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SOYBEAN OIL

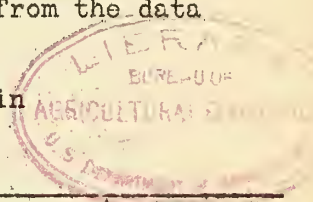
Composition and Physical Properties

Crude soybean oil is ordinarily produced by pressing or solvent-extraction of mature, sound soybeans. Although the method of processing soybeans results in minor variations in the chemical composition of the oil, it is normally found to consist of 95 to 98 percent of the glycerides of saturated and unsaturated fatty acids having, for the most part, a chain length of 18 carbon atoms. Minor components, principally 1.5 to 3 percent of phosphatides and 0.5 to 2 percent of unsaponifiable matter, are present in the crude oil. The fatty acids of the mixed glycerides normally comprise about 12 percent of saturated and 88 percent of unsaturated acids; of the latter oleic acid constitutes 25 to 35 percent, linoleic acid 45 to 55 percent, and linolenic acid 3 to 10 percent of the total acids.

The chemical and physical characteristics of crude soybean oil likewise vary with the method of production, but the following values may be considered as a normal range: Iodine number, 125 to 135; thiocyanogen number, 80 to 85; refractive index, 1.4700 to 1.4740_D²⁵; viscosity, 0.50 to 0.65 poises at 25° C.; acid number, 0.5 to 2; flash point, 300° to 320° C.; fire point, 350° to 355° C.; break, 0.1 to 1.00 percent; refining loss, 1.0 to 7.0 percent; Lovibond color, 70Y 12R to 70Y 30R (133 mm. cell).

The chemical composition and properties of soybean oil place it intermediately between the nondrying and the drying classes of oil, and consequently it finds use in both of these channels. At various times in the past 25 years it has been used principally as a drying oil, as a soap oil, and as an edible oil. In recent years the primary outlet for soybean oil has been in the field of edible products, as is evident from the data of the following table:

Factory production and consumption of soybean oil in the United States



| Year | Total factory production | Shortening | Oleo-margarine | Other edible products | Soap | Drying oil industry | Miscellaneous |
|------|--------------------------|------------|----------------|-----------------------|-----------|---------------------|---------------|
| | 1,000 lb. | 1,000 lb. | 1,000 lb. | 1,000 lb. | 1,000 lb. | 1,000 lb. | 1,000 lb. |
| 1931 | --- | 10,869 | 823 | --- | 3,816 | 8,901 | 2,051 |
| 1932 | 39,445 | 4,889 | 3 | 180 | 5,571 | 11,593 | 1,875 |
| 1933 | 26,533 | 489 | 7 | 460 | 4,235 | 14,274 | 2,626 |
| 1934 | 35,366 | 2,735 | 24 | 509 | 1,354 | 13,353 | 2,109 |
| 1935 | 105,056 | 52,452 | 1,740 | 9,421 | 2,549 | 17,871 | 1,665 |
| 1936 | 225,297 | 113,897 | 14,262 | 21,598 | 5,023 | 17,419 | 3,405 |
| 1937 | 194,411 | 90,798 | 31,793 | 15,530 | 10,274 | 17,157 | 3,038 |
| 1938 | 243,613 | 143,318 | 39,885 | 11,280 | 10,897 | 18,847 | 5,340 |

For use in the production of soap, in some types of blended paint oils, and in certain miscellaneous products, soybean oil is used with little or no treatment other than settling and filtration. When used in the manufacture of most paints and also in varnishes, enamels, linoleum, oil-cloth, printing inks, and similar products of the drying oil industry, it is generally refined, either by one of the so-called mechanical refining processes or by treatment with alkali. For use as a salad or cooking oil, it is alkali-refined, bleached, winterized, and deodorized; and, if the oil is to be used in the production of shortening or oleomargarine, it is subjected to hydrogenation in order to harden it.

Soaps and Detergents

Like most oils and fats, soybean oil may serve as a raw material for the production of soap, although it is not especially well suited for this purpose. In one year during the first World War, when an acute shortage of fats occurred in all countries, the United States consumed 124 million pounds of Manchurian soybean oil in the production of soap; but with the return of normal conditions its use for this purpose decreased quite markedly. At the present time about 10 million pounds of soybean oil are consumed annually in the soap industry, together with considerable quantities of so-called "foots" which are produced during the process of refining the oil. Except when it is blended with other fats, soybean oil, in general, is not adapted to the production of high-grade soaps for toilet purposes and for washing delicate fabrics.

