Storage Properties of Dehydrated Applesauce Made from Explosion Puffed Pieces

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SUMMARY

Dried applesauce powder was made from explosion-puffed apple pieces by comminuting the dried pieces and blending with sucrose and a fruit acid. Keeping properties of the powder were determined by periodic evaluations over a 9-month period. Air and N_2 packed samples were stored at 0, 38, 73 and 100°F. Initial moisture content of the powder was 1.4% and SO_2 content was 175 ppm (MFB). Evaluations included taste, color, rehydration and chemical analyses.

Results show that N_2 packing prolonged shelf life and allowed room temperature (73°F) storage for at least 9 months. Air packed samples stored at 38° and 73°F developed off-flavors in 5 months, but were still acceptable in flavor at that time. At 100°F storage, both air and N_2 packed samples were unacceptable in flavor at about 6 months. Severe caking occurred at 100°F but not at 73°F or below. Color changes took place in all samples ranging from a darkening at 100°F to a lightening at 73°F and below. Less color change took place in N_2 packed samples (except 100°F) than in air packed. Color of the 73°F, N_2 packed sample, at end of period, was essentially the same as the 0°F, N_2 packed sample. It was considered "Fancy" grade. Use of 5-hydroxymethylfurfural content as a criterion for sample deterioration was of doubtful value in this test.

INTRODUCTION

Dehydrated applesauce is not a new product, but the explosive-puffing process used in its preparation is a recent innovation. Explosion-puffed products resemble freeze-dried products since both are porous. This porous product is produced by the instantaneous flashing of pressurized superheated liquid within the pieces, when discharged from a specially designed gun (Heiland *et al.,* 1965). The porosity of these pieces, after drying, permits a much more rapid rehydration than conventionally hot-air dried pieces of comparable size.

A comparison made by Saravacos (1967) of freeze-dried, explosion-puffed and air-dried pieces showed that the puffed pieces had a partially porous structure (as in freeze-dried) and a partially compact structure (as in air-dried). Comparative porosities (surface connected pores as percent total piece volume) were shown by Eisenhardt *et al.* (1968) to be 88.2% for freeze-dried, 61.5% for puffed and 10.7% for air-dried.

Although the explosive-puffing process is intended primarily to produce relatively large pieces such as apple segments or dice, its use permits more flexibility in plant operations where several products are made including baking mixes and sauce. Production of the dehydrated material can readily be proportioned between large pieces or comminuted pieces as product demand shifts.

The many and varied processing techniques used in preparing dehydrated apple products have a pronounced effect on the composition, structure and physical state of the end products. The amorphous, glassy structured fruit juice powders described by Strolle *et al.* (1966) are quite different from a porous freeze-dried apple piece. Hence to ascribe similar storage properties to dried apple products in general would be fallacious. For example, storage tests conducted on a powdered apple juice product (Turkot *et al.,* 1955) showed no significant difference in storage stability when powders were packed in air, N_2, or under vacuum. However, tests made on apple nuggets, when reconstituted to applesauce (Anon., 1944) showed that inert gas packing markedly improved keeping qualities over air packed samples. Both storage tests had been conducted at nearly the same moisture contents and temperatures.

Since the explosive-puffing process differs from other methods of preparing dehydrated products, the storage evaluation of instant applesauce, made from puffed pieces, was undertaken.

Samples of dehydrated applesauce mix were both air and N_2 packed, stored at 0, 38, 73 and 100°F, and examined periodically during a 9-month storage. Evaluations were made on flavor, color, ease of reconstitution, Brix, acid (as malic), Brix-acid ratio, O_2 content of N_2 packed samples, SO_2, moisture content and hydroxymethylfurfural (HMF) content. Changes in HMF content were to be an indication of "deterioration" as cited by Luh *et al.* (1963) for canned applesauce.

EXPERIMENTAL

Sample preparation. Mature, sound apples of York Imperial variety were peeled, cored, sliced and segmented. The segments were dipped 5 min in a 1.5% aqueous solution of sodiumbisulfite to preserve color, then screened to remove undesirable small pieces. Segments were hot-air dried at 180°F to 15% moisture content, equilibrated to assure uniform moisture distribution, then explosion-puffed.

The puffed segments were further dried by hot air at 150°F to a moisture content of 2.5% or less. The final drying time was 2½ hr, showing that vacuum drying in this final stage was not necessary because of piece porosity imparted during puffing.

