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Stability of Frying Oils Used for Frying Snacks and Fast Foods

Han, M. J.
Department of Food Science and Nutrition, Kyunghee University

Degradation of Frying Oils During Deep Fat Frying

Deep fat frying is one of the most commonly used procedure for preparation of food in the world (Chang *et al.*, 1978a; Chang *et al.*, 1978b). In deep fat frying, the fat acts as a conductor of heat, is absorbed and becomes an important ingredient of fried food. Potato chips contain 35.3~44.5% of absorbed fat; corn chips 32.8~37.6%; doughnuts, 9.2~31.4%, French fries, 7.9~16.2%; chicken thighs, 7.3~21.7%, fish pieces, 6.6~17.5% (Morton and Chidley, 1988).

During deep fat frying, the fat is exposed to elevated temperature in the presence of air and moisture (Fig. 1). Under these conditions, many chemical reactions, including oxidation, hydrolysis, and polymerization, occur (Stevenson *et al.*, 1984). Therefore, valatile decomposition products (VDPs) and nonvolatile decomposition products (NVDPs) are formed during the frying process (Fig. 2). The formation rate of decomposition products differ with the food being fried, the fat being used, the fryer design and the nature of the operating conditions (Stevenson *et al.*, 1984; McGill, 1980). Some VDPs are detrimental to the oil and food others contribute to the appetizing charactor of the food being fried. The NVDPs, which consist of high molecular weight compounds, are formed by thermal oxidation and polymerization of the unsaturated fatty aci (Perkins, 1967). The formation and accumulation of NVDPs are responsible for physical changes in frying fat such as increases in viscosity, color and foaming as well as chemical changes such as increases in free fatty acids, carbonyl value and decreases in unsaturation (Stevenson *et al.*, 1984).

Fats and Oils Used in Korea

Beef tallow is valued for its distinctive flavor, stability with less absorption of frying oil into the product and cost less per pound than vegetable oils. In 1985, 460,000 M/T of edible tallow went into bakery and frying in U.S.A., but this had declined to 289,000 M/T in 1990. The comsumption of soybean and cottonseed oils has increased. Fast food chains .switched from tallow/cottonseed oil blends to vegetable oils for frying (Anon, 1992). This trends are dut to the growing health consciousness of the consumer (Anon, 1991). In recent study, unsaturated fat and non-cholesterol are im-

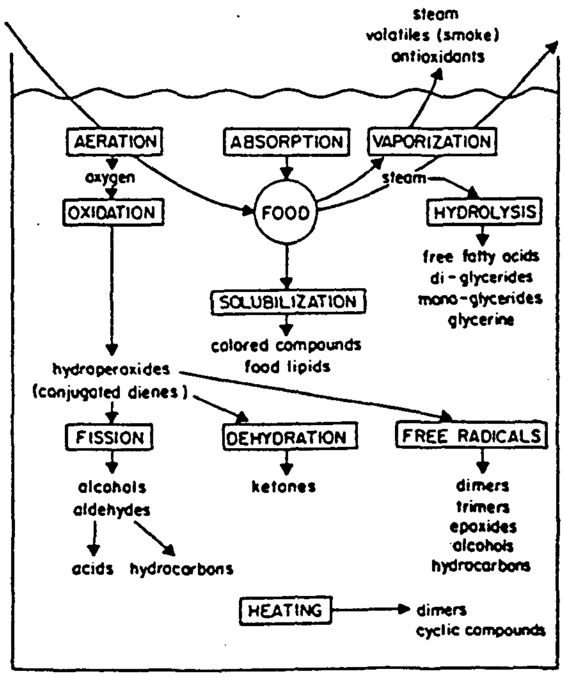

Fig. 1. Changes occurring during deep fat frying (Stevenson *et al.*, 1984).

