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ELECTRO-ACOUSTIC DEWATERING (EAD) A NOVEL APPROACH FOR FOOD PROCESSING, AND RECOVERY

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ABSTRACT

Separation of liquids from fine particle suspensions plays an important role in many industrial processes. In the past few years a number of technologies have been developed for the separation of slurries with coarse particle suspensions and intermediate particle sizes. However, separation of fine particles from their suspensions can be difficult and prohibitively costly.

Battelle has developed a solid/liquid separation technology that utilizes differences in electrokinetic and acoustic properties to enhance the efficiency of conventional solid/liquid separation techniques such as vacuum filters or presses. This method can dewater colloidal stable suspensions better than conventional techniques. Typical applications of this technology to food processing will be presented. Mechanisms involved during separation will also be discussed.

INTRODUCTION

The food processing industry handles many solid-liquid suspensions that are difficult to dewater employing current mechanical dewatering equipment. This often leads to increased reliance on energy intensive thermal drying operations. Also, in many instances, it means poorer resource utilization and/or more troublesome waste disposal.

Under a cost shared program with US DOE and several members of food processing industry, a comprehensive development program is being carried out on the application of EAD to food processing. The initial phase of the two-phase program has been completed. This paper presents and discusses key food applications data for EAD based on batch, continuous and bench scale investigations.

Dewatering refers to removal of water from a product without a phase change in the associated water. Dewatering is sometimes referred to as "Post-filtration" process(1) where the water held between the particles or within pores can be removed by applying an external body force (d.c. electric, sound). The application of pressure or vacuum in filters can be considered as boundary forces.

In considering the dewatering phenomenon it is important to identify different types of water associated with a solid particle such as:(2)

- Bulk or free water
- Micropore or capillary bound water
- Chemisorbed or monomolecular layer adsorbed water.

Figure 1 shows the types of water associated with a solid particle.

The success of the dewatering process depends upon the relative amount of the above types of water associated with the solid particle present in the suspension. For example, water in a typical colloidal suspension may be present in following ratio:

- Bulk water - 40 percent
- Micropore water - 40 percent
- Colloidal water - 10 percent
- Chemisorbed water - 10 percent

Dewatering technology in the food industry has relied on solid-liquid separation equipment that removes bulk water such as vacuum filters, centrifuge or belt presses. Major advances in this technology in recent years have been related to the use of filter aids, surfactants, or other additives in conventional systems to remove additional water. Although both electrically and acoustically enhanced techniques are known, only limited commercial applications have been developed using these techniques.

Electro-acoustic dewatering technique (EAD) combines d.c. electrical and acoustic fields in the presence of a vacuum or pressure to promote synergistic effects(3). The principles and mechanisms of electric, acoustic and electroacoustic dewatering have been discussed in detail elsewhere.(4,5) A brief summary is provided below.

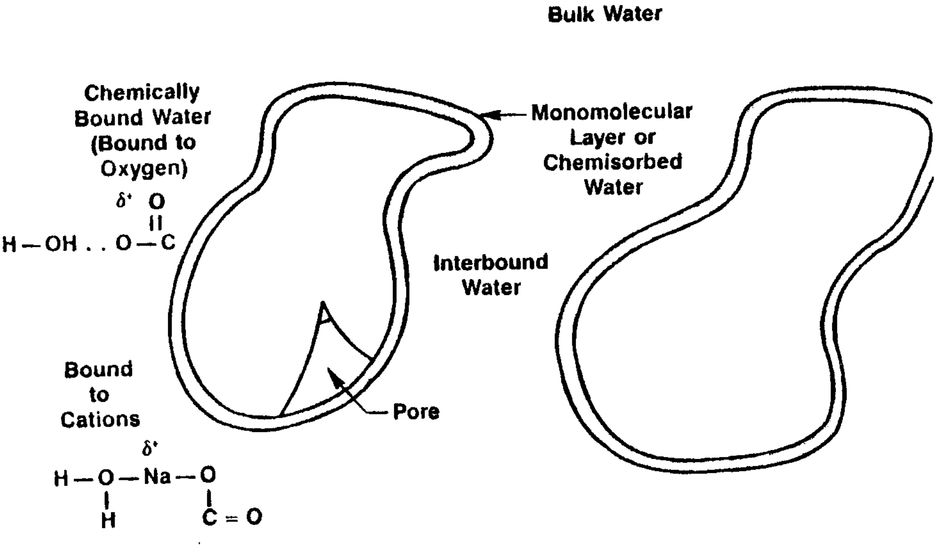

FIGURE 1. TYPES OF WATER ASSOCIATED WITH A SOLID PARTICLE(4)

Electroseparation

When particles are suspended in water, they carry a charge, generally negative. The mutually repelling effect of these charges keeps the particles dispersed and makes a suspension difficult to separate. When an appropriate electrical field is applied, one or more effects can be employed to achieve a separation. These effects include:

- Charge neutralization, which augments particle agglomeration;
- Particle movement from the filter electrode, which minimizes the filter blinding potential;
- Electro-osmosis, which greatly enhances the rate of water flow and ultimate removal.

