DESIGNING A FREEZE-DRYING PLANT-SOME ECONOMIC CONSIDERATIONS*

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How much investment is needed to get into freeze-drying? How complex is freeze-drying? What products appear to have the greatest potential? What markets seem important for freeze-dried foods? Questions such as these are constantly being referred to the Department of Agriculture. This talk supplies some answers.

Let's first look at freeze-drying's past, outline some general principles, and examine the process, products, and present volumes. Then, we shall discuss business considerations. We end up with an overall appraisal of industry prospects.

The whole dehydration industry, of which freeze-drying is but a small part, has been growing more important. Until recent years, food drying was used only during wars or national emergencies. Now, however, a wide assortment of dry foods are currently stocked on grocers' shelves. These are of a quality suitable for peace-time use.

Although freeze-drying has been used experimentally for drying food since the late 1930's, it was not until the late 1950's that commercial freeze-dried products were available. In that two decade interval, a significant development included lowering of drying time. Along with increased efficiency, quality of freeze-dried foods showed corresponding improvements. Packaging, one of the major bottlenecks, has constantly improved.

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Principles, Process and Products

Freeze-drying is removal of moisture from frozen food through a combination of vacuum and heat without allowing the frozen food to melt. 1/

The major processing steps involved in freeze-drying include: (1) Food preparation. This may include cooking, eliminating inedible portions such as bone, fat, and skins. Also involved is getting the right particle size by slicing, dicing, powdering, or making into a sirup or slurry. Large or irregular-size pieces of food are difficult to freeze-dry. (2) Freezing. Almost always foods to be freeze-dried are frozen outside the drying cabinets. For some foods it is possible to vacuum-freeze or plate-freeze inside the drying chamber. (3) Drying. At present, frozen foods are placed in trays which are then inserted on racks in the cabinet. Cabinets are designed so that heat is close to each food particle. At the same time, pressure within the cabinet is lowered to one millimeter or less, Hg., absolute. Temperatures may be 250°F at the beginning of the cycle and later taper down to 120°F so the product does not burn. Drying takes about 8 to 30 hours. The food is dried to about two percent moisture. The cabinet is finally back-flushed with nitrogen to prevent re-entry of oxygen and moisture into the dried food. (4) Packaging. A final step in freeze-drying is placing the food into an air-tight, moisture-proof, light-proof package. Generally, packages are nitrogen-gassed to prevent oxidation during storage. This is particularly important for items such as meats that are high in fat.

If processed and handled correctly, freeze-dried foods have a good shelf life. Some food processing companies require a two-year, 70°F shelf life, and this is now achievable with many freeze-dried foods. 2/

1/ To be successfully freeze-dried, it is essential that the product not melt. Thus, the critical temperature is the eutectic temperature which is the lowest melting point. Eutectic temperatures vary with different products. For example, full strength orange juice may melt at 28°F while orange juice concentrate of 58°Brix may melt at 0°F. Foods with low eutectic temperatures are difficult to freeze-dry since this requires careful handling and pressures as low as 500 microns. For foods with a eutectic temperature of 0°F, it is of value to have the drying cabinet equipped with refrigeration coils to maintain low temperature while loading and lowering the pressure.

2/ A rule of thumb is that 18°F is equivalent to halving or doubling the shelf life. Thus, two years at 70° equals one year at 88° or four years at 52°. All dried foods have a much longer shelf life is the temperatures are lowered.

Major foods now being freeze-dried for the commercial market are meats and vegetables for soups, shellfish, coffee, tea, berries and fruits for cereals, and mushrooms. The armed forces buy for regular mess and for specialized uses as combat rations and space flights. Other specialized uses are for camping, and for ingredients in remanufacturing. New products include chives, cottage cheese, peaches, strawberries, and ice cream.

Volumes--Present and Future

In the United States, 11 plants are in operation. Canada has several. In Europe and the rest of the world, there are 20 to 25 plants. Most are now fairly small, compared with freezing or canning plants--but a few are of economical size.

1963 volumes in the United States were about 11 million pounds (frozen food equivalent). By 1970, United States volumes will be at a level of 250 million pounds and over 40 plants will be in business.

