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AN EVALUATION OF GAMMA IRRADIATION FOR PRESERVATION OF CITRUS SALADS IN FLEXIBLE PACKAGING

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Abstract. **Fruit salad was made from melon, pineapple, grapes and enzyme-peeled oranges in acidified sugar syrup, packed in high-barrier film. Addition of preservatives and use of irradiation (mean dosage 0.43 kGy) were optional treatments. Long-term protection from spoilage was achieved with addition of sodium benzoate and potassium sorbate whether or not the product was irradiated. Ethanol content approximately doubled during 6 months' storage at 5°C.**

Chilled citrus sections (or segments) are the unheated, perishable produce preserved in acidified sugar syrup with antimicrobial additives, packed in glass jars and stored under refrigeration. In the 1971-2 citrus season approximately 40,000 M.T. grapefruit and 20,000 M.T. oranges were used to make chilled citrus sections (Rouse and Moore, 1974). However, because the traditional method of making citrus sections was very labor-intensive, their manufacture in the United States was virtually discontinued.

Enzyme technology for making citrus sections drastically reduces the labor requirement and may make it possible to once again manufacture citrus sections in areas with higher labor costs. This new technology was developed in our laboratory (Bruemmer, 1981; Baker and Bruemmer, 1988).

Chilled citrus sections are preserved by a combination of measures. Use of antimicrobial additives, control of acidity and refrigeration, all three together, combine to give this produce a long shelf life. In one study, samples were reported in good condition after storage at 0°C for one year (Rouse and Moore, 1974). A shelf-life of six months was used in about 1980 by a manufacturer of chilled sections stored at 0 to 7°C (Landsman, Bartow Citrus Industries, Inc., personnel communication).

The maximum amount of sodium benzoate allowed as an antimicrobial agent in foods by 21 CFR 184.1021 is 0.1%, benzoic acid equivalent. This is approximately the amount used in the industry (Rouse and Moore, 1974). Chilled citrus sections currently available in Florida supermarkets, packed in glass, contain both potassium sorbate and sodium benzoate.

The acidity of chilled sections depends somewhat on whether the sections are packed with juice or syrup containing sugar and citric acid. Rouse and Moore (1974) observed pH of 3.7 ± 0.1 for orange sections packed in syrup, and pH 3.3 ± 0.1 for grapefruit sections packed in syrup. Specifications used by a manufacturer in the 1980's were pH 3.5 ± 0.2 for orange or grapefruit segments packed in juice, or pH 3.7 ± 0.2 for a mixture of grapefruit, orange and pineapple segments packed in sugar syrup.

Irradiation of whole grapefruit with dosage of 0.08 to 0.9 kGy has been shown not to adversely affect the flavor of ex-

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tracted juice (Moshonas and Shaw, 1984). In the present study, we undertook to determine if low-dose gamma irradiation could be used in lieu of antimicrobial preservatives.

Materials and Methods

One day before processing, cantaloupe (*Cucumis melo*), pineapples (*Ananas comosus*) and red grapes of unknown variety (*Vitis sp.*) were purchased in supermarkets in Winter Haven. 'Hamlin' oranges (*Citrus sinensis* (L.) Osbeck were harvested from groves near Winter Haven. All except the grapes were washed with Fruitcleaner 395 (FMC, Lakeland, FL). All were rinsed with 530 ppm NaOCl. To remove the peel, the oranges were scored three times around the fruit to a depth of 3 mm and submerged for 30 minutes in a solution made up of 0.7 g Pectinex Ultra SP-L (Novo Enzymes, Danbury, CT) per liter of distilled water. For the first 2 minutes of this period 26" vacuum was applied in order to draw the enzyme solution into the albedo (Baker and Hagenmaier, 1997). The peel was removed and the sections separated manually. The cantaloupe and pineapple were cut with knives into pieces 5-10 g. The grapes were used whole.