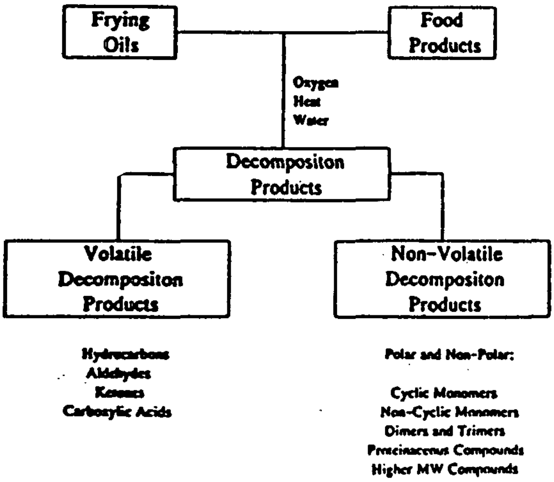

Fig. 2. Decomposition products in frying (Anon, 1991).

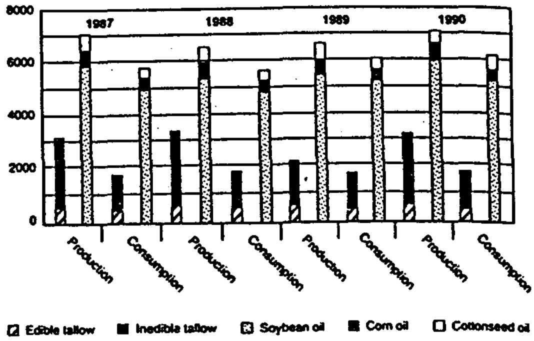

Fig. 3. U.S. production and consumption of animal fats, selected vegetable oils (Anon, 1991).

portant nutritive factors in food selection (Christine, 1992). U.S. production and consumption of fats and oils are showed in Fig. 3. As shown in Fig. 3, in 1991, soybean oil is most commonly used oil, followed by cottonseed oil, corn oil and edible tallow in that order.

The domestic production of fats and oils in Korea from 1985 to 1989 are shown in Table 1. Seasame oil, rice bran oil, soybean oil, perilla oil are important domestically produced oils. However, self sufficiency of fats and oils in Korea was 11.7% in 1989 (Table 2). Most fats and oils are imported from foreign country. Table 3 showed the imported fats and oils from 1985 to 1986. Soybean oil and palm oil are imported in large quantity followed by tallow, coconut oil and cottonseed oil. Even though soybean oil is produced domestically (8,971 M/T in 1989), most soybean oil is imported (151,677 M/T in 1989). The consumption of fats and oils in Korea (g/day/person) from 1985 to 1989 are showed in Table 4. Korean consumed 29.31 g of fats and oils/day/person in 1989. Among them, 85% were vegetable oil and others were animal fat. Soybean oil and palm oil are most important vegetable oils in Korean diets (Table 4). Also, Corn oil, cottonseed oil and rice bran oil are used in small extent.

Soybean oil

Soybean oil was consumed 39.8% of vegetable oils in 1989 (Table 4). Its cost is usually somewhat below that of other vegetable oils (Weiss, 1983). As shown in Table 5, soybean oil contains high

Table 1. Domestic production of fats and oils in Korea (M/T)

	1985	1986	1987	1988	1989
Soybean oil	–	1,710	1,103	1,317	8,971
Seasame oil	12,600	12,280	14,522	11,172	13,507
Perilla oil	4,850	4,800	6,529	6,242	6,340
Rapeseed	3,020	2,2200	2,745	2,643	2,643
Rice bran oil	18,150	16,840	13,028	9,731	10,244
Corn oil	300	0	252	360	2,290
Cottonseed oil	210	0	0	0	0
Red pepeer seed oil	240	520	579	503	399
Fish oil	4,400	950	1,096	2,500	6,265

Food balance sheet (1990).

Table 2. Self sufficiency of fats and oils in Korea (%)

	1985	1986	1987	1988	1989
Self sufficiency	15.5	14.0	10.0	8.7	11.7

Food balance sheet (1989).

content of linolenic acid which can cause flavor problem due to oxidation. Reverted soybean oil flavor is described as beany and grassy in its early stage, and fishy and painty in later stage. The most important precursor of the reverted flavor is the terminal pentene radical in linolenic acid. This reversion flavor is not affected by the presence of antioxidants and occurs with very little exposure to oxygen (Smouse and Chang, 1967; Smouse, 1985). Partially hydrogenation of soybean oil can improve its flavor stability since it reduces

Table 3. Imported fats and oils in Korea (M/T).

