

The Flavor Problem of Soybean Oil

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In the years after the Second World War, soybean oil sold for 1 to 9 cents less a pound than competing oils, although in many ways it equals or surpasses other oils. The only apparent explanation for that difference in price is the peculiar flavors that develop in soybean oil on aging. While cottonseed oil grows rancid on standing, soybean oil reverts—that is, it becomes painty or grassy.

Whether a rancid cottonseed oil or a stale corn oil is better or worse than a reverted soybean oil is a matter of consumer preference. It does seem that the American housewife has decided in favor of corn and cottonseed oils. Her decision costs the soybean industry and growers annually 10 million to 90 million dollars, calculated on the differential of 1 to 9 cents a pound. Many people believe that unless research workers succeed in improving the flavor of soybean oil, the wartime expansion in production of soybeans, processing capacity, and edible soybean-oil products may recede before the competition of other well-established edible oils. Industrial, university, and Government institutions are cooperating in efforts to find an answer to the problem.

The problem is not simple. One can taste and smell an off-flavor or bad odor in a concentration of only a few parts per billion. Few chemical or physical tests can rival the sensitivity

of the human sense of taste and smell, and we have no such test to measure the off-flavor of soybean oil. Until we can devise an objective physical or chemical test, we have to rely on the variable human senses.

The procedure evolved at the Northern Regional Research Laboratory for conducting taste tests conforms to a definite order. A pair of samples is presented to each of 12 tasters in a blind test; that is, samples are identified only by number. The tasting is done in individual booths in a quiet, air-conditioned room. The samples are held at the same temperature by a heated aluminum block. Each taster records evaluations of odor and flavor on a standardized sheet. Later, flavor scores are averaged and the significance of the results are analyzed by statistical methods. When these precautions are taken, reproducible data can be obtained. The development is a milestone in research progress, because without reliable methods of evaluation we cannot determine when improvements in processing treatments have been made.

SEVERAL THEORIES try to explain the cause of the peculiar flavor instability of soybean oil. Many European refiners believe that traces of lecithin remaining in the oil cause the instability. They use elaborate precautions, involving thorough degumming operations, for removing the lecithin. Exhaustive degumming experiments in our Laboratory and in commercial plants of cooperating refiners, however, have demonstrated no benefits from such operations. Controversial also are the hypotheses that unsaponifiable constituents and isolinoic acid cause the off-flavors.

One of the oldest theories centers around linolenic acid as the flavor-

unstable substance or precursor of the off-odor. The acid is one of the component fatty acids of soybean oil, linseed oil, perilla oil, and other oils that develop painty-grassy flavors. It is absent in cottonseed, peanut, and sesame oils, which are considered flavor-stable or undergo typical rancidity upon storage. The linolenic acid theory has rested, therefore, on this bit of indirect, circumstantial evidence—the coincident occurrence of linolenic acid and flavor reversion.

Direct evidence indicting linolenic acid as the unstable precursor of off-flavors has now been developed in the Northern Laboratory. It was obtained in this way: Highly purified linolenic acid is introduced into the glyceride structure of flavor-stable cottonseed oil according to a recently discovered method. The oil is deodorized with steam until it is bland in flavor. This modified cottonseed oil is stored along with unmodified cottonseed oil and soybean oil until characteristic flavors have developed. The three samples are then presented to the taste panel for identification. Soybean and cottonseed oils are correctly identified, but the modified cottonseed oil containing linolenic acid is identified as soybean oil because its flavors are those of soybean oil. This and other supporting evidence that singles out linolenic acid as a flavor-unstable precursor is of cardinal importance in orienting current research.

Investigators seem now to have agreed on one way in which off-flavors develop. Oxidation is believed to play a part. Even this point has been disputed, however, because of experiments in which off-flavors developed although oxygen was thought to have been removed by exhaustive evacuation or by flushing with an inert gas. The effect of oxygen has frequently been missed because of the low peroxide value at which reversion occurs. Whereas lard rancidity is detected when it reaches a peroxide value of approximately 30, soybean-oil reversion is detected at the low peroxide value

of 2 to 3. After the sensitivity of the peroxide method was increased in our laboratory, a relationship of peroxidation to flavor deterioration became apparent. On samples refined from a single drum of soybean oil, an inverse correlation coefficient of 0.8 was found between flavor score and the logarithm of the peroxide value.

It is pertinent to mention here that conventional antioxidants, which have been used with such marked success in animal and some vegetable fats, are quite ineffective for increasing the storage life of soybean oil. Perhaps this is because of the unusually low peroxide level at which off-flavors develop in soybean oil.

Definite progress is being made in combating the flavor instability of soybean oil. Certain research developments are yet in the laboratory stage, while others have been incorporated in present commercial practice.

For example, the approach suggested by the laboratory experiments on linolenic acid lies both in the laboratory and in commercial practice. This line of attack for improving the flavor characteristics consists in the removal of fat molecules that contain linolenic acid by fractionation processes. However, the completeness with which these fractionations can be made ultimately depends on the pattern of arrangement of fatty acids in the fat molecules of soybean oil. We have employed the most efficient fractionating methods that we know—fractional crystallization, countercurrent extraction, and chromatographic adsorption techniques—and it becomes apparent that the structure of the fat molecules themselves will limit the completeness of removal of linolenic acid. The possibility of fractionating soybean glycerides to remove linolenic acid is not without hope, however. With the combined application of chemical reactions and physical fractionation the restrictions of glyceride structure are removed, in theory at least. Whether practical fractionations can be improved is the subject of current investi-

gation and constitutes one research frontier.

