(70° F.) distilled water. Test the filtrate with basic lead acetate which should produce no precipitate and then add sulfuric acid (1:4) to precipitate the excess lead. Filter the solution into a 300 c.c. volumetric flask washing the precipitate with cold water and test filtrate with a small amount of acid to be certain that all excess lead has been precipitated. The filtrate is diluted to the 300 c.c. mark and a 25 c.c. aliquot of the filtrate is used for the glycerol determination.

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The Solvent Extraction of Soy Beans

By W. E. MEYERWEISSFLOG

Extractochemie A.-G., Zurich

DURING the last couple of years a good deal of attention and work has been done on the continuous extraction of vegetable oil seeds by means of solvents.

The results obtained with this most modern method of oil production seem to deserve a short description of this process as well as some brief remarks about the experiences with it in practice.

Pressing.

It has not been long since pressing was the only possible method to get the fat content out of oleaginous substances in a satisfactory manner.

But in spite of the great progress made in the meantime in constructing oil presses, it had not yet been possible to reduce the remaining fat content in the press cake below 5 to 7 per cent.

This remaining oil content represents a loss which has been unavoidable so far. It is a practical loss because the oil left in the cake can not be sold at the high oil price but only at the much lower cake and meal price.

Especially in working poor fat containing oil seeds, as soy beans, for instance, where the residual fat content represents almost one-third of the whole oil content, the possibility of avoiding such a great loss logically is of greatest commercial interest.

Extraction in Kettles.

Towards the middle of the last century the solution of the old problem of extracting oil seeds by means of solvent so as to obtain as nearly as possible the complete oil content was accomplished for the first time. At that time the extraction was done with carbon bisulphide.

The extractors generally consisted of kettle-like containers or rotary cylinders. Their operation was somewhat complicated. They had to be charged first with the material to be extracted; second, with the proper amount of solvent and discharged and cleaned after extraction.

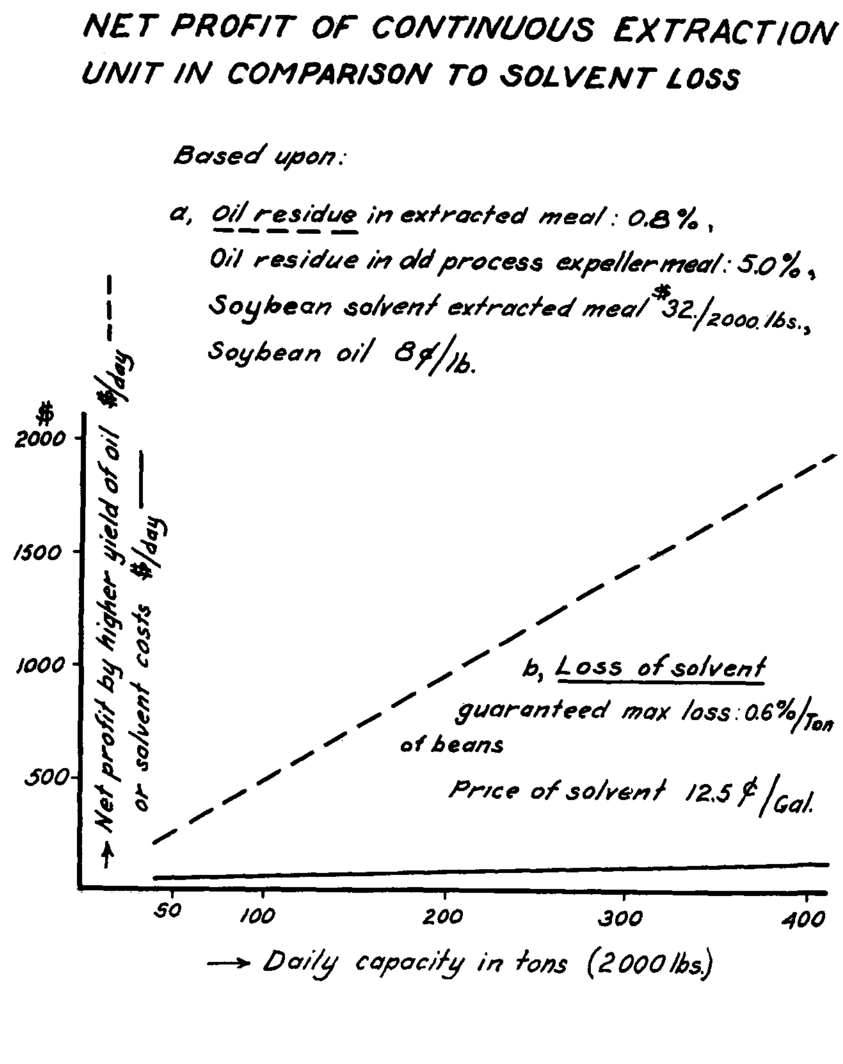
Initially, considerable work was done on extracting olive pulp by the batch process; later the process was applied to other seeds.

