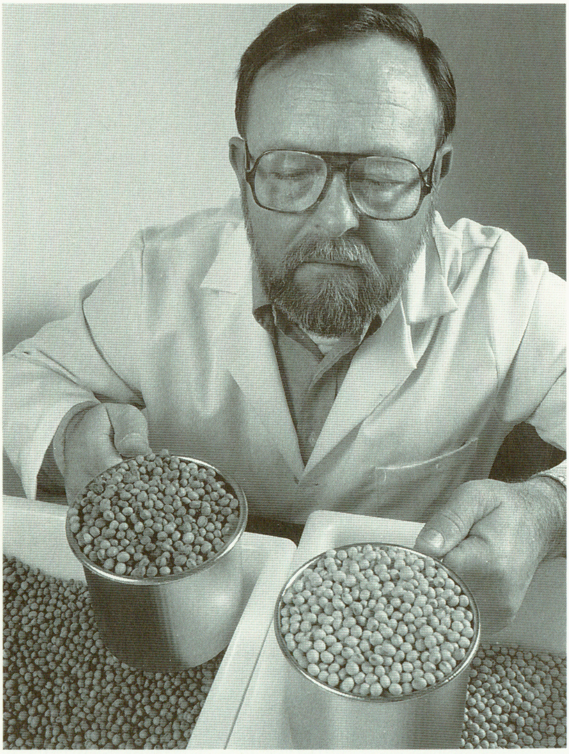
Soybean Oil

A Peoria research scientist aptly referred to the soybean of 50 years ago as the "the ugly duckling" of U.S. agriculture. It was certainly that. When Congress created the four regional research centers some 50 years ago, lawmakers couldn't have guessed at the spectacular future that lay ahead for that hard little bean from Asia, then a minor crop grown mostly for forage. Contrary to all expectations, the soybean within a few decades would become the Nation's second biggest row crop, the second biggest cash crop, and the biggest export crop. It would also grow into America's number one source of vegetable oil and of oilseed meal for livestock and poultry.



NRRC chemist Gary List contrasts dark, low-quality soybeans damaged by weather with high-quality soybeans that can be processed with a minimum loss of oil.

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In 1938, the U.S. soybean crop was an insignificant 62 million bushels, harvested from about 3 million acres. During the 1980's, an average of 2 billion bushels of soybeans were being harvested each year from 60 to 70 million acres, with the annual value of the crop to farmers exceeding $10 billion. Never in the history of this country has a crop increased in importance as quickly as has the soybean. And it was scientific research, much of it conducted at the Northern center in Peoria, that helped transform the ugly duckling of forage crops into the swan of high-protein feeds and vegetable oils.

In the 1940's, a chemist recalls, soybean oil made neither a good industrial paint nor a good edible oil. Shortages of cooking fats in World War II had forced processors as a last resort to add it to margarine, but even then, their upper limit was 30 percent. The flavor of soybean oil in those days was variously described by consumers as "grassy" or "beany" or "fishy," and it tasted even worse after it had been stored for awhile.

Without too much enthusiasm, Peoria researchers set out to improve soybean oil as much as they could. They decided that as an essential first step, they would have to establish some uniformity of judgment about how various soybean oils tasted. They selected taste panels and had panelists rate the flavors of soybean oil with numerical values instead of with imprecise adjectives. These more objective methods for assessing flavor and odor meant that the ratings of panelists in one processing plant could be compared with those in another plant and that panel results could be reproduced elsewhere. A scientist observes that while this early research may sound trivial, "it turned out to be the first significant milestone in improving soybean oil."

Guided by judgments of taste panels, NRRC researchers identified the source of many of the off-flavors in soybean oil as trace metals, particularly iron and copper. Even extremely small amounts of these contaminants sped oxidation of the oil, shortening its storage life and promoting undesirable flavors. Responding to these findings, industry removed brass valves in refineries and substituted stainless steel for the cold rolled steel in equipment that came in contact with soybean oil. These actions alone improved the flavor of the oil.