As of this date, there are about 50 or 60 freeze-dried foods on the market. More are being developed each month.

Business Considerations

A business man investing in freeze-drying would be especially interested in amount of capital needed, products, processing costs, source of raw material, market, type of package, source of power, location of plant, length of processing season to expect--and finally his chances of success and probable rate of return. I cannot answer all of these questions, although we have information on costs, investment needed, and markets.

Investment in a freeze-drying plant will vary from $300,000 upwards to $2 million. 3/ The first figure, $300,000, will equip a small unit having a capacity of about 8,000 pounds of water per day. This plant would have 2,000 square feet of shelf area composed of four 500 square foot cabinets. Included would be the drying equipment, material handling equipment. Extra equipment would be needed for packaging and food preparation. Steam boilers would not be included in the estimate. Nor

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3/ Figures quoted pertain to equipment for a production plant. Laboratory model sublimators may cost $3,000 to $7,000 for one square foot of shelf area model. Laboratory sublimators of three square feet (7 liter capacity) may cost $5,000 to $8,000. 12 square foot models range in price from $10,000 to $15,000. Prices vary with controls, instrumentations, accessories, and capacity.

would there be provision for refrigeration equipment for freezing the food. Refrigeration for sublimators is included.

A $2 million plant, eight times larger than the one described above, has a capacity of extracting 32 tons of water per day. In neither example would these dollar investments be large enough to put the two plants in operation. Additional capital would be needed for labor payroll, frozen food used as raw material, packaging supplies, finished product inventory, and product promotion. A minimum-sized operation might be financed the first year for $200,000 to $300,000, in addition to the above quoted investment in plant. Clearly, an optimum-sized freeze-drying plant cannot be built and operated on a "shoestring." These statements may sound overly cautious, yet economies are possible. For example, a freeze-drying operation must be installed in a freezing plant. In a set-up such as this, the freeze-drying operations may buy refrigeration and heat and may also lease building and office space. As a consequence, it could save considerably on investment. Steam, if available at a low cost, may be used for vacuum pumping as well as for heating the plates.

In calculating freeze-drying equipment investment for a 4-ton-per-day plant, we may use $150 per square foot of shelf area. An 4-ton-per day plant would have its shelf area requirements calculated as follows: If this plant were capable of evacuating 8,000 pounds of water per day, volume of frozen chicken input product is 13,063 pounds. 4/ This assumes 62

4/ J. P. Ottenheimer, Plant Manager of Armour's Concentrated Foods Dept., suggests this method for calculating input weight.

W = Wet weight
62% moisture of frozen chicken
2% moisture of dried chicken
.62 W = Water fraction
.38 W = Solids fraction

1.02 x (.38 W) = Total weight of dried chicken including 2% water
Water removed is W - (1.02 x .38W)
W - (1.02 x .38W) = 8,000 lbs.
W = 13,063 lbs.

With 13,063 pounds of frozen food and 8,000 pounds of water removed, we end up with 5,063 pounds of dried weight of which 101 pounds is water.

An article useful in understanding dryness of freeze-dried foods is "Freeze-Drying: With or Without Vacuum" by John P. O'Meara of the Vacudyne Corp. in the Sept. 1963 issue of Food Engineering. This article points out that in a product such as mushrooms with 90 percent initial moisture content drying to two percent is not complete until 99.77 percent of the initial water is removed.

percent moisture in the frozen food and two percent moisture in the dried food. Assuming an eight hour drying cycle, this 13,063 pounds of food to dried equals 4,354 pounds per eight-hour drying cycle. If we load $2\frac{1}{2}$ pounds of frozen meat per square foot of shelf area, 1,742 square feet of shelf area are required. Most cabinets manufactured today contain 500 square feet of shelf area so four 500 square foot cabinets are needed. Our 2,000 square feet of shelf area multiplied by $150 per square foot means an investment of $300,000. In this example, we have designed a plant with about 15 percent more shelf capacity than is needed.

