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Osmotic Dehydration

A cheap and simple method of preserving mangoes, bananas and plantains

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ABSTRACT: About 40% of the water can be removed from certain tropical fruits by a simple process. For bananas and plantains, this involves immersing slices in a concentrated sugar solution for about 18 hours; for ripe mango, it involves the same treatment for about 4 hours; for green mango, it involves immersion in a concentrated salt solution for about 24 hours. The economics of the process probably depend on the availability of cheap sugar and on the possibility of using spent sugar solutions in canning, bottling, or soft-drink plants. Final treatments by drying in the sun or in air currents are suggested, as well as methods of preserving dried fruit with sulfur dioxide. A detailed report is given of experiments carried out in Ottawa together with recipes that could be used in processing plants.

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RÉSUMÉ: Il est possible, au moyen d'un procédé peu compliqué, de retirer de certains fruits tropicaux 40% environ de l'eau qu'ils contiennent. Pour ce qui est des bananes et des plantains, cette opération comporte l'immersion, pendant 18 heures environ, des tranches de ces fruits dans une solution de sucre concentrée; pour ce qui est des mangues mûres, elle comporte un traitement identique pour une période de 4 heures; pour ce qui est de la mangue verte, elle comporte l'immersion dans une solution de sel concentrée pour une période d'environ 24 heures. L'aspect économique de ce procédé est probablement subordonné à la disponibilité du sucre à prix modique ainsi qu'à la possibilité d'utilisation des solutions de sucre épuisées dans la fabrication des conserves et des boissons. On propose la conclusion du traitement par le séchage soit au soleil, soit au moyen des jets d'air, ainsi que des méthodes de conservation des fruits secs à l'aide de l'anhydride sulfureux. On fournit un rapport détaillé des expériences réalisées à Ottawa ainsi que des recettes qui pourraient être utilisées dans les usines de transformation.

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Tests carried out in Ottawa have shown that a scientific principle known and used by rule of thumb for centuries can be commercially applied for preserving foods and reducing their weight. When employed in the manner described here, it forms the basis of a relatively cheap and simple method applicable particularly to tropical fruits in sugar-producing countries.

The principle involved is osmosis, which has long been used to extract water from foods in order to preserve them: for example, in the salting of fish. Osmosis involves the passage of a solvent from a less concentrated to a more concentrated solution through a membrane. In the example of the fish, the solvent (water) passes from the less concentrated solution inside the fish cell membrane, through the membrane, to the more concentrated salt solution outside.

In principle any plant or animal tissue can be dehydrated by immersion in a strong solution of sugar or salt in water. But until now, methods were lacking that would produce uniform results with specific foods and could thus be adapted to commercial use.

The methods described in this report may be directly used for banana, plantain, ripe mango and green mango. The procedures would be similar for other fruits, but the lengths of exposure to the osmotic solution and the optimum solution concentrations need to be determined by experiment, for each fruit.

RECOMMENDED METHODS

Banana and Plantain

(1) Prepare a strong solution of cane sugar in unheated water: one containing about 67 percent soluble solids would consist of 20 kilograms of sugar and 10 litres of water, making about 11 litres of syrup. Stronger solutions cannot conveniently be made without heating the mixture. Heating is undesirable because of the danger of caramelization and discolouration of the syrup.

(2) Select fully ripe but firm fruit, peel and slice crosswise into uniform pieces 2-4 centimetres thick. Stainless-steel or bamboo knives should be used. Do not use iron or steel knives because they may discolour the fruit.

(3) Place the banana slices in four times their weight of sugar solution, and allow them to stand for 18 hours, gently mixing occasionally. This will remove about 40 percent of the original moisture from the banana pieces. An end-over-end cylindrical mixer, such as a barrel churn, will increase the rate of moisture removal by 8-10 percent. Speed of rotation should not exceed 20 revolutions per minute or the fruit may be damaged.

(4) Prepare a 60 percent sugar solution containing one percent sulfur dioxide (15 kilograms sugar with 300 grams potassium metabisulfite in 10 litres of water). Transfer the banana slices to this solution and hold for one hour.

(5) Remove the slices and drain thoroughly. A very brief dip (1 minute) in clear cold water is recommended at this stage to reduce subsequent stickiness.