When used alone, the electro-osmosis effect can be ineffectual; but, in combination with acoustics and the overall vacuum or pressure force, electro-osmosis becomes a major factor in dewatering.

Acoustic Separation

Sonic or ultrasonic is a mechanical form of energy that propagates as waves through a material. The cyclic inertial and elastic forces created by the acoustics can be very high because of phase (liquid, solid) impedance can differ by a factor of 3 to 8. These acoustical forces can overcome viscous and surface forces which promotes water movement from a particle and, hence, dewatering. Other acoustical effects include agglomeration and rectified diffusion and these also promote water removal.

Combined Effect

When applied in the correct combination, the electrical and acoustical phenomena can improve dewatering or phase separation because of the enhancement of water movement and flow. An important aspect is to remove the water in a bulk sense; otherwise, re-adsorption and re-adsorption will occur. Thus, EAD uses electro-acoustics in combination with conventional vacuum/pressure filtration to achieve higher rates and/or higher solids concentration. The combination of forces also contributes to phase and component transfer being proposed for hazardous materials applications.

METHODS

In this paper, basically two experimental methods are discussed namely, the application of EAD with vacuum and pressure.

Figure 2 is a schematic diagram of the batch dewatering apparatus which is made of pyrex glass. A cylinder 5 cm in diameter and 130 cm long is connected through a stainless steel grid B which acts as a filter disc to a Buchner funnel C where vacuum can be applied. The stainless steel grid B acts as an anode. The rubber gaskets seal the cell at the base. There is a moving electrode D which passes through the cap C. This electrode acts as the cathode. This is also made out of stainless steel. Electrical connections are denoted by + and -. Ultrasonic energy is applied by a suitable transducer and a wave guide (horn) designed for these experiments. The stainless steel cylindrical horn is immersed in the slurry to couple the ultrasonic energy directly into the slurry for dewatering. In this unit either pressure or vacuum can be applied.

A continuous unit bench scale EAD has also been used for dewatering a variety of food products and sludges. This unit has feed capacity of 10-20 lb per hour depending on the initial solids concentration of feed. This unit is designed to be operated similar to commercial horizontal vacuum filters with two endless belts serving as electrodes. A detailed description is provided elsewhere.(6)

