QUICK-COOKING DEHYDRATED POTATO PIECES PRODUCED BY AN EXPLOSIVE PUFFING PROCESS

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Nearly 30 percent of the potatoes used for food are now sold in processed form. Although potato chips and frozen French fries constitute the lion's share of processed potato products (43 percent and 36 percent, respectively, for the 1963 crop), dehydration accounts for about 16 percent of the total. Dehydrated products include instant mashed potatoes and diced or sliced pieces for use in a variety of products such as hash brown potatoes, au gratin, scalloped, salad mixes and canned hash and stews. Production of dehydrated potato products has not expanded as rapidly as production of frozen potato products but a great potential exists for continued growth of dehydration as well as for freezing, particularly in the Pacific Northwest. Dehydration minimizes the competitive disadvantage of shipping either fresh potatoes or processed products containing substantial quantities of water to distant points of consumption. Quality and consumer acceptance, of course, are considerations of primary importance in expanding the sales of any product.

Food consumption patterns during the past 10 years have shown increasing emphasis on "convenience," "ready-to-eat" and "instant" qualities for new products. Modern military feeding developments have shown even greater emphasis on food products that do not require refrigeration and which can be rapidly rehydrated.

Many of the dehydrated vegetables on the market today are slow to rehydrate in preparation for serving. This is especially true of potatoes and carrots, which require about 20 and 30 minutes boiling, respectively, to rehydrate 3/8-inch cubes and make them soft enough for eating. The larger the piece the more difficult it is to rehydrate or reconstitute the material. A dehydration process has long been needed to fulfill the following objectives: 1) capable of operation at a cost comparable to conventional hot-air drying; 2) capable of handling relatively large pieces of fruits and vegetables, and 3) obtaining products that reconstitute rapidly.

A new process, called explosive puffing, has been developed by the Eastern Regional Research Laboratory of the U.S. Department of Agriculture located at Philadelphia, Pennsylvania, which it is believed will meet the above-mentioned objectives. This process consists of partially dehydrating the pieces by conventional means, heating these pieces in a closed vessel or "gun" having a quick-opening lid until the water contained within the pieces becomes superheated, then instantly discharging the intact pieces from the gun. The flashing of water vapor from within the pieces creates a porous structure that permits both a more rapid final dehydration and a much more rapid rehydration. The porous structure remains intact during the final dehydration in which a moisture content sufficiently low to insure good storage stability is attained. Explosive puffing does not create a large increase in volume as in the case of the familiar puffed wheat and rice breakfast cereals.

Potato and carrot cubes of 3/8-inch size made by explosive puff drying rehydrate in 5 or 6 minutes simmering in water as compared with the 20 to 30 minutes required for the regular product. Original shape and texture

return with the absorption of liquid.

The explosive puffing treatment has been applied successfully to potatoes, carrots, beets, rutabagas, sweet potatoes, apples and blue berries.

Details of the Process

The potatoes are first peeled, trimmed, dipped in a sulfite solution to prevent enzymatic darkening before further processing, and sliced into dice are washed thoroughly to remove surface starch which may otherwise cause sticking in the first-stage dehydration and in the puffing gun. After washing, the dice are again sulfite dipped and then screened to eliminate small pieces. This is done in order to obtain a uniformly-sized lot of raw material that will dry evenly and have as near a uniform moisture content as possible when placed in the puffing gun. After screening, the dice are preheated and cooled. Preheating or precooking, as it is commonly called, consists of heating in water for about 15 minutes at 160° F. followed by cooling in water at 50°F. for 15 minutes. This treatment has been found effective in minimizing sloughing when the dehydrated product is reconstituted, especially when high-solids potatoes are used as the raw material. The diced potatoes are then blanched in steam for 6 minutes to inactivate enzymes and dipped in a sulfite solution (also containing calcium chloride for further firming action if high-solids potatoes are used) for protection of quality during dehydration and to enhance product storage stability.

Partial dehydration to obtain a moisture content optimum for explosive puffing (about 28-35 percent) is done in a conventional dryer such as a tray dryer or a continuous belt-type hot-air dryer, using conditions of time and temperature that are typical of those regularly employed in a commercial dehydration plant. Uniformity of moisture content of the partially dried product is improved by "tempering" or holding in closed bins for several hours to equilibrate moisture within and among individual pieces. A uniform moisture content is essential for proper puffing in the puffing gun.

