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Use of a Combination Process of Osmotic Dehydration and Freeze Drying to Produce a Raisin-Type Lowbush Blueberry Product

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ABSTRACT

A raisin-type product was prepared from lowbush blueberries using a sequence of osmotic dehydration, freeze drying, and thermal plasticization. Qualities of osmotically dehydrated blueberries, residual syrup, and final products were studied using various ratios of berry and sugar. An accelerated storage test was also conducted. IQF berries were preferred to fresh berries as a starting material, and a berry/sugar ratio of 3:1 or 4:1 was appropriate. Final products had good texture, flavor, overall acceptability, and a predicted shelf life of 16 and 64 months at 25° and 5°C storage, respectively.

INTRODUCTION

THE LOWBUSH BLUEBERRY of Northeastern North America, *Vaccinium angustifolium* Ait., has a brief harvest season and fresh berries may not be kept for more than 6 wk after harvesting. Until now, most of the crop was frozen with only a small portion canned. The usual harvest in Maine ranged 20–25 million pounds. In recent years, however, records of 40–45 million pounds were harvested (e.g., 1983, 1985, 1986) due to improved horticultural technology as well as favorable weather conditions. This huge and somewhat unanticipated crop had promoted more effort in developing new products from this fruit (Yang, 1984a,b; Yang and Atallah, 1985; Yang and Yang, 1986).

Dehydration as a preservation method may be easily applied to the lowbush blueberries due to the relatively small size of the fruits. An intermediate moisture (IM) blueberry product containing 16–25% water may have several advantages: a high nutritional content because dehydration has little effect on the mineral content, and vitamin losses equal to or less than other preservation methods. The same weight of IM blueberry may have more than five times the mineral and stable vitamin contents compared to the fresh counterpart. The ready-to-eat texture and easier rehydration have made the IM berries a promising product in the snack and convenience food industry. While sun drying is one of the primitive and inexpensive methods of drying certain fruits, it is limited to climates with hot sun and dry atmosphere, and is not applicable to such fruits as blueberries (Somogyi and Luh, 1975). An explosion-puffing process has been applied to dry cultivated and Rabbiteye blueberries (Eisenhardt et al., 1964, 1967; Sullivan et al., 1982) but no data were available for the lowbush blueberries; its smaller size, thinner skin, and delicate flavor might cause a severe quality deterioration of the finished products under the high pressure and temperature of operating conditions. Freeze drying has been found to give excellent results of the said varieties of blueberries (Hanson, 1961; Rahman et al., 1970; Scharschmidt and Kenyon, 1971), but no such process had been applied to the lowbush variety. In addition, most berries dried with these mechanical methods are used for rehydration purposes; a blank flavor and a spongy, woody texture are found when these dry products are consumed directly.

A major drawback of freeze drying is the economics of the process which prohibits its large-scale application. Besides those accelerated methods proposed by Hanson (1961), Vollink et al. (1971), Scharschmidt and Kenyon (1971), osmotic drying, proposed by Ponting et al. (1966) and Farkas and Lazar (1969), can pre-dehydrate the fruits by removing 50% of the initial weight of the fruit with either dry sugar or syrup. Since the cost of freeze drying depends on the amount of moisture removed, the pre-treatment with osmotic drying would reduce the processing expense. Also, the syrup remaining after osmotic drying can be recycled as suggested by Bolin et al. (1983) and further reduce the cost. Attempts had been made to produce a direct-consumed fruit chip by Koshida et al. (1982) who first soaked diced or sliced fruit chips in a 5–30% sugar syrup and proceeded with a sequence of freeze drying, vacuum-microwave drying, and a final vacuum drying to achieve a final moisture of less than 5%. The product can be consumed as a crunchy confection-type snack. Rahman et al. (1970) proposed a thermal conditioning to plasticize the crunchy and sometimes fragile freeze-dried fruits to produce a space-saving, compressed, dehydrated product; this approach was adopted in this experiment to induce the chewiness of the finished freeze-dried blueberries.

The objectives of this study were to develop a semi-moist, raisin-type snack from lowbush blueberries through a sequence of osmotic and freeze drying, and a final thermal conditioning, and to examine several preparation variables, the quality of the finished products, and their shelf stability.

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MATERIALS & METHODS

Blueberries

Both freshly harvested (1984 crop) and individually quick frozen (IQF; 1983 crop) lowbush blueberries were obtained from a local plant.