Soybean oil and its derived fatty acids can be converted into sodium and potassium soaps which are semi-solid or liquid products. Soaps of this type are primarily used for washing cars and other metal surfaces and for cleansing marble, tile, and terrazzo floors. Calcium soap derived from soybean oil is used in certain types of lubricating greases. When properly hydrogenated, soybean oil can be substituted for tallow in the production of laundry and certain types of toilet soaps, while the soaps derived from the sulfonated oil are used as wetting and emulsifying agents. In the course of the conversion of soybean oil into soap or fatty acids, there is simultaneously produced approximately 10 percent of glycerine which is recovered and marketed for various purposes.

Paints, Varnishes, and Related Products

The drying or semidrying property of soybean oil results principally from its content of linoleic and linolenic acids which normally comprise 45 to 55 percent and 3 to 10 percent, respectively, of the total acids of the oil. The drying and film-forming properties of the crude oil are inhibited by the presence of phosphatidic and anti-oxygenic materials which tend to retard the uptake of oxygen; and, as a consequence of the presence of about 25 percent of oleic acid, the resulting film is more flexible than that produced by linseed oil under

the same conditions. Failure to appreciate the effect of the natural inhibitors which are present in crude soybean oil has been responsible for some of the failure in adapting it to certain uses in the drying oil field.

With increasing knowledge of the best methods of treating soybean oil, it has found wider application in the manufacture of paints, varnishes, enamels, linoleum and allied products, printing inks, synthetic resins, caulking compounds, core oils, and factice. Although detailed estimates are for the most part unavailable, it is known that the soybean oil consumed annually in these products amounts to 25 million pounds, of which approximately 10 to 12 million pounds are used, when blended with linseed, perilla, or tung oils, in the production of exterior paints. These blended paint oils generally contain 20 to 45 percent of soybean oil, but small quantities of 100-percent soybean oil paint are currently marketed. For use in paints soybean oil should be alkali- or mechanically-refined, and it may also be blown or oxidized to improve the drying and gloss of the paint film. When mixed with linseed oil in amounts up to 30 percent, refined soybean oil increases the elasticity of the paint film without materially affecting the drying time. Such films flow more freely and work better under the brush than do similar films prepared with pure linseed oil. Lead-manganese and cobalt driers, preferably in the form of resinates and linoleates, or lead-manganese eleostearates, when used with these mixtures, produce films which dry fairly hard within 24 hours.

Pigments grind readily in soybean oil, and it is especially suitable for the production of soft pastes which hold their tints remarkably well and do not harden on long standing. Because of the latter characteristic soybean oil is especially suited for the preparation of caulking compounds and plastic ship bottom paints. Crude, semirefined, and varnish grade soybean oils, either alone or when mixed with linseed oil, have been used as core oils; and cores made with soybean oil or soybean-linseed oil mixtures have been found to have suitable tensile strengths for most foundry operations.

Crude expeller and similarly pressed oils, when kettle-bodied, generally tend to darken and even to break with the separation of highly colored gummy materials and the production of an orange-colored oil. Consequently, crude oils of this type are not suitable for the production of varnishes. However, after alkali- or mechanical-refining, these oils show no break when heated to 288° C. and above, and tend to bleach at elevated temperatures. Furthermore, refined soybean oil is remarkably free from yellowing and discoloration when used in white or light tinted products applied to interior walls or objects exposed only to artificial or diffused light. This superior color retention, as well as its freedom from wrinkling, makes it highly suitable for use in heat-reactive resin formulations such as baking alkyd resins. As a consequence of these properties, soybean oil has found a very definite place in the production of modified synthetic resins for use in baking alkyds and in similar air-drying enamels. These products are prepared in a variety of ways, either directly from soybean oil or from its derived fatty acids.

More recent practice involves heating soybean oil with an excess of glycerol to convert it to the monoglyceride and adding, toward the end of the reaction, minor amounts of tung or other oils to improve the ultimate water resistance of the finished product, which in turn is followed by the addition of phthalic or other acid anhydride, and completion of the reaction by further heating. The final reaction products, or alkyd resins as they are called, find extensive use in finishing motor cars, refrigerators, and similar metal products.

