7. Holman, R.T., W.O. Caster and H.F. Wiese, J. Clin. Nutr. 14:70 (1964).
8. Holman, R.T., Prog. Chem. Fats Other Lipids 9:275,555,661 (1970).
9. Burr, G.O., and M.M. Burr, J. Biol. Chem. 82:345 (1929).
10. Paulsurd, J.R., L. Pensler, C.F. Whitten, S. Stewart and R.T. Holman, Am. J. Clin. Nutr. 25:897 (1972).
11. Soderhjelm, L., H.F. Wiese and R.T. Holman, in "Progress in the Chemistry of Fats and Other Lipids," Vol. 9, Part 4, Pergamon Press, New York, 1970.
12. Alfin-Slater, R.B., and L. Aftergood, Physiol. Rev. 48:758 (1968).
13. Collins, F.D., A.J. Sinclair, J.P. Royle, D.A. Coats, A.T. Maynard and R.F. Leonard, Nutr. Metab. 13:150 (1971).
14. Recommended Dietary Allowances, Food and Nutrition Board, National Academy of Sciences–National Research Council, 8th Edition, Publ. 2216, Washington, DC, 1974.
15. Jones, R.J.J., JAOCS 51:251 (1974).
16. Rose, G., H. Blackburn, A. Keys, H.L. Taylor, W.B. Kannel, O. Paul, D.D. Reid and Stamler, Lancet 1:181 (1974).
17. Horwitt, M.K., Am. J. Clin. Nutr. 27:1182 (1974).
18. Bieri, J.G., and R.P. Evarts, Ibid. 28:717 (1975).
19. Dunnell, R.H., E. DeRitter and S.H. Rubin, Ibid. 28:706 (1975).
20. Carpenter, D.L., and H.T. Slover, JAOCS 50:372 (1973).
21. Harris, P.L., and N.D. Embree, Am. J. Clin. Nutr. 13:385 (1963).
22. Lange, W., JAOCS 27:414 (1950).
23. Hilditch, T.P., and P.N. Williams, "The Chemical Constitution of Natural Fats," 4th Edition, 1964.
24. Bernardini, E., "The New Oil and Fat Technology," 2nd Edition, 1973.
25. Stansby, M.E., Fish Oils (1967).
26. Tabla de Composición Química de *Alimentos Chilenos*, Quinta Edición, Santiago-Chile, 1974.
27. De Tomas, M.E., R.R. Brenner and P. Cattáneo, Rev. Argent. Grasas Aceites 5:53 (1963).
28. Stansby, M.E., JAOCS 56:793A (1979).
29. Kinsella, J.E., J.L. Shimp and J. Weihrauch, Ibid. 54:424 (1977).
30. Masson, L., M.A. Castillo and A. Borzutzky, Grasas Aceites (Seville) 23:7 (1972).
31. Masson, L., M.A. Castillo and R. Viani, Ibid. 22:188 (1971).
32. Masson, L., and M. Alonso, Oli Grassi Deriv. 7:30 (1971).
33. Masson, L., and M.T. Burgos, Grasas Aceites (Seville) 24:327 (1973).
34. Masson, L., and M.A. Mella, "Tabla de Composición Química de Acidos Grasos de Materias Grasas de Consumo Habitual y Potencial en Chile," in preparation.
35. Gopakumar, K., and M. Rajendranathan Nair, J. Sci. Food Agric. 26:319 (1975).
36. Bandyopadhyay, C.H., and A. Gholap, J. Agric. Food Chem. 21:496 (1973).
37. Williams, G., B.C. Davidson, P. Stevens and M.A. Crawford, JAOCS 54:328 (1977).