Continuous Extraction in General.

The deciding forward step in the development of the extraction process, however, has only been made within a very short time. Wide use of industrial continuous extraction processes is only about five years old.

Although the kettle extraction compared with the pressing method offered many advantages, it could but partly satisfy because of its complicated working system. The main efforts of the industry in regard to extraction on a large scale have been in the direction to automatize the extraction process and to develop it as a continuous working system.

In view of the enormous quanti-



ties to be handled by a modern oil mill, only a continuous process could give the capacity and rationalization desired. The results of these efforts, however, during long years were not very encouraging; in a few cases they succeeded in getting satisfactory results for certain raw materials, but the apparatus did not prove satisfactory for versatile application.

It was in Europe, poor in raw material, and especially in Germany where the parties concerned have been forced to keener study to solve this problem that different solutions have been found as a result of these efforts.

The principle on which all these processes are based is the following:

The material which is to be extracted and which by means of suitable preparation has become of a loose structure in order to allow an easy penetration of the solvent is conducted through an extractor in continuous current and on its way through the extractor comes in contact with the solvent. The different processes differ from each other mainly in the method of transporting the oleaginous material through the extractor.

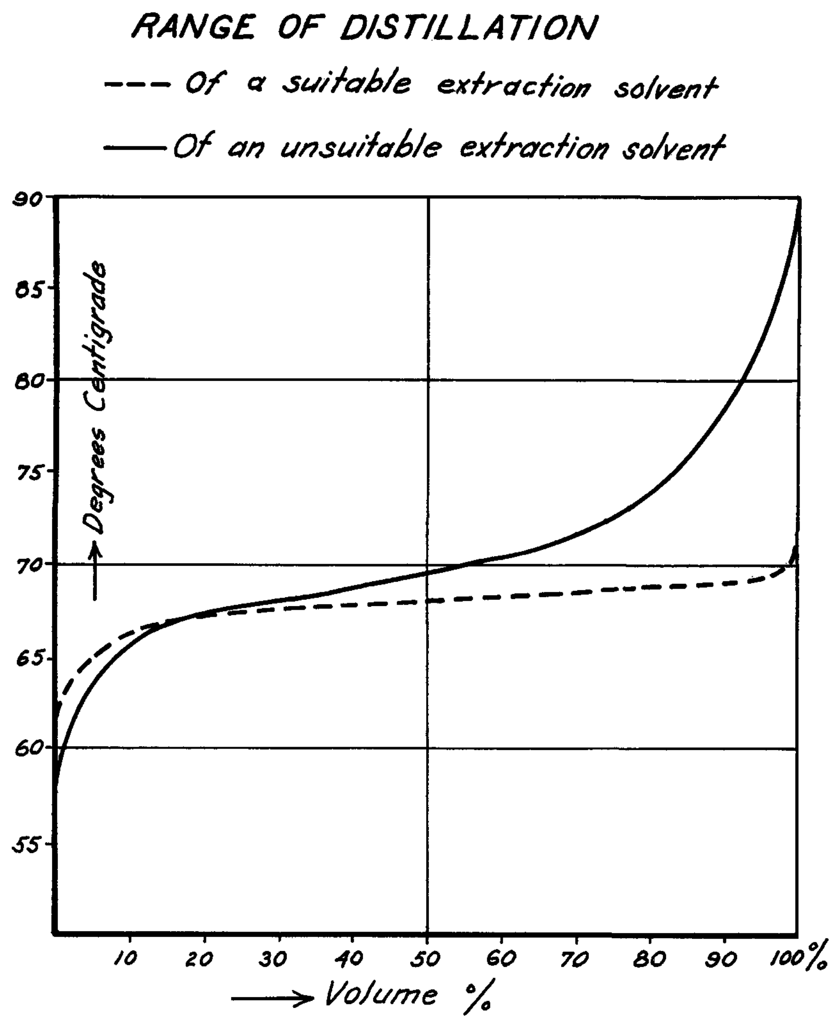
The solvent flows through the material and the extractor in continuous counter current. The various systems show considerable differences in the course through which the solvent flows.

