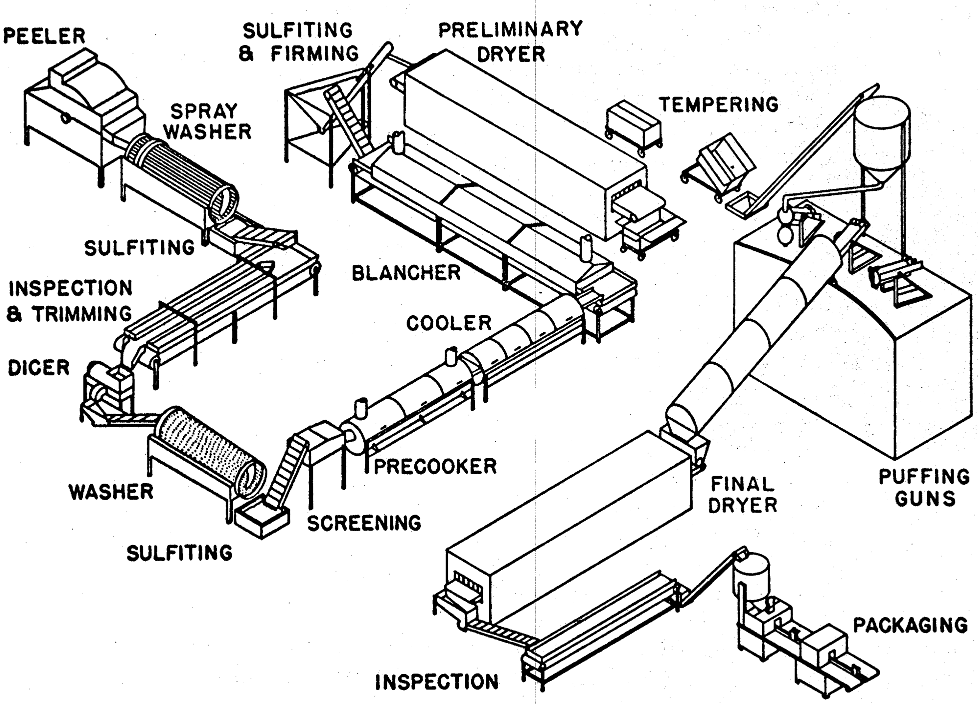

FIG. 1—Flow sheet shows potato process as it may be done commercially. Note the mounted puffing guns at extreme right.

Puffing gun process produces . . .

Quick-Cooking Dehydrated Potato Pieces

Commercially feasible method is suitable for large vegetable pieces that reconstitute rapidly and retain original character

AMONG CONVENIENCE foods which have been expanding rapidly in acceptance are the dehydrated soup mixes. Generally the mushrooms (except the finely ground) and the meat ingredients are freeze-dried. But most vegetables, which cannot justify this expensive process, are dried conventionally in hot air.

Because of the limitations of hot-air drying, the pieces are very small, for they must be ready for eating after about 10-min boiling. Larger pieces require longer boiling times than this. For example, 3/8-in. potato dice, hot-air dried, require about 25-min boiling. Still larger pieces would be desirable in some cases. These would require prolonged dehydration cycles if hot-air dried, resulting in increased processing costs and quality impairment.

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Need for Method

There has long been a need for a dehydration method suitable for large pieces of vegetables such as might be used in a dehydrated stew, yet one which would be much less costly to operate than freeze-drying. To be practical as a convenience item, the product would have to reconstitute rapidly without prolonged soaking or boiling.

These requirements have now been met by a process developed in the pilot plant of the Eastern Utilization Research and Development Div. of U.S. Dept. of Agriculture, near Philadelphia (Ref. 1). It has thus far been applied successfully to potatoes, carrots, beets, rutabagas, sweet