Sample preparation

Blueberries were thoroughly mixed with dry sugar and left at room temperature (25°C) for 24 hr; room temperature soaking was used as suggested by Ponting et al. (1966) for practical and economical reasons. The osmotically exuded liquid mixed with sugar to form a syrup which was drained and collected for analysis. The partially dehydrated and sweetened berries were then rinsed with running water for 30 sec in a colander and frozen in an air blaster (400 cfm; −40°C) for 20 min. Frozen berries were then freeze-dried under a vacuum of 10–25 torr with a platen temperature of 25°C and a condenser temperature of −40°C for 15–24 hr until terminal moisture content of 16% was attained. The vacuum was released abruptly to cause the shrinkage and wrinkling of the freeze dried berries. A subsequent thermoplastic process was followed by placing the dry berries in an oven at 90°C for 10 min. The finished product was cooled to room temperature (25°C) and used for further analyses.

Table 1—Effect of fruit-sugar ratio on osmotic-dried blueberries, residual syrup, and the finished products

	Osmotic-dried blueberries			Residual Syrup			Finished Products		
Berry:Sugar ratio	% Wt[a] loss	Moisture (%)	Soluble solids (%)	% Wt[b]	pH	Soluble solids (%)	Freeze dry time to reach 16% moisture (hrs)	Sticki-ness[c]	Instron texture[d] (kg)
2:1	43.7	63.0	28.3	61.2	3.15	46.6	24	+	325[a]
3:1	38.9	67.6	25.3	52.7	3.15	37.2	18	–	278[b]
4:1	37.2	69.5	24.7	49.2	3.15	32.0	15	–	254[c]

[a] Calculated as [1 – (wt osmotic-dried berries/initial wt berries)] × 100%.
[b] Calculated as (wt. residual syrup/initial wt. berries and sugar) × 100%.
[c] Sensed by touching between fingers at room temperature; +: yes, –: no.
[d] Data are means of three determinations; means within the column having a common superscript letter are not significantly different ($P \geq 0.05$).

Table 2—Accelerated shelf-life results of the 3:1 (berry/sugar) batch raisin-type blueberry products[a,b]

Storage				Sensory evaluation[c]		
Time (mo)	Temp. (°C)	Moisture (%)	Texture (kg)	Flavor	Texture	Overall quality
	5	—	—	—	—	—
0	25	16.0	278	8.7	8.2	8.5
	45	—	—	—	—	—
	5	16.2[a]	279[a]	8.6[a]	8.3[a]	8.5[a]
0.5	25	16.1[a]	283[a]	8.6[a]	8.4[a]	8.5[a]
	45	16.0[a]	282[a]	8.6[a]	8.4[a]	8.5[a]
	5	16.1[a]	282[b]	8.4[a]	8.2[a]	8.2[a]
4	25	16.2[a]	278[b]	7.9[a]	7.5[a]	7.5[a]
	45	15.3[b]	324[a]	4.2[b]	5.2[b]	4.7[b]
	5	16.2[a]	280[b]	8.2[a]	7.1[a]	7.4[a]
8	25	16.2[a]	274[b]	8.3[a]	7.6[a]	7.6[a]
	45	14.1[c]	342[a]	3.1[b]	2.2[b]	2.5[b]

[a] Data are means of three determinations.
[b] Means within columns having a common superscript letter are not significantly different ($P \geq 0.05$).
[c] Sensory score: 9 = excellent; 7 = good; 5 = fair; 3 = unacceptable; 1 = very unacceptable.

Osmotic dehydration-freeze drying study

Blueberry/sugar ratios (w/w) of 2:1, 3:1, and 4:1 were used on each 30 lb batch of blueberries. Weight loss and moisture of the osmotically dehydrated berries, percentage weight and pH of the residual syrup, and soluble solids of both berries and syrup were measured. Moisture was determined by the AOAC vacuum oven procedure (1980), and an Abbe Refractometer was used for soluble solids determination. Freeze-dry time to reach the final 16% moisture was determined, and stickiness of the finished products was determined by a group of 10 semitrained panelists. Each panelist was asked to roll a sample between the thumb and the index finger three times before separating; a sticky remark (i.e., "+") was chosen when the sample adhered to either finger after separating. The result was pooled and a majority decision was chosen thereby. Texture measurements similar to that of Bolin (1976) on raisins were made using an Instron Universal Testing machine (Model 1000; Instron Inc., Canton, MA) equipped with a 10-blade compression cell (C-370) which determined the force required to push the blades through 90g of the raisin-type blueberries at room temperature (25°C). The Instron machine was operated at 500 kg range with a crosshead speed of 50 mm/min and a chart magnification factor of 2. All measurements were done in triplicate.

Shelf-life study

An accelerated shelf-life test proposed by Nury et al. (1960) was adapted. The 3:1 (berry/sugar) finished product was stored at 5°, 25°, and 45°C in glass jars and in a dark environment. Sampling for moisture, texture, and sensory panel evaluations was done at 0, 2 wk, 4 months, and 8 months of storage. Samples were packed in separate glass jars so that each time a new jar was evaluated.

