Smoke, Flash, and Fire Points Of Soybean and Other Vegetable Oils [1]

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SOYBEAN oil is utilized industrially in considerable volume under conditions which necessitate heating it in an atmosphere of air at relatively high temperatures. Its use in deep fat frying in the food preparation industry, in oil bodying, in resin and varnish manufacture, and in other similar operations necessitates heating the oil for more or less prolonged periods of time at elevated temperatures. In the processing industries, experimental pilot plant operations, laboratory research, and wherever the oil is subjected to high temperatures, a knowledge of the smoke, flash, and fire points is of importance in controlling operations and warding against possible fire hazards.

It has, for example, been observed repeatedly in the course of studies on the production of desirable types of soybean oil varnishes that the reaction time may be reduced by as much as one-third by an increase in the temperature from 585° to 600° F. (307° to 315° C.) (1). The marked decrease in reaction time which accompanies this relatively slight increase in temperature appears to be indicative of the existence of a critical polymerization temperature in the vicinity of 600° F. Although some operators do not consider this temperature especially hazardous, others hesitate to heat large batches of soybean oil above 585° F. by the open kettle process.

A search of the literature reveals little information relative to the smoke, flash, and fire points of soybean oil, and such data as have been recorded are somewhat conflicting. Jamieson (2), for example, gives the flash point of soybean oil as 500° to 556° F. (260° to 291° C.), but fails to mention either the kind of oil or the method used in its determination. No mention is made of the smoke or fire points. Dickhart (3) reported the results of the examination of a large number of vegetable oils by the Cleveland open cup method. He recorded the smoke point of soybean oil as 280° (138° C.) and the flash point as 580° F. (304° C.), but gave no information relative to the source or type of oil examined and no data on the fire point. The International Critical Tables (4) records data for the smoke, flash, and fire points of nineteen different vegetable and animal oils, but omits any reference to soybean oil.

In view of the paucity of existing data relative to the smoke, flash, and fire points of soybean oil, a number of representative types of this oil were examined for flash and fire points by the gas-heated, Cleveland open cup method as prescribed by the American Society for Testing Materials Standard D92-33 (5). A number of other oils which are commonly subjected to the same or similar types of processing treatments were examined for comparative purposes. The smoke, flash, and fire points of these oils are recorded in Table I, together with information relative to the kind and degree of treatment to which they were subjected during processing. Comparative data are also reported for soybean oil fatty acids. The data for the normal soybean oils are summarized in Table II.

Table I.—Smoke, flash, and fire points of soybean and other oils

Sample No.	Oil	Smoke point °F.	Smoke point °C.	Flash point °F.	Flash point °C.	Fire point °F.	Fire point °C.
70	Soybean, cold-pressed, crude	377	192	580	304	657	347
73	Soybean, expeller, crude	357	181	564	296	664	351
74	Soybean, expeller, crude	357	181	560	293	665	352
75	Soybean, expeller, crude	350	177	588	309	668	353
46	Soybean, extracted, crude	328	164	605	318	680	360
72	Soybean, extracted, crude	253	123	490[1]	254[1]	557[1]	292[1]
80	Soybean, extracted, crude	410	210	603	317	670	354
114	Soybean, extracted, crude	425	218	615	324	675	357
88	Soybean, extracted, crude	409	209	600	316	670	354
43	Soybean, expeller, mechanically-refined	382	194	620	327	682	361
73a	Soybean, expeller, adsorption-refined	466	241	625	329	682	361
111	Soybean, expeller, adsorption-refined	460	238	625	329	680	360
112	Soybean, extracted, adsorption-refined	472	244	628	331	682	361
80r	Soybean, extracted, alkali-refined	492	256	618	326	673	356
123	Soybean, extracted, alkali-refined	428	220	625	329	685	363
83a	Soybean, expeller, alkali-refined, edible grade	485	252	625	329	682	361
71	Soybean, extracted, alkali-refined, edible grade	465	241	625	329	685	363
100a	Soybean, extracted, crude	400	204	585	307	665	352
100b	Soybean, extracted, alkali-refined	465	241	625	329	682	361
100c	Soybean, extracted, alkali-refined, bleached	471	244	622	328	682	361
100d	Soybean, extracted, alkali-refined, bleached, deodorized	465	241	630	332	680	360
31Pr	Soybean, expeller, crude, acylated	300	149	505[2]	263[2]	655[2]	346[2]
18Pr	Soybean, mechanically-refined, acylated	304	151	555[2]	291[2]	662[2]	350[2]
27Ac	Soybean, extracted, alkali-refined, acylated	415	213	605[2]	318[2]	675[2]	357[2]
27Pr	Soybean, extracted, alkali-refined, acylated	290	143	445[2]	229[2]	650[2]	343[2]
70a R_4	Soybean, cold-pressed, crude, molecularly distilled	481	249	505[2]	263[2]	668[2]	353[2]
101	Soybean fatty acids, commercial	235	113	405	207	442	228
SBFA	Soybean fatty acids, commercial	<230	<110	410	210	450	232
85a	Corn, crude	352	178	562	294	655	346
86a	Corn, refined	440	227	618	326	678	359
25	Olive, virgin	391	199	610	321	682	361
11	Castor, refined	392	200	568	298	635	335
24	Castor, dehydrated	348	176	570	299	638	337
12	Linseed, raw	325	163	549	287	667	353
102	Linseed, mechanically-refined	312	156	547	286	662	350
103	Linseed, alkali-refined	320	160	588	309	680	360
15	Perilla, crude	321	161	575	302	678	359
106	Perilla, mechanically-refined	312	156	547	286	675	357
107	Perilla, alkali-refined	352	178	608	320	685	363
108	Perilla, alkali-refined	408	209	615	324	685	363
116	Menhaden, light-pressed, laboratory-refined	366	186	575	302	668	353
117	Fish, refined, not completely deodorized	316	158	568	298	675	357
118	Fish, kettle-refined, deodorized, U viscosity	278	137	535	279	672	356

[1] Omitted in the calculations of the averages; apparently deterioration of the oil had taken place.