	1985	1986	1987	1988	1989
Soybean oil	133,850	152,450	162,518	155,633	151,677
Cottonseed oil	16,660	4,970	10,764	10,994	20,291
Palm oil	84,550	117,990	124,552	124,706	119.483
Coconut oil	16,870	10,740	24,037	32,070	33,011
Others	–	–	–	–	1,492
Tallow	42,600	24,920	42,419	42,986	57,124
Lard	5,000	3,260	1,060	658	0
Fish oil	6,130	6,310	3,715	3.219	0

Table 4. The consumption of fat and oils in Korea (g/day/person)

	1985	1986	1987	1988	1989
Vegetable oil	20.5	22.2	24.9	24.82	25.04
Soybean	8.9	10.1	10.7	10.14	9.97
Seasame	0.9	0.8	1.0	0.85	1.12
Perilla	0.3	0.3	0.4	0.41	0.52
Rapeseed	0.2	0.2	0.2	0.16	0.22
Rice bran	1.2	1.1	0.9	0.63	0.85
Cottonseed	1.1	0.3	0.7	0.71	1.23
Red pepper seed	0.1	0.0	0.0	0.03	0.03
Palm	5.6	7.4	8.1	8.05	7.26
Coconut	1.1	0.7	1.6	2.08	2.00
Corn	1.2	1.3	1.3	1.75	1.75
Others	0.0	0.0	0.0	0.00	0.08
Animal Fat	4.8	3.4	3.4	3.48	4.27
Tallow	3.5	2.4	2.9	2.99	3.62
Lard	0.6	0.3	0.1	0.11	0.14
Fish	0.7	0.5	0.3	0.38	0.52
Butter	–	0.2	0.3	0.25	–
Total	23.3	25.6	28.3	28.30	29.31

Food balance sheet (1989).

Table 5. Fatty acid composition of selected fat and oils

	Oil							
	Soybean	Palm	Cottonseed	Corn	Rapeseed	Canola	Ricebran	Tallow
16 : 0	10.5	46.8	25.0	11.5	4.0	4.3	17.0	29.1
18 : 0	3.2	3.8	2.8	2.2	1.3	1.7	1.5	18.9
18 : 1	22.3	37.6	17.1	26.6	17.4	59.1	41.5	44.0
18 : 2	54.5	10.0	52.7	58.7	12.7	22.8	38.0	0.3
18 : 3	8.3	–	–	0.8	5.3	8.2	1.0	–
20 : 1	–	–	–	–	45.6	0.9	–	–

Weiss (1983) and Sakada (1985).

linolenic acid in the oil to less than 3.0% (Sherwin, 1976).

Hydrogenation of linolenic acid in soybean oil also produces isolinoleic acids, a mixture of isomeric dienes. Upon oxidation, these dienes produce compounds similar to those formed from linolenic acid and impart and objectionable odor and flavor to soybean oil called hardening flavor (deMan, 1983; Frankel, 1980; Nawar, 1985). However, it prevents the development of fish odors in the air, hydrogenated soybean oil is usually used for frying instead of unhydrogenated form (Weiss, 1983).

Palm oil

Palm oil is an important deep fat frying medium in Malaysia (Augustin *et al.,* 1987). The use of palm oil in various prous products depends more on its cost and availability (Weiss, 1983). The consumption of palm oil is not significant content in U.S.A. (Fig. 3) because it contains high saturated fatty acids (Table 5). It has better oxidative stability than other oils. As shown in Table 4, in 1989, Palm oil supplied 29% of vegetable oils in Korean diets.

Cottonseed oil

Unhydrogenated summer cottonseed oil is the favored oil for frying potato chips. Upon reversion, cottonseed oil has a nut-like flavor which is very acceptable to consumers in mayonnaise and potato chips as well as other fried food. The reversion flavor of cottonseed oil is fairly strong in intensity and masks the less desirable reversion flavor of other oils if they are blendded with cottonseed oil (Weiss, 1983). However, the availability of cottonseed oil has declined along with the decrease in planted cotton acreage, which was maximum at 46 million acres in 1925, but by 1980 had decreased to 13~14 million acres (Pryde, 1980).

Rice bran oil

To increase self sufficiency of fats and oils in Korea, we need to planting more oil sources. However, it is not possible to increase the planting the oil sources. The potential vegetable oil source in Korea is rice bran which contains 16~20% of oil.

