Drying Moist Cottonseed Protein Products

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Abstract

A practical procedure is described together with data obtained during its experimental application, for drying moist oilseed protein products. Specific data are given for drying defatted, raw cottonseed meats, containing as much as 30% of water, to a granular, free-flowing meal with a moisture content of 10% or less at temperatures below 150 F. This is accomplished by adjustment of pH of the mixture during agitative drying to control its rheological properties so as to keep power requirements within a practical range.

Introduction

Worldwide interest in the development of sources of edible protein has resulted in increased interest in oilseed protein products (1). Emphasis has been placed on extraction of the oil from decorticated oilseed under mild processing conditions which prevent destruction, or reduction in availability of essential amino acids in the protein—thus preserving its digestibility and nutritive value. Further processing of the defatted solids of the seed may be necessary to remove inedible fiber, such as hull fragments, or other unwanted materials such as gossypol and residual cyclopropene acid (in the case of cottonseed) and to remove traces of metabolic products of mold (aflatoxins) with which the seed may have become contaminated during production, storage or processing. In some instances additional processing may also be required to improve the appearance (color) and palatability of the manufactured product and to separate the protein mixture into desired fractions.

In many steps in the manufacture of edible protein products the use of water as a processing and reaction medium is often necessary or desirable. In general, the addition of appreciable quantities of water has been avoided in the past because of mechanical difficulties encountered, due to its presence, in the manufacturing process. This has been a discouraging factor in commercial development of improved oilseed protein products.

When moderate quantities of water have been incorporated into oilseed protein mixtures, a plastic, gluelike consistency of the mixture may develop, which requires a departure from the usual solids handling techniques.

This is particularly true when it becomes necessary to dry the moist product for conversion into a meal or flour, or other solid form necessary for storage, transportation and use.

If the moisture content of comminuted oilseed protein exceeds 12% by weight, it may undergo metamorphosis into a homogeneous, semifluid, viscous state upon application of heat or mechanical action. This change of state from solid, friable material to material of viscous, semisolid consistency requires application of entirely different rheological techniques for further processing.

During experimental research on processing oilseed protein products at this laboratory a study was made of this problem of changing state and ways of dealing with it in a practical manner. Of immediate concern was the need to remove approximately 2–10% of water from material consisting of processed defatted and degossypolized cottonseed meats of 12–20% moisture content to convert it from a sticky, plastic physical state to a granular free-flowing meal of 5–10% moisture content. This was necessary for use in animal feeding experiments.

[1] So. Utiliz. Res. Dev. Div., ARS, USDA.
[2] Presented at the AOCS Meeting, New York, October, 1968.

It was found that moist defatted meats containing 15–18% of water could be dried to a moisture content below the critical 12–16% range by simply spreading it out in thin layers in warm, dry air for a day or two provided it was maintained in porous clumps to allow circulation of dry air under ambient conditions. This permitted moisture vapor from the wet meats to escape into the air. A large amount of floor space or numerous drying racks were required. The desired result was achieved if the humidity and temperature conditions were correct and if care were exercised to preserve the porous physical condition of the material. If the wet protein is compressed, or mechanically stirred, it tends to become compact and assume a homogeneous form due to its fluidity. This reduces the area exposed to the air and greatly increases the drying time. If all of the proper drying conditions are not maintained an inordinate drying time may be necessary, under ambient conditions, and deleterious mold growth may develop throughout the product at this stage. Furthermore, it is impractical to dry appreciable quantities of moist oilseed protein products in this manner because of the large space required under favorable conditions of temperature, humidity and air circulation. If the drying space is air-conditioned, some of these conditions can be controlled, otherwise the weather must be just right for successful air drying.

It was found, experimentally, that if the moist, porous material was placed on trays in thin layers and warmed, even slightly, in a vacuum oven, the protein became fluid and lost its porosity. Case hardening developed and a longer time was required to reduce the moisture content to the desired level than if it had been left in the air to dry at atmospheric temperature and pressure.