The partially dried pieces are then charged (up to about 20 pounds per charge) into the preheated puffing gun. This gun is similar in type to that used puffing cereals. It consists of a cylinder 12 inches in diameter, 30 inches long and a stainless steel wall 5/16 inch thick. One end of the cylinder is closed and the other has a hinged lid fitted with a special lock for closure as well as for instant release. The cylinder is motor driven to rotate on its long axis and has two external gas burners for heating. A picture of the puffing gun in the charging position is shown in Figure 1.

The gun is placed in a horizontal position during the heating period (Figure 2) and the temperature of the wall of the gun is maintained at 350°F. for about 2 minutes by means of the gas flame. Superheated steam at about 500°F. and 60 pounds per square inch is then admitted to the gun. The 2-minute warming up period serves to prevent condensation of the steam on the potato pieces. A small orifice in the lid of the gun permits escape of air and a little steam. The gas burner continues to supply external heat to keep the wall temperature at 350°F. Full pressure is reached after about 1 minute. This is maintained for approximately 1-1/2 minutes, the gas is shut off, the gun is tilted (Figure 3) while rotating to bring the charge to the muzzle. Rotation is stopped, the gun is tilted downward into a chute in which the product is collected (Figure 4) and the cycle is repeated.

Final drying is accomplished by conventional means but the drying time is only about 1-3/4 hours, as compared to approximately 7 hours for regular dice of the same size and at the same moisture level, to reach the final moisture of 5-6 percent.

Explosive puffing has been successfully applied to pieces larger than 3/8-inch dice, to French fry strips and to thin slices of potato in experimental trials. However, close control of operating conditions with respect to time, temperature, and moisture content must be maintained for all materials. Exploding at too high a pressure, for example, causes scorching if moisture content is too low, or disintegration if it is too high. Exploding at too low a pressure fails to puff the pieces. Reducing sugar content of the raw potatoes should not be over 1.25 percent on the moisture-free basis, otherwise browning may occur during puffing.

Recent investigations on explosive puffing have been devoted primarily to improving gun design and operation which will lead to early commercialization. Under present conditions which do not yet necessarily represent the optimum, one gun can handle approximately nine 18-pound charges per hour of 3/8-inch dice containing 22% moisture. This amounts to more than 1-1/2 tons per day of finished product. Four guns and two collection chutes installed with instrumentation should cost about $45,000. This capital investment would be largely offset by saving in drier capacity, since the overall drying time for explosively puffed materials is only about half that of non-exploded pieces. A 4-gun plant would have a capacity of approximately 6-1/2 tons per day of finished product. Experience to date indicates that it is commercially feasible to explosively puff potatoes at a cost only a little above that for conventionally hot-air-dried material. Development of continuous puffing equipment can ultimately be expected. This should lower costs per unit of product and result in wider commercial applications.

Carrots and Beets

Preparation of the raw material, preliminary drying, explosive puffing and final drying steps for carrots and beets are basically the same as those described for potatoes. Only minor variations are made to adapt the process in each case. With beets, for example, it is unnecessary to screen out small pieces after the dicing operation but a longer blanching time is required as compared with carrots because beets take longer to cook than carrots.

Storage tests on explosive puffed quick-cooking dehydrated carrots and beets have not yet been completed. However, observations indicate that the color and flavor of the carrots are generally superior to that of a freeze-dried product. Beet products are also of good color and flavor initially and after storage in nitrogen for several months. Further storage data is being collected. On the basis of previous experience with hot-air dried carrots it is recommended that explosive puffed carrots be packed with nitrogen at a moisture content not over 4 percent and with a content of from 500 to 1000 parts per million of sulphur dioxide for best retention of flavor and carotent during prolonged storage.

Apple Slices

Apple slices were one of the first products to be dehydrated by the explosive puffing method at the Eastern Regional Research Laboratory. Mature sound apples are mechanically peeled, cored and sliced (12's). The segments are

dipped in a sulfite and citric acid solution to control color during subsequent processing and storage. Partial dehydration is conducted in a hot-air dryer until a moisture content between 20% and 30% is reached. The remaining moisture is equilibrated among the pieces for a number of hours as in the case of potatoes in order to insure a uniform puffing action. Explosive puffing is conducted in a manner similar to that already discribed and the resulting product is finally dried to a moisture content of about 2% in the tray dryer. The latter drying step requires about 5 hours as compared with about 12-1/2 hours for unpuffed slices of the same moisture content.