Further treatment is necessary if the product is to be stored. Drying to a moisture content of 15 percent or less is one alternative. The slices should be loaded in a single layer on wooden, plastic or stainless-steel trays. A cabinet dryer operating at 48°C, 50% relative humidity and a linear air flow of 300 metres per minute will dry the slices in 18 hours. Sun- or shade-drying are also satisfactory but may take longer because of the lower temperatures, higher humidities or slower rates of ventilation that may be encoun-

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tered. The optimum conditions of drying need to be determined in the prevailing local environment.

Dried slices should be bulked for 24 hours or more to permit equalization of moisture content and then sealed in moisture-proof packages.

Ripe Mango

The process for ripe mango is similar to that for banana with the following exceptions. After peeling, the flesh is sliced from the stone and cut in pieces 1-2 centimetres thick and about 4 x 4 centimetres square. The pieces are then dried osmotically in 67 percent sugar syrup for four hours. The subsequent sulfur dioxide treatment should be a dip for two minutes in a 0.8% sulfur dioxide solution (15 kilograms sugar and 250 grams potassium metabisulfite in 10 litres water).

Green Mango

(1) Prepare a solution containing 25 percent sodium chloride (3.33 kilograms of salt in 10 litres of water).

(2) Peel the mangoes and remove the flesh from the stones in slices 1-1½ centimetre thick. Cut the slices in pieces about 5 x 5 centimetres and place in the salt solution for 24 hours. Occasional gentle mixing or end-over-end agitation, as described for banana, will increase the rate at which water is removed.

(3) Remove the slices from the solution, drain and finish drying as for bananas. Satisfactory moisture content will be reached in 8-9 hours in a cabinet dryer operating at 48°C, 50% relative humidity and a linear air flow of 300 metres per minute.

Dehydrated fruit must be protected from changes in the moisture content of the surrounding atmosphere because it absorbs water. It is also subject to damage from insects in storage and during shipment. These facts must be borne in mind when selecting packages or packaging materials.

Re-use of Solutions

The osmotic solutions become diluted because of loss of sugar, salt and sulfur dioxide as well as through the uptake of water from the fruit. Salt solutions may be reconcentrated by evaporation with heat (e.g. in the dryer) and be re-used several times. Because sugar solutions tend to darken and caramelize when heated, it is preferable simply to concentrate the sugar solution by adding more sugar and sulfur dioxide without heating. Salt solutions can be re-used many times, but sugar solutions cannot be kept more than 6-7 days because they are likely to ferment. However, if the osmotic dehydration process is carried out in a small factory in which the canning and bottling of fruits, or the bottling of soft drinks is practised, the "spent" osmotic sugar solution can be satisfactorily used in these other processing operations. It is also possible to integrate the osmotic drying procedure with an alcoholic or other fermentation process as a means of economically utilizing the spent sugar solution.

Cost of Preparation

Preparation costs are difficult to specify because they vary from place to place. The figures given in Table 1 may serve as indicators. One hundred kilograms of raw banana will require 8.8 man-hours of labour for peeling and handling, will absorb 7.75 kg of sugar from the solution and will yield 17.5 kg of a product with 13.27 percent moisture.

The economic feasibility of this process probably depends on the availability of cheap sugar and/or a satisfactory disposal of the spent solutions. Recycling spent syrups through a sugar refinery for purification and re-use may be one way to ensure the process is economic.

DETAILS OF INVESTIGATION

The procedures described here were carried out at the Food Research Institute, Canada Department of Agriculture. The purpose was to determine the technical feasibility of applying osmotic dehydration to the drying of foodstuffs in sugar-producing countries, probably in villages