Clearly, a method was needed to quickly and conveniently reduce the moisture content of such material to the desired point. Commercial drying equipment, such as rotary kilns, heated screw-conveyor dryers, and belt dryers utilize either mechanical action or heat, or both. These are the two principal physical factors which cause agglutination and compaction of the wet protein mass, both of which defeat the purpose of the accelerated drying operation.

During experimental processing of oilseeds, such as cottonseed, soybeans, peanuts and other commercially important proteinaceous, oil-bearing seeds, it may be desirable, or even necessary, to treat the oilseed meats with aqueous reagents and solvents at some stage of the process. Such a step may be necessary to bring about the desired physical and chemical changes in the heterogeneous material of which the seeds are composed. For example, rendering of the glyceridic oils from their natural sites in the seed (to cause them to coalesce into droplets, or a continuous phase, suitable for mechanical or solvent extraction) is usually facilitated by the action of added moisture. In the case of cottonseed, the addition of moisture also aids in the rupture of the pigment glands, exposing their contents to desirable chemical reaction or extraction by solvents.

During the experimental work it was found that drying of moist, viscous and tacky vegetable protein mixtures may sometimes be successfully accomplished by agitating the viscous mass so as to continuously move the moist inner material to the surface from which moisture can escape to a surrounding dehydrating atmosphere in the form of vapor. This was found to be true whether the dehydrating atmosphere is dry air at ambient (atmospheric) pressure or at reduced pressure (vacuum). However, when viscous, moist, sticky protein masses are dried in this manner, a

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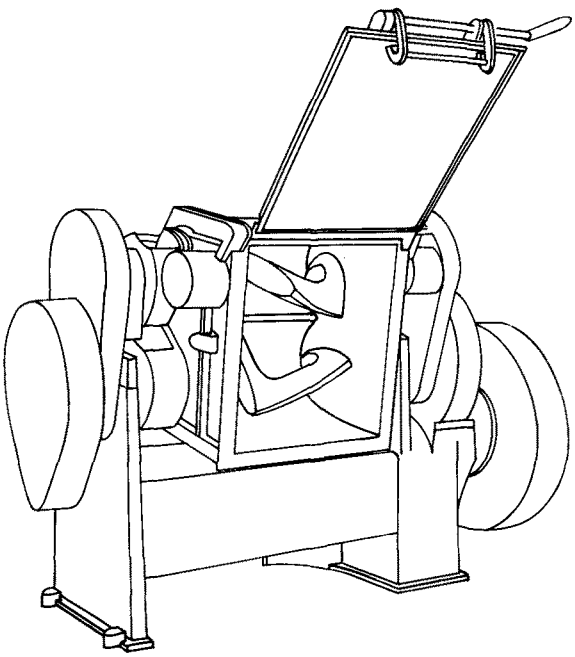

FIG. 1. Sigma-Blade Mixer-Dryer.

point is reached during dehydration when the viscosity and, at a later stage, the toughness and hardness of the mass require excessive mechanical power to stir the mixture. As a matter of fact, when moisture is reduced to approximately 10–20% by weight the mixture becomes so tough and brittle that excessive power is required to stir, chop or break the mass so as to comminute it into particles suitable for further drying.

For example, five pounds of defatted cottonseed flaked meats containing 30% by weight of water were placed in the mixing chamber of a Baker-Perkins laboratory mixer (Baker-Perkins, Inc., Saginaw, Mich.) (Fig. 1).

This equipment is a steam-jacketed steel mixer equipped with a vapor-tight removable cover. It consist of a cubical mixing chamber with two rotating sigma blades which knead, or mix, the contents of the chamber, depending on the physical state of the charge. The bottom of the chamber contains two close-fitting, rounded channels which provide minimum clearance for the rotating Z-shaped blades designed to insure complete mixing of the contents. These rotating blades are vacuum sealed and are rotated by a