Conventionally dried apple slices require a minimum 5-hour soaking before use. Slices which have been explosion-puffed are ready for use in pies after only 5 minutes boiling.

Instant Applesauce

When explosive-puffed apple pieces are coarsely ground and sweetened, a free-flowing granular material results that can be converted instantly to applesauce by adding hot water. The sauce not only has good flavor, it also has the desirable "grain" of that made from fresh apples. Explosive-puffed apple slices are crisp and can readily be crushed to any degree of fineness. The new dehydrated product, called "instant applesauce," is made by granulating the slices and passing them through a 20-mesh screen and adding sugar in an amount appropriate to the variety of apples used. If protected from moisture pickup, instant applesauce will keep for a long time under kitchen conditions. Since the weight of this product is only about one-fifth that of canned applesauce, it is much cheaper to ship and takes less space in storage.

Prospects for Commercialization

Very favorable responses have been received by the Eastern Regional Research Laboratory to many of the thousands of samples of explosively puffed vegetables and fruits that have been distributed to interested persons or organizations. Several companies have bought or built their own guns, probably from ERRL designs, judging from the numerous requests for construction drawings.

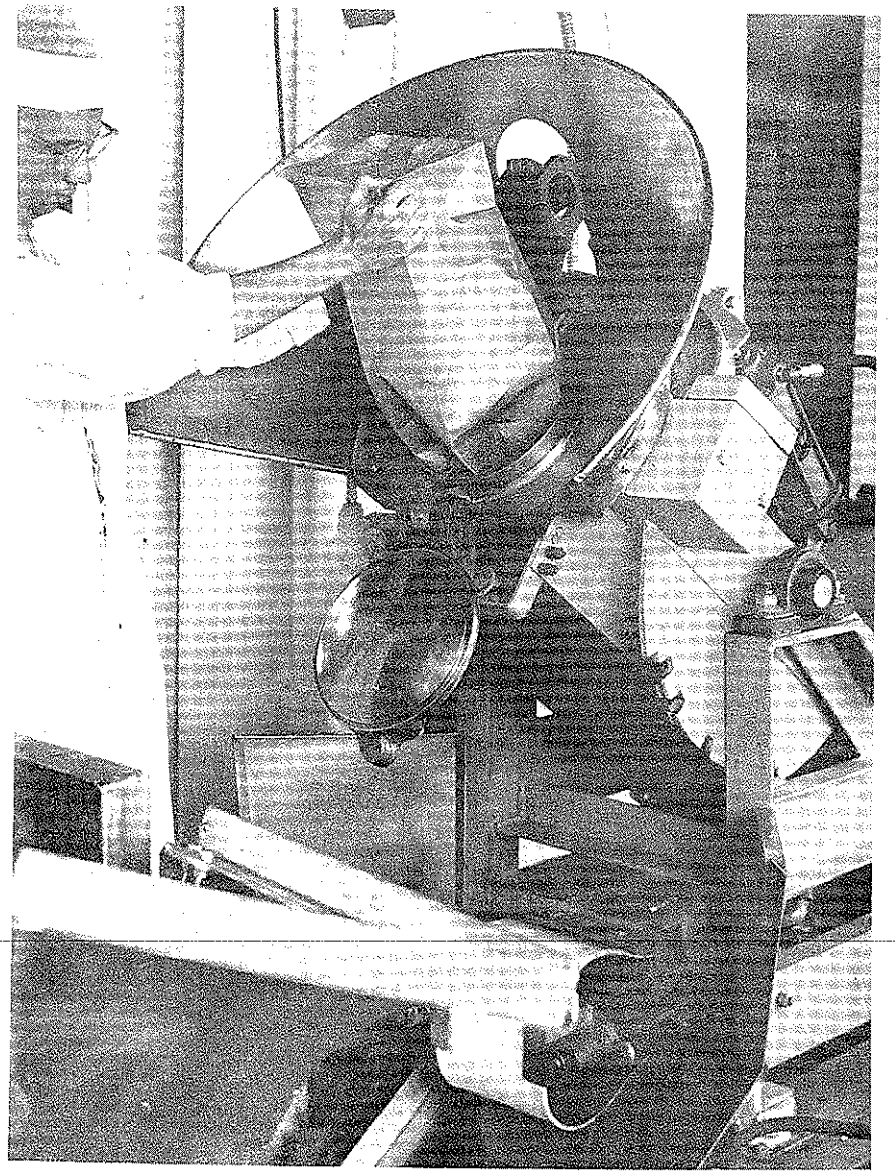
A vegetable dehydrating firm in California is reported to be producing commercial quantities of puffed carrot dice by a version of the ERRL basic process as already mentioned. The new product is selling at a premium over the conventionally dried dice. The company reports better flavor retention on storage of the new product as compared with the regular product. A plant is reported to be under construction in Japan and samples of the Japanese products are said to be of excellent quality. Experimental quantities of explosive puffed products are also being made in Europe.