TABLE 1

Production data – osmotic dehydration of fruits

	Banana	Ripe Mango	Green Mango
Peeling & trimming loss (%)	43.5	41.8	42.5
Recovery: dried product from fresh fruit (%)	17.5	11.9	19.1
Recovery: dried product from prepared fruit (%)	31.8	20.6	33.4
Dehydration ratio	140/100	148.6/100	138/100
Preparation time in minutes (hand operation) per 100 kg. raw product			
Peeling, trimming, slicing	242	397	353
Solution makeup	44	44	44
Handling in solutions	44	44	44
Loading dryer trays	253	253	253
Unloading trays	201	201	201
Sugar loss from solutions	7.75%	5.6%	
Weight loss: 4-hour osmosis	40.0%	40.5%	
Product characteristics (4-hour osmosis in 67% sucrose + 18 hours at 40°C + 50% RH)			(18 hours osmosis in 25% Na Cl + 0.5% SO_2 + 8 hours at 48°C + 50% RH)
Moisture content (%)	13.27	10.54	12.42
Reducing sugar (%)	10.46	11.51	
Total sugar (salt) (%)	22.44	21.01	(40.50)
Water activity	0.882	0.866	0.330
SO_2 ppm (2-min dip in 60% sucrose + 0.8% SO_2)	1126	345	

by commercial companies, and to produce data from which basic industrial costs might be computed. The work involved a re-examination of available information (notably Jackson and Mohamed[1] and Ponting[2]), the development of standard procedures for mangoes, plantains and bananas, and an investigation of inputs required to produce osmotically-dried fruit.

Procedure

The fruit was prepared by removing the peel and other inedible parts and then cutting in slices or chunks. The prepared pieces were placed in strong solutions of cane sugar or table salt in water by one of four methods: (1) holding the fruit below the surface of a static solution by means of a screen (2) holding the fruit below the surface whilst gently circulating the solution with an impeller-type mixer (Lightnin) (3) completely filling a cylindrical container with the fruit and solution, closing the cylinder, and then gently mixing by an end-over-end rotation (Vol-u-meter) (4) holding the pieces below the surface of a solution that was maintained at its original concentration by continual removal of the "spent" solution and replacement with a fresh one. The rate of movement of moisture from fruit to solution was estimated from changes in the refractive index of the solution.

After the osmotic treatment the pieces of fruit were further dried in a Proctor and Schwartz cabinet dryer on trays with stainless-steel mesh bottoms. In order to approximate the conditions of sun drying, the intake air was adjusted to 48°C and 50 percent relative humidity.

McIntosh apples used in preliminary experiments had been stored about six months at the Food Research Institute. Bananas and mangoes were purchased from a local importer (Top Banana Ltd.) and were not of uniform maturity, variety or source.

Moisture, sugar, salt (sodium chloride) and sulfite content of fruit were determined by the Association of Official Agricultural Chemists methods. The refractive index of solutions was measured with an Abbé refractometer.

Results

Concentration of Solution: The higher the starting concentration of the solution the higher was the percentage water loss from the fruit in a given period of time (Table 2). However, it is difficult to prepare sugar solutions of high concentration without heating and consequent discolouration or caramelization. Rate of water removal is increased by maintaining the original concentration of the syrup and circulating it through the submerged slices (Table 3). This increase amounted to 8 percent in four hours.

Temperature: Increase in temperature is accompanied by increase in the rate of diffusion (Table 4). Water loss was almost 1½ times as much at 37 as at 20°C. However, diffusion of flavours and odours from the fruit to the syrup was also increased at higher temperatures and solutions became discoloured more quickly.

Time of Exposure: There was a rapid loss of water during the first 4-5 hours, after which the movement of water from the tissues to the solution proceeded more slowly for the next 18 to 24 hours. The rate of loss differed considerably in different fruits: a 40 percent loss of weight

TABLE 2

Percent water loss (by weight) from apple slices immersed 18 hours in sucrose solutions[1]

Starting Concentration	Water loss
55	30.0
60	30.8
65	33.1
67	34.5
69	36.2
71	37.3

[1] Weight of slices: weight of syrup = 1:4 solution stirred

TABLE 3

Percent water loss (by weight) from apple slices immersed 4 hours in sucrose syrup of constant and changing strength.[1]

	Syrup Concentration		Water
	Beginning %	Ending %	loss %
Stirred	70.0	66.4	22
Circulated	70.0	70.0	30

[1] Weight of slices: weight of syrup 1:4

TABLE 4

Water loss from apple slices immersed 18 hours in 70 percent sucrose syrup [1] and held at different temperatures.