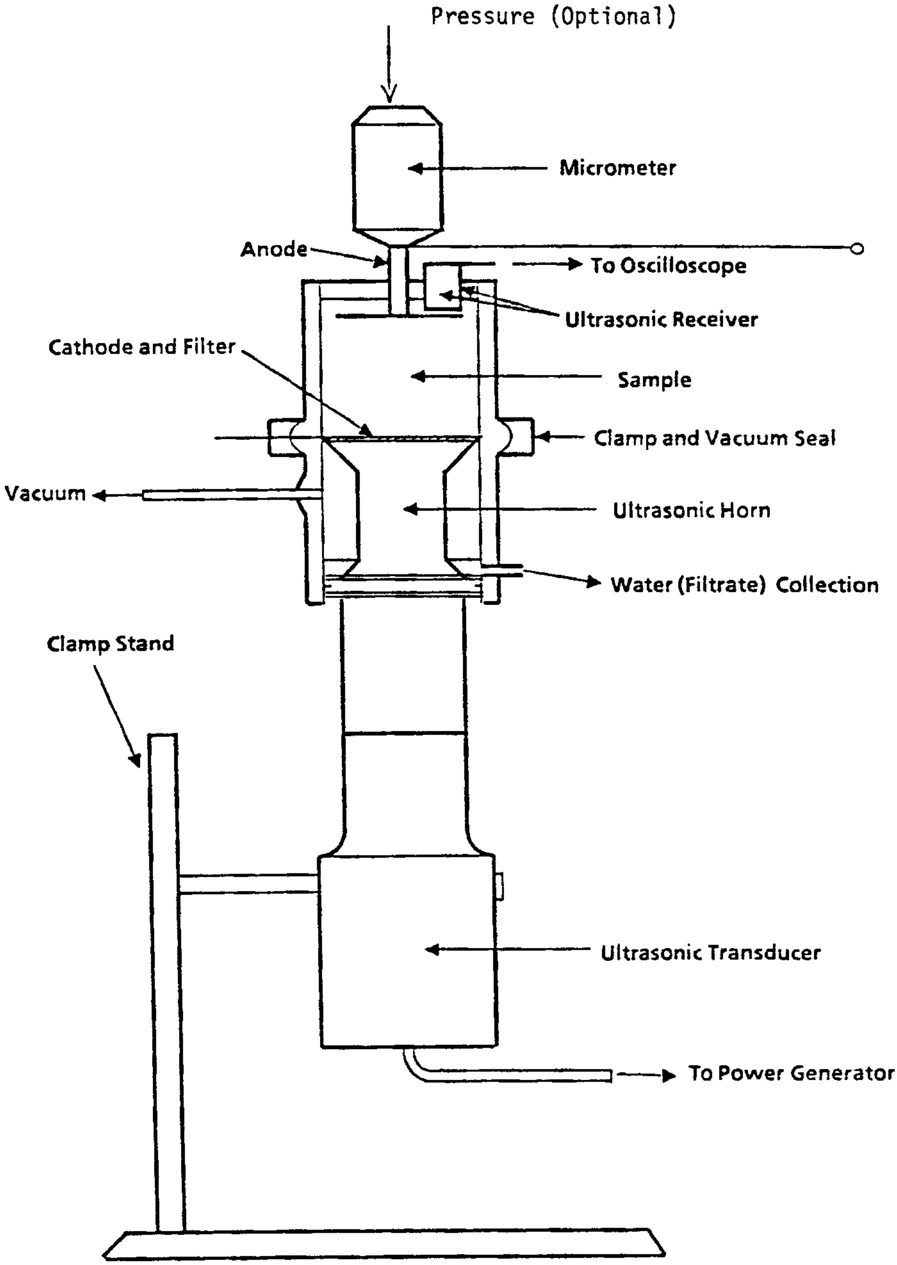

FIGURE 2. EAD BATCH UNIT (VACUUM OR PRESSURE OPTION)

TABLE 1

Material	Suspended Solids Type	Solids Content, wt% Initial	Conventional	EAD	Extra Liquid by EAD Over Conventional wt%(a)
Hydrolyzed vegetable protein	Colloidal	48.4	48.4	60.2	38
Corn gluten slurry	Colloidal	13.1	35	46.3	38
Starch slurry	Colloidal	2.1	2.1	18.4	90
Brewer's yeast	Colloidal	5	22	40	58
Corn fiber	Fibrous	8.8	27	58	73
Apple pomace	Discrete/fibrous	30.7	30.7	49.7	55
Sugar beets	Discrete/fibrous	23.1	23.1	26.7	18
Fruit sacs	Discrete	5.8	5.8	22	78
Coffee grounds	Discrete	22.0	22.0	34.4	46
Orange pulp	Discrete	16.9	16.9	26	42
				Average	54

(a) Expressed as a percentage of the liquid remaining in cake after conventional filtration.

RESULTS

Results of both vacuum EAD and pressure EAD investigations will be discussed in the following paragraphs. Under a cost shared program with US DOE and a number of members of food processing industry, a research program is being carried out on the application of EAD to food processing. The initial phase of the two-phase program has been completed. During Phase I 10 different food suspensions were tested and the overall results are shown in Table 1. This paper describes results of rice starch and corn products. Other results are described elsewhere.(5)

Results of Vacuum EAD Experiments

Rice Starch Slurry. The objective of dewatering rice starch slurry was to reduce the suspended solids content of the filtrate so that filtrate could be used in process water. Rice starch slurry is a colloidal suspension and very difficult to dewater by conventional techniques.

Batch dewatering tests were conducted on a sample of rice starch slurry. The initial solids content of the prepared slurry was in the range of 1.08-3.03 percent.

Figure 3 shows the variation of solid content after dewatering with ultrasonic power in the presence of 20 v electric field. In these series of tests ultrasonics was applied at the beginning of 2 minutes until the end of 7.5 minutes experiment. The application of 7.5 watts ultrasonic power increased the solids content of the cake to 16 percent, while the application of 10 watts gave 11 percent solids compared to 8.2 percent in the control experiment. These results clearly suggest that it is important to understand the ultrasonic mechanisms before one applies it. In this case, the results demonstrate that higher power levels disrupt the cake structure formation and hinder the dewatering efficiency by electro acoustics. The results also suggest that there are certain optima and one has to give careful thought to understanding the mechanisms before choosing a set of experimental conditions.

Energy Requirement For Rice Starch. The energy requirement for dewatering the rice starch slurry described above is shown in Figure 4. Based on the curve, the energy required to remove a pound of water from an initial 2.0 percent solids to 10.0 percent is about 0.025 kwHr. At this level about 82 percent of liquid is removed.

Corn Gluten Slurry. Corn gluten slurry is one of the products of corn wet milling. A sample of the corn gluten slurry had an initial solids concentration of 13.01 percent. The corn gluten slurry is a colloidal, low conductivity slurry with high zeta potential values. Figure 5 shows the synergistic effect of combining electric and ultrasonic field. The data shows the variation of solid content as a function of dewatering time in minutes.