Rapeseed oil

Rapeseed oil (Table 5) contains high erucic acid, which has been shown to cause heart muscle lesions followed by other cardiac problems in rats, and high glucosinolate. Therfore, rapeseed oil is no longer used for edible purposes in U.S.A. (Weiss, 1983). The Canadian government encouraged the palnting of rapeseed as a domestic source of vegetable oil. Also, research in Canada resulted in the development of a low erucic acid and low glucosinolate variety of rapeseed. Canadian planting were converted to low erucic acid varieties which were essentially completed by 1974. Low erucic acid and glucosinolate oil has been named canola oil (Table 5) which is being produced on a commercial scale in Canada and Europe (Slinger, 1977). Domestic rapeseed oil also contain

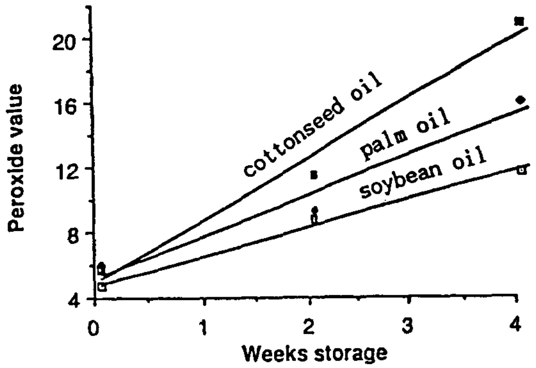

Fig. 4. Peroxide value (meq/kg) of oil from potato chips fried in different oils and stored in light for 0 to 4 weeks at room temperature. Equation for cottonseed oil is Y=4.7+3.9X, for palm oil, Y=5.0+2.5X and for soybean oil, Y=4.4+1.8X where Y=peroxide value and X=weeks storage.

high level of erucic acid (46.3%) and glucosinolate (Koo and Rhee, 1985). Thus, planting of low erucic acid and glucosinolate varieties is needed.

Stability of frying oils

Autoxidation is the main reaction causing oxidative deteroration of the frying oils. Factors affecting the rate of oxidation are degree of unsaturation, oxygen concentration, temperature, moisture, prooxidants, light exposure and antioxidants (Chan *et al.*, 1982; Nawar, 1985). Nawar (1985) inicated that the relative rates of oxidation in linolenic, linoleic and oleic acids are 20, 10 and 1 respectively. Therefore, high linolenic acid oil, such as soybean and canola oil (Table 5), are partially hydrogenated to reduce linolenic acid. Most finished vegetable oils contain high percentage of unsaturated fatty acid, thus they are very susceptible to oxidative deterioration (Table 5). Tocopherols in vegetable oils resist development of oxidative rancidity. A high proportion of the existing tocopherols survive oil processing and are present in the finished vegetable oils. These residual levels of tocopherols appear to be optimum for providing oxidative stability (Sherwin, 1976).

Information concerning the stability of various frying oils during deep fat frying snacks and fast foods are needed for a better understanding of

Table 6. Mean sensory scores of potato chips fried in different oils

Sensory scores[a]	Oil		
	Soybean	Palm	Cottonseed
Favor	4.34[b]	3.98[b]	3.44[c]
Acceptability	4.32[b]	3.94[b]	3.43[c]

[a]8-point scale where 1=like extremely and 8=dislike extremely.
[b,c]Means in a row followed by different superscripts are significantly at the $p<0.05$ level.

deterioration of the oils. Fig. 4 showed peroxide value (meq/kg) of oil from potato chips fried in partially hydrogenated soybean oil, cottonseed oil and palm oil, and stored in light for 0 to 4 weeks at room temperature. For the potato chips stored in the light there was a linear relationship between peroxide value of the chips fried in each oil over storage. These data indicates that potato chips fried in cottonseed oil underwent more extensive oxidation during storage in light than chips fried in palm oil or soybean oil. Mean flavor and acceptability scores of potato chips for different oils are given in Table 6. Potato chips fried in cottonseed oil had more desirable flavor and higher acceptability than chips fried in soybean oil or palm oil ($p<0.05$). These results showed that acceptability was based on flavor. There were no significant differences in the flavor or acceptability of chips fried in palm oil versus those fried in soybean oil. The results of sensory evaluation of the stored chips compared with their peroxide values show that the peroxide value is not a good indicator of flavor desirability when comparing chips fried in different oils. Although chips fried in cottonseed oil had the highest peroxide value of all the chips fried in the three oils, those chips had the most desirable flavor of all chips in the this study.