The fruit salad was made of about 50% enzyme-peeled oranges, 25% sliced fresh cantaloupe, 20% sliced pineapple and 5% whole red grapes. This was mixed with 21°Brix syrup made up of water, sucrose, 1.45% citric acid and sufficient sodium benzoate and potassium sorbate to bring their levels to 0, 0.04 or 0.1% of the mixture. Sodium citrate was added when preservative concentration was 0% or 0.04% (0.5 moles sodium citrate replaced 1.0 mole of benzoate or sorbate).

The product was sealed in plastic bags of 200 g net weight with an impulse sealer (TEW Electric Heating Equip. Co.). The seal was made below the liquid line, leaving no headspace in the bags. The bags were made of 50 mm thick, high-barrier film, oxygen transmission rated at 3-6 cc/m^2 day at 4°C (type B540, Cryovac, Duncan, SC).

Four 100 g samples per treatment were prepared for microbial analysis by agitating the product for 90 s in a paddle blender (Masticator, IUL, S.A., Barcelona, Spain). Each sample represented a separate bag. Three appropriate dilutions were plated out. Plate count agar (Difco Laboratories, Detroit, MI) was incubated at 35°C for 2 days to determine mesophilic population. Potato dextrose agar (Difco), acidified to pH 3.5, was incubated at 25°C for 3 days to determine yeasts and molds. Populations were expressed in colony forming units per g of product (cfu/g).

Ethanol content of macerated samples, with n-propanol as internal standard, was determined with a gas chromatograph (Model 5890, Hewlett Packard, Avondale, PA) using a FFAP column (50 m × 0.32mm, Hewlett Packard) and flame ionization detector. Column flow was 4 ml/min. Column temperature was 55°C for injection, increased thereafter 3°C/min. Ascorbic acid analysis was according to the HPLC method of Gökmen and Acar (1996). Brix was determined with a refractometer, and acid by titration to pH 8.2. For all these analyses, two separate pooled samples were prepared from 4 bags of fruit salad, each sample analyzed twice.

Triangle tests combined with preference ratings were used for sensory evaluation. Significance was determined from Roessler et al. (1978). The preference ratings were used only for those panelists who correctly paired the samples. The error bars in the figures show the pooled standard errors, except where these are smaller than the symbols.

Results and Discussion

In preliminary experiments, orange sections irradiated at 0.5 kGy were compared with sections not irradiated, containing no benzoate. Only 8 of 26 panelists correctly identified the different sample (not significant) with 6 preferring the non-irradiated and 2 the irradiated orange sections. Orange sections irradiated at 0.5 kGy were different from benzoated control; 21 of 25 correctly identified the odd sample (significant at $\alpha = 0.001$). However, no preference was indicated; 10 preferred the benzoated sample and 11 the irradiated samples. These results suggest that irradiation of chilled orange sections may be acceptable from flavor considerations. Microbial populations of fruit salad one day after irradiation were reduced over 90% by irradiation at mean dosage of 0.32 kGy (Fig. 1).

Such a low dosage cannot be expected to sterilize the product, but currently is about all that can be achieved, considering current regulations that set the maximum dose received by any of the product at 1 kGy (FDA, 1995), because in commercial situations some parts of the batch may receive a dosage as small as 33 to 50% of the maximum (Diehl, 1995).

Fruit salad was stored for extended times at 5°C after irradiation at mean dose of 0.43 kGy (0.36 kGy minimum, 0.49 maximum). For samples without sodium benzoate and potassium sorbate, the microbial populations increased with storage time (Fig. 2). The populations consisted of 85 and 92% yeasts, for irradiated and non-irradiated respectively (data not shown). For the samples with preservatives the populations decreased for about 40 days, and during this period the yeast populations were <1 cfu/g, but after 180 days storage amounted to 85 or 92% yeasts, for irradiated or non-irradiated respectively.