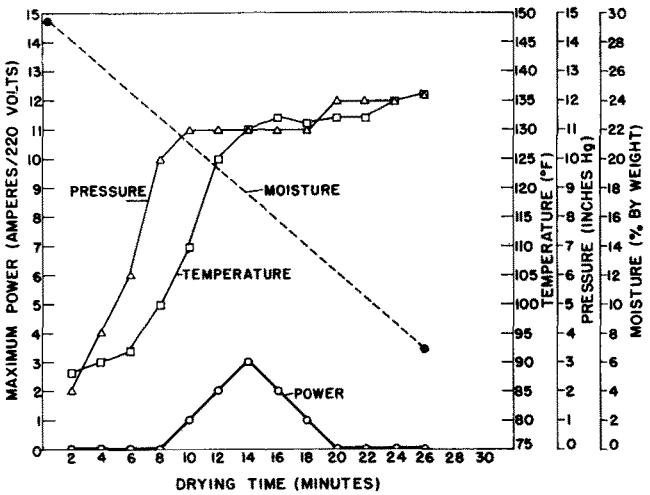

FIG. 3. Drying data for moist, defatted cottonseed meats with added sodium hydroxide.

220 v electric motor through a speed-reducing link-belt drive. The blades are hollow and are heated by steam passing through them. The capacitiy of the mixing chamber is ½ ft³—part of which is occupied by the mixing blades. The steam jacket was preheated to a temperature of 350 F and maintained at this temperature throughout the drying operation. Rotation of the mixing blades was started immediately upon addition of the charge and was continued until the dried material was discharged. The apparatus is equipped with a vacuum gauge and a thermometer well. The latter extends into the material being agitated and dried. The boxlike chamber can be tilted over on its side to discharge the dried material, after the vacuum is released and the cover is removed. Vacuum was applied to the system from a steam aspirator line. The material being stirred became plastic, viscous and doughlike, and the electric current required to keep the motor running, as measured by an ammeter in series with the 220 v power line to the motor, varied as shown in Figure 2.

The time of stirring and the pressure within the chamber, as well as the temperature of the mass of material being dried, are also shown in this figure. It will be noted that as the drying progresses the power, measured in amperes of electric current at 220 v, rises sharply as the moisture

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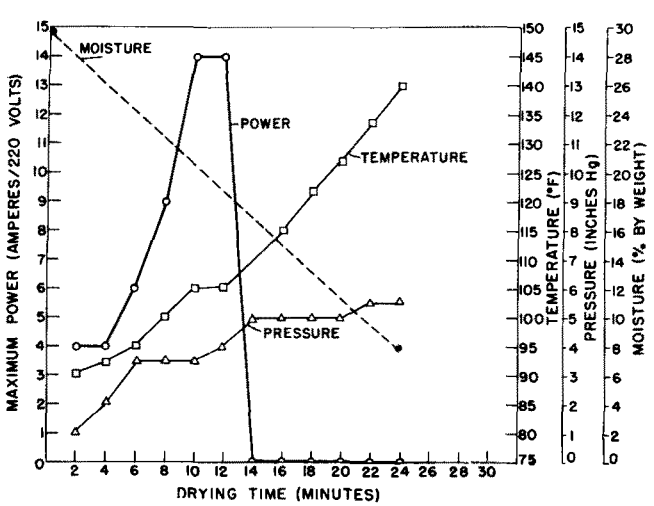

FIG. 2. Drying data for moist, defatted cottonseed meats (no added chemical).

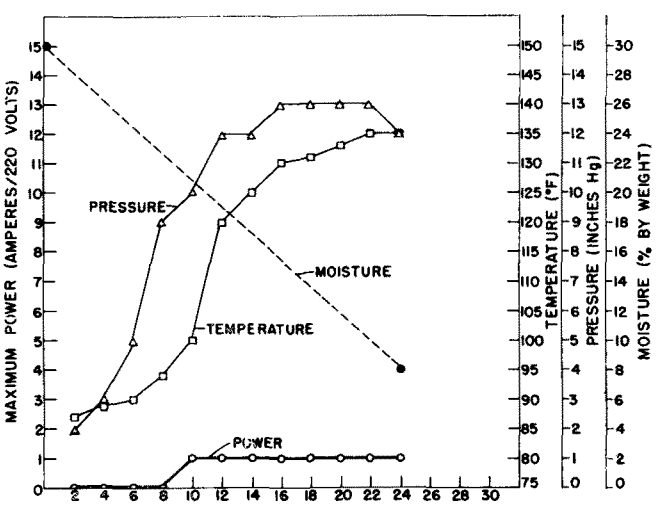

FIG. 4. Drying data for moist, defatted cottonseed meats with added phosphoric acid.

