Steam-Refined Soybean Oil: I. Effect of Refining and Degumming Methods on Oil Quality[1]

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ABSTRACT

A lot of commercially extracted crude soybean oil was water degummed with and without a phosphoric acid pretreatment. The degummed oils were bleached and then deacidified-deodorized in a single step to yield physically (steam) refined soybean salad oils. Their flavor and oxidative stability were compared to caustic-refined oils given otherwise identical processing treatments. Physically refined oils without a phosphoric acid pretreatment were of poor initial quality compared to those given the phosphoric acid pretreatment. However, caustic- and steam-refined oils processed with the phosphoric pretreatment were of comparable quality.

INTRODUCTION

The principles of physical refining have been known for many years and are extensively practices in Europe to deacidify high-acid fats to low levels prior to caustic refining (1-3). Generally, physical refining is only advantageous when processing high-acid fats (2). The recent influx of palm oil into the world market has stimulated domestic interest in physical refining. In 1973, a plant was built in Portland, Oregon, capable of producing 10 metric tons/hr of steam-refined palm oil (2). Further interest in steam refining arises from a need to alleviate soapstock pollution and disposal problems associated with caustic refining.

Although it has been reported (3) that soybean oil can be successfully steam refined, little information has been published on the flavor and oxidative stability of such fats. The present investigation was undertaken to compare the quality of caustic- and steam-refined soybean oils and to study the role of phosphoric acid pretreatment in soybean oil processing.

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MATERIALS AND METHODS

A single lot of commercially extracted crude soybean oil was processed into salad oils according to the following procedures.

Degumming

Approximately 1 gal of crude oil was charged into a 5-liter, three-necked, round-bottomed flask fitted with a thermometer and a stirring shaft with a Teflon blade driven by a 5000 rpm stirring motor. After the contents were purged with nitrogen, the stirring motor was started, and the oil temperature was brought to 60 C. The degumming agent, either phosphoric acid (4) or water, was added at concentrations of 0.2% or 2% by weight, respectively. After being stirred for 15 min at 60 C, gums were separated by centrifugation and decantation.

Caustic Refining

Degummed oil was recharged into the flask as described above and brought to 60 C under a nitrogen blanket. The required amount of 14°Be′ and 0.5% excess lye were added (5). After being stirred for 15 min at 60 C, the soap stock was separated from the refined oil by centrifugation and decantation. The oil was washed twice (20% by weight) with water.

Bleaching

Bleaching and final drying were carried out by bringing the oil to 90 C under vacuum. After the vacuum was broken with nitrogen, 0.5% by weight super filtrol bleaching earth was added, the vacuum was redrawn, and the temperature was brought to 105 C. After this temperature was held 15 min with magnetic stirring, the oil was cooled to 60 C and filtered under vacuum through a bed of Celite filter aid.