It is reasonable to expect that explosively puffed vegetables and fruits will be further commercialized, and that those products will bridge the great gulf of price and quality that lies between conventional hot-air-dried and freeze-dried material.

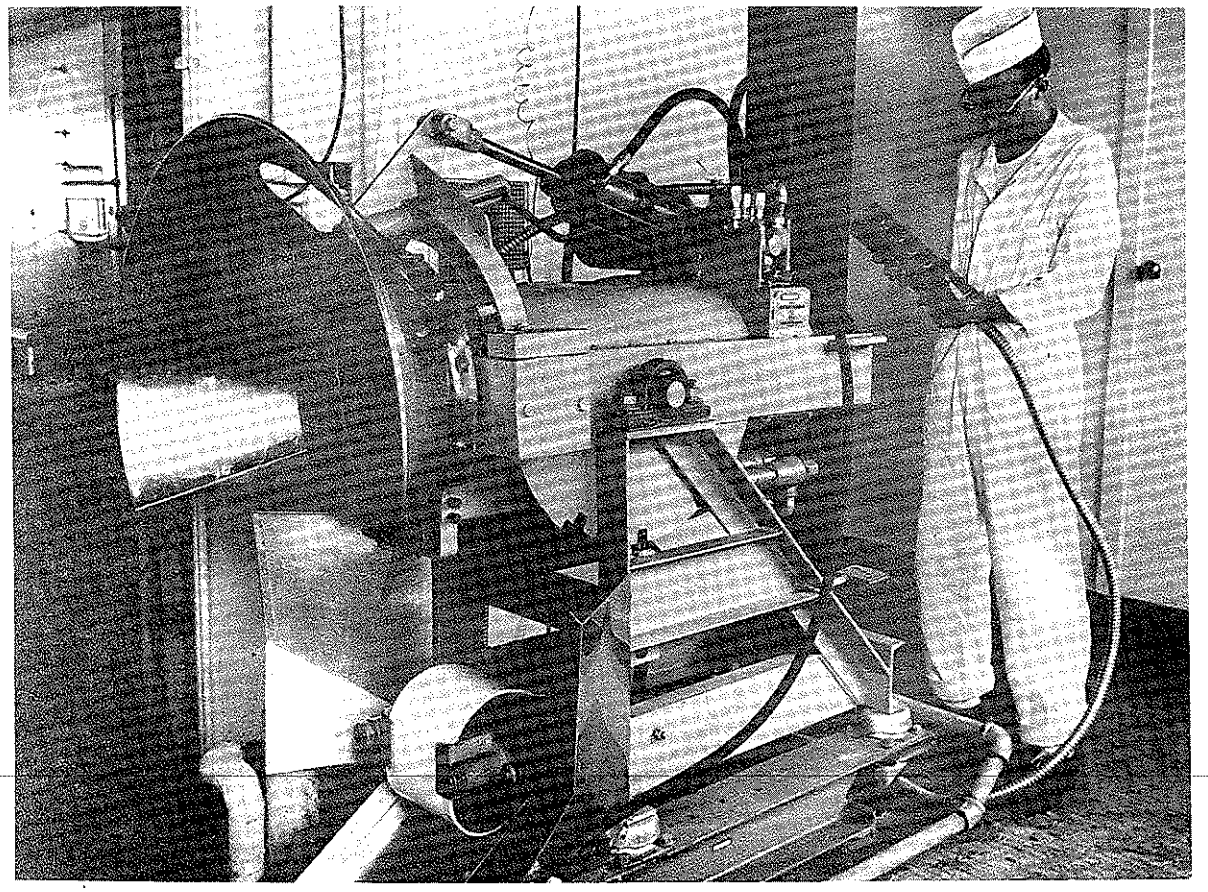
As is the case with any new process, however, much research and development is required before full-scale commercialization is realized. Often it is desirable for a processor to try out the process on a small scale in his own plant before making a large investment for equipment and facilities. In addition, a plant set up for explosive puffing will probably need to process several