If freezing equipment is available and need not be purchased, we may lower the investment needs as follows: It takes approximately 10 tons of refrigeration to sublimate 100 pounds of food per hour. Our input of 13,063 pounds per day equals 544 pounds per hour. A Freon 22 or equivalent refrigeration system costs about $1,400 per ton, so sublimation refrigeration needs of 54 tons would cost $76,000. 5/ By not purchasing sublimation refrigeration equipment, equipment investment would be lowered by this amount to $224,000.

We may also calculate building investment. A well-equipped air-conditioned building used for food processing may cost $15 per square feet of floor space. A freeze-drying plant of a size to handle 13,063 pounds of frozen chicken per day would require about 3,000 square feet, giving an estimated building cost of $45,000.

Materials-handling equipment for this size plant would probably be $3,000. The 100 tons of refrigeration equipment for freezing the food would cost about $14,000.

Other investment costs may be calculated, but are not done here. Chicken eviscerating, cooking, deboning, dicing, and supplementary equipment are examples of additional investment needs. Packaging equipment would be extra, too.

Number of hours per year a plant operates is important to costs. A medium-sized plant drying chicken has costs of 6.1 cents per pound of water removed, operated 250 days per year. Operated only 100 days per year, that same plant shows costs of 10.8 cents per pound of water removed. A larger, more completely mechanized, plant has even more reason to run continuously. A new plant should operate at least 100 days its first year in business. In its second year of operation, it should have a potential of operating 200 days. During its third year it should anticipate running at full capacity of 250 24-hour days. Days a plant actually runs depends on capacity of the plant, the market it has for its dried products, and many other factors.

5/ I am indebted to Lucien St. Onge of the Patterson-St. Onge Co. of York, Pa. for help with refrigeration cost estimates.

What can be done to keep a plant operated at capacity? First, the plant should be designed to be of a size that can be operated almost continuously in accordance with the volume of product that can be marketed. It is not economical to build a large plant and then run it part-time. For instance, if it were anticipated that 10,000 pounds of food were to be dried per day, the ideal plant would be one designed to dry exactly 10,000 pounds per day. A 20,000 pound per day plant run a half capacity would not have costs so low as the 10,000 plant run at full capacity. To keep a plant running at full capacity per day and per year, it may be necessary to have several products each of fairly large volume, or to have a large number of products of smaller volumes. Both methods are commonly used today.

How complex is freeze-drying? Food materials with a high degree of perishability are processed in freeze-drying plants. Slight differences in operating temperature, pressures, and cycle times may spell the difference between the production of an acceptable product and one unpalatable or hard to rehydrate. Equipment now being designed and used may be suitable for some food but completely unsuitable for others. Freeze-drying is a complicated process. Therefore, management and technical help of a high caliber are needed.

A 4-ton-per-day plant would be expected to use about 11 full-time workers, and a 32-ton-per-day plant would have about 22 full-time workers. In addition, there would be several salaried workers including managers and secretary-clerks.

Markets for the Products. An important question concerns what products may be freeze-dried. In general, any food that freezes well, will freeze-dry. Foods high in fat or sugars are difficult to freeze-dry because they freeze poorly. Foods such as melons and cucumbers freeze, but because of their loose physical structure they will not easily rehydrate back to their original form.

At present, the largest single buyer of freeze-dried foods is the Quartermaster Corps of the U. S. Armed Services. I would guess the Quartermaster Corps takes 15 to 25 percent of current production. However, the largest market is the institutional one. Second is the remanufacturing market. I am referring to the sales of dried food to food processors who combine them with other ingredients to make dried soups, dried stews, dry cereals, and mixes. The government market is third in importance, and probably the camping market is fourth. The retail grocery market has not developed to any degree, and at the moment I can think of only a few items on retail grocery shelves. Chives are now sold on the West Coast. Mushrooms have been market tested, as have strawberries in corn flakes. Cottage cheese and one or two other dairy products have been tried. In May of 1964, a prominent coffee company will be testing its freeze-dried instant blend. All other items sold in retail grocery stores have been sold as mixes. These are creole, four brands of dried soups, and several stews. The nationwide retail grocery market is difficult to assess and expensive to break into with new brands and unusual products. Most freeze-dry processors are understandably cautious about tackling it. —