Temperature °C	Water loss %
20	34.8
24	36.8
27	42.0
37	47.2

[1] Weight of slices: weight syrup = 1:4

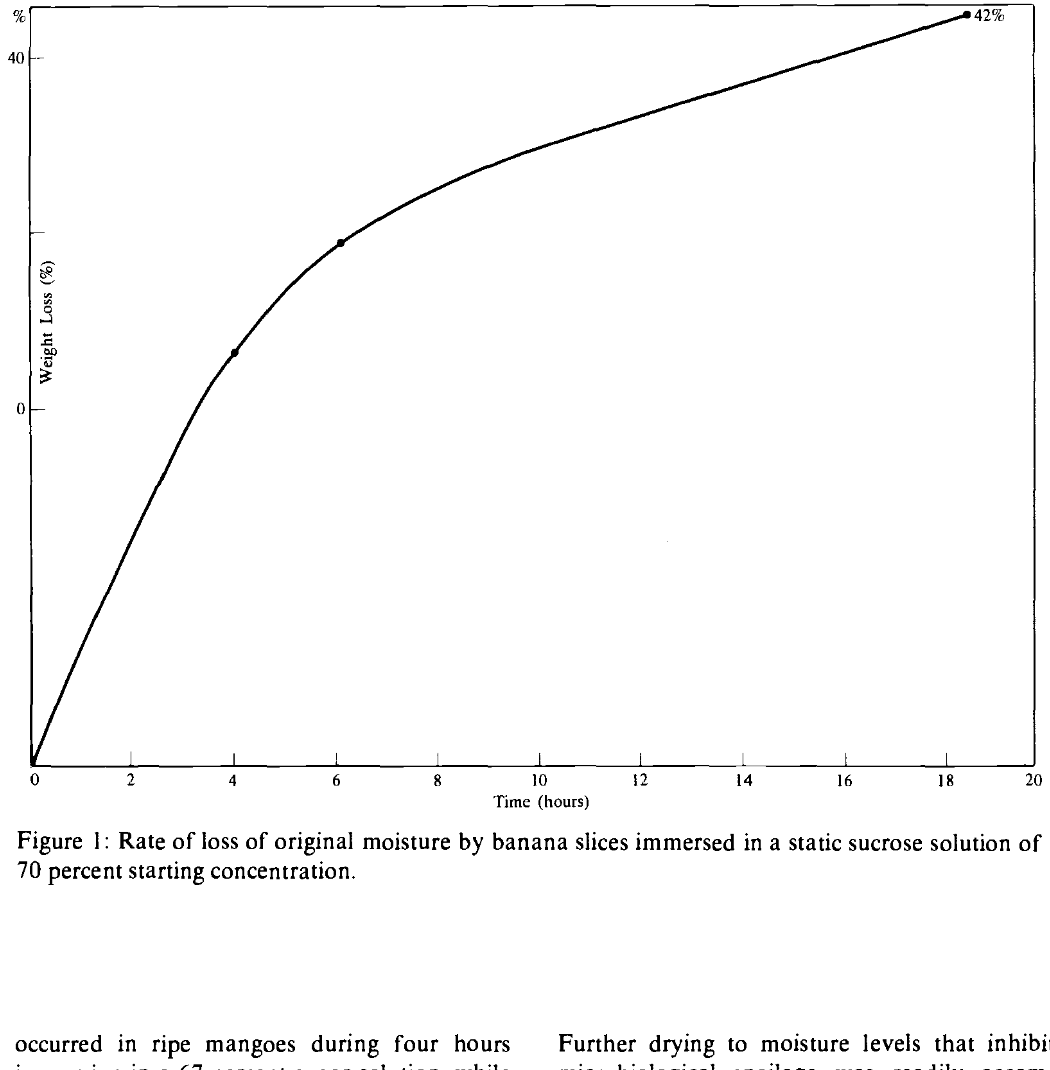

Figure 1: Rate of loss of original moisture by banana slices immersed in a static sucrose solution of 70 percent starting concentration.

occurred in ripe mangoes during four hours immersion in a 67 percent sugar solution, while firm ripe bananas took 18 hours to lose an equivalent amount of moisture in a similar solution (Figs. 1 & 2).