38. Jensen, R., M. Ragerty and K. McMahon, Am. J. Clin. Nutr. 31:990 (1978).
39. Insull, W., J. Hirsch, J. James and E. Ahrens, J. Clin. Invest. 38:443 (1959).
40. Read, W.W., P.G. Lutz and A. Tashjian, Am. J. Clin. Nutr. 17:180 (1965).
41. Jelliffe, D.B., and E.F. Jelliffe, Ibid. 31:492 (1978).
42. Masson, L., C. Hurtado, E. Atalah, P. Bustos, H. Oliver, M. Ruz and M.A. Mella, "Revista Chilena de Pediatría," in press (1980).
43. Massiello, F.J., JAOCS 55:262 (1978).
44. Masson, L., and M.A. Mella, ISF/AOCS World Congress presentation, New York, NY, 1980.
45. Abdellatif, A.M.M., and R.O. Vles, Nutr. Metab. 12:285 (1970).
46. Abdellatif, A.M.M., and R.O. Vles, Ibid. 15:219 (1973).
47. Beare-Rogers, J.L., E.A. Nera and B.M. Craig, Lipids 7:548 (1972).
48. Beare-Rogers, J.L., E.A. Nera and B.M. Craig, Ibid. 7:46 (1972).
49. Beare-Rogers, J.L., Prog. Chem. Fats Other Lipids 15:29 (1977).
50. Ackman, R.G., Lipids 9:1032 (1974).
51. Alfin-Slater, R.B., P. Wells and L. Aftergood, JAOCS 50:479 (1973).
52. Alfin-Slater, R.B., L. Aftergood, H.H. Hansen, R.S. Morris, D. Melnick and C.M. Gooding, Ibid. 43:110 (1966).
53. Kummerow, F.A., J. Food Sci. 40:12 (1975).
54. Anteproyecto Reglamento Sanitario de Chile, 1977.
55. Sgoutas, D., and F.A. Kummerow, Am. J. Clin. Nutr. 23:1111 (1970).
56. Kummerow, F.A., JAOCS 51:255 (1974).
57. Spritz, N., and M.A. Mishkel, J. Clin. Invest. 48:78 (1969).
58. Vergroesen, A., J. Proc. Nutr. Soc. 31:323 (1972).
59. Mattson, F.H., E.J. Hollenbach and A.M. Kligman, Am. J. Clin. Nutr. 28:726 (1975).
60. Reitz, R.C., W.E.M. Lands, W.W. Christie and R.T. Holman, J. Biol. Chem. 243:2241 (1968).
61. Lands, W.E.M., M.L. Blank, L.J. Nutter and O.S. Privett, Lipids 1:224 (1966).
62. Going, L.H., JAOCS 44:414A (1967).
63. Slater, L.E., Food Eng. 25:72 (1953).
64. Quimby, O.T., R.L. Wille and E.S. Lutton, JAOCS 30:186 (1953).
65. Andia, A.G., and J.C. Street, J. Agric. Food Chem. 23:173 (1975).
66. Tappel, A.L., Fed. Proc. 32:1870 (1973).
67. Poling, C.E., W.D. Warner, P.E. Mone and E.E. Rice, J. Nutr. 72:109 (1960).
68. Nolen, G.A., J.C. Alexander and N.R. Artman, Ibid. 93:337 (1967).
69. Nolen, G.A., JAOCS 49:688 (1972).
70. Masson, L., and M. Craddock, IFT meeting presentation, Philadelphia, PA, 1977.
71. Masson, L., H. Oliver, E. Wittig, M. Lutz and E. Lucas, 5th Conferencia Internacional del Raps. Malmo, Suecia, 1978.
72. Feely, R.M., P.E. Criner and B.K. Watt, J. Am. Diet. Assoc. 61:134 (1972).