[2] Omitted in calculations of the averages; for two of these oils (Nos. 18Pr and 27Pr) low values were apparently due partly to incomplete removal of acylating agent.

Table II.—Summary of Flash and Fire Points of Soybean Oils

Type of soybean oil	No. of determinations averaged	Average flash point °F.	Average flash point °C.	Average fire point °F.	Average fire point °C.
Crude expeller	4	573	300	664	351
Crude solvent-extracted	5	602	316	672	355
Refined	11	624	329	681	361

Except in three cases, Nos. 100d, 27 Pr, and SBFA, where the quantity of oil was limited, at least two determinations were made for each oil. Whenever duplicate determinations of the flash and fire points did not agree within 5° F., additional runs were made. Some difficulty was experienced in maintaining exactly the required heating rate of 9 to 11° F. per minute

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[2] A cooperative organization participated in by the Bureaus of Agricultural Chemistry and Engineering and Plant Industry of the U. S. Department of Agriculture, and the Agricultural Experiment Stations of the North Central States of Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin.

from a temperature approximately 50° below the flash point up to the fire point. Results of a number of duplicate determinations indicated, however, that minor variations from the specified heating rate had no influence on flash and fire points within the limit of accuracy of the method. The flash points of crude expeller soybean oil and crude corn oil were of a fugitive nature, and were difficult to observe in contrast to the other oils whose flash points were more sharply visible and definitely observable. The lowest temperature at which smoke was emitted during heating of the sample of oil in the course of the determination of the flash and fire points was recorded as the smoke point.

Coincidentally with the appearance at about 480° F. of "break" material in the case of crude expeller and cold-pressed soybean oils, the temperature was observed to fall abruptly to a minimum of 425° to 455° F., depending on the amount of "break" material which separated. The same phenomenon was observed to a lesser extent in crude corn oil and one of the crude extracted soybean oils, No. 100a, where "break" material also separated during heating. It was not observed in the other crude extracted soybean oils or in crude linseed, perilla, or olive oils, where no "break" material formed during heating.

The results may be generalized by stating that crude expeller soybean oils have lower smoke, flash, and fire points than is the case with mechanically-refined, adsorption-refined, or alkali-refined soybean oils. Also, crude solvent-extracted soybean oil was found to be superior to crude expeller oil with respect to thermal stability. An exception was noted in the case of oil No. 72 which apparently had deteriorated, since the free fatty-acid content was abnormally high; and, in addition, it contained an appreciable amount of foots.

The effect of refining operations on the smoke, flash, and fire points may be observed in the case of the oils Nos. 100a to 100d, which represent (a) crude extracted, (b) alkali-refined, (c) alkali-refined and bleached, and (d) alkali-refined, bleached, and deodorized oils, respectively, originally derived from the same source. Alkali refining appears to result in a marked improvement of all three thermal characteristics, whereas subsequent processing operations have little effect on these properties.

The lower values obtained with two of the acylated oils, Nos. 18Pr and 27Pr, may be attributed in part at least to the incomplete removal of the acylating agent as was indicated by the severe corrosion of the copper cup. Sample No. 70aR_4 represents an oil which had been stripped of its free fatty acids and unsaponifiable matter by molecular distillation at a maximum temperature of 465° F. (246° C.).

To determine the effect of prolonged heating on its thermal characteristics, a crude extracted soybean oil was allowed to cool in air from the fire point to room temperature, and the thermal points were redetermined on the same sample. The smoke and flash points thus obtained were, respectively, 87° and 30° F. lower than values for the first run, while the fire point remained unaffected.

Summary and Conclusions

A number of representative soybean oils were examined by the Cleveland open cup method with respect to their smoke, flash, and fire points. Average values for typical oils were found to be as follows:

Type of soybean oil	No. of determinations averaged	Average flash point °F.	°C.	Average fire point °F.	°C.
Crude expeller	4	573	300	664	351
Crude solvent-extracted	5	602	316	672	355
Refined	11	624	329	681	361

The results obtained indicate that crude expeller oil exhibits lower smoke, flash, and fire points than does mechanically or alkali-refined soybean oil. Solvent-extracted oil likewise appears to be superior to ordinary expeller oil with respect to these properties. Alkali refining results in improvement of the thermal stability of soybean oil, whereas subsequent processing has little additional effect on this property. Soybean oil appears to be superior in smoke, flash, and fire point characteristics to all other oils of corresponding type which were examined, and it may be concluded that good quality soybean oil, free from excessive quantities of free fatty acids and foots, may be safely heated to 600° F. (315° C.) and above without undue risk of fire.

LITERATURE CITED

(1) Lewis, A. J. Unpublished results of the U. S. Regional Soybean Industrial Products Laboratory.
(2) Jamieson, G. S., Vegetable Fats and Oils, pp. 266. The Chemical Catalogue Company, New York (1932).
(3) Dickhart, W. H., Smoke-Flash-Fire Points of Certain Fixed Oils. Amer. Jour. Pharm., 104, 284 (1932).
(4) International Critical Tables, 2, 211 (1927).
(5) American Society for Testing Materials, Standards, Part II, p. 892 (1936).

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