Various constructions of continuous extraction apparatus have been devised. We may mention the Fauth and Bollman system. The best known system in this country, no doubt, is the Hildebrandt system. Two extraction units of 100 long tons capacity have been constructed at the respective Chicago plants of the Archer-Daniels-Midland Company, Minneapolis, Minnesota, and the Glidden Company, Cleveland, Ohio. Both units are working soy beans exclusively. Another unit has been constructed for the Clinton Company, Clinton, Iowa, for the extraction of corn germ oil.

The Continuous Extraction.

The Hildebrandt continuous extraction process, which is used by several concerns in this country on various seeds, will be discussed. This system is handling soy beans, peanuts, linseed, rape seed, palmkernels, cotton seed, olive pulp, etc. All these oil seeds are handled in practical daily work.

In this system the oil seed which is to be extracted is moved through an U-shaped cylinder by means of a screw. Benzine is flowing through this cylinder in the opposite direction. The meal from which the oil has been extracted passes through a drying unit which completely removes all residual solvent by heating. The meal obtained is of highest quality and absolutely free of solvent odor and taste.



The miscella (solvent and oil mixture) saturated with oil is cleaned and decoloured by a special process. The benzine is separated from the oil by continuous distillation. Here the application of lowest possible temperatures is of great importance to avoid superheating. Such superheating of the oil would cause a deterioration of the oil quality and at the same time would lead to higher refining losses.

The oil produced is suitable for edible purposes without refining if a first-class non-acidiferous quality of seed has been the raw material.

The continuous extraction process is especially characterized by the simplicity of the apparatus. There are no fast-moving parts so that wearing out as well as repairs are reduced to a minimum. Naturally it requires excellent coordination of the various apparatus and skillful work by the supervising staff.

Undoubtedly the greatest advantage of this process when compared with pressing is the low oil residue in the meal. The maximum residue of oil in the extracted meal is about 0.8 per cent, whereas in pressing a minimum 5 per cent of the oil in the cake or meal is unavoidable.

As already mentioned, the price obtained for extracted meal is at least the same as that for old process meal. The increase in oil yield by extraction is a profit not obtained in the old expeller process.

In handling one ton (2,000 lbs.) of soy beans by pressing in expellers the oil content of the cake will be 73 lbs. These 73 lbs. of oil would be extracted in handling the same one ton by continuous extraction. One pound of soy bean oil costs about 8c; 1 lb. of soy bean meal costs only 1.6c. The possibility of a higher yield of oil offered by the continuous extraction process will lead to the net profit of $73 \times 8 - 1.6c =$ \$4.67. The average capacity of a good-sized extraction unit will be 100 long tons per 24 hours and the net profit by higher yield of oil alone will be $100 \times \$4.67 =$ \$467 per day.

