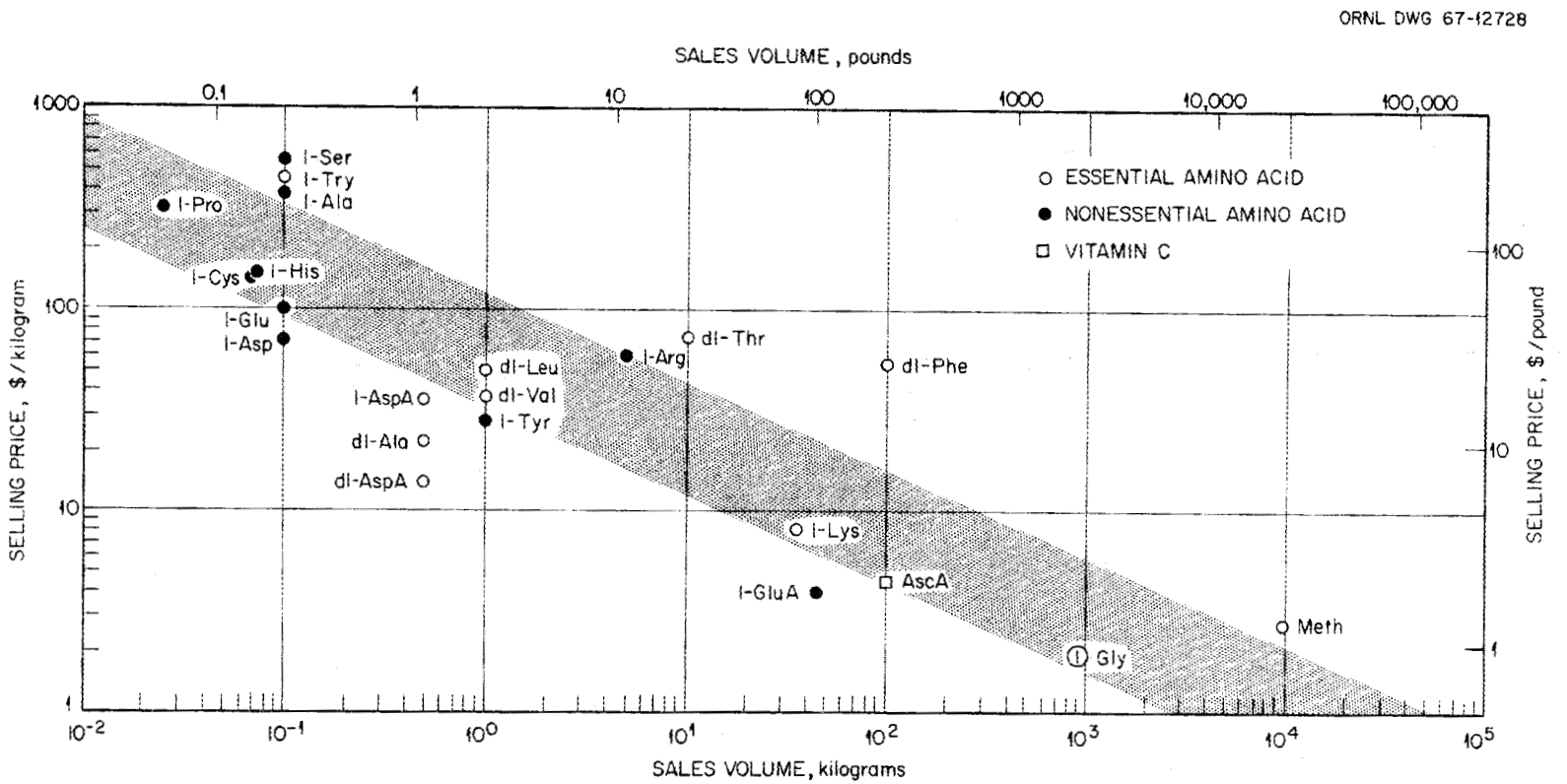
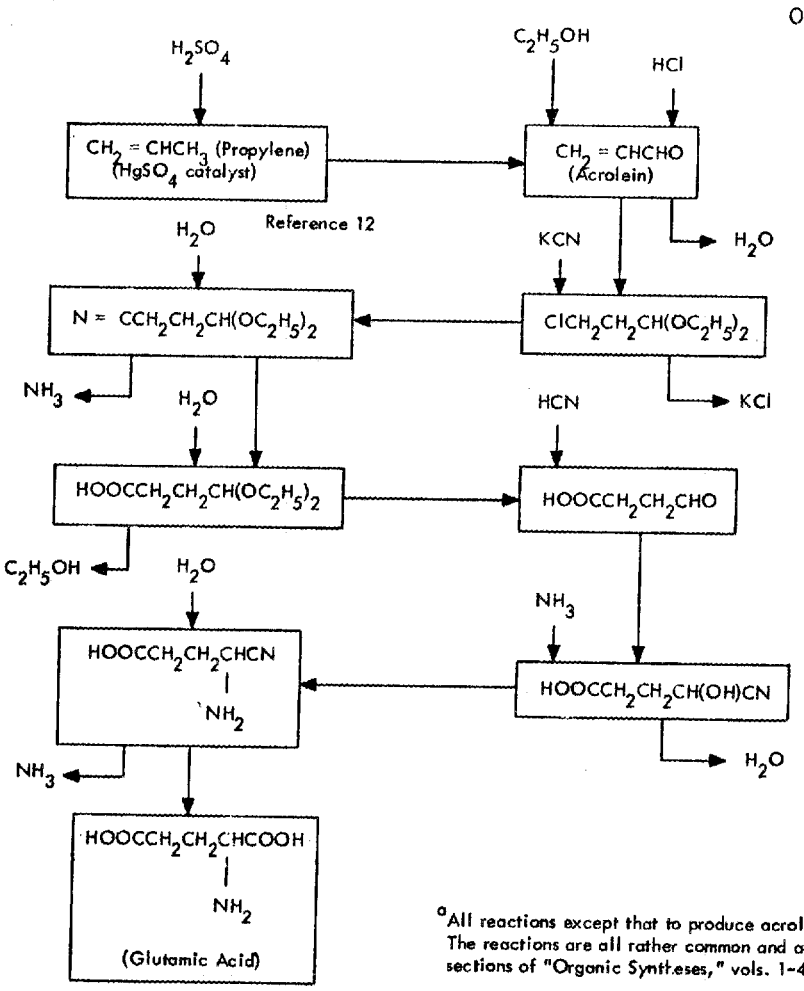


Fig. 1. Variation of Selling Price of Amino Acids with Sales Volume.

Table 2. References on Preparation of Amino Acids

	Method of Preparation	Reference
Alanine	Chemical	1
Arginine	Biochemical (from gelatin)	10
	Chemical	11
Asparagine	Chemical (from aspartic acid)	
Aspartic Acid	Chemical	1
Cysteine	Chemical	8
Glutamic Acid	Biochemical (from wheat gluten)	8
	Chemical	9
Glutamine	Chemical	8
Glycine	Chemical	1
Histidine	Biochemical (from blood proteins)	1
	Chemical	8
Isoleucine	Chemical	1
Leucine	Chemical	1
Lysine	Chemical	1
Methionine	Chemical	1
Phenylalanine	Chemical	1
Proline	Chemical	8
Serine	Chemical	1
Threonine	Chemical	1
Tryptophan	Biochemical (from casein)	1
	Chemical	8
Tyrosine	Chemical	8
Valine	Chemical	1



[a]All reactions except that to produce acrolein are taken from reference 9. The reactions are all rather common and are described in detail in various sections of "Organic Syntheses," vols. 1-4.

Fig. 2. Possible Flowsheet for Production of Glutamic Acid by Wholly-Chemical Processes.[a]

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