The sensory panel test, adapted from Waletzko and Labuza (1976), was conducted with a group of 10 semitrained panelists who were presented 20g test samples brought to room temperature (25°C) before serving. The panelists were seated in individual booths illuminated with white fluorescent lights. They rated the samples on a 9-point scale (9 = excellent; 7 = good; 5 = fair; 3 = unacceptable; 1 = very unacceptable) for flavor, texture, and overall quality. The evaluation was repeated 3 times.

Effect of the storage temperature on the color of the samples was examined after 8 months' storage. Reflectance color was measured with a Hunter LabScan II spectrocolorimeter with an 1-3/4 inch aperture. Alcohol extractable color was determined according to the method of Nury et al. (1960). A 15-g sample of well-mixed, ground freeze-dried fruit was placed in 300 mL Erlenmeyer flask containing 200 mL 50% ethanol. The flask was covered with Parafilm and allowed to remain at room temperature (25°C) for 24 hr with occasional shaking. The colored solution was then filtered through Whatman No. 2 filter paper and the color reading taken with the Hunter meter; the filtrate was further diluted 10-fold with 50% ethanol and the color reading made with the aid of a Bausch and Lomb spectrophotometer (Spectronic 20) at 440 mu with a 1.2-cm cell using a 50% ethanol solution for zero adjustment. The results were recorded in absorbance units and the data were converted to a moisture-free basis by division of the observed absorbance value by the fraction of the original sample that was total solids.

Statistical analysis

The data were analyzed by Statistical Analysis System (SAS, 1982) with a Waller-Duncan Test at k ratio of 100 (approximately 5% level of probability).

RESULTS & DISCUSSION

THIRTY POUNDS 3:1 (berry:sugar) fresh blueberries took approximately 50 hrs to be osmotically dehydrated to a 25% total solids as compared to 24 hrs for the IQF berries; the waxy surface of the fresh berries might have reduced their permeability to water and thus hindered the osmotic dehydration. Several methods have been developed to accelerate the dehydration by removing the waxy coating with oleate or cracking the fruit skin with caustic dipping (Petrucci et al., 1974; Somogyi and Luh, 1975); however, the taste thresholds problem of oleate treatment (Guadagni et al., 1975; Guadagni and Stafford, 1979) and high temperature and stickiness problem of the caustic

Table 3—Color measurements of 8-month raisin-type blueberry products stored at different temperatures

	Reflectance color			Alcohol extractable color			
Temp. (°C)	*L*	*a*	*b*	*L*	*a*	*b*	Absorbance at 440 mu
5	13.66[a]	1.56[b]	0.11[b]	5.38[a]	13.20[a]	3.32[a]	0.70[b]
25	12.66[b]	1.58[b]	0.12[b]	4.98[b]	12.49[b]	3.11[b]	0.78[a]
45	14.23[a]	2.30[a]	0.35[a]	5.37[a]	12.90[a]	3.32[a]	0.63[c]

[a,b] Data are means of three determinations. Means within columns having a common superscript letter are not significantly different (P≥0.05).

dipping (Grncarevic, 1963; Ponting and McBean, 1970) have limited the application of these methods in such fruits with mild and delicate flavor as lowbush blueberries. The freeze-thaw effect in the IQF berries might peel away the waxy coating or slightly crack the skin thus facilitating transfer of liquid through the skin without any chemical treatment; hence, IQF berries were used in the subsequent studies.

Osmotic drying study

To obtain optimum ratio of dry sugar to fruit to be used in osmotic dehydration, Ponting et al. (1966) suggested selecting an adequate reservoir of sugar to achieve the desired water removal without significantly lowering the drying rate, yet ensuring a proper solubility of the residual sugar at the end point to facilitate draining. Results showed that more sugar (e.g., 2:1 berry:sugar) tended to reduce weight of berries more (Table 1) yet a significant amount of residual sugar remained in the 2:1 batch even after a prolonged soaking. Both the rate of weight loss and extent of dehydration slowed down after 24 hr. The weight loss was attributed to the loss of moisture from the berries, indicating an increasing soluble solids in the berries (IQF blueberries had 86% moisture and 11% soluble solids) and a large amount of residual syrup. The pH of the syrup was similar to that of the thawed, ground IQF blueberries (i.e., pH= 3.4), indicating an equilibrium of the acid on both sides of berry skin. The soluble solids of the syrup can be easily used as an index for determining the endpoint instead of repetitive, tedious draining and weighing of berries. This syrup contained high acidity and sweetness, and a strong fresh berry flavor which would make it a suitable ingredient for such products as table syrup, concentrate, beverage, wine, fruit roll-ups, jellies, and flavorant, etc.