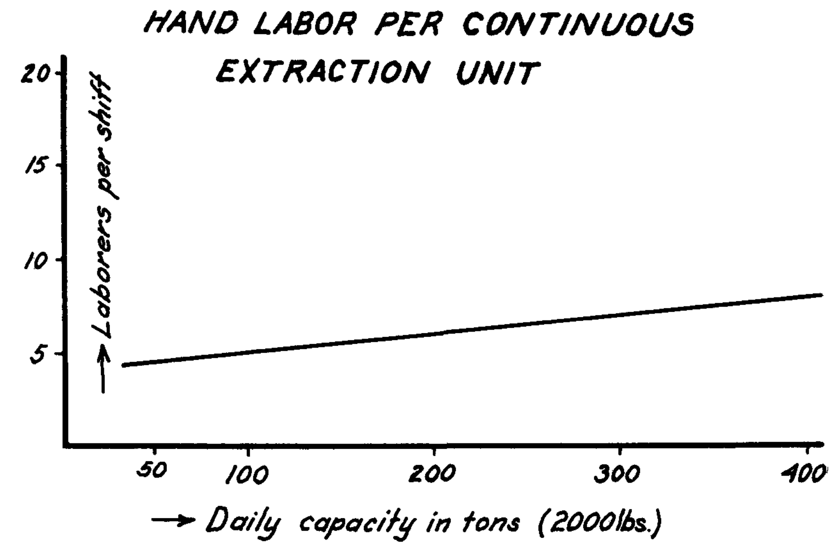
Comparison of Production Expenses of Pressing and Extracting.

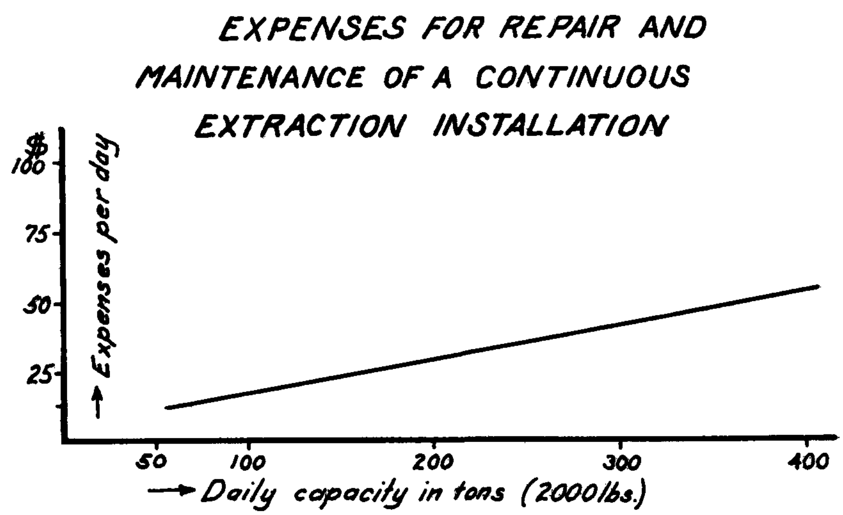
(The graphs will show the expenses involved by the extraction process.)

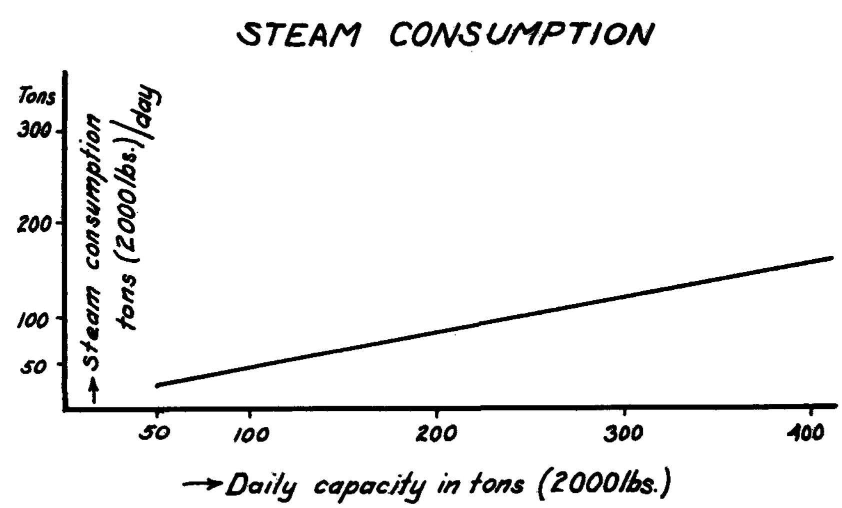
It is obvious that the only considerable expense in extraction is the loss of solvent. But an efficient extraction process will reduce these expenses for solvent to a very low figure. An average loss of solvent of 0.6 per cent of the weight of beans worked should be guaranteed by the construction company. An extraction unit of 100 long tons daily capacity will involve a solvent loss of: 0.6 per cent of 2,000 lbs. = 12 lbs. or about 2.05 gal. of solvent x 100. The price of solvent is about 12.5c per gal. which will lead to a total amount of \$25.70 as daily expenditure for solvent.