Edible Products

In recent years the principal outlet for soybean oil has been in the edible field and, as mentioned above, it is essential that the oil be refined, bleached, winterized, and deodorized to remove part or all of the color and odorous constituents. These operations are highly technical and are carried out on a large scale. The completely refined oil can be used as a salad oil and in the preparation of mayonnaise and salad dressings, in packing fish, and in deep-fat frying of such food products as potato chips, nuts, and doughnuts. For these purposes it is usually blended with cottonseed, corn, or similar oils. Because of the tendency of highly refined soybean oil to undergo flavor reversion, care must be exercised in its use in edible products. Because of the high tinctorial properties of soybean oil it can be used to produce a bright-colored mayonnaise and for coloring oleomargarine.

In the production of shortening and oleomargarine, soybean oil is hydrogenated after it is refined, and then bleached and deodorized. For use in the manufacture of oleomargarine it is usually blended with some other oil, especially cottonseed or coconut oils, although considerable quantities of oleomargarine made wholly from milk and soybean oil are currently produced. In this case the oil is usually hydrogenated to an iodine number of about 75. Whole milk is inoculated with a mixed culture and incubated or ripened to produce the necessary amount of lactic acid and flavoring constituents required to impart the essential butter flavor to the finished product. After introduction of the salt and other minor ingredients, the milk and hydrogenated oil are properly proportioned and fed to the emulsifying churns or high-speed homogenizers, where they are emulsified to form a creamy liquid which on crystallization forms the finished product known as oleomargarine.

By far the largest single outlet for soybean oil is in the production of vegetable shortenings and lard compounds. For these uses the oil is hydrogenated to a degree of hardness which depends on the experience of the manufacturer and the type of product desired. The hydrogenated oil is blended with other fats and oils, especially hydrogenated cottonseed oil. In some cases the soybean oil is hardened to a rather high titer and blended with less highly-hydrogenated cottonseed or other oil in order to improve the flavor stability and retain the requisite plasticity in the finished product.

Phosphatides

Soybean oil contains a variable mixture of glycerophosphoric acid esters which are collectively designated as phosphatides. The apparent phosphatide content of the oil varies with the method by which it is removed from the seed, but generally ranges from 1.5 to 3.0 percent. The mixed phosphatides comprise both lecithins and cephalins, the former being present to the extent of about 30 to 35 percent of the total. Lecithins are distinguishable from the cephalins by their ready solubility in alcohol and ether in contrast to the lesser solubility or complete lack of solubility of the latter in alcohol.

The commercial soybean lecithins consist of a group of closely related compounds whose properties vary somewhat with the source and method of manufacture. So-called soya lecithin is usually produced from solvent-extracted oil by hydration and subsequent separation of oil and phosphatides in high speed centrifugals. About 30 percent of oil remains in some loose combination with the phosphatides and serves as a carrier and inhibitor of oxidation to which the phosphatides are especially susceptible. After drying in vacuo to remove the water used in hydrating the phosphatides, the product may be bleached to reduce the color. Commercial soya lecithin is available in a number of grades and in carriers other than soybean oil. The product is used in small quantities as an emulsifying, wetting, or stabilizing agent in a large variety of products including confections, pharmaceuticals, shortening, and textile and leather finishes.

Sterols

The unsaponifiable fraction, amounting to 0.5 to 2 percent of the original crude soybean oil, is of little commercial value at the present time. Somewhat less than half of the total unsaponifiable matter of the crude oil consists of a mixture of sterols, principally sitosterols, dihydrositosterol, and stigmasterol. During the process of alkali refining, a portion of the unsaponifiable matter is separated from the oil along with the soap stock. After acidulation and distillation of the soap stock, the unsaponifiable matter accumulates in the pitch, or still residue, from which the crude mixed sterols can be separated by solvent extraction. The same mixed sterols may also be obtained by saponifying crude phosphatide residues and working up the unsaponifiable fraction.

Because of the interest in stigmasterol as a source material for the preparation of certain sex hormones, the recovery of this substance from the crude mixed sterols has attracted considerable attention. The stigmasterol content of crude oil is probably not over 0.1 percent and its recovery entails many operations of a highly technical character.