The results confirm that the rate of dewatering and solid content increase with simultaneous application of electric and ultrasonic field. For example at 6 minutes with a vacuum field, a cake with about 34 percent solids was achieved. However, in the presence of electric and ultrasonic fields and vacuum, the solid content increased to 46 percent and, simultaneously, rate of filtration increased by about 2.4 times.

Effects of Ultrasonic Power With Corn Gluten. Figure 6 shows the effect of ultrasonics at different power levels on the rate of filtration when dewatering the corn gluten slurry. The ultrasonics was always applied in the presence of vacuum and electric field.

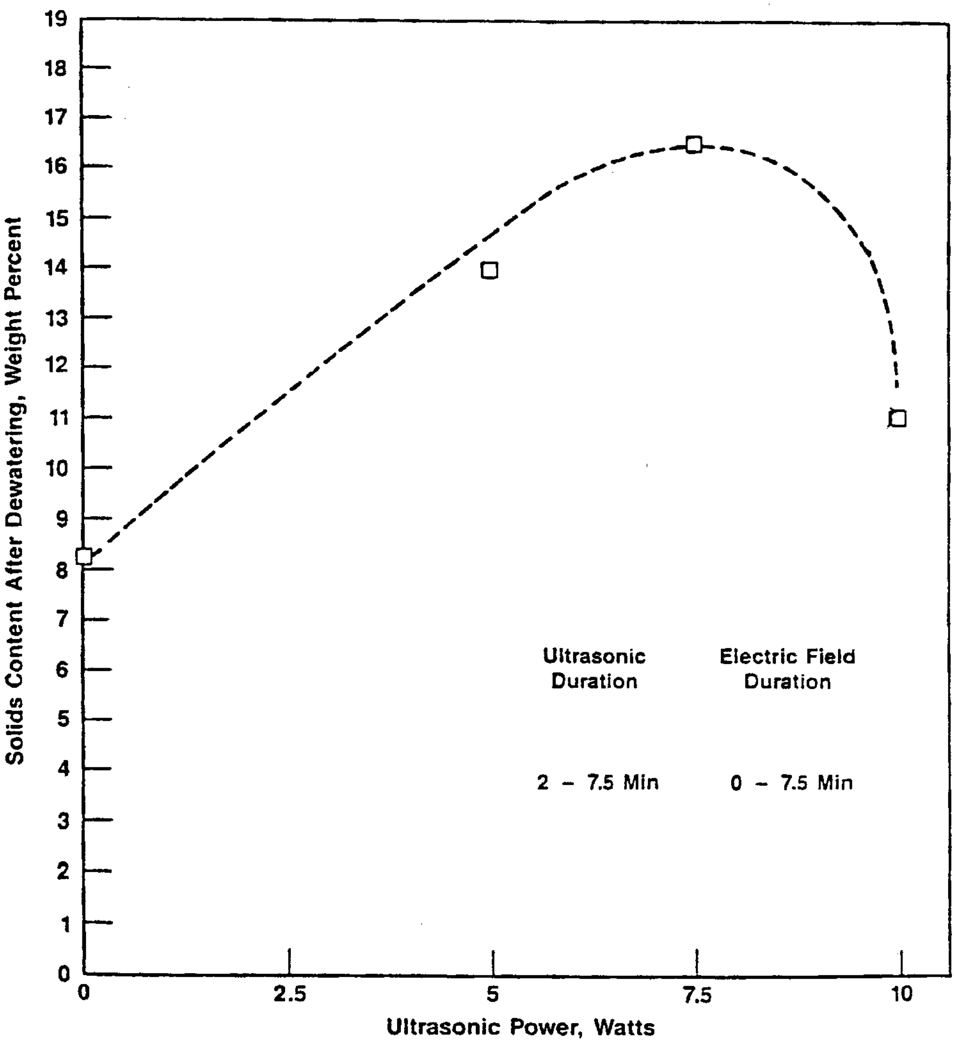

FIGURE 3. EFFECT OF ULTRASONIC POWER AND DURATION OF APPLICATION ON PERCENT SOLIDS FOR RICE STARCH SLURRY [2.1 percent solids in feed; 15-in. (Hg) vacuum].