Steam Refining and Deodorization

Degummed, 2X washed, and bleached oils were steam

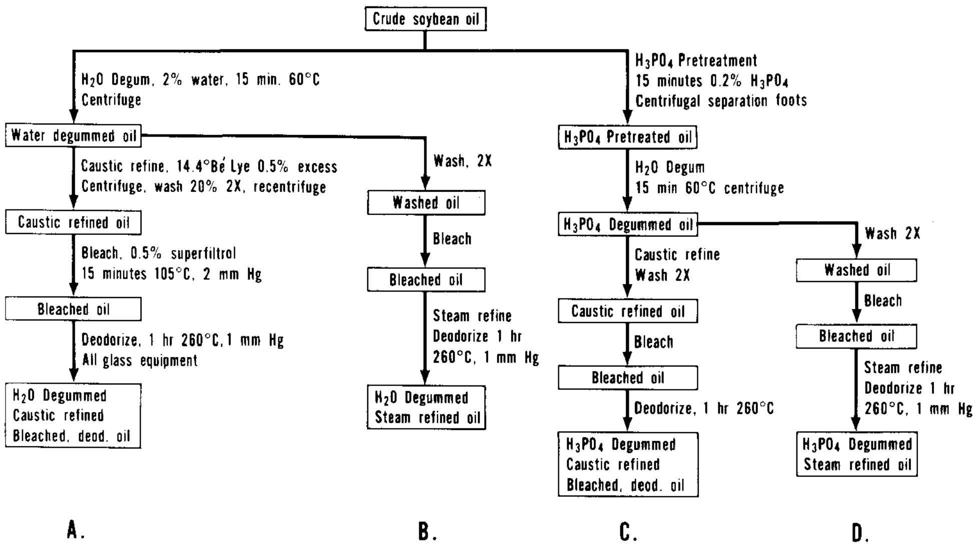

FIG. 1. Flow sheet showing processing of crude soybean oil into salad oils by caustic and steam refining.

TABLE I

Flavor and Oxidative Stability of Caustic- and Steam-Processed Soybean Oil: Effect of Degumming and Refining Methods

Days storage (60 C)	Flavor intensity scores and sig[a]		
Section 1	Water degummed, steam refined		Phosphoric acid degummed, steam refined
0	5.9 (0.1)	**	7.5 (0.1)
4	5.7 (2.0)	+	6.2 (0.5)
8-hr AOM peroxide value	15.8		11.1
Section 2	Water degummed, caustic refined		Phosphoric acid degummed, caustic refined
0	7.7 (0.6)	+	7.9 (0.4)
4	6.3 (1.5)	**	7.1 (2.1)
4-hr Light exposure	6.5 (1.8)	+	5.9 (2.0)
8-hr AOM peroxide value	5.6		8.0
0	6.8 (0.1)	+	7.8 (0.1)
4	6.1 (1.4)	**	7.2 (1.4)
8-hr AOM peroxide value	14.8		9.8
Section 3	Phosphoric acid degummed, caustic refined		Phosphoric acid degummed, steam refined
0	7.8 (0.1)	+	7.1 (0.1)
4	7.2 (1.4)	**	5.9 (1.7)
8-hr AOM peroxide value	9.8		11.1
0	8.1 (0.6)	+	8.3 (0.4)
4	6.1 (2.5)	+	6.5 (3.2)
4-hr Light exposure	6.0 (1.6)	*	5.3 (2.0)
8-hr AOM peroxide value	8.0		11.6

[a]+ Denotes no statistical significance, * significant at 5% confidence level, ** significant at 1% confidence level. Values in parentheses are peroxide values at time of tasting; all oils treated with 0.01% citric acid during deodorization. AOM = active oxygen method.

refined in a four-unit deodorizer described previously (6). Steam refining was conducted for 1 hr at 260 C under a vacuum of less than 1 mm Hg.

Caustic-refined oils were deodorized under the same conditions. All oils were treated with 0.01% citric acid on the cooling side of deodorization.

Flavor Evaluations

Organoleptic evaluations were conducted by methods described by Moser et al. (7-9) with a modified score sheet. The score sheet is essentially that illustrated in a previous publication (10) except that the oil quality scale where 1 = bad and 10 = bland has been replaced by an odor and flavor intensity scale with 1 = extreme and 10 = bland. The modification was made in an attempt to evalute the oil on the basis of intensities of odors and flavors rather than on a subjective conclusion as to the overall quality of the oil. A further discussion of this method will be presented elsewhere. Sensory evaluations were performed by a 17-member panel, and all results were obtained by a paired sample technique. Peroxide values were determined by a modification of the 1 min, Wheeler method (11).

RESULTS AND DISCUSSION

The schemes by which the crude soybean oil were processed into salad oils are shown in Figure 1 and are believed to be similar to commercial operations. The refining of crude soybean oil is essentially a four-stage process consisting of degumming, alkali deacidification, bleaching, and deodorization (12). By contrast, physical or steam refining is a two-stage process consisting of a prerefining (degumming and bleaching) and a simultaneous deacidification-deodorization step (3).