Vitamins

The vitamins present in soybean oil have not been completely characterized, and the effect of various processing treatments on these substances is for the most part unknown. Such information as is available indicates that crude soybean oil is moderately rich in growth-promoting vitamin A, but relatively poor or completely lacking in the antirachitic vitamin D. The antisterility vitamin E content of crude soybean oil appears to be quite low. The presence of the antihemorrhagic vitamin K has been reported although in relatively low concentration. The literature contains a number of reports with reference to nutritional factors which cannot be related to any presently known vitamin. The crude oil appears, for example, to contain a preventive against nutritional encephalomalacia in chicks and nutritional muscular dystrophy in rabbits.

SELECTED REFERENCES

The following publications may be consulted in most technical libraries or large public libraries:

Composition and Physical Properties

1. Baughman, W. F., and Jamieson, G. S. The chemical composition of soybean oil. *J. Am. Chem. Soc.*, 44, 2947-2952 (1922).
2. Bickford, W. G., Dollear, F. G., and Markley, K. S. The effect of hydroxyl groups and acetylation on the apparent diene values of soybean and other vegetable oils. *Oil and Soap*, 15, 256-259 (1938). Cf. *J. Am. Chem. Soc.*, 59, 2744-2745 (1937).
3. Cruz, A. O., and West, A. P. Composition of Philippine soybeans and soybean oil. *Philippine Jour. Sci.*, 48, 77-88 (1932).
4. Dollear, F. G., Krauczunas, P., and Markley, K. S. Composition of a soybean oil of abnormally low iodine number. *Oil and Soap*, 15, 263-264 (1938); The chemical composition of some high iodine number soybean oils. In press.
- ✓ 5. Groen, T. G., and Hilditch, T. P. Nature of antioxygens present in natural fats. III. Occurrence of antioxygenic compounds in extracted soybean oil-cake. *J. Soc. Chem. Ind.*, 56, 23-26T (1937).
6. Griffiths, H. N., and Hilditch, T. P. Oleic-elaidic acid transformation as an aid in the analysis of mixtures of oleic, linoleic, and linolenic acids. *J. Soc. Chem. Ind.*, 53, 75-81T (1934).

7. Hall, W. L. Some analyses of commercial soybeans. Bur. Agr. Econ., U. S. Dept. Agr. (1937). 10 pp. Mimeo.
8. Hashi, K. Studies on soybean oil. IV. Separation of its glycerides by bromination. J. Soc. Chem. Ind. Japan, 31, 117-123 (1928).
9. Hashi, K. Soybean oil. II. Isolation of oleodipalmitin. J. Soc. Chem. Ind. Japan, 30, (Suppl. binding), 222-223 (1927).
10. Hilditch, T. P., and Jaspersen, H. The occurrence of traces of hexadecenoic (palmitoleic) acid in vegetable fats. J. Soc. Chem. Ind., 57, 84-87 (1938).
11. Hilditch, T. P., and Jones, E. C. Regularities in the glyceride structure of some technically important vegetable fatty oils. J. Soc. Chem. Ind., 53, 13-21T (1934).
12. Kaufmann, H. P. Studien auf dem fettgebiet. Pp. 137-140. Berlin, Verlag Chemie, G. M. B. H., 1935.
13. Kaufmann, H. P., Baltes, J., and Buter, H. XXXV. Diene synthesis in the field of fats. Ber., 70B, 903-911 (1937).
14. Kimura, Wasaburo. Application of the thiocyanate number. IV. Analysis of soybean oil. J. Soc. Chem. Ind. Japan, 33 (Suppl. binding), 325 (1930).
15. Long, J. S., Reynolds, J. B., and Napravnik, J. Studies in the drying oils. XVIII. Specific heat and features of heating drying oils. Ind. Eng. Chem., 26, 864-868 (1934).
16. McNicholas, H. J. The color and spectral transmittance of vegetable oils. J. Res. Natl. Bur. Stds., 15, 99-121 (1935); Oil and Soap, 12, 167-178 (1935).
17. Nakamiya, J. Gadusene, an unsaturated hydrocarbon occurring in animal and vegetable oils. Sci. Papers Inst. Phys. Chem. Res. (Tokyo), 28, 16-26 (1935).
18. Schmalfluss, H., and Treu, A. Concerning methyl-n-nonyl ketone from the etheral oil of soybeans (Glycine soja Lieb.). Biochem. Z., 189, 49 (1927).
19. Suzuki, B. Separation of glycerides. II. Soybean oil. Proc. Imp. Acad. (Japan), 3, 529-530 (1927); 5, 265-268 (1929).