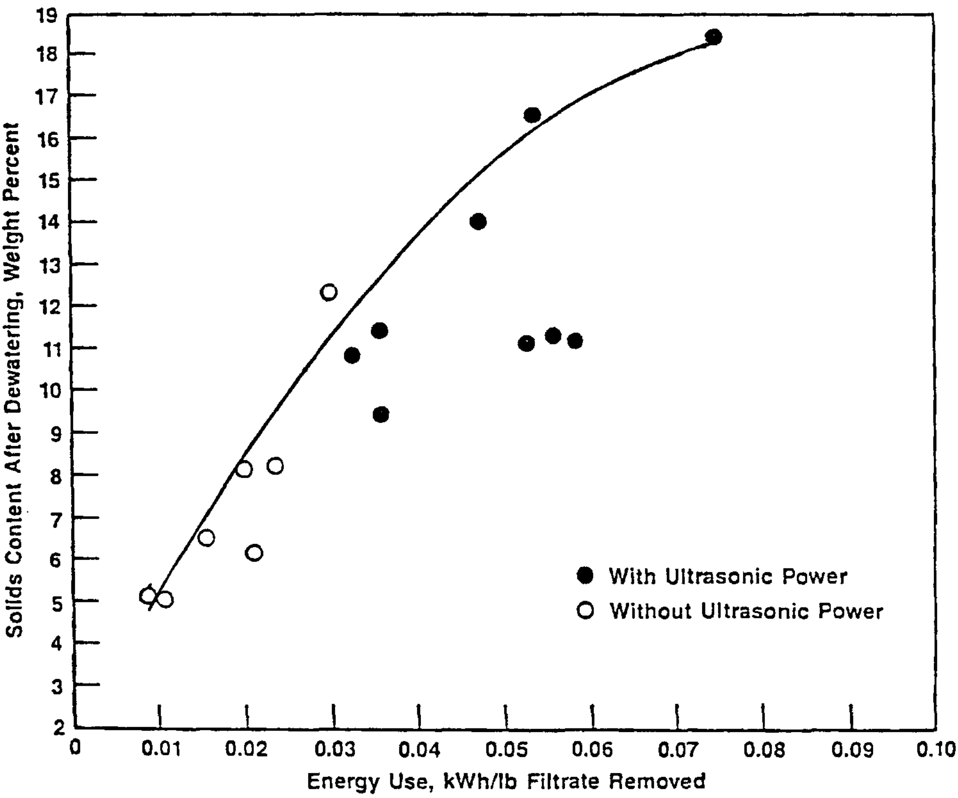

FIGURE 4. ELECTRICAL ENERGY USE FOR VACUUM BATCH EAD OF RICE STARCH SLURRY (2.1 percent solids in feed)

The solids content did not change significantly, however, the filtration rate increased from 5.3 to 5.9 lb/hr. sq. ft. in the presence of 25 watts ultrasonic power. The above tests were conducted in a continuous EAD device (20 lb/hr. feed) described earlier. Typical EAD performance of other food suspensions tested is reported in Table 1.

<u>Comparison of EAD to Other Corn Gluten Processes</u>. The corn gluten slurry typically consists of 8-10 percent solids. It is currently dewatered with rotary vacuum filters or solid bowl