Vegetable Oils: Effects of Processing, Storage and Use on Nutritional Values

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ABSTRACT

At the present time, vegetable oils are the source of most of the visible fat in the U.S. diet. They are used as salad and cooking oils, in salad dressing, margarine and shortening. Processing methods include extraction, refining, hydrogenation and interesterification. During storage and use, the products are exposed to oxygen and/or heat, particularly during frying. Processing, storage and use are related to changes in composition, nutritive value and physical characteristics of vegetable oils. Refining removes undesirable minor

components present in crude oils. Refined polyunsaturated vegetable oils are the primary dietary source of tocopherols. Hydrogenation modifies physical characteristics and improves sensory and oxidative stability. This process converts some of the polyunsaturated fatty acids to new fatty acid isomers. Although the biochemical effects of these isomers are still being studied, long-term animal feeding trials and human experience have demonstrated that the partially hydrogenated oils in margarines and shortenings are wholesome foodstuffs. Abusive overheating of fat in air sharply decreases its palatability and nutritive value and may create minor amounts of carcinogenic materials. However, long-term animal feeding studies with properly used frying fats have revealed little, if any, effect on life span and incidence of pathological conditions.

INTRODUCTION

At the present time in the U.S., the primary vegetable oil source is soybean (1). Much smaller amounts of safflower and sunflower seed are processed for oil. Corn, cottonseed and peanut oils are by-products of other uses of the seeds. In addition, certain oils are imported, primarily from warmer countries. Vegetable oils are the source of most of the visible fat in the U.S. diet. They are used as salad and cooking oils, in salad dressings, margarine and shortenings (2). Processing methods include extraction, refining, hydrogenation and interesterification (2). In storage, the fat may be altered by exposure to air and during frying, the fat is subjected to both air and moisture at elevated temperatures. These can cause more or less oxidation, polymerization and hydrolysis.

The major processing and use conditions are described and related to effects on composition and nutritive values.

PROCESSING

Extraction

The first step in processing is separation of the oil from the source, i.e., soybeans, cottonseed, corn germ, dried coconut or other oil-rich plant material (2). Details of the process are different for each source, but the general pattern is the same for all. Historically, oil was expelled by pressing, with or without deliberate heating. At present, the usual process is to roll the seed or germ into thin flakes (in which some oil is expelled) which are then extracted with hexane. This gives a higher yield of oil with generally fewer impurities and less heat damage. The hexane is distilled off and none remains in the crude oil.

The crude vegetable oil consists of the desired triglycerides and unsaponifiables together with small amounts of other substances which contribute undesirable characteristics to the oil, such as color, flavor, odor, instability and foaming. Pesticides are a comparatively recent addition to this list but when one recognizes the almost universal use of pesticides, many of which are highly soluble in fats, their presence in crude, unprocessed vegetable oils should not be surprising (3).

Refining

The first step in processing crude oil (Table I) is a treatment with dilute aqueous alkali—usually caustic soda or soda ash (2). This converts free fatty acids to soaps and hydrates phosphatides, mucilagenous and proteinacous substances so that they become insoluble in the oil. The oil is separated by centrifuging. Some of the pesticides remain in the soap or gummy sludge.

Bleaching

Next comes treatment with bleaching earth or clay (e.g., Fuller's or diatomaceous earth) and filtration (2). This adsorbs color-producing substances and some pesticides.

TABLE I

Crude Vegetable Oil Refining

Treatment	Components removed
Water & alkali & centrifugation	Free fatty acids Mucilagenous substances Pesticides Phosphatides Proteinaceous substances
↓	
Bleaching earth & filtration	Colors Pesticides
↓	
Steam (deodorization) & partial vacuum	Colors Flavors Pesticides
↓	
Low temperature (winterization) & filtration	Resins Triglycerides - high melting Waxes
↓	
Refined vegetable oil	

Deodorization

Undesirable flavors and odors are removed by bubbling steam through the oil, usually under partial vacuum (2). The last of the pesticides also are volatilized and removed by steam.

Winterization

Some, but not all, vegetable oils are refrigerated so that any resins, waxes and high-melting triglycerides crystallize. These are removed by filtration (2). The resultant oil, then, will remain clear at refrigerator temperatures—a desirable characteristic for a salad oil.

The net effect of refining, bleaching, deodorization and winterization is to remove pesticides and other potentially toxic compounds naturally associated with the oilseeds and to improve taste, odor and stability in storage and use.