Another improvement followed the end of World War II in Europe. Warren H. Goss, a chemical engineer from the Peoria laboratory, was commissioned in the Army as a major and ordered to follow Gen. Patton's tanks into Germany to investigate the German oilseed industry. The rumor was that during the war, the Germans had somehow succeeded in making soybean oil palatable. When Goss reached Hamburg, he found what he described in a letter home as "a strange process" for stabilizing soybean oil. Without doubt, it improved the odor and flavor of the product, but it consisted of many arcane steps, including repeated washings and mysterious chemical treatments. Goss took the details of the process back to Peoria, where nearly all of the complex refining steps were found to be useless. One step, however, the addition of citric acid to the deodorizer, was what made the German process work. The discovery that citric acid would deactivate the trace metals in soybean oil soon led to finding many other chemicals that could do the job. Industry response was prompt, and today practically all soybean oil is protected during processing by citric acid.

But questions remained unanswered. Metal contaminants could speed the development of off-flavors, but chemists wondered what caused the flavors to develop in the first place. The answer turned out to be linolenic acid, a fatty acid that makes up from 7 to 9 percent of soybean oil. That is about double the proportion in other vegetable oils, and it is this constituent that was causing soybean oil to turn rancid on the shelf or when it was heated repeatedly in deep fryers.

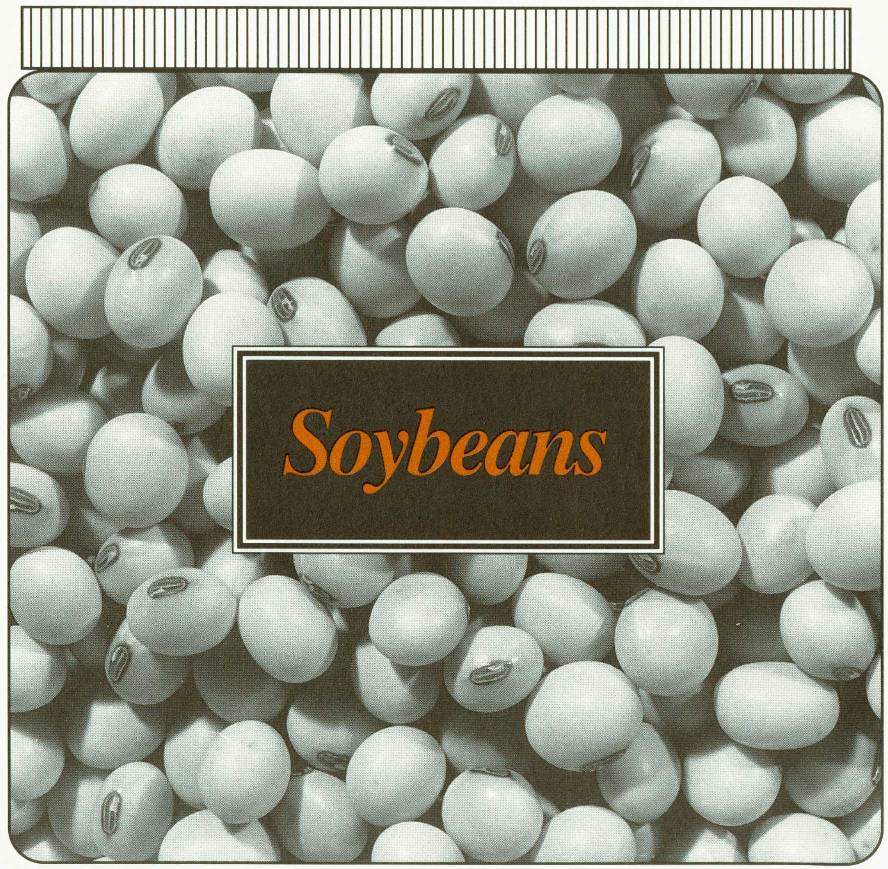
After long and often disappointing research, Peoria investigators discovered a "highly selective" copper-chromium catalyst that would enable processors to remove much of the linolenic acid. In the process, hydrogen was bubbled through the oil (hydrogenation) to combine with the fatty acid and solidify it. Presence of the catalyst assured that large amounts of the linolenic acid could be solidified selectively, leaving other, more desirable, fatty acids in liquid form. The oil was then chilled and the solidified linolenic acid removed.