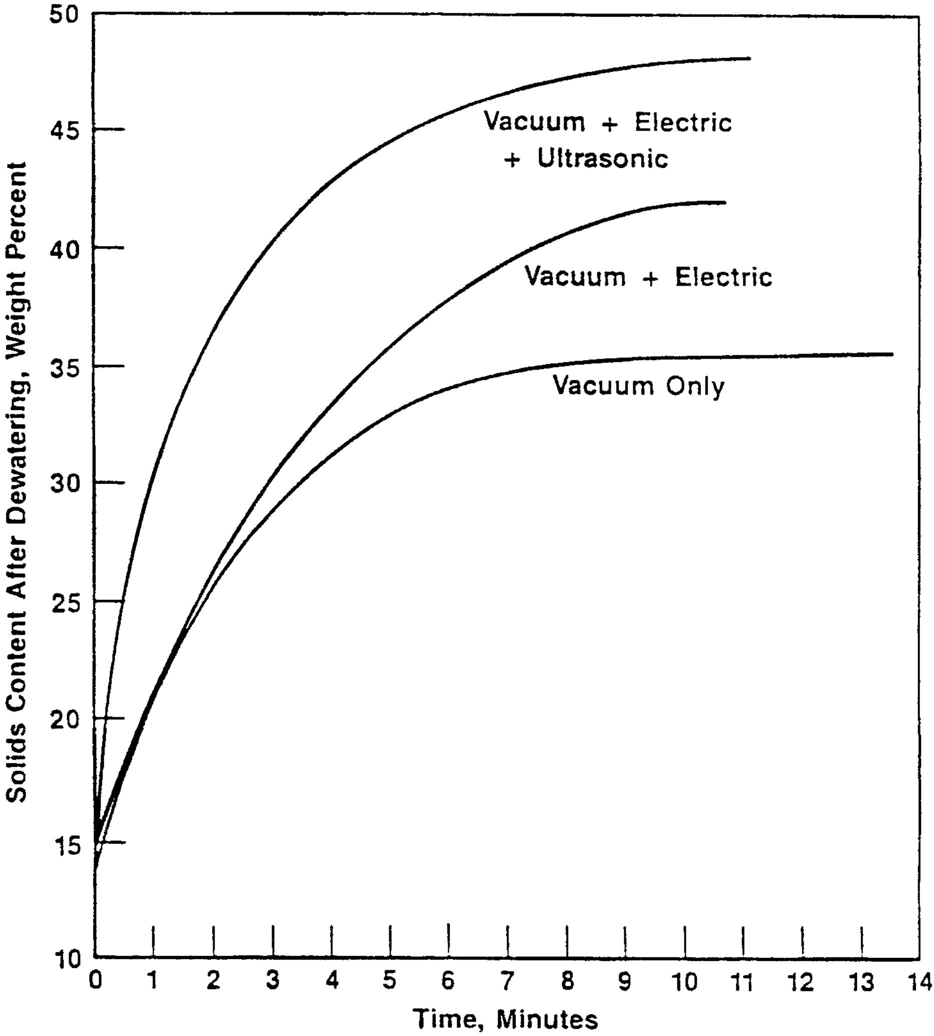

FIGURE 5. SYNERGISTIC EFFECT OF COMBINING ELECTRIC FIELD AND ULTRASONIC FIELD WITH VACUUM DEWATERING OF CORN GLUTEN SLURRY (13.1 percent solids in feed).

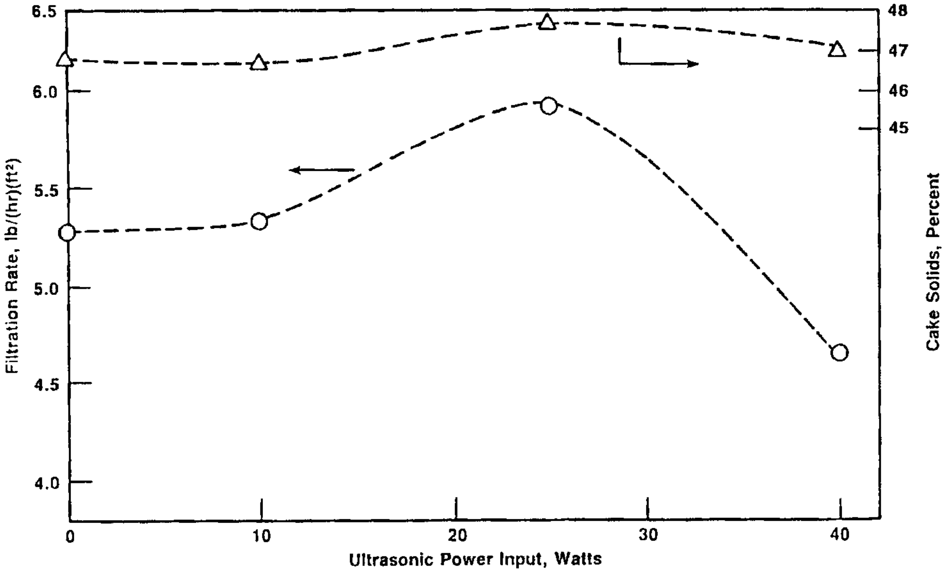

FIGURE 6. VARIATION OF FILTRATION RATE AND PERCENT SOLIDS WITH INPUT ULTRASONIC WATTS FOR CONTINUOUS CORN GLUTEN (2.7 percent solids in feed)

centrifuges to about 30 percent solids. In Battelle's tests, 35 percent solids was achieved with vacuum only which compares well to industrial results. But with EAD, solids content level as high as 45 percent was achieved. These comparisons are shown in Figure 7.

Energy Requirement For Corn Gluten. The specific energy requirements for EAD of corn gluten slurry as a function of weight percent solids is shown in Figure 8. The curve drawn shows the energy used under a preferred set of conditions tested. Based on experimental data, the energy required to remove a pound of filtrate from an initial 13 percent to 45 percent solids is approximately 0.015 KWHr (150 BTU) compared to thermal (evaporative drying) energy requirements of 0.15 - 0.25 KWHr (1500-2500 BTU) to remove a pound of water.