Composition of Refined Vegetable Oils

A comparison of the nutritive values (Table II) of four important refined vegetable oils shows that all of these oils are good sources of essential polyunsaturated fatty acids (4-6). Cottonseed oil is higher in saturates than the other three oils. Soybean oil contains considerably more linolenic acid and this may be, in part, responsible for its poor flavor stability (7,8). Corn oil is higher in phytosterols than the other oils; it is the only one containing a significant amount of ubiquinone, an antioxidant, and, in addition, has a high ratio of γ- to α-tocopherol. These may help explain its excellent stability against oxidative rancidity. All of these oils have a good ratio of tocopherols (vitamin E) to polyunsaturates. Polyunsaturated vegetable oils are the primary dietary source of tocopherols (8-10). All of the refined oils are essentially free from phosphatides and contain only very low levels of free fatty acids.

Hydrogenation

Some vegetable oils are partially hydrogenated to improve their stability, resistance to oxidation or to change their physical characteristics for special uses (2). This commercially important process converts some of the polyunsaturated fatty acids to fatty acid isomers. Although the biochemical effects of these isomers are still being studied, long-term animal feeding trials and human experience have demonstrated that the partially hydrogenated oils in margarines and shortenings are wholesome foodstuffs. The effect of hydrogenation processing on nutritional value (8,11-14)

TABLE II

Typical Compositions of Refined Vegetable Oils[a]

Oil components	Percent by weight			
	Corn	Cottonseed	Soybean[b]	Sunflower
Triglycerides, total	98.8	99.1	99.0	99.2
Fatty acids				
Polyunsaturated[c]	60.4	52.5	61.3	68.7
Linoleic	59.9	52.2	54.1	68.2
Linolenic	0.5	0.3	7.2	0.5
Monounsaturated[d]	25.0	19.5	22.5	18.6
Saturated[e]	13.4	27.1	15.2	11.9
Unsaponifiables, total	1.2	0.9	1.0	0.8
Tocopherols, total	0.07	0.07	0.07	0.07
α-Tocopherol	0.02	0.04	0.01	0.05
γ-Tocopherol	0.05	0.03	0.06	0.02
Ubiquinone	0.02	–	–	–
Free fatty acids	0.07	0.07	0.07	0.07
Phosphatides	–	–	–	–

[a]Individual values are based on analysis data and references 4-6.
[b]Values shown are for soybean oil prior to partial hydrogenation to stabilize the oil.
[c]Polyunsaturated fatty acids (PUFA) include linoleic and linolenic.
[d]Monounsaturated fatty acids = 100 – (PUFA + SFA + unsaponifiables).
[e]Saturated fatty acids (SFA) include lauric, myristic, palmitic and stearic.

is discussed thoroughly in an article by T.H. Applewhite in this proceedings.

Interesterification

Another form of processing, interesterification, or molecular rearrangement (2), can be used to change the physical characteristics of a fat or oil. During this process, a fat or mixture of fats is warmed with a small amount of alkali or acid. This causes simultaneous hydrolysis and esterification with the net effect of causing fatty acids to trade places in the triglycerides. The fatty acid composition of the fat or oil does not change during the interesterification process, so the nutritional value is unchanged. This process can be applied to any fat or mixture of fats, i.e., lard, tallow, vegetable oils or partially hydrogenated oils. The process has been used chiefly in making shortenings. However, it might also be used in manufacturing a good quality margarine containing little or no *trans*-isomers by interesterification of an oil with a highly saturated fat (14).

STORAGE AND USE

Oxidation

Unsaturated fatty acids are subject to chemical reactions (2,9,15) which can occur upon exposure to air (oxidation) and during deep fat frying (oxidation, polymerization, hydrolysis). A double bond, whether it be in a monounsaturated or polyunsaturated fatty acid, is a point of chemical reactivity. This is as true for fats and oils as for any other compound, and is an important factor to consider in regard to effects on health and nutritive value.

Under the usual storage conditions, oxidative rancidity occurs so slowly that there is no particular effect on nutritive values. Vegetable oil processors refine oils in such a way as to retain the naturally occurring tocopherols. They provide protection against oxidative rancidity, thus contributing greatly to the stability of vegetable oils during storage and use.