Further Treatment required: Fruit pieces left in a solution of salt or sugar for a long enough period (e.g. two days) reached a moisture content in equilibrium with the solution. In batch-type operations with fruit containing about 80 percent water in a solution of 65-70 percent sugar in a proportion of 1:4, the moisture content of the fruit at equilibrium was about 44 percent. This is not low enough to prevent spoilage.

Further drying to moisture levels that inhibit microbiological spoilage was readily accomplished by exposing the fruit pieces to a current of warm air. Drying to a satisfactory level of moisture could be accomplished in 3-4 hours at starting wet-bulb temperatures of 70°C, as recommended by Jackson and Mohamed[1]. It was found, however, that adjusting the cabinet dryer to duplicate the lower temperatures and higher humidities likely to be encountered in sun drying extended the required drying time to 18-20 hours (Fig. 3). Fruit pieces exposed to such slow drying conditions suffered loss of flavour and undesirable change in colour. This was particularly true of banana, less so of ripe and green mango.

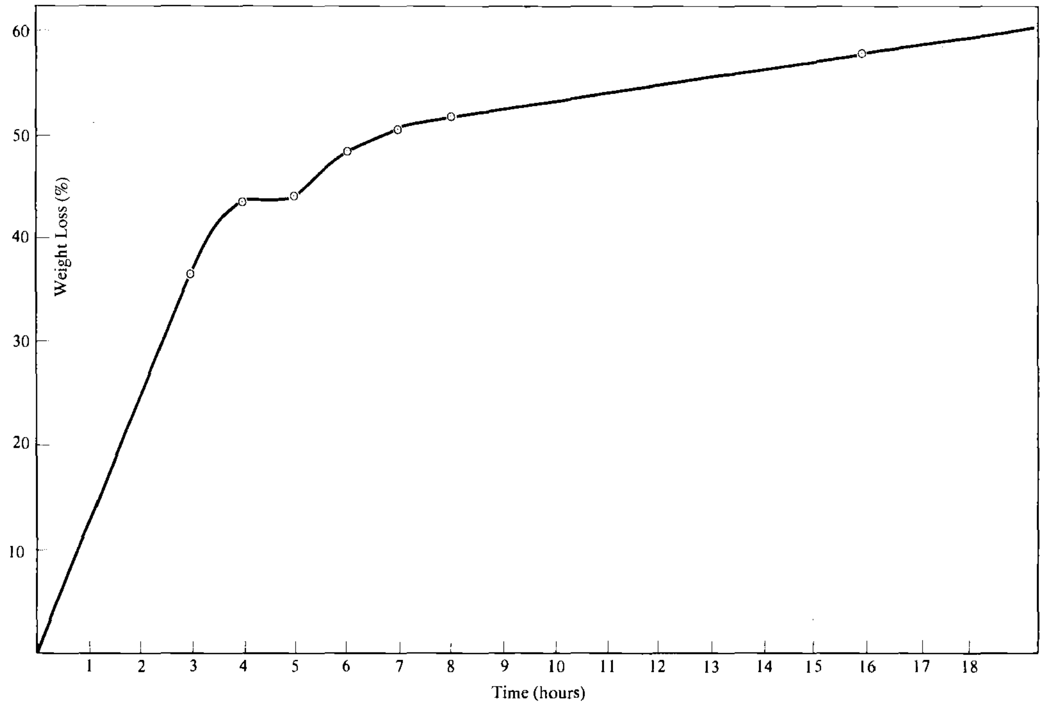

Figure 2: Rate of loss of original moisture by ripe mango pieces immersed in a static sucrose solution of 70 percent starting concentration.