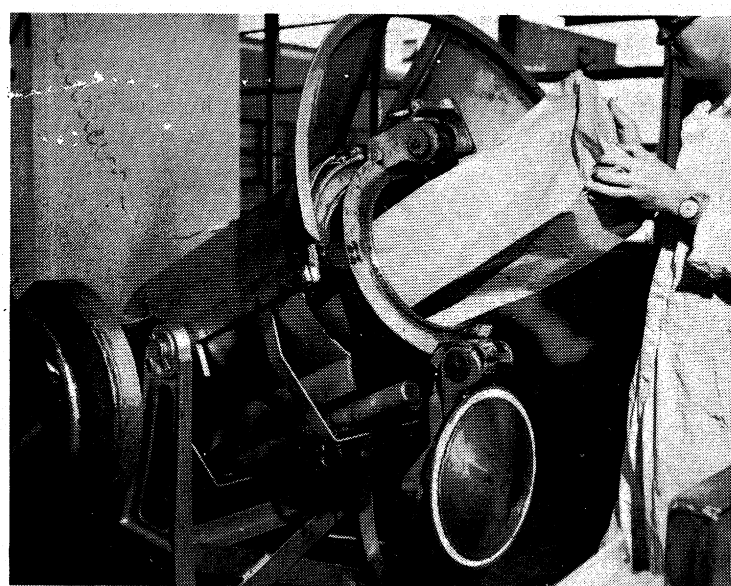

FIG. 2—Puffing gun being charged here is a cylinder with 12-in. diam., 30 in. long, and a wall thickness of 5/16 in. made of 18-8 stainless steel.

potatoes, apples (pie slices and random pieces) and blueberries. The details of the processes for carrots, beets and sweet potatoes have been published (2, 3). These products may serve as dehydrated soup ingredients or they may be reconstituted and eaten as individual vegetables.

Explosion puffing of cereals has long been known and, more recently, similar procedures have been used for precooked snack items (5). The process described here, however, is unique in that it is applicable to fruits and vegetables in particulate form. It yields products which can be reconstituted quickly to their original form (6).

The Process Itself

A flow sheet of the process for potatoes as it might be carried out commercially is shown in Fig. 1. Conventional methods of softening and loosening the skins may be used—lye, steam or combination lye and steam should all be satisfactory. The loosened skins are removed by high-pressure water jets. Then the peeled potatoes are dipped in a sodium bisulfite-citric acid solution to prevent enzymatic discoloration on the trim table. If steam peeling is used, this dip may not be necessary since surface enzymes would be inhibited in the steam peeler.

After trimming to remove rot, sunburn and other blemishes, the potatoes are diced, for example to nominal ⅜-in. cubes. The dice are washed thoroughly to remove surface starch which may otherwise cause sticking in the first-stage dehydration and in the puffing guns.

The dice are sulfite-dipped after washing and then screened to provide fractions of more uniform size. This is a requirement of the explosive-puffing step wherein moisture content controls porosity when pieces are puffed at a given pressure. Since, during drying, small pieces in a mixture of large and small pieces dry faster, reasonable uniform moisture can only be obtained in fractions of limited size range.

Some 12% by weight of the output of the dicer would go to other processing (flakes, frozen, etc.). The remainder, about 88%, is handled separately in subsequent operations. About 70% of the operating time would be on the larger fraction (over 5/16-in. screen) and 30% on the smaller (through 5/16, over 3/16-in.).

By dividing the operations in this manner the larger fraction can be handled during the first two shifts. The smaller fraction would be accumulated over this period and run off on the third shift. During the third shift the peeling, trimming, dicing, and screening operations are suspended. This reduces personnel as well as operating costs on this shift. It also allows time for adjusting or repairing the equipment not in operation.

After screening, the dice are precooked and cooled to minimize sloughing or rehydration and blanched in steam to inactivate enzymes. They are then dipped in a sodium bisulfite solution (containing calcium chloride to firm if high-solids potatoes are used) for protection during dehydration and to enhance product storage.

Partial drying to the moisture-content optimum for explosive puffing (about 28-35%) is done in the preliminary dryer. A continuous belt-type hot-air dryer may be used. Uniformity of puffing is improved by "tempering," or holding in closed bins to equilibrate moisture within and among pieces.

Explosive puffing is accomplished in a battery of guns and a final dryer, of the same type as the preliminary dryer. It takes the moisture down to 6-7%. Inspection and packaging requirements should not differ greatly from those of unpuffed air-dried dice.

Pilot Plant Development

Pre-Drying Steps

In pilot plant work, Russet Burbank potatoes were used. Reducing-sugar content was kept below 1.25% M.F.B., by conditioning when necessary.

The potatoes were peeled by immersion for 7½ min in a 20% by weight solution of NaOH at 150F. The lye-softened skins were removed by high-pressure water sprays. The potatoes were dipped for ½ min in a solution of 0.5% each by weight sodium bisulfite and citric acid to prevent discoloration during handling. Eyes and blemishes were removed by hand trimming and the potatoes were then cut into nominal ⅜-in. dice, using an Urschel Model B dicer. The starch liberated by cutting was washed from the surfaces and the dice were again dipped in the bisulfite-citric acid solution. Sulfite picked up in these two dips is not retained to any significant degree during subsequent steps.