Extensive oxidation (8,15,16) would eventually destroy carotenoids (vitamin A), essential fatty acids and tocopherols (vitamin E). The reaction is accelerated by exposure to light, by higher temperatures and by metals which may act as catalysts, e.g., copper or iron. To remove the traces of these metals present in crude vegetable oils, a chelating agent such as phosphoric or citric acid is frequently used as a processing aid during refining (2). In addition, the rate of oxidation of an oil during storage can be greatly decreased by presence of antioxidants, by lower storage temperatures and by packaging under nitrogen or vacuum rather than air. If the fat contains insufficient tocopherols, other antioxidants may be added to provide protection against oxidative rancidity and loss of nutritive value.

Oxidation is, of course, accelerated at the higher temperatures occurring in frying of foods. The rate is roughly proportional to the degree of unsaturation: linolenic, with three double bonds, is much more susceptible than oleic, with only one. Linoleic is intermediate. This is one reason why high linolenic acid soybean oil is not a satisfactory frying oil whereas corn oil is a good one. Commercially available soybean oil is stabilized by partial and selective hydrogenation to reduce the linolenic acid content.

Polymerization

Heat also accelerates another reaction of polyunsaturates, i.e., polymerization (15). Although the mechanisms are not completely understood, the result is large molecules formed by carbon-to-carbon and/or carbon-to-oxygen-to-carbon bridges between several fatty acids. If the concentration of polymers becomes high enough, there is a marked increase in viscosity of the frying fat.

Hydrolysis

Moisture in foods that are fried in fat may cause some hydrolysis (15) to free fatty acids, but it also helps create a steam blanket over the frying kettle, thereby minimizing contact with air, and, in addition, helping to volatilize and remove peroxides, flavors and odors.

Deep Fat Frying

The kind of food being fried also affects the fat in the kettle. If the food is a piece of chicken, e.g., some chicken fat will cook out and blend with the frying fat. Breaded or batter-coated foods may contribute flavors and tiny particles which burn and add to the color of the frying fat. Onions and fish are obvious contributors of strong flavors. It is customary to add fresh fat to the kettle to maintain constant volume, replacing that removed by the food. If

food is breaded or batter-coated, the fat is filtered periodically to remove particles that might accelerate deterioration.

Obviously, this is not a simple system—a fact that impacts on any attempt to evaluate changes in nutritive values which may occur during deep fat frying. Overall, a used frying fat as compared to a fresh one is stronger in flavor and odor and darker in color. It contains free fatty acids and extractives from food that cause foaming. Contents of tocopherols and polyunsaturates are lower. But, it is important to emphasize that the content of saturated fat does not increase (2), except on the rare occasions when beef or lamb is being fried and saturated fat is extracted from the meat. Conditions of frying do not result in formation of a hydrogenated fat, as some people believe. It is the usual practice to discard frying fat when (a) addition of moist food to the hot fat causes excessive foaming, (b) the fat smokes (a sure sign of overheating), or (c) strong odors and dark color are apparent (15). A good chef always discards the fat when the quality of the fried food begins to drop. This is an extremely important point to remember in connection with the interpretation of animal feeding studies when used frying fats are part of the diet.

In an attempt to simplify the system and maximize the effects of heat and oxygen, investigators (15-17) have bubbled oxygen or air through a hot fat for many hours and then used the product in animal feeding studies. Such a system is intended to destroy polyunsaturates and cause extensive polymerization. In no way does it resemble deep fat frying (15,16,18,19). The product is unpalatable, dark, viscous and people would not eat it! But the rats had no choice. They survived, but grew poorly and looked very unthrifty. Because these products were poorly digested and assimilated, the animals were, in effect, starving and malnourished. Not unexpectedly, it was possible by chemical fractionation to isolate small amounts of carcinogenic substances from the polymers. It is important to note that the effect of even such severely damaged fat could be largely counteracted by addition of fresh fat to the diet (17) (Fig. 1). It is a major error to use data from such studies with fats oxidized at high temperatures in predicting what the response to properly used frying fats would be.