The explosion-puffed, dehydrated pieces were ground so that 100% would pass through a U. S. Standard No. 20 sieve. This resulted in a smooth-textured sauce on reconstitution. A palatable balance of sweetness and tartness required an adjustment in the Brix-acid ratio by addition of sucrose and a food acid (malic) to the apple powder. A food-grade, anti-caking agent, calcium stearate (0.25% by weight), was added only to the 100° storage series.

A reconstituted applesauce with an apple solids to sugar ratio of 2.5 to 1, a Brix of 19.5° and a Brix-acid ratio of 45 was considered pleasing in flavor, texture and consistency. The dry ingredients were mixed proportionately so that 70 g would yield the above on reconstitution with 300 ml of boiling water.

Samples were air or N_2 packed in 202 × 212 (4-ounce) enameled tin cans and stored at 0, 38, 73 and 100°F. Initial moisture content was 1.4%, the

Table 1. Taste panel evaluation of stored applesauce.

Storage time (days/mos.)	100° N_2	100° Air	73° N_2	73° Air	38° N_2	38° Air	0° N_2	0° Air
46/1.5	Excel	Excel	....	....	....	....	Excel	Excel
100/3.3	Good	Fair	....	....	....	....	Excel	Excel
155/5.1	Fair[1]	Fair[1]	Excel	Fair[2]	Excel	Fair[2]	Excel	Excel
210/6.9	Poor[3]	Poor[3]	Excel	Fair Poor[2]	Excel	Poor[4]	Excel	Excel
265/8.7	Poor[3]	Poor[3]	Excel	Poor[4]	Excel	Poor[4]	Excel	Good[2]

[1] Acceptable—has slight "browning" taste but is not unpleasant.
[2] Acceptable—"hay-like" flavor.
[3] Not acceptable—"burnt sugar" taste.
[4] Not acceptable—pronounced "hay-like" flavor.

SO_2 level was 175 ppm, and the O_2 level in N_2 pack was 2.0% or less.

ANALYTICAL PROCEDURES

Reconstituted applesauce at room temperature was used for determining Brix-acid ratio, hydroxymethylfurfural and color measurements. Moisture content and SO_2 analyses started with dry sauce powder.

Brix-acid ratio. The refractive index of a small portion of squeezed apple juice was determined using an Abbé refractometer. Sucrose concentration (Brix) was obtained from a standard table. Values were corrected for temperature. Results are expressed as grams sucrose per 100 g reconstituted applesauce on an "as is" basis.

Titratable acidity was determined by the Glass Electrode method as described in AOAC (1965). One hundred g reconstituted applesauce was diluted with 300 ml distilled H_2O and mixed thoroughly in a Waring blender. A 50 ml aliquot of this mixture was titrated with 0.100*N* NaOH using a Beckman Zeromatic pH meter. Titratable acid was calculated as g malic acid per 100 g reconstituted applesauce on an "as is" basis.

Brix-acid ratio is the ratio of these two values.

Hydroxymethylfurfural. Hydroxymethylfurfural (HMF) was determined by the Method B of Keeney *et al.* (1959), employing the modifications outlined by DellaMonica *et al.* (1968). The sample was prepared for analysis by squeezing reconstituted applesauce through cheesecloth and diluting 5 ml of this juice to 250 ml in a volumetric flask. A 5-ml aliquot of this solution was diluted to 10 ml and analyzed. A reagent blank containing 10 ml H_2O was also determined. Results are reported as micro moles HMF per 100 ml squeezed apple juice.

All optical density measurements were made with a Beckman Model B Spectrophotometer using 1-cm Pyrex cells.

Color measurement. A Gardner Automatic Color Difference Meter, Model AC-2A was used for all color measurements. The reconstituted applesauce was placed in glass cells and the color values for each sample were obtained in terms of Hunter a, b and R_D units. The instrument was standardized each time with a standard color tile #CMY 0021 (R_D = 27.1, a = −2.2, b = +34.3). The total color difference was determined using the Hunter-Scofield equation (Mackinney *et al.*, 1962):

$$\Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2}.$$

(The R_D values were converted to L values using conversion tables.)

Headspace oxygen. The oxygen content of the headspace gas in the cans of applesauce was determined using a Beckman Model E-2 oxygen analyzer. The instrument was standardized with pure nitrogen gas and an oxygen-nitrogen mixture (8%–92%).