Even with incomplete separation of linolenic acid, the fractionation of soybean oil lowers its reversion tendencies. Countercurrent extraction of soybean oil with furfural has been studied in detail on a pilot-plant scale in this laboratory in an attempt to recover linolenic acid containing glycerides from soybean oil for paint uses. The edible fraction of lowered linolenic acid content has poor oxidative stability, apparently because the extraction removes tocopherol antioxidants along with linolenic acid containing fat molecules. After stabilization with antioxidants and metal deactivators, however, these oils of lowered content of linolenic acid do have less reversion tendencies than the unfractionated oils. The process of countercurrent extraction is now being employed industrially on a tank-car-a-day scale. The high linolenic acid fraction is used in paints, while the low linolenic acid fraction finds its way into shortening. After hydrogenation and blending, the oil also is reported to have a valid position among edible fats because of its good plasticity and color.

Hydrogenation increases the oxidative and flavor stability of soybean oil. We do not know whether it is a result of a reduced level of unsaturation of fatty acids or a result of reduction of linolenic acid content. It should be noted that hydrogenated oils go into different uses than do the salad oils, which have been discussed up to this point. As shortenings, hydrogenated oils are used for high-temperature applications, such as deep frying. Thus the advantage of greater stability gained by hydrogenating oils is reduced by the more exacting nature of the high-temperature applications of the oils.

Increased stability has also resulted from the knowledge that oxidation is a major factor in off-flavor development. This information has led to wider use of inert atmospheres to protect oils from oxidation. There are the so-called

blanketing operations, in which oxygen-free gas, generally a mixture of carbon dioxide and nitrogen, is used to fill the empty space in tank cars of oil during shipment and to cover tanks of hot oil during refining. Bleaching may be carried out under a layer of inert gas or under reduced pressure in certain plants. It has been general practice to break the vacuum over oil in decolorization tanks with air, but inert gas is now used in many plants. Traces of metals, which are picked up during processing and which catalyze or speed up the oxidation of the oil, are becoming a matter of considerable practical concern, as will be discussed more fully later. In general, any method of preventing oxidation improves flavor stability.

There is also developing a general awareness that present processing practice may be overly drastic in one or more steps. It is difficult to conceive of any food product other than oil that may be heated during the tempering of the flake, refined with steam, hot alkali, and bleaching earth, and deodorized by holding in excess of 400° F. with steam passing through continuously for 8 hours—and with all this drastic treatment come out an edible product.

After investigation of the refining procedures in commercial processing plants and checking the results against those obtained in the laboratory, we can put a finger on several steps where loss of stability may occur. For example, in the commercial extraction plants, the final traces of solvent are removed from the oil in tall stripping columns by passing superheated steam countercurrently through the oil. The oil has been found to be damaged in columns of certain plants, where presumably excessive heating or contamination by metals occurred. Degumming and alkali refining remove or destroy naturally occurring stabilizers, such as lecithin and tocopherols. Bleaching earths used in refining to adsorb pigments and to lighten the color of the oil also remove protective

antioxidants and thus lower the flavor stability.

Perhaps the most drastic step in the refining procedure is deodorization, which is, in effect, a steam distillation at a high temperature. It removes not only volatile flavor constituents but also the tocopherols and antioxidants. High temperature and steam are conducive to corrosion of the iron of which many deodorizers are constructed. The result is that pro-oxidant metal catalysts are introduced into the oil. In recognition of this hazard of contamination by metals, many processors are replacing iron materials in deodorizer construction with stainless steel and nickel. Also, tank cars for shipment of salad oils are frequently lacquered where the oil comes in contact with metal.

An interesting chapter in the improvement of the flavor stability of soybean oil covers the use of metal deactivators. At the close of the Second World War, Warren H. Goss, then on the staff of the Northern Laboratory, was assigned to investigate the German oilseed industry under the Army's Technical Industrial Intelligence Committee.

Among other things, he learned that citric acid was widely used in deodorization to inactivate traces of lecithin remaining after the double degumming and alkali refining. In subsequent tests at this laboratory, we found that the addition of citric acid was highly effective, not for the reason German processors advanced but because the citric acid complexed metallic pro-oxidants. Hence the description, metal deactivators. Compounds other than citric acid, including sorbitol and mannitol, were found to be active. Free, unesterified polybasic acids, or polyhydric alcohols in general, exhibit these metal-complexing properties. The addition of the compounds to the extent of 0.01 percent at the beginning of deodorization is being widely adopted in this country. Not only does the deactivator afford protection to the oil during deodorization but it also enhances its subsequent flavor stability.

In reviewing the status of soybean oil over the past few decades, it is apparent that marked progress has been made on the flavor problem. In fact, as we observe now the tremendous volume of soybean oil going into edible uses and note the slight differential in price between it and cottonseed oil, we are tempted to believe that we have achieved part of the goal of improving soybean oil until it can compete with other edible oils. However, the industry still considers the flavor stability of the oil to be its first research problem.

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Number and distribution of mills in United States processing various oilseeds in 1949

Oilseed	Number of mills	States located in
Cottonseed.....	372	16
Soybeans.....	268	29
Peanuts.....	74	11
Flaxseed.....	51	15
Copra.....	16	5
Corn germ.....	12	7
Tung nuts.....	12	5
Babassu.....	5	2
Safflower.....	3	3

Data compiled from International Green Book, 1949-1950.