Several two-year feeding studies (18,19) have been done with rats receiving diets in which the sole source of fat had been used under practical deep fat frying conditions until foaming became excessive when food was inserted. This is the point at which a restaurant operator normally throws away the fat, cleans the kettle and refills it with fresh fat. At this point the used fat is rather dark-colored and somewhat strong in flavor, but is still reasonably palatable. The precise changes in analytical values depend, of course, on the experimental conditions.

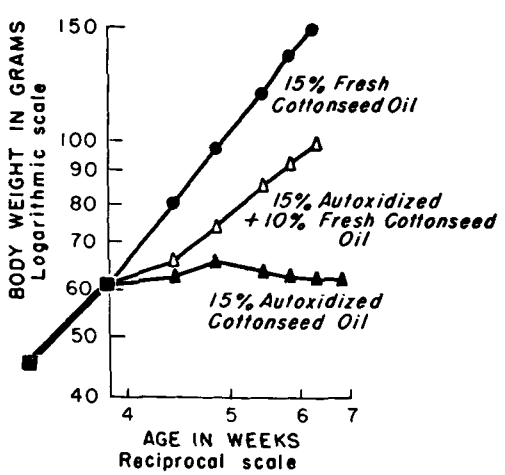

FIG. 1. Growth of rats fed 15% fresh cottonseed oil, 15% autoxidized cottonseed oil, 15% autoxidized cottonseed oil + 10% fresh cottonseed oil. From Kaunitz et al. (17).

A rat feeding study (18) was conducted in which the conditions used in preparation of the used fats simulated conditions of intermittent frying in a restaurant. The fat was heated to 182 C in 60-kg, gas-fired kettles each weekday from 8:00 a.m. to 4:00 p.m. At 9:00 a.m. and 2:00 p.m., 3.95 kg each of frozen potatoes, breaded scallops and onion rings (typical low-fat fried foods) were fried for 5, 2.5 and 3 min, respectively. At 4:00 p.m., 2.47 kg of the specific fats were added to the respective kettles. The fat was allowed to cool to room temperature overnight and on weekends.

Under these conditions, partially hydrogenated soybean oil (commercially available) could be used for up to 60 hr of deep fat frying. Changes in iodine value (IV) and composition of used partially hydrogenated soybean oil (HSBO) are compared (Table III) with unhydrogenated, unused, soybean oil (SBO), unused HSBO and HSBO used for 216 hr in the presence of a silicone antifoam. The used HSBO had slightly lower IV and polyunsaturated fatty acids than the unheated HSBO, and more free fatty acids and polar lipids.

Rat growth rates on the used HSBO were somewhat lower (Table IV), reflecting a slightly decreased digestibility/absorbability. Obviously, the differences are small; there is no obvious pattern. Overall, they indicate no life-shortening effect of the used HSBO.

The overall incidence of pathological conditions also does not suggest the presence of a major toxin in the used fat. The pattern for the unheated, lightly hydrogenated soybean oil was comparable to that for unheated, non-hydrogenated soybean oil. Use in frying did not increase incidence of tumors or other pathological conditions and might even have caused some decrease.

These data are typical. However, other researchers using other fats and/or other experimental conditions have obtained somewhat different values. The conclusion from all such studies (19) is that, apparently, no unusual health hazards are associated with properly used frying fats. "Proper" means (a) use at the correct temperature with the avoidance of overheating, smoking and marked darkening, (b) correct storage, preferably chilled if there is a considerable interval between periods of use, (c) and discarding of the fat when insertion of food in the kettle causes excessive foaming of the hot fat and/or the fat develops strong flavors and odors. Good culinary practice requires proper use of frying fats (15).