What are the chances of success? Only one freeze-drying plant has gone out of business in the U. S. and Canada. Until about six or eight months ago, however, personnel in many of the drying firms felt that business was slow in developing. During the last half of 1963, I noted a feeling of optimism among freeze-dry processors. Most now have enough business to keep their facilities working around the clock, and anticipate a steady volume during the next year. 6/ Two new plants are being constructed in this country, and abroad there are probably four or five under construction. This current note of optimism does not imply that chances of success are good. It does mean, however, that business is picking up. Freeze-drying is still new enough to be considered risky. I made a prediction several months ago that freeze-drying would achieve a volume of 250 million pounds in 1970. From what I have seen since, I see no reason to change that prediction.

An overall prediction. Freeze-drying, as a developing industry, has a future that looks promising. I look upon this food dehydration method not as a large volume food processing method replacing or competing with canning, freezing, spray-drying, or roller-drying. I don't anticipate huge volumes for any particular food items although results of the tests on strawberries and coffee may make me reconsider. I do forsee fairly substantial output of some products and feel the technique is applicable for many foods where a dried food is needed and where a better quality than presently available dried food is indicated.

6/ In introducing a new product on the national market, a considerable part of this initial volume fills the "pipeline of the market." Sometimes this large beginning volume leads food processors to feeling the market is larger than actually exists.

Freeze-Drying Equipment

The following list includes manufacturers in the U. S. and Canada listed alphabetically with no attempt at classification. Several European firms manufacture freeze-driers, and some have U. S. representatives. Designation of manufacturers does not imply recommendation--mention means only that these particular firms would likely be satisfactory, but other equipment sources may prove equally good.

AMERICAN INSTRUMENT CO.
8030 Georgia Ave.
Silver Spring, Maryland
Jerry Scott, Sales Mgr.
Design, mfg. lab. and pharmaceutical sublimators

AMERICAN STERILIZER CO.
2424 W. 23rd St., Erie, Pa.
James J. Wingenback, Sales Mgr.
Design, mfg. sublimators

CHEMET ENGINEERS, INC.
2560 E. Foothills Blvd.
Pasadena, Calif.
C. N. Sjorgren, Pres.
Design, mfg., install complete line of sublimators

DEL-VAC ENGINEERING
461 N. Eucalptus Ave.
P. O. Box 722, Inglewood, Calif.
John E. Baling Jr., Pres.
Design, mfg., install sublimators

DRESSER VACUUM DIV., Dresser Indus.
P. O. Box 111, 150 "A" St.
Needham Heights, Mass.
H. A. Herzig, V. P.
Design, mfg., install Leybold equipment in North America

EDWARDS HIGH VACUUM, INC.
3279 Grand Island Blvd.
Grand Island, N. Y.
Represents Edwards High Vacuum, Ltd. In U. S.

F. J. STOKES CORP.
5500 Tabor Rd., Phila. 20, Pa.
John Maguire, Mgr., Food Equip. Div.
Design, mfg., install complete line of sublimators

FMC CORP., Central Engr. Lab.
P. O. Box 580, Santa Clara, Calif.
Design, mfg., install complete line of sublimators

FREEZE-DRINAMICS SYSTEMS, INC.
6920 Melrose, Los Angeles 38, Calif.
William R. Ulrich, Pres.
Design, mfg., install sublimators--sale or lease

FREEZE-DRY PRODUCTS, LTD.
224 Merton St.
Toronto 7, Ontario, Canada
J. E. Margison, Pres.
Design, mfg., install sublimators

HULL CORP.
Hatboro, Pa.
Lewis Hull, Pres.
J. H. Leary, Sales Mgr.
Design, mfg., install sublimators

J. P. DEVINE MANUFACTURING CO.
49th St. & A.V.R.R.
Pittsburgh, Pa.
G. R. Cox, Pres.
Design, mfg., install sublimators

RePP INDUSTRIES
Route 208, Gardiner, New York
T. N. Thompson, Adm. Ass't.
Design, mfg. pharma., lab. sublimators

VACUDYNE CORP.
375 E. Joe Orr Rd.
Chicago Heights, Ill.
Fred Lindstrom, V. P.
Design, mfg., install complete line of sublimators