Moisture. Moisture content was obtained by the standard vacuum oven method. Moist samples (>10%) were dried at 70°C under vacuum for 16 hr. Dry samples (<10%) were dried at 84°C under vacuum for 6 hr. Results are expressed on an "as is" basis.

Sulfur dioxide. Sulfur dioxide was determined by the method of Nury *et al.* (1959) with modifications.

A 15 g sample of dry sauce was extracted with a mixture containing 45 ml of a special buffer solution (Ross *et al.*, 1960) plus 240 ml of distilled water.

An aliquot of the blend was weighed into a tared 100 ml volumetric flask, then 2 ml of 0.5*N* NaOH was added. The solution was swirled 30 sec. It then stood an additional 1½ min before 2 ml of 0.5*N* HCl was added. Then 20 ml of sodium tetrachloromercurate solution containing sulfamic acid (0.60 g/l) was added to prevent interference of nitrogen dioxide (West *et al.*, 1962). Mixture was made to 100 ml mark with water, mixed, and filtered. Two ml of the filtrate was used for the colorimetric analysis.

RESULTS AND DISCUSSION

Flavor. Evaluations were made by a 4-member trained taste panel on reconstituted sauce at room temperature. Results are shown in Table 1.

It is apparent that a low O_2 level is necessary for storage at 73° and lower. N_2 packing did not prevent off-flavor development at 100°F. N_2 packed samples stored satisfactorily at 73°F for 9 months but air packed samples were only "fair" after 5 months. Samples with an initial moisture content of 1.4% and stored at 100°F developed non-enzymatic browning off-flavors as shown by Johnson *et al.* (1964). No difference in flavor was detected between 100° samples with and without added calcium stearate. The "hay-like" flavor that developed in the air packed samples stored at 73°F or lower was not detected at 100°. This flavor could have been masked by the "burnt-sugar" taste of 100° storage.

Hydroxymethylfurfural (HMF). HMF analyses were made on the stored samples. Results are shown in Fig. 1. In all instances, HMF values decreased on storage with 38°F showing the greatest decrease, followed by 0, 73 and 100°F. Both N_2 and air pack samples were very nearly the same in value for 0° and 100° storage. The N_2 pack stored at 73° showed a greater decrease than the corresponding air pack.

HMF values apparently were not indicative of the degree or kind of off-flavor, since 0, 38 and 73° have about the same values at the conclusion of the test. Reynolds (1965), in her review of non-enmymatic browning, pointed out that at pH 3.6, HMF had

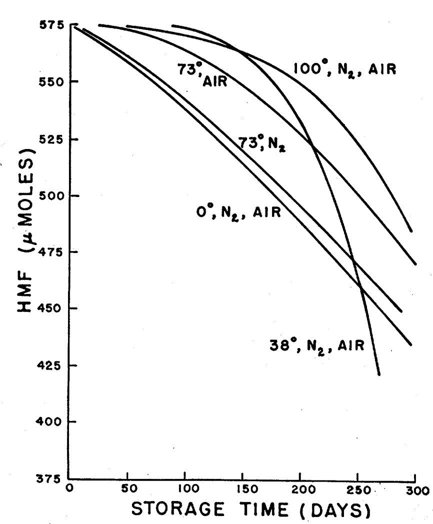

Fig. 1. Changes in HMF values of stored applesauce.

a minor role in pigment formation (pH of our sauce was 3.8), also HMF tended to polymerize at "high" temperature and to decompose at "low" temperature. HMF is apparently an intermediate or a side product in off-flavor development and was not a reliable guide in our applesauce evaluation tests.

Color. Color evaluations were made on the reconstituted applesauce by visual observation and with the Color Difference meter. Visual observations can be summarized as follows: 100°F both air and N_2 pack darkened equally and by the end of test were dark brown in color. The 0°, 38° and 73° N_2 packs retained a medium yellow color apparently unchanged throughout the test. The 0°, 38° and 73° air packs became lighter in color (pale yellow) with the least change at 0° and the most change at 73°. No brown color was noted in these samples.