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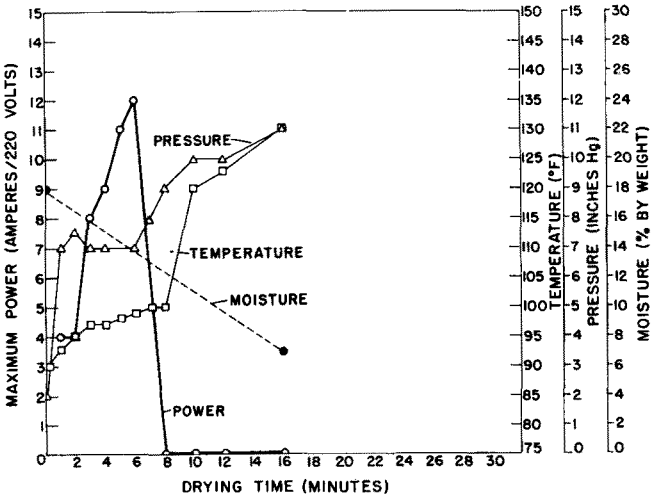

FIG. 5. Drying data for mixed-solvent-extracted cottonseed meats (no added chemical).

is reduced. Then as the tough material breaks up the power drops to that required to operate the electric motor while simply idling.

In some instances it was impossible to complete the drying cycle under these conditions. For example, another five-pound charge of the same material was treated in the same manner. This time the hard, tough, semiplastic mass, after drying for 9 min, jammed the mixing blades and stopped the motor, which had an overload cutoff. The material had to be removed from the blades and chamber with a chisel and hammer.

In order to determine the effect of raising the pH of the moist protein, a 5 lb charge of the same material was placed in the drying apparatus as in the two foregoing experiments. Then 30 g of NaOH dissolved in 150 ml of water were added when stirring began. Due to the efficient mixing action of the apparatus, this reagent was immediately distributed throughout the plastic mass. The cover was replaced, vacuum was applied, and the electric current data of Figure 3 were obtained.

The comminuted, soft, granular, free-flowing meal which was discharged from the apparatus was found by analysis to contain 7% moisture.

Another 5 lb charge was treated with 25 ml (43 g) of 85% H_3PO_4 (orthophosphoric acid) made to 100 ml with

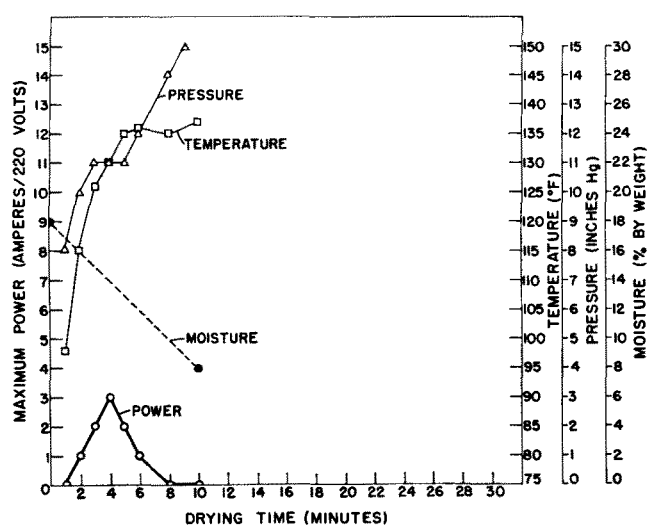

FIG. 6. Drying data for mixed-solvent-extracted cottonseed meats with added sodium hydroxide.