commodities in order to extend the operating season over a profitable length of time. A location such as the Columbia Basin may have a distinct advantage from this standpoint. Either potatoes, apples, or carrots, for example, are available here for practically the entire year.

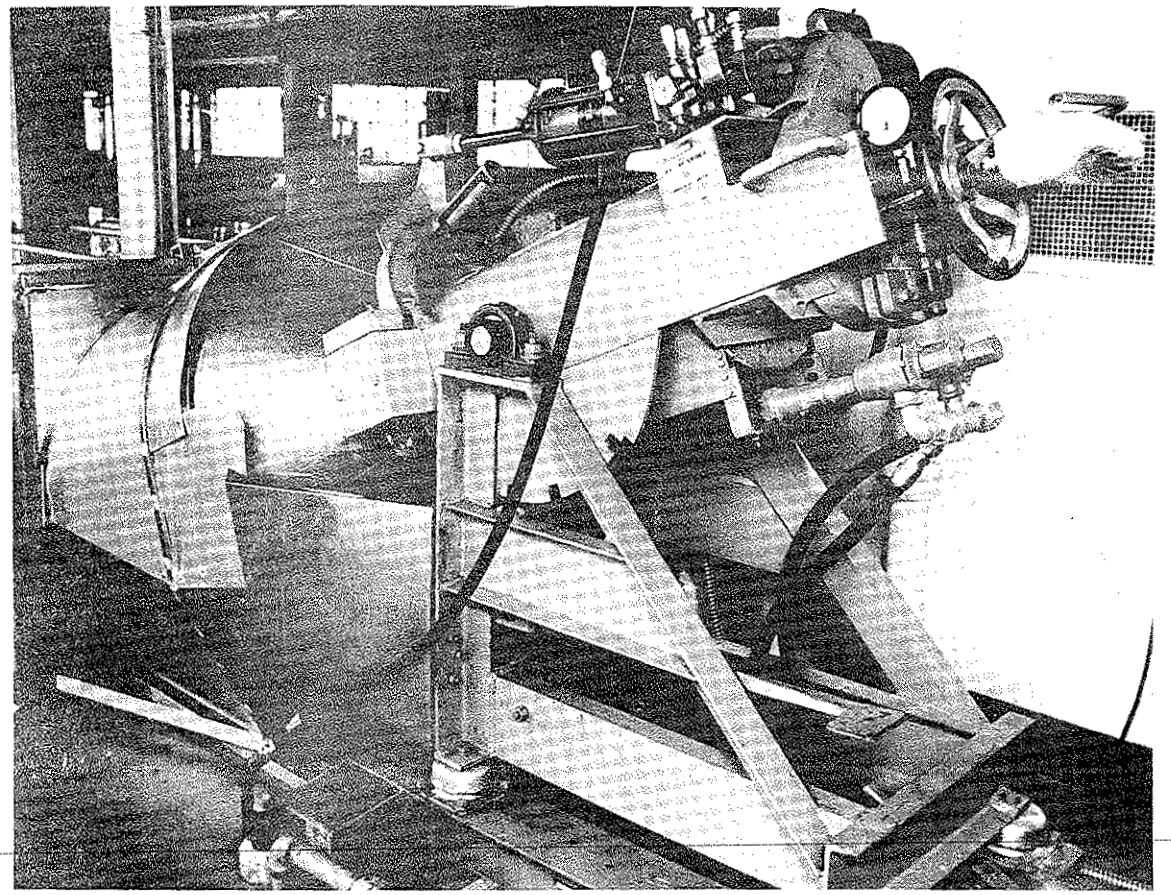
Further and more detailed information about the explosive puffing process and product samples may be obtained upon request from the Eastern Regional Laboratory, U.S. Department of Agriculture, Philadelphia 18, Pennsylvania.