The steam consumption of the extraction process is naturally considerably smaller than in the old pressing process. A guarantee that the maximum consumption of steam would be 1,000 lbs. per one long ton should be given by furnishers of extraction installations. But apart from the consumption for the drying process of soy beans the expenses for steam will be considerably higher in the case of the pressing process. The beans may be handled by extraction processes even though they contain that normal amount of moisture that is found in elevator stored beans; whereas the predrying of the beans for the expeller process requires a great amount of steam which is completely saved in the extraction process.

Another great advantage of an extraction process is the very small need of driving power. A good extraction process should not need more than twenty-seven kilowatt hours per long ton. Any remark about the enormous advan-







tage of the extraction process in comparison to the expeller process with its heavy consumption of power is superfluous.

Another outstanding advantage is in the saving of expenses for repair and maintenance. It is well known how serious the charges are for this account in an expeller plant. Also there is much depreciation in such a plant. Only small capital is needed in running an extraction installation because repairs, maintenance and depreciation are hardly noticeable. There are no parts to wear out and there has not even been a demand for spare parts for any of the continuous extraction installations in the United States of America which have been constructed by European firms.

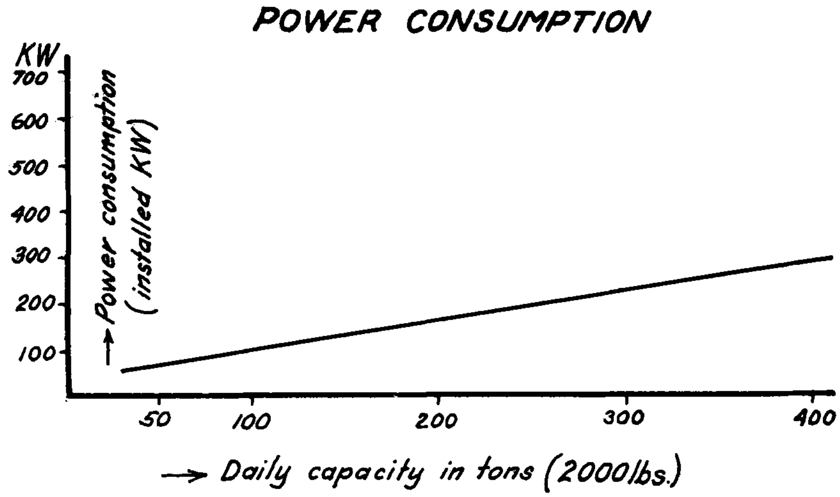
As to the expenses for labor costs continuous extraction units only need a small supervising staff. Three men per shift for a production of 100 long tons daily are more than sufficient. These three men will be sufficient to supervise a unit with a capacity of 5 hundred or more tons per day. This is an outstanding economical feature of continuous extraction processes.

A very well-known by-product in extracting soy beans is lecithin. The apparatus for producing lecithin from soy bean oil is very simple and the production expenses very small. The content of lecithin in soy beans runs as high as 0.5%. In handling 100 tons of soy beans per day the yield of lecithin will be about 1,000 lbs. per day. The approximate price of lecithin being 30c per lb., the total profit on lecithin production will consequently be $300 per day on a hundred tons extraction unit. It is well known that commercial lecithin production is impossible by the old expeller process.