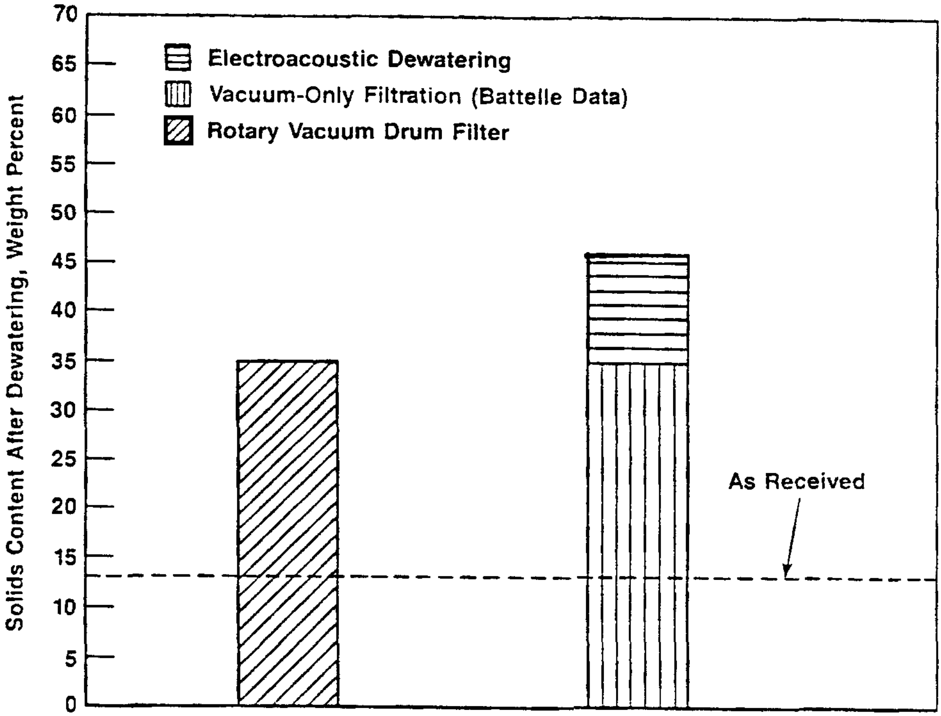

FIGURE 7. COMPARISON OF PERFORMANCE OF EAD PROCESS WITH OTHER SOLID-LIQUID SEPARATION PROCESSES FOR CORN GLUTEN SLURRY (13.1 percent initial solids, Batch EAD data)

Results of Pressurized EAD Experiments

Corn Fiber Slurry. At the present time, screw presses are utilized in the industry to dewater a corn fiber slurry. Typically a solids concentration of about 38 percent is achieved. Hence, experiments were performed in pressurized dewatering equipment described earlier. The variation of solids content as a function of dewatering time is shown in Figure 9. The results clearly indicate that a combination of electric and ultrasonic fields in the presence of pressure was always better than either electric or ultrasonic field alone in the presence of pressure alone. For example, at 60 seconds with 25 psig pressure alone, the solids content achieved was 27.5 percent. However, under the same condition, in the presence of ultrasonic and electric fields, the