Soaps and Detergents

20. Chemische Fabrik Stockhausen and Cie. Brit. Pat. 449,132 (June 22, 1936); Ger. Pat. 660,736 (June 1, 1938).
21. Erasmus, P. The cleavage of fats. *Allgem. Öl. u. Fettztg.*, 27, 201-202, 222-223 (1930).
22. Hirose, M. Artificial beef tallow. II. Relation between the properties of soap and the degree of hydrogenation of oils used. *J. Soc. Chem. Ind. Japan*, 29, 203-212 (1926).
23. Horvath, A. A. Soybean oil for soap making. *Chem. Ind.*, 55, 691-693T (1936).
24. Klemgard, E. N. Lubricating greases, their manufacture and use. P. 153. New York; Reinhold Publishing Corp., 1937.
25. Nakae, D., and Nakamura, K. The autoclave process of oil splitting. *J. Soc. Chem. Ind. Japan*, 37 (Suppl. binding), 583 (1934); *Ibid.*, 38, 7-8 (1935).
26. Norris, M. H., and McBain, J. W. A study of the rate of saponification of oils and fats by aqueous alkali under various conditions. *J. Chem. Soc. (London)*, 121; 1362-1375 (1922).
27. Sato, M. Preparation of a liquid fuel resembling petroleum by the distillation of the calcium salts of soybean oil fatty acids. *J. Soc. Chem. Ind. Japan*, 25, 13-24 (1922); 26, 297-304 (1923); 29, 109-115 (1926); 30, 242-267 (1927). Cf. Haga, S. Catalytic decomposition of soybean oil by active carbon. *Ibid.*, 30, 618-624 (1927).
28. Winokucki, K., and Toriyama, M. Sulfonated oils. XXV. Reaction between soybean and herring oils and concentrated sulfuric acid. *J. Soc. Chem. Ind. Japan*, 39 (Suppl. binding), 94 (1936).

Paints, Varnishes, and Related Products

29. Burlison, W. L. Recent developments in the utilization of soybean oil in paint. *Univ. of Ill. Coll. of Agr. Cir.* 438, 3-8 (1935).
30. Casberg, C. H., and Schubert, C. E. An investigation of the suitability of soybean oil for core oil. *Univ. of Ill. Eng. Expt. Sta. Bull.* 235 (1931); Cf. *Bull.* 221 (1931).
31. Chang, H-Y., and Chang, T-H. Experiments on air blowing of soybean oil. *Chemistry (China)*, 2, 296-301 (1935).

32. Chatfield, H. W. The heat treatment of varnish oils. II. Paint Mfg., 7, 144-145 (1937).
33. The drying qualities of soybean oil. Natl. Paint, Varnish and Lacquer Assn. Cir. No. 471, 321-328 (1934).
34. Fryer, P. J. Substitutes for linseed oil in the paint industry. Chem. Age (London), 4, 496 (1921).
35. Gardner, H. A. Soya oil in paints. Paint, Mfg. Assn. Cir. No. 50 (1917); Driers for soya oil. Ibid., No. 69, 1-12 (1919); Soybean oil and perilla oil. Ibid., No. 137 (1921).
36. Hadert, H. Soybean oil products in the varnish and adhesive industry, Farben-Chem., 7, 452-455 (1936).
37. Heberer, A. J. Some uses of soybean oil in paints and varnishes. Oil and Soap, 14, 15-16 (1937).
38. Hodgins, T. S. Improving the drying properties of oils. U. S. Pat. 2,167,206.
39. Hodgins, T. S. Process for improving the drying properties of oils. U. S. Pat. 2,133,894 (Oct. 18, 1938).
40. Kaufmann, H. P., and Mardner, P. The field of fats. LVII. The production of films by sulfurizing thin layers of drying oils. Fette u. Seifen, 44, 177-179 (1937).
41. Kemmer, H. Perilla and soybean oil. Farbo u. Lack., 595-596 (1937).
42. Lewis, A. J., and Markley, K. S. Soybean oil varnishes. Paint, Oil and Chem. Rev., 99, No. 26, 5-6 (1937); The utilization of soybean oil in paints and varnishes. Ibid.; 100, No. 22, 8-9 (1938).
43. Oda, R. Preparation of castor oil-like product from soybean oil. J. Soc. Chem. Ind. Japan, 41 (Suppl. binding), 195-196 (1938).
44. Ogura, M. Lithographic varnish making. II. Cooking linseed, perilla, and linseed-soybean oil mixtures in an atmosphere of carbon dioxide. J. Soc. Chem. Ind. Japan, 40 (Suppl. binding), 377-381 (1937).
45. Pearce, W. T. Off. Digest Fed. Paint and Varnish Prod. Clubs. March 1937.
46. Scofield, F. The drying time and hardness of some oils and oil mixtures. Paint Mfg. Assn. Cir. No. 519, 271-281 (1936); Further data on drying time of oil mixtures and some notes on durability. Ibid., No. 522, 295-301 (1936).