Previous reports (1,2) have indicated that the prerefining stage associated with steam refining is particularly important in producing quality fats and that prooxidant metals and phospholipids must be removed prior to the deacidification-deodorization step. Sullivan (2) has reported that phosphoric acid pretreatment is advantageous for the prerefining step. One of our objectives was to compare the quality of oil produced with and without the phosphoric acid pretreatment and to ascertain its role in the steam refining of soybean oil. As shown in Figure 1, phosphoric acid degumming consists of pretreating the crude oil followed by a centrifugal separation of any foots and a second degumming with water. Hereafter, the term phosphoric acid-degummed oil indicates tha the oil was degummed with both phosphoric acid and water.

The effects of phosphoric acid pretreatment on flavor and oxidative stability of steam-refined oil are shown by the results presented in section 1, Table I, comparison of water-degummed and phosphoric acid-degummed oils (oils B and D, Fig. 1). Evaluations of freshly deodorized oils showed that phosphoric acid-degummed oils scored significantly higher than the water-degummed oil. However, after 4-days' storage at 60 C, the difference was not significant. Based on the poor initial quality of the water-degummed, steam-refined oil, further studies of this processing technique were not conducted.

Section 2, Table I, presents the results of replicate evaluations (from separate refining) showing the effects of degumming methods on the quality of caustic-refined oils (oils A and C, Fig. 1). Evaluations at zero days' storage showed that the quality of oil produced by either degumming method is high and equal with no significant differences. However, comparison made after 4-days' storage showed that phosphoric acid-degummed oils are superior to water-degummed oils. In both tests (separate refinings) the differences favoring phosphoric acid degumming are significant at the 1% confidence level. These observations are in accord with other reports (12).

Section 3, Table I, presents evaluations of the quality of refined oil (oils C and D, Fig. 1) produced from phosphoric acid-degummed oil, caustic-refined vs. steam-refined. The quality of refined oil produced from phosphoric acid-degummed oil by both caustic and steam refining was variable. In one test, initial evaluations showed that phosphoric acid-degummed, caustic-refined soybean oil was significantly better than the steam-refined oil. Similar results were

TABLE II

Flavor Intensities of Caustic- and Steam-Refined Soybean Oil

Degumming method	Refining method	Flavor intensity[a] score	Flavor intensity value[b] (FIV)						
			Bland	Buttery	Beany	Grassy	Rancid	Painty	Other[c]
						Initial			
Water	Steam	5.9	---	0.5	0.4	0.3	0.8	0.2	0.6
Phosphoric acid	Steam	8.3	---	0.8	0.1	—	0.3	—	0.4
Water	Caustic	7.7	0.1	0.5	0.3	0.1	0.1	—	0.6
Phosphoric acid	Caustic	7.9	0.1	0.5	0.1	---	0.1	0.2	0.8
						4-Day storage, 60 C			
Water	Steam	5.7	---	0.6	0.4	0.6	0.7	0.4	0.5
Phosphoric acid	Steam	6.5	---	0.6	0.5	0.4	0.4	0.1	0.4
Water	Caustic	6.3	---	0.6	0.5	0.2	0.2	0.1	0.4
Phosphoric acid	Caustic	7.1	---	0.8	0.3	0.3	0.3	0.1	0.2

[a]See Table I.

[b]Flavor intensity value = $\frac{1\,[\text{No. weak}] + 2\,[\text{No. moderate}] + 3\,[\text{No. strong}]}{[\text{No. tasters}]}$.

[c]Miscellaneous reponses, nutty most common, no cucumbery or melony flavors.

obtained after 4-days' storage at 60 C. However, in the second test, evaluations of freshly deodorized oils showed that steam- and caustic-refined oils scored high and equal with no significant differences. Accelerated storage tests showed that the oils deteriorated to the same extent.

Although extensive tests were not made on the stability of oils under exposure to fluorescent light (4 hr), results showed that phosphoric acid-degummed, caustic-refined, and deodorized oil has significantly better flavor stability than steam-refined and deodorized oil degummed under the same conditions. However, evaluations of caustic-refined and deodorized oils made under light exposure conditions failed to demonstrate any significant difference between water- and phosphoric-degumming treatments.