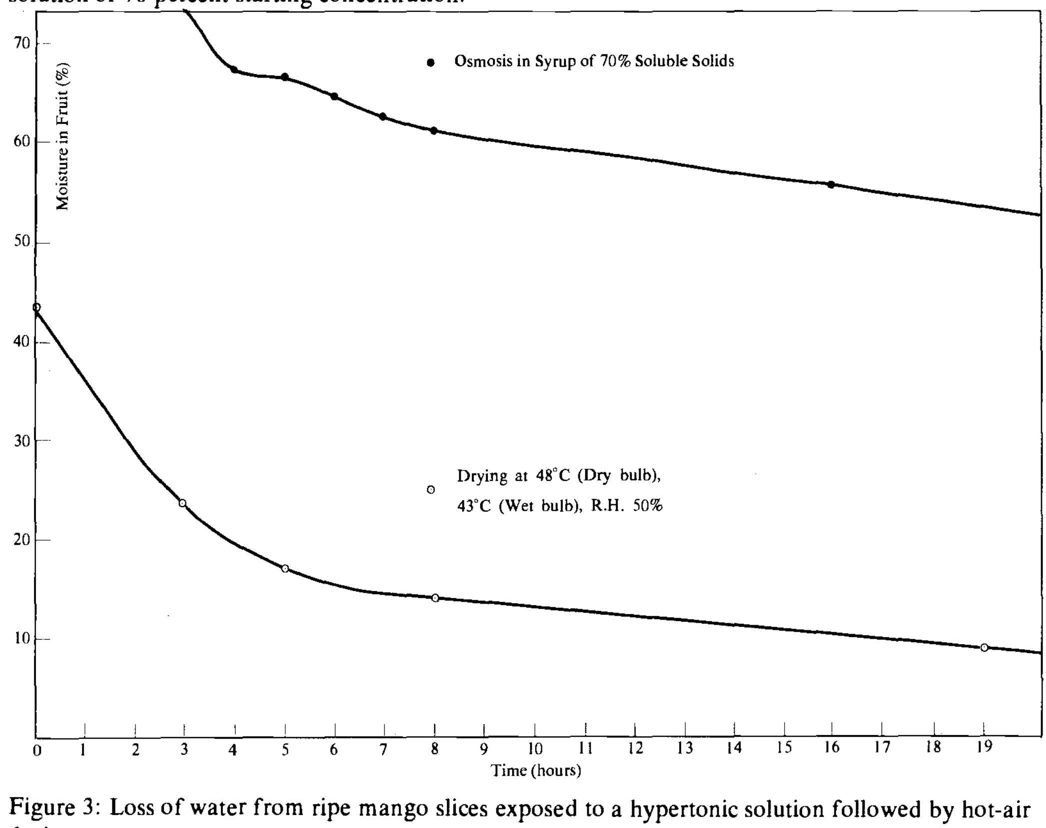

Figure 3: Loss of water from ripe mango slices exposed to a hypertonic solution followed by hot-air drying.

TABLE 5

Colour retention and sulfur dioxide content of treated banana slices

Colour Rank[1]	SO_2 Content ppm	Method used in treatment
1	1758	0.50% SO_2 in 65% sucrose syrup for 18 hours
2	453	0.25% SO_2 in 65% sucrose syrup for 18 hours
3	314	0.50% SO_2 in water for 2 minutes before osmosis and 0.50% SO_2 in dilute syrup 1 hour after.
4	483	0.50% SO_2 in dilute syrup 2 hours following osmosis.
5	268	0.50% SO_2 in water for 5 minutes before osmosis and 0.25% SO_2 in dilute syrup for 2 hours after.
6	445	0.50% SO_2 for 2 hours in dilute syrup after.
7	460	0.50% SO_2 in water for 5 minutes before and 0.50% SO_2 in dilute syrup for 2 hours after.

[1] Colour ranks above 7 were considered undesirably dark and are not reported here.

It was found that sulfur dioxide would protect the pieces from such undesirable change during drying and subsequent storage. Several methods of applying SO_2 were examined: (a) dipping in a solution of sodium metabisulfite before immersion in the salt or sugar solution (b) adding sodium metabisulfite to the osmotic solution itself (c) dipping in dilute syrup containing sodium metabisulfite after osmosis (d) combinations of these three. Different levels of SO_2 concentration in the various solutions were also investigated.

Sulfur dioxide levels sufficiently high to protect colour could be attained by any of several methods (Table 5). The one giving the highest protection, 0.5 percent SO_2 in the hypertonic solution, gave a residual content too high to be acceptable from the standpoint of taste. The best and most convenient methods were the addition of 0.25 percent SO_2 to the solution or a two-hour soak in 60 percent syrup containing 0.5 percent SO_2 following the osmotic treatment.

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