Sizing of the dice is necessary so that uniform moisture content can be obtained in the preliminary drying step. A Day-Roball screener fitted with two stainless steel slotted screens was used. Screen sizes were 5/16 x 3 in. and 3/16 x 3 in. In the pilot plant, only dice passing over the two screens were used. Each fraction was processed separately.

The pieces were precooked in water at 160F for 15 min, and then cooled in water at 50F for 15 min. The first of these two steps gelatinizes the starch **in situ;** the second retrogrades it, making it more insoluble. The combination minimizes sticking and agglomeration of the pieces in the puffing gun. "Sloughing," or disintegration of the pieces during rehydration is also minimized thereby.

To inactivate enzymes, the dice after cooling were blanched in steam at 212F for 6 min. Tests for peroxidase indicated complete inactivation at the above conditions of blanching. For protection (against non-enzymatic browning) during dehydration and to ensure a residual sulfur dioxide content of 200 to 500 ppm in the final product for storage protection, the blanched pieces were immersed for 2 min or less in a solution containing ½% sodium bisulfite. To prevent sloughing of high-solids content potato pieces, a solution containing ½% calcium chloride as well as bisulfite was used.

First-Stage Drying

With potato dice, as with other commodities in explosion puffing, there is an optimum moisture content at which best puffing occurs. Too high a moisture content causes disintegration on puffing, while pieces of too low a moisture content will not puff. Also, too high a moisture content causes the pieces to agglomerate during heating in the puffing gun.

A tray dryer was used in the pilot plant for both the preliminary and final drying steps. Drying conditions and procedures were typical of those employed in drying dice, with commercial belt type, through-flow driers. Dice were loaded to a depth of 3 in. on 28-in. square perforated-bottom trays. At the 3-in. depth, a tray loading of 10 lb per sq ft of tray area was obtained.

For the first half of the preliminary drying cycle (until half the weight of water to be removed had been evaporated) airflow was upward through the bed, and for the second half, downward. Air dry bulb temperature was maintained at 200F and air velocity at 200 ft/min.

The contents of the trays were not stirred during drying. Change of air-flow direction was relied on to obtain uniform moisture content of the dice. By the end of the preliminary drying cycle the bed depth had decreased to 1 in. and moisture content of the dice was reduced from about 80% to 28% in 105 min.

Tempering for Uniform Moisture

In addition to size separation before initial drying and reversing air flow direction during drying, holding the partially-dried pieces in closed containers aids in obtaining more uniform moisture content within pieces. Uniform moisture content is required for uniform puffing.

In pilot plant experiments, the dice after initial drying were held in plastic bags inside fiber drums for 24 hr at room temperature. After this treatment only an estimated 1% of the pieces from the puffing operation remained unpuffed because of too low moisture content. And few were disintegrated because of too high moisture content. This compares with 5-10% of unpuffed pieces for untempered batches puffed immediately after preliminary dehydration.

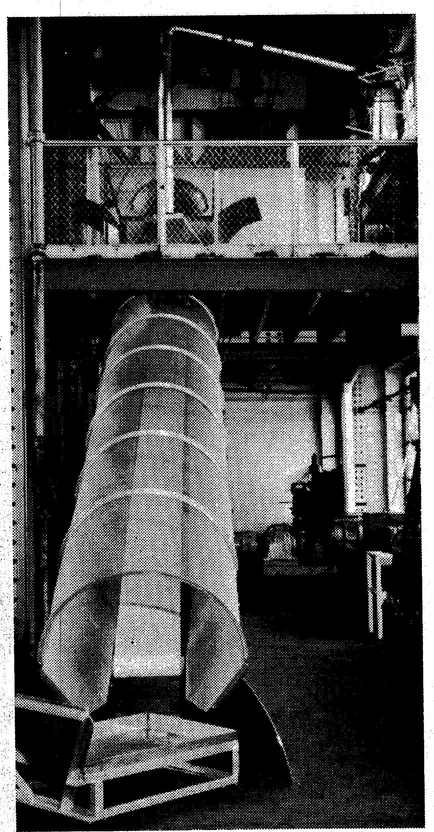

FIG. 3—Collector receives pieces exploded from puffing gun. About 30 ft long, it consists of a trough having a hemicylindrical cover of wire mesh to permit easy escape of steam while retaining the flying pieces.