Total color differences, ΔE, were calculated for respective differences between the sample and a reference. Compared with the initial values of the sauce at the beginning of the test, the results show that *all* of the samples underwent a change (Fig. 2). The deviations for 100° N_2 and air, and 38° and 73° air packs are apparent. It is difficult, however, to differentiate between 0° N_2 and air pack, and 38° N_2 and 73° N_2 packs. When the individual values for 0° N_2 pack samples were used at each testing period as a reference, then results were as shown in Fig. 3. These indicate that for all practical purposes 38° N_2 and 73° N_2 packs are indistinguishable in color from 0° N_2. Air pack samples at 0, 38 and 73° show similar color changes more rapidly as temperature increases. Again N_2 packing at 100° storage is shown to be ineffective in preventing color change.

The visually observed color of the 0°, 38° and 73° N_2 pack was apparently unchanged from the original; however, the Color Difference Meter showed that some changes had occurred. The difficulty in correlating visual acceptancy of food products with color responses has been shown by Mackinney *et al.* (1962). No attempt was made with these data to attach significance to amount of ΔE change from the original sample in the 0°, 38° and 73° N_2 pack samples.

Brix, acid and brix-acid ratio. Throughout the storage test, none of the reconstituted samples showed a significant change in Brix from the original value. Small differences in Brix appeared to be random and were probably due to minor variations in reconstitution. Since Brix and acid would retain the same ratio (B/A) regardless of dilution, this ratio was calculated to see if trends were present. Over the 9-month period, an increase in B/A was observed in all samples, which indicated a decrease in acidity. The B/A change for 100°F storage samples was the most pronounced. It showed a 22% increase. Differentiation between the other samples on relative degree of B/A change could not be made, but averaged about an 11% increase.

The phenomenon of B/A increase was observed during processing of the apple pieces, and the B/A for reconstituted apple powder was consistently higher than the B/A of the original apple. Analyzed before processing and after final drying (reconstituted), the results showed that titratable acid decreased by 38% during processing, while Brix increased to 18% above the original value. (All comparisons were on a dry weight basis using apple with no added sugar). However, cooking the fresh apples, as done in making sauce, caused little change in the soluble solids and titratable acid. In our processing, the greatest increase in soluble solids along with a decrease in titratable acid occurred during the predrying step prior to puffing. Little change occurred beyond the predrying step.

Lee *et al.* (1967) showed that hot air dehydration reduced fruit acidity while soluble solids, reducing sugars and total reducing sugars increased. This would account for the B/A change during processing. Since the reactions may not have been completed before the storage test was begun, an increase in B/A probably continued at a slower rate during storage.

Reconstitution. Severe caking occurred at 100°F in samples with or without added calcium stearate during the 46 days that preceded the first test. Apparently the "sticky-point temperature" (Lazar *et al.,* 1966) had been exceeded, but after the lumps were broken, the sauce rehydrated easily. No caking occurred at 73° or lower during the test, and all samples rehydrated easily. The sauce consistency remained the same for all samples during the storage test.

SO_2 and moisture. No trends could be shown in SO_2 level or moisture content in any of the storage series.

The deleterious changes that take place during storage can be retarded by low temperature and inert gas packing. Since N_2 packing had little apparent effect at 100°, and browning took place, it suggests that a different reaction mechanism might be involved than at 73° and lower. Further studies would be needed to confirm this view.

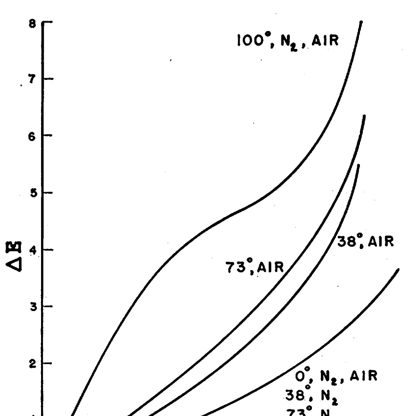

Fig. 2. Effect of storage on sample color differences (ΔE) when referred to the original values.

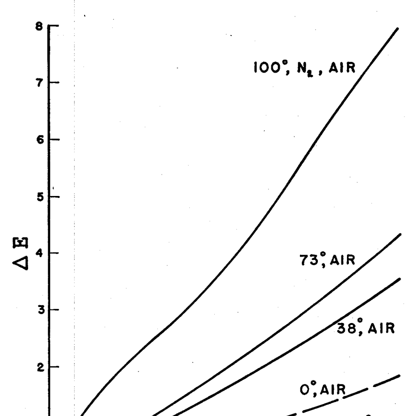

Fig. 3. Effect of storage on sample color differences (ΔE) when referred to 0°F storage sample.

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