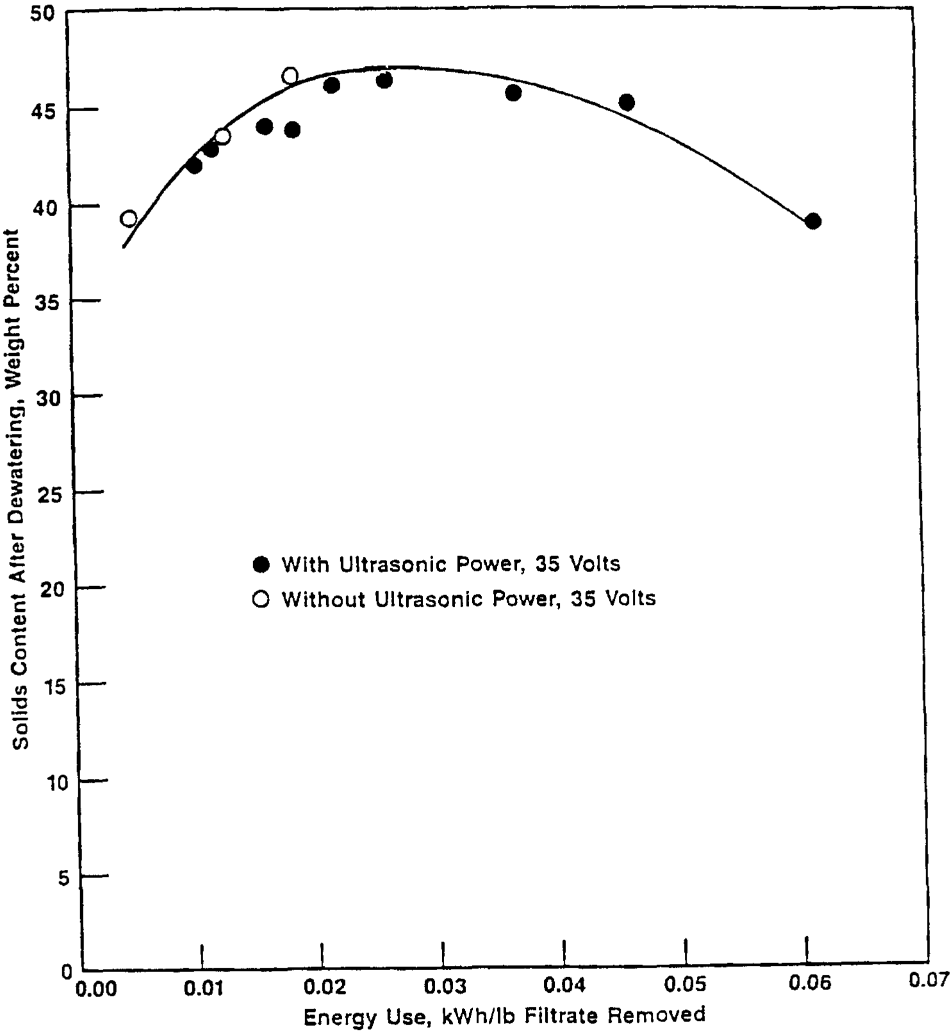

FIGURE 8. ELECTRICAL ENERGY CONSUMPTION FOR VACUUM BATCH EAD OF CORN GLUTEN (13.1 percent solids in feed)

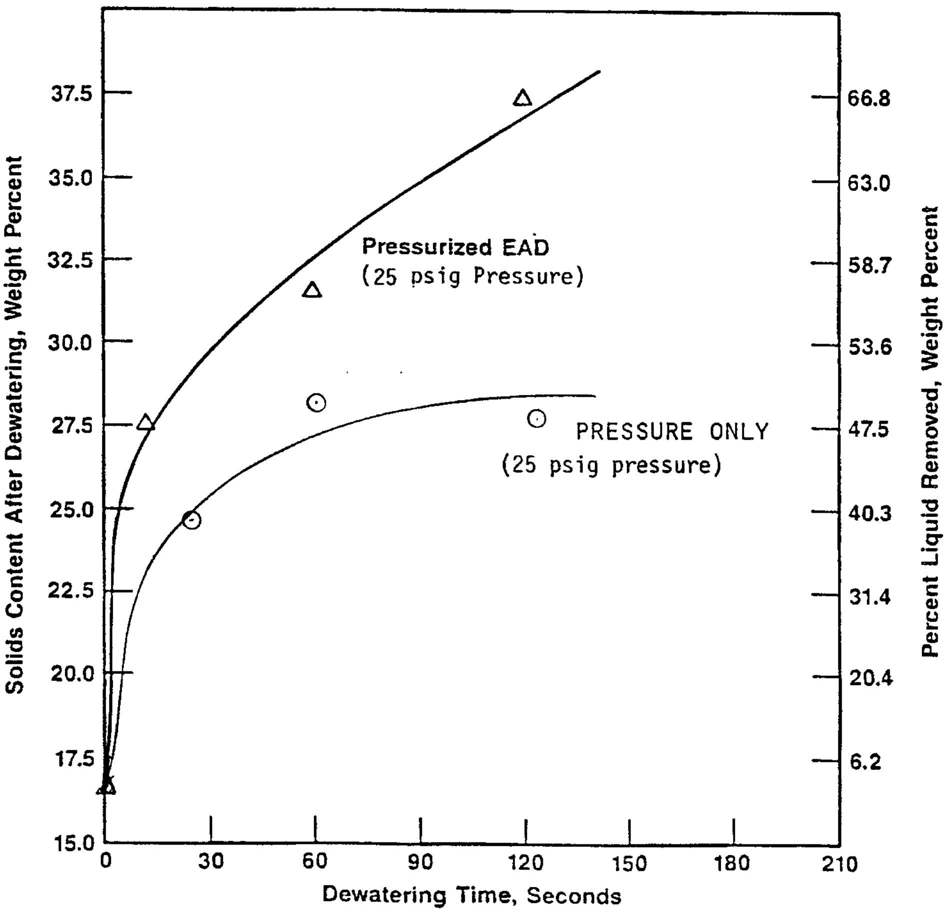

FIGURE 9. EFFECT OF DEWATERING TIME ON SOLID CONTENT OF PRESSURIZED DEWATERED CORN FIBER SLURRY (16.6 percent solid in feed)

solids content achieved was 32 percent. However, it should be mentioned that the extra amount of liquid removed was about 20 percent.

Process Scale Up

At the present time, the EAD process technology is being scaled up at a proof of concept demonstration scale. Specifically, EAD has been adapted to two small commercial units, a screw press and a belt-press. These units are designed to handle feed capacities of about 10-100 tons/day. These EAD retrofitted units will be tested from November, 1987 thru the first half of 1988 for food applications.

CONCLUSIONS

The above results indicate that the Electroacoustic Dewatering (EAD) process can be successfully applied to different types of suspensions having varying properties including physical, chemical and electrokinetic. The EAD technology has many benefits which include:

- Synergistic effect of electric and ultrasonic fields in the presence of vacuum or pressure which results in lower energy requirements and higher product recovery.
- Higher solids concentration is achievable which reduces or can eliminate thermal drying requirements thus resulting in energy conservation.

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