Rinsing the clinging sugar or syrup from the osmotically dehydrated berries is extremely important. Sugar removal would not only facilitate freeze drying by preventing clumping of the berries but prevent stickiness of the finished product. The water pick-up after a 30 sec rinsing was negligible.

Freeze dried product characterization

Although more sugar removed more water from berries through osmosis, it took a longer time for freeze drying (Table 1). Higher concentration of sugar in the berries would increase the viscosity of intercellular fluid, causing a lowering of the freezing rate (Luh et al., 1975), and the resulting ice crystals were larger than those of 3:1 or 4:1 batch, thus slowing down the freeze drying rate (Hanson, 1961). Higher concentration of sugar also caused more stickiness and a harder texture (Table 1). Grape raisins, at 16% moisture, had a texture close to that of the berry product prepared from 3:1 or 4:1 batch (Bolin, 1976). It seems, therefore, more practical to use a fruit-to-sugar ratio of 3:1 or 4:1. Products prepared by osmotic-freeze drying had more fruit flavors than the ones simply freeze dried (Ponting et al., 1966); a similar result with blueberries was observed in this laboratory (Yang, 1986). Sugar, as one of the flavor protectants commonly used in berry fruits, tends to protect the flavor from oxidative breakdown (Shewfelt, 1975). Crystallization development, usually occuring on the surface of higher moisture raisin (Bolin, 1976), was not observed in the 3:1 blueberry products after protracted storage. Higher sugar contents in the blueberries after osmotic dehydration and freeze drying would bind more water and make it less available for this problem to occur. The increasing viscosity of intercellular fluid in the berries would cause formation of numerous, small ice crystal after subsequent freezing, and eventually prevent the non-uniform drying commonly occurring in freeze dried products observed by King et al. (1976). Sudden release of the vacuum after freeze drying could cause flushing off of the residual moisture in the core of the fruit and further distribute moisture uniformly.

Accelerated storage study of raisin-type blueberry products

A 16% moisture in the finished products was similar to that of raisins, an intermediate moisture food; its low water activity (a_w) would provide a shelf stability without refrigeration or thermal processing (Kaplow, 1970; Brockmann, 1970; Labuza et al., 1970). This moisture level started to decline after 4 months of storage at 45°C (Table 2), and the product showed an increase in hardness. Labuza et al. (1970) and Waletzko and Labuza (1976) had reported an increase in textural hardness with age without any moisture loss in an intermediate moisture model system. They related the browning deterioration to the toughening of a product during storage. Hence, the hardening effect on this blueberry product might be attributed to both decreasing moisture and/or browning deterioration. Although dried blueberries are naturally dark brownish-purple and discoloration is difficult to distinguish visually, it is possible to measure these changes by objective analyses (Nury et al., 1960). Skin color, measured by reflectance, showed a lighter appearance (i.e. higher *L* value) after 8 months of storage in products stored at 5°C or 45°C than those stored at 25°C (Table 3). The latter showed a significantly higher level of red and yellow pigments (i.e. higher *a* and *b* values, respectively). The reddish-yellow color is a typical result of browning reaction which resulted in an anthocyanin degradation and an increase in yellow hue (Skrede, 1985). The alcohol extractable color of the ground products also showed a similar result except that both 5°C and 45°C batches had higher red and yellow color. The result suggested a color change occurred simultaneously as storage temperature varied, and the internal change was more pronounced than that on the skin of the samples stored at 5°C.

Blueberries dehydrated by osmosis and freeze drying were not subjected to a high temperature over an extended time, so heat damage to flavor was minimized. However, one of the disadvantages of sugar-treated fruit was a tendency to become rancid after prolonged storage due to the greater retention of flavor oils in osmotically treated fruits (Ponting et al., 1966). An off-flavor was observed by the panel evaluation after 4 months of storage at 45°C (Table 2), and after 8 months of storage it became unacceptable. The hard texture and off-flavor had contributed to an overall unacceptability for this sample.

For intermediate moisture foods, Waletzko and Labuza (1976) offered a conservative prediction of shelf-life that deviated from an Arrhenius relationship of log (rate) vs $°K^{-1}$ when higher temperature data were projected to lower temperature. Therefore, it is safe to predict the 25°C and 5°C samples would have a predicted shelf-life of at least 16 and 64 months, respectively.

CONCLUSIONS

FROZEN BLUEBERRIES are preferred to fresh berries as a raw material. Using a berry:sugar ratio of 3:1 or 4:1 for osmotic dehydration, followed by a sequence of thorough rinsing, freeze drying with abrupt release of vacuum, and a thermal conditioning, it is feasible to produce a raisin-type blueberry product. The product exhibits good flavor, texture, and overall quality, and a long shelf stability. These results were obtained in a small scale, laboratory processing unit and should be evaluated by individual companies before adoption.

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