47. Soybean oil in interior enamels. Natl. Paint, Varnish and Lacquer Assn. Cir. 568, 389-402 (1938).
48. Taggart, M. F. Use of soybean oil in paint. Proc. 16th Ann. Meeting Amer. Soybean Assn. Pp. 47-48 (1936); Value of recent developments in soybean oil. Drugs, Oils and Paints, 53, 177-178 (1938); U. S. Patent 2,113,358 (Apr. 5, 1938).
49. Ulrich, H. Oils of interest for enamels and lacquers. Farben-Ztg., 40, 1037 (1935).
50. Ware, E. E. Soybean oil in the paint industry. Ind. Eng. Chem., 28, 903-906 (1936).

Edible Products

51. Dean, D. K., and Chapin, E. H. Continuous deodorization of edible oils. Oil and Soap, 15, 200-202 (1938).
52. Durkee, M. M. Soybean oil in the food industry. Ind. Eng. Chem., 28, 898-903 (1936).
53. Gill, A. H., and Ma, Y. M. Hydrogenation of soybean oil. Oil and Fat Ind., 5, 348-351 (1928).
54. Hilditch, T. P., and Moore, C. W. Selective hydrogenation. J. Soc. Chem. Ind., 42, 15-17T (1923).
55. Kino, K. The preparation of ketones from higher fatty acids. IV. The preparation of ketones from the fatty acids of coconut and hardened rapeseed and soybean oils. J. Soc. Chem. Ind. Japan 40 (Suppl. binding), 331-332 (1937).
56. Mazume, T. Hydrogenation of fatty oils. VII. Formation of isooleic acid by the hydrogenation of soybean oil. J. Soc. Chem. Ind. Japan, 31, 467-469, 111-112B (1928).
57. Richardson, A. S., Knuth, C. A., and Milligan, C. H. Heterogeneous catalysis. I. Selective action of catalytic nickel in hydrogenation of certain vegetable oils. Ind. Eng. Chem., 16, 519-522 (1924).
58. Shinozaki, Y., Kagawa, S., and Sato, M. The high-pressure hydrogenation of soybean oil. V. The preparation of light hydrocarbon oil. J. Soc. Chem. Ind. Japan, 39 (Suppl. binding), 22 (1936).
59. Shinozaki, Y., and Kubo, H. The high-pressure hydrogenation of soybean oil. I, II, and III. J. Soc. Chem. Ind. Japan, 37 (Suppl. binding), 677-678, 678-679, 780-781 (1934); Ibid., 38, 21 (1935).

60. Ueno, S., Yamashita, M., Ota, Y., Okamura, Z. Nutritive value of hydrogenated oils. J. Soc. Chem. Ind. Japan, 30, 378-385 (1927).
61. Waterman, H. I., and Bertram, S. H. The hydrogenation of oils. J. Soc. Chem. Ind., 48, 79-80T (1929).
62. Waterman, H. I., Van Tussenbroek, M. J., and Van Dijk, J. A. Influence of pressure and temperature on the hardening of soybean oil. Rec. trav. chim., 50, 793-795 (1931).
63. Waterman, H. I., and Van Vlodrop, C. Effect of varying conditions in the catalytic hydrogenation of fatty oils on the nature of the reaction product. IV. Rec. trav. chim., 56, 521-525 (1937).
64. Yamaguchi, E., Azami, M., and Takagi, T. Catalysts prepared by thermal decomposition of metallic compounds in an oily medium. I. Hydrogenation of soybean oil by the formate process. J. Soc. Chem. Ind. Japan, 40 (Suppl. binding), 366 (1937).