What is the conclusion of the items stipulated above?

Even assuming that the production costs are equal in handling soy beans by extraction and expeller process, the net profit of the extraction process will exceed the profit of the expeller process by the amount of higher yield of oil plus the value of the produced lecithin minus the small losses of the meal produced.

But there are other considerable advantages of the extraction process besides the one of higher yield of oil and lecithin. They consist in the better quality of the products. This will be clear by the following example:



In most cases for the sake of saving expenses the pressing process is carried out by one pressing. No doubt high temperatures are necessary for this operation in order to get a high oil yield. On the other hand these high temperatures are injurious to the quality of the oil produced. The value of such an oil is comparatively low and another drawback is found in the heavy refining losses of such an oil.

These harmful experiences have shown the advisability of splitting this production into two independent sections. A pre-pressing with very low temperatures and a supplementary pressing with high temperatures.

By means of the new extraction process we get to the same end with greater savings and considerable advantages: With seeds of high oil content it is advisable to apply a light cold pressing followed by extraction. The result will be the following:

1. Good quality of oil produced by cold prepressing.
2. Considerably higher yield of oil by the final extraction process, and production of lecithin.
3. Quality of extracted oil is far superior to oil obtained by pressing at high temperatures.
4. Large saving of production expenses.

Objections Against Oil Seed Extraction

The method of recuperation of fat contents out of all kinds of oleaginous substances by means of pressing goes back as far as human culture. No doubt an entirely different way of producing the oil will meet rather broad prejudice.

The first and almost universal argument and objection to the extraction process is the opinion that it is impossible to eliminate the last traces of solvent from the extracted meal. The consequence of solvent remaining in the oil and in the meal is that these products are not suitable either for human consumption or for feeding to livestock and poultry. The common but completely unjustified judgment about extracted meal is to consider it as inferior to old process meal or even to consider it as injurious to health. This rumor is mainly due to the inefficient method and apparatus used when the extraction method first was adopted for industrial purposes. These installations certainly have not been able to do this very delicate work efficiently. In addition to this imperfection the solvents at that time were not of proper qualification for the enterprise. Ordinary gasoline which contained high boiling point fractions had been used.

But the greatest inconvenience was caused by the use of trichlorethylene. This solvent offering a great advantage by being non-inflammable and non-explosive and in addition having high solvent capacity has resulted in a very serious drawback to extraction.

The meal extracted by means of trichlorethylene was not readily eaten by cattle and was responsible for considerable losses in livestock where it was fed.

All parties concerned were at a loss to know the origin of these casualties until careful studies gave the solution. It was due to the use of trichlorethylene as solvent that cattle were poisoned by feeding on soy bean meal (Sir Stewart Stockman, in the Journal of Comparative Pathology and Therapeutics. Vol. XXIX 1916, 95). As soon as trichlorethylene was replaced by gasoline in extracting soy beans, the cases of poisoning in cattle disappeared completely. It is supposed that meal extracted by trichlorethylene does not contain essential elements for livestock because these elements have been taken out of the meal by trichlorethylene as solvent. In addition to this lack of important nutrient elements poisonous matters have been found in this meal.

Today the petrol industry is well able to furnish the extraction industry with an entirely satisfactory solvent. Efficient machinery and newly developed special solvents make possible the elimination of the slightest trace of solvent in the products. A solvent having a very evenly increasing boiling characteristic is of a high solvent capacity. The following table will show the boiling range of an unsuitable solvent and the boiling range of an up-to-date satisfactory solvent for extraction. Besides the human test of smelling, the best proof is the willingness of cattle to take the meal. When the finest analytical methods fail to show any residues of solvent, human smell will be able to detect them. Even the very best methods can not find any remaining solvent in the extracted meal of an up-to-date continuous extraction unit.