The oils used for the evaluations presented in Table I were all treated with citric acid during deodorization to inactivate metals. Thus, the peroxide values obtained after accelerated storage (4 days, 60 C) and under active oxygen method conditions (8 hr) are low and in the range normally encountered with commercially processed soybean salad oils (13). Although the results are not presented here, the same evaluations were performed comparing citrated and noncitrated samples. As would be expected, the results invariably showed that significant improvements in flavor and oxidative stability were achieved through use of citric acid to inactivate metals (14). These improvements were most marked in samples aged under accelerated 60 C storage conditions.

The excellent metal-inactivating properties of phosphoric acid in fats and oils have been known for many years (15,16). However, fats treated with phosphoric acid often develop "melony or cucumbery" flavors, thereby limiting its use in oil processing (16). Table II presents representative flavors and their intensities for oils previously discussed. All of the oils, with the exception of the water-degummed, steam-refined oil, were initially described as predominantly buttery with a few rancid and beany responses noted. Nutty was the most common flavor in the "other" category shown in Table II. No cucumbery or melony responses were observed in any of the freshly deodorized oils. The poor quality of the water-degummed, steam-refined oils can be attributed to the rather intense rancid responses. Although no cucumbery or melony responses were obtained for this sample, some panelists described it as fishy, burnt, and sulfur.

Flavor intensity values after accelerated storage (4 days) at 60 C show an increase in undesirable grassy flavors; these flavors are essentially absent in freshly deodorized oils. Similar trends were observed for rancid and painty flavors. As we observed in the initial samples, no cucumbery or melony flavors developed in the oils after accelerated storage.

These results indicate that phosphoric acid, a precursor of these flavors (11), was thoroughly removed in the processing (water washing) steps.

Results presented here indicate that crude soybean oil can be successfully steam refined into a salad oil having flavor and oxidative stability comparable to caustic-refined oils. The data clearly demonstrate that phosphoric acid pretreatment is needed in the prerefining stage and that a thorough degumming is necessary to produce quality oils by the steam-refining technique. The second paper in this series will present data concerning the function of phosphoric acid as an adjunct in the degumming of soybean oil.

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REFERENCES

1. Anderson, A.J.C., in "Refining of Oils and Fats for Edible Purposes," Edited by P.N. Williams, Pergamon Press, New York, 1962, pp. 92-99.
2. Sullivan, F.E., JAOCS 53:358 (1976).
3. Martinenghi, G.B., in "Physical Refining of Oils and Fats," Corbella, Milan, 1971, p. 13.
4. Sullivan, F.E., U.S. Patent 2,702,813 (1955).
5. Bailey, A.E., in "Industrial Oil and Fat Products," Edited by D. Swern, 3rd Edition, John Wiley and Sons, New York, 1964, pp. 736-737.
6. Schwab, A.W., and H.J. Dutton, JAOCS 25:67 (1948).
7. Moser, H.A., H.J. Dutton, C.D. Evans, and J.C. Cowan, Food Technol. 4(3):105 (1950).
8. Moser, H.A., C.M. Jaeger, J.C. Cowan, and H.J. Dutton, JAOCS 24:291 (1947).
9. Moser, H.A., C.D. Evans, W.F. Kwolek, and J.C. Cowan, Ibid. 42:30 (1965).
10. Warner, K.A., J.O. Ernst, B.K. Boundy, and C.D. Evans, Food Technol. 28(11):42 (1974).
11. Wheeler, D.H., Oil Soap 9:89 (1932).
12. Braae, B., Chem. Ind. (London) 1152 (1958).
13. Evans, C.D., G.R. List, H.A. Moser, and J.C. Cowan, JAOCS 50:218 (1973).
14. Dutton, H.J., H.A. Moser, and J.C. Cowan, Ibid. 24:261 (1947).
15. Eckey, E.W., U.S. Patent 1,993,152 (1935).
16. Evans, C.D., A.W. Schwab, P.M. Cooney, and J.C. Cowan, Abstract 84, Minnesota AOCS Meeting 1954).

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