Phosphatides

65. Belozerskii, A. N., and Kornev, I. S. Comparative study of phosphatides of the embryos and cotyledons of soybeans. Biokhimiya, 2, 894-901 (1937).
66. Eichberg, J. Lecithin - Its manufacture and use in the fat and oil industry. Oil and Soap, 16, 51-54 (1939).
67. Evans, E. I. Antioxidant properties of vegetable lecithin. Ind. Eng. Chem., 27, 329 (1935).
68. Halliday, G. E. Changes in the phosphatide content of crude soybean oil during storage. Oil and Soap, 14, 103-104 (1937).
69. Hefter-Schönfeld. Chemie und technologie der fette und fettprodukte. Phosphatide by Ad. Grün 1, 456-516 (1936).
70. Hilditch, T. P., and Pedelty, W. H. The component fatty acids of the phosphatides of soybean and rape seeds. Biochem. J., 31, 1964-1972 (1937).
71. Horvath, A. A. Soya phosphatides. J. Chem. Ed., 14, 424 (1937).
72. Jamieson, G. S., and McKinney, R. S. Phosphatides in American soybean oil. Oil and Soap, 12, 70-72 (1935).

73. Levene, P. A., and Rolf, I. P. Plant phosphatides. I. Lecithin and cephalin of the soybean. *J. Biol. Chem.*, 62, 759-766 (1925); Bromo-lecithins. I. Fractionation of brominated soybean lecithins. *Ibid.*, 65, 545-549 (1925); II. Lecithin, cephalin, and so-called cuorin of the soybean. *Ibid.*, 68, 285-293 (1926).
74. McKinney, R. S., Jamieson, G. S., and Holton, W. B. Soya phosphatides. *Oil and Soap*, 14, 126-129 (1937).
75. Suzuki, B., and Nishimoto, U. Cephalins of soybean. *Proc. Imp. Acad. (Japan)*, 6, 262-265 (1930).
76. Suzuki, B., and Yokoyama, Y. Soybean lecithin. I. The separation of α - and β -series. *Proc. Imp. Acad. (Japan)*, 6, 341-344 (1930).
77. Working, E. B. The chemistry of phosphatides and their utilization in industry. *Oil and Soap*, 13, 261-263 (1936).
78. Yokoyama, Y., and Suzuki, B. Soybean lecithin. II. Lecithins of the α -series. *Proc. Imp. Acad. (Japan)*, 7, 12-14 (1931).

Sterols

79. Bonstedt, Kurt. Über einige sterine des pflanzenreichs. *Z. Physiol. Chem.*, 176, 269-281 (1928).
80. Butenandt, A., and Westphal, U. The preparation of the corpus luteum hormone from stigmaterol. *Ber.* 67B, 2085-2087 (1934).
81. Butenandt, A., Westphal, U., and Cobler, H. Decomposition of stigmaterol to substances acting on the corpus luteum. *Ber.*, 67B, 1611-1616 (1934).
82. Fernholz, E. The preparation of the corpus luteum hormone from stigmaterol. *Ber.*, 67B, 2027-2031 (1934).
83. Fernholz, E. Über die konstitution des stigmaterins. *Ann.*, 507, 128-138 (1933).
84. Jantzen, E., and Gohdes, W. Über das vorkommen von glucosidisch gebundenen sterinen im sojaöl. *Biochem. Zeit.*, 272, 167-171 (1934); Cf. Kondo, K., and Mori, S. Sitosterol- α -glucoside from soybeans. *J. Chem. Soc. Japan*, 57, 1128-1131 (1936).
85. Klobb, T., and Bloch, A. Sur le phytostérol du soja. *Bull. Soc. Chim. Paris*, (4) 1, 422-428 (1907).
86. Matthes, H., and Dahle, A. Ueber sojabohnenöl. *Arch. Pharm.*, 249, (6), 424-444 (1911).

87. Steiger, M., and Reichstein, T. Δ^5 -3-hydroxyetiocholenic acid and some of its transformation products. *Helv. Chim. Acta.*, 20, 1040-1054 (1937).