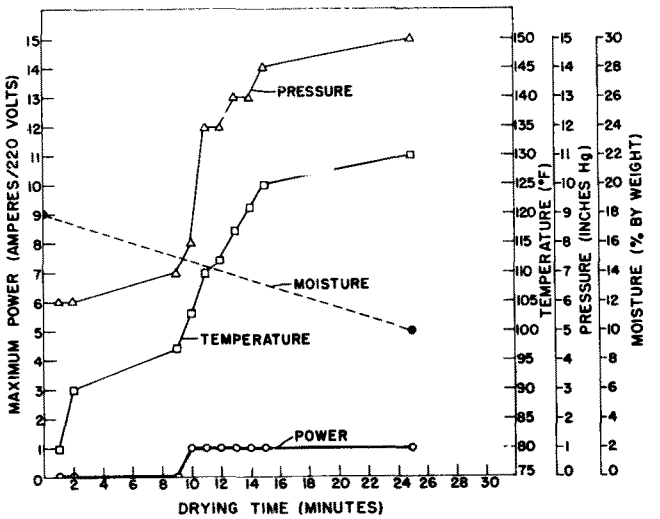

FIG. 7. Drying data for mixed-solvent-extracted cottonseed meats with added phosphoric acid.

water. The time, temperature, pressure and power relationships are shown in Figure 4.

The comminuted, soft, free-flowing, granular meal was found to contain 8% moisture.

From this data it can be seen that the addition of either a food alkali (e.g., NaOH) or food acid (e.g., H_3PO_4) has a pronounced beneficial effect on the physical properties of moist, plastic, oilseed protein masses under conditions of agitative drying. This effect appears to be essentially a prevention of agglutination of the mixture, thus eliminating consequent hardening into a tough, semisolid material which requires exorbitant power to comminute into particles suitable for further drying in conventional processing equipment.

The use of food acid or alkali not only does not impair the nutritive properties of the dried protein product but may actually increase the nutritive value by supplying mineral nutrients to foods prepared from them. Furthermore, the physical properties of the protein particles so prepared are such as to increase the digestibility of the protein components by increased solubility and ease of disintegration and dispersion in an aqueous biological system (2). The pH of natural cottonseed protein is 6.3. The slight increase (pH 7–8), or decrease (pH 4–5) in basicity or acidity of the proteinaceous product of the process is minimized by the buffering action of the natural proteins of the mixture. No corrosion of conventional food processing machinery was evident during any of the experimental work.

The foregoing data outline the techniques developed for removal of water from vegetable protein products. Mixed organic solvents containing water can be removed from oilseed protein marcs in a similar manner.

Ordinarily, in the commercial extraction of preconditioned (cooked or toasted) oilseed meats with commercial hexane, the residual solvent in the final marc is removed by distillation. However, when wetting solvents, for example, aqueous volatile solvents containing nonpolar or polar mixed organic solvent, or both, are used, water is absorbed by the oilseed protein from the solvent mixture because of its hydrophilic nature. When the residual mixed solvent, which has served its purpose in extraction of the seed is removed by distillation, the more volatile organic solvents distill off first leaving behind the moist vegetable protein mixture which may contain more water than was originally present in the seed. The resulting moist mass then assumes the physical properties described above and the same special techniques are needed to complete the drying.

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It was found that agitation of the solvent-damp marc at either atmospheric or reduced pressure with application of heat to supply heat of vaporization, served to distill the volatile solvent and part of the water at low temperatures (e.g., 70–150 F). The amount of water removed in this preliminary step depends on the particular solvent combination used and whether or not an azeotropic mixture is formed which causes removal of at least part of the water with the organic solvents (3). This portion of the solvent mixture can be recovered by condensation in conventional equipment. Further drying to reduce residual moisture which may be as much as 20% by weight of the wet protein mixture, down to 10% or below to form a dry meal requires application of the techniques previously described.

For example, 8 lb of marc (derived from extraction of 4 lb of raw cottonseed meats with a mixture of acetone, hexane and water in the volume proportion of 53:44:3), which contained 70% of total volatile matter by weight, were added to the mixing chamber. The volatile matter consisted of 9% water, which included the natural moisture of the meats, and 91% of acetone-hexane mixture. The steam jacket had been preheated to 250 F and was maintained at this temperature throughout the drying operation. The constant boiling mixture of similar composition but with less water than the extraction solvent distilled at 120 F which was the temperature of the agitating marc. A plastic doughy mixture containing 18% water remained. This was dried in the same way as for the water mixtures described previously. In some instances the blades of the mixer jammed as before unless alkali or acid was added. The behavior of the wet marc in presence of the added chemicals was quite similar to the watery mixture.