Explosive Puffing

Partially dried pieces from the preliminary drying step were charged into one of two pilot plant guns. Early experiments were carried out in a small (5-in. diam x 10 in. long) cast iron unit designed for puffing cereals. Here, a larger gun was used: a cylinder with 12-in. diam, 30 in. long, and a wall thickness of 5/16 in. made of 18-8 stainless steel (7).

In Fig. 2, this gun is shown in the charging position. One end of the cylinder is closed, the other end has a hinged lid fitted with an eccentric lock for closure and instant release. The cylinder is motor driven to rotate on its long axis and has two external gas burners for heating. A thermocouple makes sliding contact with the outer wall of the barrel. And the gas rate is controlled manually to maintain a predetermined outer wall temperature of 550F, indicated by potentiometer readings.

Quantities of partially-dried dice as large as 20 lb were placed in the gun, the lid closed, rotation started, burners lighted and the pressure brought to 55 psig in about 12 min. The gas rate was controlled to maintain a skin-temperature of 550F. The pressure develops by vaporization of a small amount of water from the dice. And as a result of the pressure, the water remaining within the dice is superheated with respect to the atmospheric boiling point.

When 55-psig pressure within the gun was reached, the lid was instantly opened and the contents then exploded from the gun barrel. At the moment of explosion, a small amount of water within the pieces vaporized and formed a porous structure while escaping. Pieces charged to the gun at 28% moisture content had a moisture content of about 22% after explosion. The difference represents the amount vaporized in the gun and during explosion.

The moisture content and exploding pressure must be carefully controlled. Exploding at too high a pressure 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. At a pressure of 55 lb, good puffs have been obtained at moistures between 28 and 35%, with ⅜-in. dice. Reducing-sugar content of the raw potatoes should be 1.25% M.F.B. or lower, otherwise browning during puffing may occur due to the Maillard reaction.

The pieces exploded from the gun were collected in a tunnel-type collector as shown in Fig. 3. The collector has an effective length of about 30 ft. It consists of a trough having a hemicylindrical cover of wire mesh to permit easy escape of steam while retaining the flying pieces. A wheeled tray at the end of the trough collects the puffed pieces.

Final Drying

The same tray dryer was used for the final drying as was used for preliminary drying except that trays of smaller cross-section (15 x 15 in.) were employed. Again conditions were such as to simulate commercial drying. Trays were loaded to a depth of 3 in., air velocity was 200 ft/min or higher, air temperature was 150F dry bulb.

Final drying curves for puffed dice and for conventionally dried dice are shown in Fig. 4. The top curve represents typical commercial final drying of ⅜-in. dice. Here the last stage (about 6 hr) is customarily done in bins to bring the product from about 16% moisture down to the final moisture of 5-6%.

As shown in the lower curve, the final drying rate is increased by the porosity imparted by the explosive-puffing step. This results in a final drying time of about 1¾ hr for the puffed dice as compared to approximately 7 hr for the commercial product (8).

Since the initial drying for both forms takes about 2 hr, the comparative total drying times are 3¾ hr and 9 hr, respectively. This difference represents a tremendous increase in dryer capacity. It suggests that a plant employing explosive puffing might use only one stage of belt drying (to reach the moisture required for puffing) and then finish by rapid bin drying of the puffed product.

About the Product

When 60 grams of the product are boiled 4-6 min in 2 cups of water, the pieces fully regain their original shape. They possess a characteristic color and flavor close to that of freshly cooked potatoes.

Fig. 5 shows the appearance of (a) raw dice, (b) unpuffed conventionally dried dice, and (c) puffed dice, all boiled 6 min. It can be seen that the puffed product resembles the raw dice in appearance. The raw dice, however, are still uncooked. The unpuffed dice retain the shriveled appearance acquired during drying and do not regain their original shape even after prolonged cooking.

The work reported in the foregoing has all been done on nominal ⅜-in. cubes. Purpose was to compare with a product of the same size and shape now made commercially by hot-air drying. Preliminary experiments with other sizes and shapes, e.g., French fry strips and larger cubes, show promise that these too may be made rapidly rehydratable. Work is under way to determine optimum conditions for the preparation of these products and to obtain data for reliable cost estimation. Preliminary estimates suggest the cost may be at most about 15% higher than for conventionally air-dried dice.

NOTE: Reference to certain products or companies does not imply an endorsement by the Department over others not mentioned.