While some features of the NRRC process have been adopted by the soybean industry, others remain unadopted to this day because of their high cost. But the NRRC discovery that it was linolenic acid that caused soybean oil to go bad spurred plant breeders in ARS and state research facilities to develop soybean lines with lower linolenic acid content, a work that continues to this day. Breeders have been aided in this search by an NRRC analysis of more than 15,000 soybean samples for oil and protein content, including content of linolenic acid. Important research to breed better soybeans is conducted in several places today, most notably in ARS labs in North Carolina and Indiana. Several promising new lines of soybeans have already been bred with linolenic acid content as low as 3.5 percent. A new approach, begun by an ARS scientist at Purdue, concentrates on breeding lines that lack the enzyme responsible for oxidizing linolenic acid.

Another early research breakthrough came in the 1950's, with discoveries about so-called hidden oxidation in soybean oil after it was deodorized. The cause was found to be oxidation compounds in the oils that decomposed during deodorization of the oil and formed new compounds that brought about undesirable changes in flavor and stability. Peoria recommended certain alterations in processing the oil before deodorization that overcame the problem. From the 1950's on, production of soybeans and soybean oil—and exports—began to climb off the charts.

Many other improvements in soybeans and their oil have been made at the Northern lab. An oil additive that combines two compounds—methyl silicone and citric acid—was found to lower the odor intensity of heated soybean oil. In recent years, evaluations by taste panels have made it clear that the implementation of improved processing techniques and protection of the oil during processing produces an oil that is stable during storage. Hydrogenation of liquid soybean oil produced in this careful way and treatment with antioxidants does not improve flavor stability during storage. Hydrogenation is still required, however, for the use of soybean oil as a high-temperature cooking oil and in shortenings and margarine.

When the regional labs began, soybeans were a minor crop, grown mostly for forage. Today they are the Nation's second largest cash crop and the number one U.S. export crop.



To determine the frying and baking performance of soybean oils low in linolenic acid, NRRC food technologist Kathleen Warner (foreground) and technician Linda Parrott compare foods cooked with genetically modified oils with those prepared with commercial vegetable oil products.

In the mid-1980's, an NRRC team found that deterioration of the flavor of soybean oil exposed to light could be reduced by adding as little as 5 parts per million of beta carotene, a natural food color and a precursor to formation of vitamin A. This discovery was also widely adopted.

Metabolic data from stable isotope tracer experiments with human subjects have provided NCAUR scientists with a biochemical basis to evaluate the nutritional value and health effects of dietary fats. Information based on isotope tracer studies and human tissue analysis led researchers to conclude that concerns about the adverse nutritional qualities of hydrogenated soybean oil are over-exaggerated.

Metabolically, trans acids are not equivalent to saturated fatty acids and all saturated fatty acids are not metabolically equivalent. Information from similar isotope studies found that the human body can meet its needs for omega-3 fatty acids by converting dietary linolenic acid in soybean oil and canola oil into the same beneficial omega-3 fatty acids in fish oil.

An NRRC research team discovered in 1990 that tuning up crude soybean oil with sound waves can produce a better salad dressing. Very high frequency sound waves, known as ultrasound, get rid of gummy impurities at much less cost than current processing methods. Taste panels were unable to distinguish oil refined with ultrasound from the conventionally processed kind.

In another kind of research, Peoria scientists found that the risk of dust explosions in grain elevators could be reduced or eliminated by treating corn, wheat, and soybeans with soybean oil. One year after treatment, there was no significant impact on grain quality, including odor and germination, or on grain handling properties.

Soybean Facts

Soybeans contain 20 percent oil and 40 percent protein. Through processing, they yield oil, lecithin, a 50-percent-protein soy flour, and dietary fiber. The flour can be further processed into a 70-percent-protein concentrate or a 90-percent-protein isolate.

Food ingredients derived from soybeans are listed on hundreds of labels of supermarket products: margarine; salad dressings; cooking oils; breads; pastries; all manner of cake, muffin, and biscuit mixes; tuna fish; meat extenders; breakfast cereals; soy sauce; diet foods; and many others.

NRRC research during the last half century has helped solve many problems that confronted the food industry when they tried to use soybeans in foods. Obstacles to utilization that were successfully overcome included off flavors and odors, short shelf life, dark color, and many processing difficulties. The net result of the research is that soybean byproducts have become the most versatile and ubiquitous component of processed foods today.