Vitamins

88. Almquist, H. J., and Klose, A. A. Color reactions in vitamin K concentrates. *J. Am. Chem. Soc.*, 61, 1610-1611 (1939).
89. Almquist, H. J., and Stokstad, E. L. R. Assay procedure for vitamin K (antihemorrhagic vitamin). *J. Nutrition*, 14, 235-240 (1937).
90. Bacharach, A. L. Growth promoting properties of vitamin D. *Quart. J. Pharm.*, 1, 49-60 (1928).
91. Coombes, A. I., Elvehjem, C. A., Phillips, P. H., and Hart, E. B. Soybean oil prevents one type of chick paralysis. *Wis. Agr. Expt. Sta. Bull.* 439, 8 (1937).
92. Goettsch, M., and Pappenheimer, A. M. The prevention of nutritional encephalomalacia in chicks by vegetable oils and their fractions. *J. Biol. Chem.*, 114, 673-687 (1936).
93. Izume, S., Yoshimaru, Y., and Isao, K. The influence of ultra-violet irradiation on the antirachitic value of soybean oil. *J. Biochem. (Japan)*, 10, 177-182 (1928).
94. Izume, S., Yoshimaru, Y., and Tei, H. Vitamin D. IV. Ergosterol in soybean oil as a source of vitamin D. *J. Agr. Chem. Soc. Japan*, 9, 246-253 (1933).
95. Kishlar, L. Some nutritive developments in soybean products. *Oil and Soap*, 14, 237-239 (1937).
96. Ohtomo, S. The occurrence of vitamin A and B in soybean oil and cake. Abstracts from Rept. Central Lab. S. Manchuria Ry. Co., pp. 13-15 (1929).
97. Pappenheimer, A. M., and Goettsch, M. Transmission of nutritional muscular dystrophy to rabbits in utero. *Proc. Soc. Expt. Biol. Med.*, 34, 522-525 (1936).
98. Quackenbush, F. W., Platz, B. R., and Steenbock, H. Rat acrodynia and the essential fatty acids. *J. Nutrition*, 17, 115-126 (1939).
99. Suzuki, U., Nakahara, W., and Sahashi, Y. Further evidence for the occurrence of vitamin E in soybean oil. *Sci. Papers Inst. Phys. Chem. Res. Tokyo*, 24, 283-286 (1934); *Ibid.*, 23, 270-273 (1934).

General and Miscellaneous

100. Borst, H. L., and Thatcher, L. E. Life history and composition of the soybean plant. Ohio Agr. Expt. Sta. Bull. 494, 1-88 (1931).
101. Bur. of Census, U. S. Department of Commerce. Animal and Vegetable Fats and Oils. Annually.
102. Bur. Agr. Econ., U. S. Dept. of Agr. The Fats and Oils Situation. Monthly.
103. Bur. Foreign and Domestic Commerce, U. S. Department of Commerce. Fats and Oils Trades of the U. S. Annually.
104. Dean, H. K. Utilization of Fats. New York, Chemical Publishing Company, 1938.
105. Horvath, A. A. The Soybean Industry. Ed. 2. New York, The Chemical Publishing Company, 1939.
106. Jamieson, G. S. Vegetable Fats and Oils. New York, The Chemical Catalog Company, 1932.
107. McClelland, C. K. Soybean varieties for hay, seed, and oil production. Ark. Agr. Expt. Sta. Bull. 334, 3-44 (1936).
108. Mighell, A., Hughes, H. D., and Wilkins, F. S. Soybeans in Iowa farming. Iowa Agr. Expt. Sta. Bull. 309 (1936).
109. O'Kelly, J. F., and Geiger, M. Effect of variety, maturity, and soundness on certain soybean seed and oil characteristics. Miss. Agr. Expt. Sta. Tech. Bull. 24, 1-10 (1937).
110. Piper, C. V., and Morse, W. J. The Soybean. New York, McGraw-Hill Book Company, 1923.
111. Webster, J. E., and Kiltz, B. F. Oil and protein studies of Oklahoma-grown soybeans. Proc. Okla. Acad. Sci., 15, 32-36 (1935).
112. Woodworth, O. M. Illini soybean. Uni. Ill. Agr. Expt. Sta. Bull. 335, 547-556 (1929); Cf. Bull. 384, 1-404 (1932).

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