REFERENCES

1. **Eisenhardt, N. H., Cording, J. Jr., Eskew, R. K., and Sullivan, J. F.** "Quick-Cooking Dehydrated Vegetable Pieces. I. Properties of Potato and Carrot Products," Food Technology, Vol. XVI, (5), 143-146, 1962.
2. **Cording, J. Jr., Eskew, R. K., Sullivan, J. F. and Eisenhardt, N. H.** "Quick-Cooking Dehydrated Vegetables," Food Engineering, Vol. 35, (6), 52-55, 1963.
3. **Sullivan, J. F., Cording, J. Jr., and Eskew, R. K.** "Quick-Cooking Dehydrated Sweet Potatoes," Food Engineering, Vol. 35, (9), 59-60, 1963.
4. **U.S.D.A. Press Release No. 1998.** "New Dehydrated Apple Pieces Show Promise as Snack, Dry Cereal Ingredient," June 14, 1963.
5. **FP Staff.** "Continuous Puffing Expansion," Food Processing, Vol. 24, (9), p. 134, 135, 137, 1963.
6. **Cording, J. Jr., and Eskew, R. K.** "Process for Manufacture of Rapidly Rehydratable Dehydrated Fruits and Vegetables." U.S. Patent 3,038,813. June 12, 1962.
7. **Eskew, R. K., Cording, J. Jr., and Sullivan, J. F.** "Explosive Puffing," Food Engineering, Vol. 35, (4), 91-92, 1963.
8. **Talburt, W. F. and Smith, O.** Potato Processing. Avi Publishing Company, Inc., Westport, Conn., 1959.

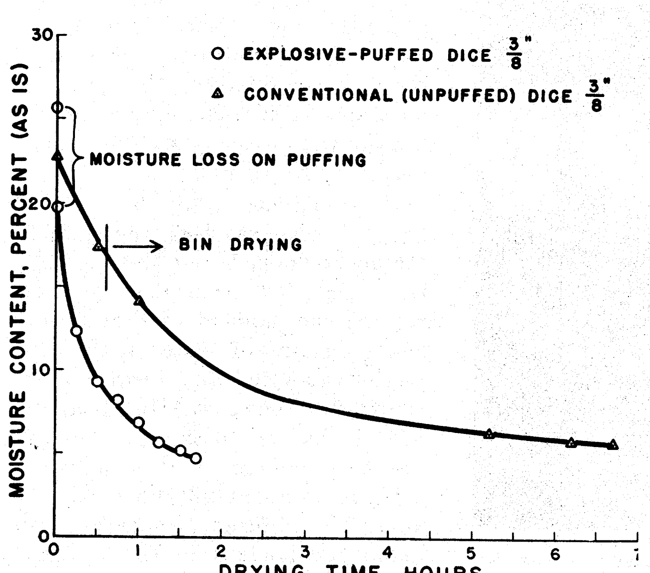

FIG. 4—Final drying rate increases as explosive puffing imparts porosity to product. Final drying time for puffed dice is about 1¾ hr as compared with about 7 hr for commercial product.

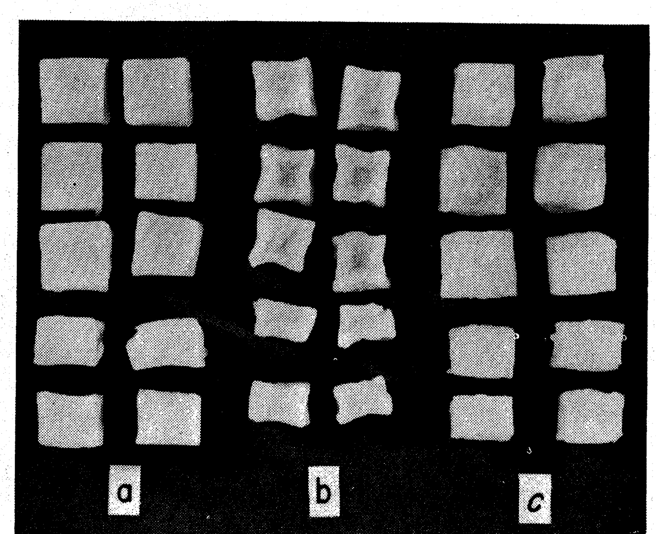

FIG. 5—After 6-min boiling, the appearance of (a) raw dice, (b) unpuffed conventionally dried, (c) puffed. Puffed resembles raw dice, and unpuffed remains shriveled even after prolonged cooking.