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REFERENCES

1. Anonymous, JAOCS 57:34A (1980).
2. "Food Fats and Oils," Institute of Shortening and Edible Oils, Inc., Washington, DC, August 1974.
3. "Bailey's Industrial Oil and Fat Products," 3rd Edition, edited by D. Swern, Interscience Publishers, New York, 1964.
4. "Dietary Fats and Oils in Human Nutrition," FAO/WHO, Rome, Italy, 1977.
5. Brignoll, C.A., J.E. Kinsella and J.L. Weihrauch, J. Am. Diet. Assoc. 68:224 (1976).
6. Bauernfeind, J.C., CRC Crit. Rev. Food Technol. 8:337 (1977).
7. "Evaluation of the Health Aspect of Hydrogenated Soybean Oil as a Food Ingredient," Fed. Amer. Soc. Exp. Biol. SCOGS-

TABLE III

Frying Fats Used in Rat Feeding Study (18)

Oil value/composition	Soybean oil	Partially hydrogenated soybean oil		
	Frying time at 182 C (hr)			
	0	0	60	216[a]
Iodine value	129	108	101	101
Polar lipids (%)	1	1	14	30
Free fatty acids (%)	0.04	0.02	0.65	8.10
Linoleic acid (%)	51	35	30	32
Linolenic acid (%)	6	4	0.3	1

[a]Silicone added to control foaming during frying.

TABLE IV

Effects of Consumption of Used Deep Fat Frying Oils on Rat Weight Gain, Fat Absorbability and Rat Survival (18)[a]

Observed effect	Soybean oil	Partially hydrogenated soybean oil		
	Frying time at 182 C (hr)			
	0	0	60	216
Weight gain (g)				
Males – 2 months	365	358	339	344
– 12	727	725	677	704
Female – 2	200	204	196	201
– 12	405	392	375	377
Oil absorbability (%)				
Males – 2 months	96.2	95.5	90.3	91.5
12	96.5	96.8	92.4	92.7
Females – 2	96.8	96.4	92.1	92.7
– 12	97.5	96.8	92.7	94.0
Survival (%)				
Males – 21 months	80	73	87	66
– 24	62	53	67	53
Females – 21	60	80	80	80
– 24	33	58	60	58
Tumors (%)[b]				
Males	20	22	18	22
Females	56	53	38	29
Respiratory disease (%)				
Males	22	16	22	20
Females	11	7	13	11
Nephritis (%)				
Males	30	24	20	22
Females	8	14	12	6
Liver pathology				
Males	24	48	6	18
Females	34	38	28	24

[a]Each group of Sprague-Dawley weanling rats contained 50 males and 50 females.
[b]Percentage of rats with the pathological condition.

70:(1976).
8. Rathmann, D.M., J.R. Stockton and D. Melnick, CRC Crit. Rev. Food Technol. 1:331 (1970).
9. Lange, W., JAOCS 27:414 (1950).
10. Rawlings, H.W., N.H. Kuhrt and J.G. Baxter, Ibid. 25:24 (1948).
11. Elson, C.E., N.J. Benevenga, D.J. Canty, R.H. Grummer, A.E. Johnson, J.J. Lalich, J.R. Porter, J. Rapacz and E.S. Shrago, Food Res. Inst. (Univ. of Wisconsin) Ann. Rept., 401 (1976).
12. McOsker, D.E., F.H. Mattson, H.B. Sweringen and A.M. Kligman, J. Am. Med. Assoc. 180:380 (1962).
13. Mattson, F.H., E.J. Hollenbach and A.M. Kligman, Am. J. Clin. Nutr. 28:726 (1975).
14. List, G.R., E.A. Emken, W.F. Kwolek, T.D. Simpson and H.J. Dutton, JAOCS 54:408 (1977).
15. Artman, N.R., in "Advances in Lipid Research," edited by R. Paoletti and D. Kritchevsky, Academic Press, New York, 1969, p. 245.
16. Rice, E.E., C.E. Poling, P.E. Mone and W.D. Warner, JAOCS 37:607 (1960).
17. Kaunitz, H., C.A. Slanetz and R.E. Johnson, Ibid. 33:630 (1956).
18. Nolen, G.A., J.C. Alexander and N.R. Artman, J. Nutr. 93:337 (1967).
19. Poling, C.E., E. Eagle, E.E. Rice, A.M.A. Durand and M. Fisher, Lipids 5:128 (1970).