Figure 5 shows data for the aqueous mixture without added chemicals.

Figure 6 shows data for the acidic mixture. Figure 7 shows data for the alkaline mixture.

The granular meal discharged from the acidic and alkaline mixtures after drying had a moisture content of 8–10% and no odor of residual solvent.

Experiments were next performed on desolventizing and drying at atmospheric pressure. A charge of 8 lb of the same marc was treated with H_3PO_4 as in the previous example. This time, however, instead of applying vacuum to the chamber after removal of the volatile organic solvents by distillation, 2 lb of meal previously dried in the presence of added H_3PO_4 were fed back to the moist, plastic mass while stirring continued. In about 1 min the mixture granulated. Mixing was continued for 30 min while a gentle stream of air from an electric fan was passed over the agitating mixture. The dry meal was discharged as before and found to contain 9% moisture with no odor of organic solvent.

Another 8 lb batch of marc was treated with NaOH, desolventized and dried at atmospheric pressure in the same way, by adding 2 lb of alkali-treated meal to reduce the moisture below the critical tough plastic stage.

While the experiments described were performed to study the behavior of wet vegetable protein under mechanical processing conditions, the information obtained can be applied to large-scale oilseed protein processing. Desolventization of the meal is a necessary step in all oilseed extraction processes. Residual traces of solvent are an ever-present problem. In some commercial hydrocarbon solvent extraction methods the final meal is sparged with steam to sweep out these traces. In the experiments with aqueous-solvent-extracted raw oilseed meals reported in this paper, the sparging (or steam-distillation step) is coincidental with removal of added water in the drying operation. Conceivably the information which may be derived from the data reported here could be useful in planning research on larger-scale experiments in oilseed processing. For example, after a brief time of residence of the solvent damp meal in agitative distillation equipment, the granulated water-damp meal could be further dried in conventional rotary, screw or belt-type drying equipment normally used commercially for such purposes (4). Commercial mixers of the type described in the foregoing are available in sizes which will handle up to nine-ton batches.

REFERENCES

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3. King, W. H. and V. L. Frampton, JAOCS, *38*, 497–499 (1961).
4. Sloan, C. E., "Drying Systems and Equipment," Chem. Eng., *74*, (No. 13) 169–200 (1967).

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• *New Literature*

A new bulletin, "Industrial Applications of Microwave Energy" is available from the Varian Industrial Microwave Operation. The bulletin is a compilation of five papers presented at the Varian Industrial Microwave Seminar held recently. The papers discuss microwave applications in the food and pharmaceutical, plastics, wood, paper, and chemical fields. The bulletin has over 100 pages of information on current and future uses of microwave energy in the processing industries. Copies can be obtained from Marketing Manager, Varian Industrial Microwave Operation, 301 Industrial Way, San Carlos, California 94070.

Infotronics Corporation now has an 8-page brochure on its new CRS-160 Digital Readout System for Mass Spectrometry. The brochure explains how the system works, showing block diagrams, printouts, and detailed information on each instrument section. The CRS-160 is an economical direct printout system that can be used with all mass spectrometers, regardless of type or model. It offers accurate, continuous, on-line printout of both ion current (6 digits) and mass number (5 digits). For more information: J. M. Cotton, Vice President, Marketing, Infotronics Corporation, 7800 Westglen, Houston, Texas 77042.

A new two-page Technical Bulletin TS-6882 "Kelecins, F, P, and 1081 Fluid, Plastic and Water-Dispersible Lecithin Surfactants" has been issued by Spencer Kellogg Division of Textron Inc. It describes a mixture of soybean organic phosphatides and triglycerides having unusual surface active properties in paint, food and industrial uses. Formulation suggestions are made as applicable to solvent and water-thinned paints and food additives. Copies of TS-6882 may be obtained from Spencer Kellogg Division of Textron Inc., 120 Delaware Avenue, Buffalo, N.Y. 14240.

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