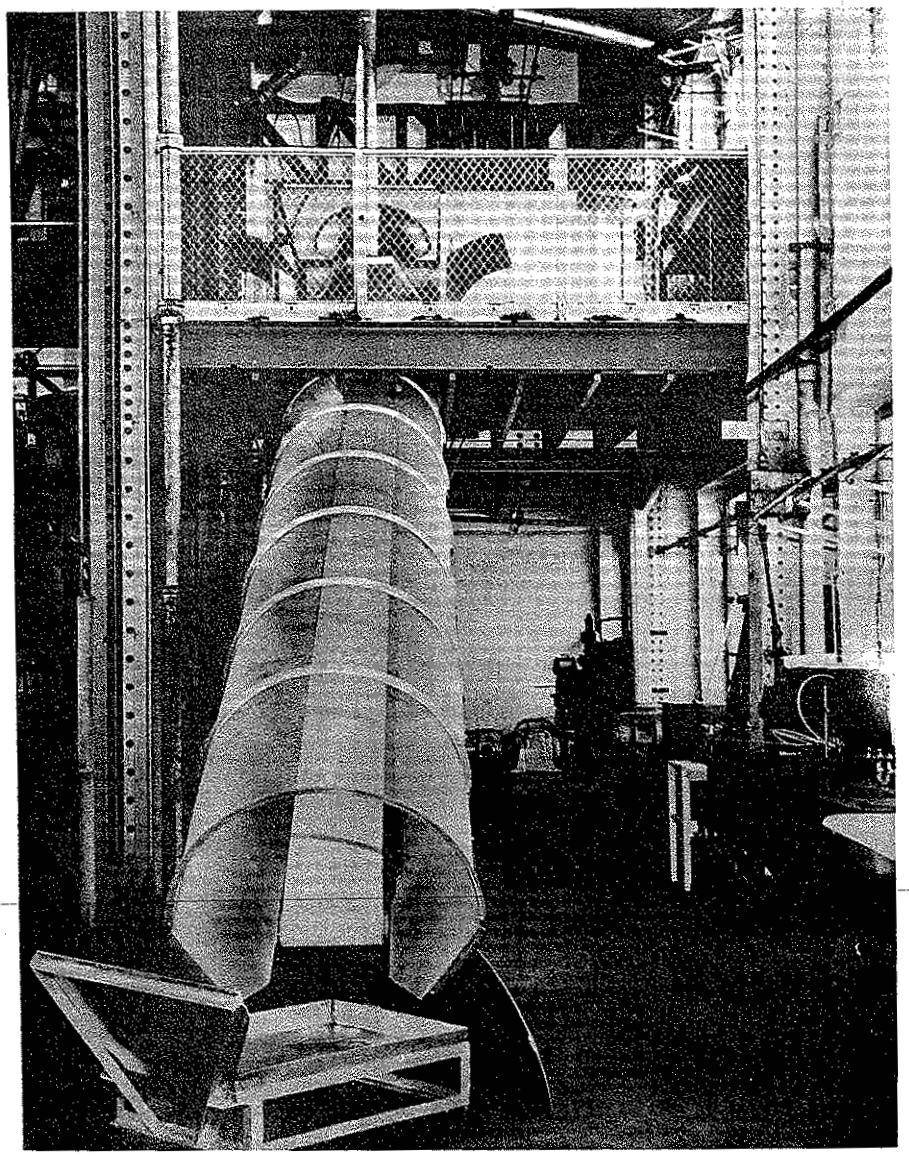
Explosive puffing gun used for producing quick-cooking dehydrated potatoes and other vegetables and fruits --- in loading position.



Explosive puffing gun used for producing quick-cooking dehydrated potatoes and other vegetables and fruits --- in operating position.



Explosive puffing gun used for producing quick-cooking dehydrated potatoes and other vegetables and fruits --- in discharge position.



Chute for collection of explosive puffed product after discharge of puffing gun.