References

1. Anon.: Some perspectives on deep-fat frying. *INFORM,* 2(2), 1091 (1991).
2. Anon: Renderers seeking to recapture. *INFORN,*

3(2), 152 (1992).
3. Bruhn, C.M., Cotter, A., Diaz-Knauf, K., Sutherlin, J.W.E., Wightman, N., Williamson, E. and Yaffee, M.: Consumer attitudes and market potential for foods using fat substitutes. *Food Technol.,* **46**(4), 81 (1992).
4. Chan, H.W.S., Coxon, D.T., Peers, K.E. and Price, K.R.: Oxidative reactions of unsaturated lipids. *Food Chem.,* **9**, 21 (1982).
5. Chang, S.S., Peterson, R.J. and Ho, C.: Chemical reactions involved in the deepfat frying of foods. *J. Am. Oil Chem. Soc.,* **55**(10), 718 (1978a).
6. Chang, S.S., Peterson, R.J. and Ho, C.: Chemistry of deep fat fried flavor. In "Lipid as a Source of Flavor; A Symposium", (Supran, M.K. ed.), ACS, (1978b).
7. deMan, J.M.: Lipids, in "Principle of Food Chemistry". AVI Publishing Co., Inc. Westport, CT pp. 35-85, (1981).
8. Food Balance Sheet: Korean Rural Economic Institute (1989).
9. Frankel, E.N.: Lipid oxidation, *Prog. Lipid. Res.,* **19**, 1 (1980).
10. Koo, C.S. and Rhee, J.S.: Techno-economic studies on utilization of soy oil in Korean food system. Food Development Institute, Dan Kook University, (1985).
11. McGill, G.A.: The chemistry of frying. The Bakers Dig., **6**, 38 (1980).
12. Morton, I.D. and Chidley, J.E.: Methods and equipment in frying. in "Frying of Food : Principles, Changes, New Approaches". (Varela, G., Bender, A.E. and Morton, I.D. ed.), Ellis Horwood Ltd., Chichester, England, (1988).
13. Nawar, W.W.: Lipids, in "Food Chemistry". (Fennema, O.R. ed.), 2nd ed. Marcel Dekker, Inc. NY. pp. 139-244 (1985).
14. Perkins, E.G.: Formation of non-valatile decomposition products in heated fats and oils. *Food Technol.,* **21**, 611 (1967).
15. Pryde, E.H.: Soybean vs. other vegetable oils as sources of edible oil products. in "Handbook of Soy Oil Processing and Utilization". (Erickson, D. R., Pryde, E.H., Brekke, O.L., Mounts, T.L. and Falb, R.F. ed.), ASA, St. Louise, Missouri and AOCS, Champaign, IL.
16. Sakata, M., Takahashi, Y. and Sonehara, M.: Quality of fried foods with palm oil. *J. Am. Oil Chem. Soc.,* **62**, 449 (1985).
17. Sherwin, E.R.: Antioxidants for vegetable oils. *J. Am. Oil. Chem. Soc.,* **53**, 430 (1976).
18. Slinger, S.J.: Improving the nutritional properties of rapeseed. *J. Am. Oil Chem. Soc.,* **54**, 94 (1977).
19. Smouse, T.H.: Flavor reversion of soybean oil. in "Flavor Chemistry of Fats and Oils". (Min, D. B. and Smouse, T.H. ed.), AOCS, Champaign, IL.
20. Smouse, T.H. and Chang, S.S.: A systematic characterization of the reversion flavor of soybean oil. *J. Am. Oil Chem. Soc.,* **44**, 509 (1967).
21. Stevenson, S.G., Vaisey-Genser, M. and Eskin, N. A.M.: Quality control in the use of deep frying oils. *J. Am. Oil Chem. Soc.,* **16**, 1102 (1984).
22. Weiss, T.J.: Commercial oil sources. in "Food Oil and Their Uses." AVI Publishing Co., Inc. Westport, CT.