Another objection to extracted meal is the argument that the solvent-extracted meal is not adaptable for feeding purposes on account of its low content of oil. Before we quote scientific proofs of the mistake involved in this argument a simple fact may be told:

No doubt the agriculture in Germany is of an especially high standard and is executed most intensively in comparison to all other European countries. In 1922 Germany crushed 3,170,000 bushels and in 1932 crushed 44,000,000 bushels of soy beans. Not a single ton of the latter was crushed by the old expeller process, but all 44,000,000 bushels were extracted by solvents. In the United States of America they crushed by the several processes only about 4,000,000 bushels in one year, 1932.

Naturally it would be a serious drawback to the extraction method if the argument were correct that solvent-extracted soy bean meal is an undesirable cattle feed on account of its low content of oil. Quite a few agricultural colleges and state agricultural experiment stations in the United States of America have conducted various experiments in this direction. Farmers and feed dealers in this country now agree that the protein cost is of vital importance in livestock and poultry feeds and that the protein content is the deciding factor. This protein content of about 45% can be consumed and biologically assimilated to the extent of more than 90%. In addition to this the carbohydrates contained in the soy bean meal are very remarkable. They are found in the extracted meal as dextrins and crystalline sugar. There is no starch contained in the soy bean meal, a reason for soy bean meal being adaptable for nourishment of diabetics.

Another great advantage consists in the low fibre content. It is commonly known that the rich content of phosphatides in the soy bean meal makes the meal especially attractive.

The experiments and feeding tests made in American experimental stations and agricultural colleges not only establishes the high value of solvent-extracted meal for feeding purposes but at the same time various experiments have been conducted to determine the difference in palatability and feeding value of the various types of soy bean oil meal. The results of these experiments are certainly known to you.

Let us cite for this reason several very interesting tests and experiments executed in Germany. They all come unanimously to the conclusion that the extracted soy bean meal is at least equal in feeding and growth value to any oil seed meal with a higher fat content.

The following experiments have been published:

Richter & Ferber, Soybean presscake compared with extracted soy bean meal on cows. Deutsche landwirtschaftliche Presse 1932, Nr. 17;
Richter & Ferber, Lamb feeding tests with oats, lincake and extracted soy bean meal; Deutsche landw. Tierzeitung 1931, Nr. 20;
Dr. G. B. van Kampen, The Dürener epidemic. Die landwirtschaftlichen Versuchsstationen, Band 108;
Dr. Bünger, Lamprecht, Dr. Meetz und Heinrichs, Two feeding tests with extracted linseed meal on calves and cows, Landwirtschaftliche Jahrbücher, Band 68;
F. Honcamp, P. Malkomesius und A. Petermann, Tests regarding composition, digestibility and feeding value of lincake and extracted linseed meal. Zeitschrift für Tierzüchtung und Zuchtungsbiologies, Band XV, Heft 2;
Dr. Wolfgang Heinichen, Feeding tests on lambs with extracted linseed meal compared with linseed meal of press cake.

Another interesting publication will be found in the Biological Journal, 1937, St. Kon & Markuze.

Other experiments have been executed by Paul Bondy, Germany; Prof. Stocklasa, Tschechoslovakia; Prof. Rubner, Germany.

Large quantities of solvent-extracted soy bean meal are consumed for human alimentation. The use of soy bean meal for this purpose is still increasing on account of its favorable high nutritive composition. Twenty per cent of soy bean meal can be added to bread flour or other kinds of bakery flours. Its high digestibility and its very agreeable taste are much appreciated.

Let us mention again the high lecithin content of the solvent-extracted soy bean meal. It is known that this product in solvent extracting is of great commercial interest and that this lecithin is a very important vegetable phosphatide which has replaced to a very large extent the lecithin formerly produced from eggs.

The development of the oil industry and the respective machinery has shown the distinct trend to change over from mere pressing to either a combination of pressing and extracting or to exclusive extraction. In Europe extraction is not confined to soy beans, but other vegetable oils are produced by this means. Nutritional knowledge resulted in prices for extracted meal in Europe that are up to 5% higher than prices for meal from presses.

Recent scientific and agricultural progress has placed soy beans among the major crops in the United States. Very favorable natural, political and agricultural conditions will accelerate this development to the end that the American soy bean industry will grow and enjoy a prosperous increase.