Mean ascorbic acid content of the fruit salads was 215 ± 40 ppm, and was not significantly influenced by storage time, addition of benzoate or irradiation (data not shown). Ethanol content was likewise not influenced by irradiation, but did rise with increase in storage time (Fig. 3). The ethanol contents were virtually the same for samples with 0.04 or 0.10% sodium benzoate and potassium sorbate (Fig. 3). In contrast, the samples with preservatives had much lower ethanol than

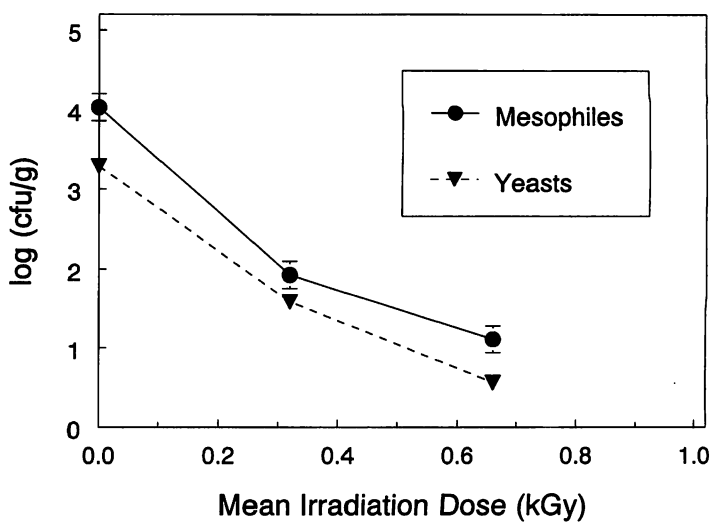

Figure 1. Mesophilic and yeast populations of fruit salad without preservatives stored 1 day at 2°C after irradiation at mean doses of 0.33 or 0.66 kGy.

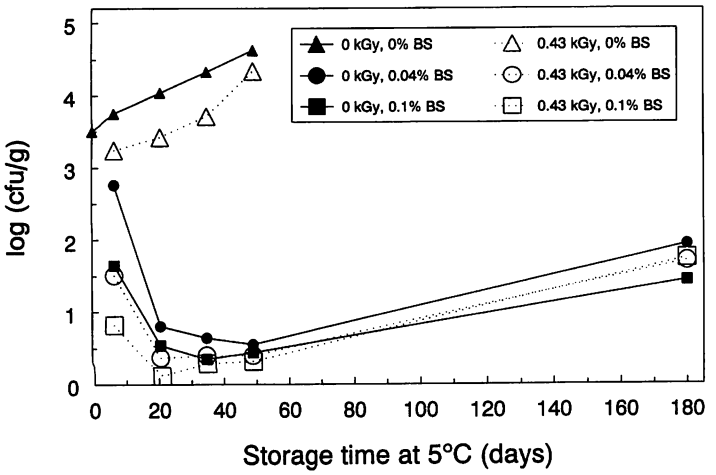

Figure 2. Mesophilic population of fruit salad with three levels of preservatives stored in sealed plastic bags (0%, 0.04% and 0.10% BS indicate these levels of sodium benzoate and potassium sorbate). Samples without preservatives were discarded after 62 days, when it was observed most were swollen.

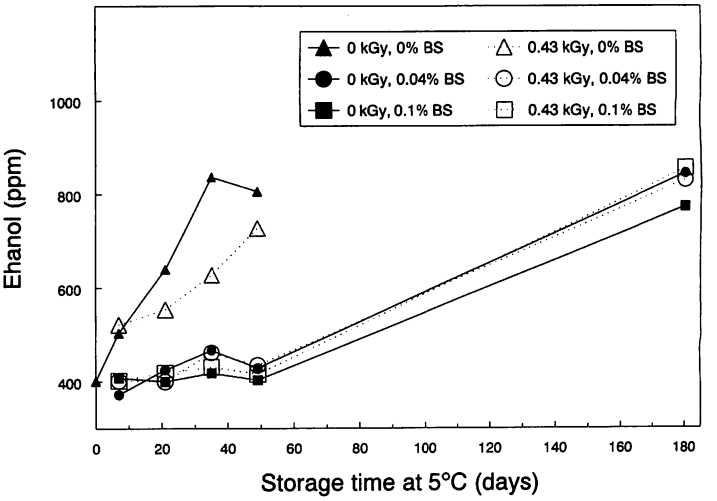

Figure 3. Mean ethanol content of fruit salad with three levels of preservatives stored in sealed plastic bags (0%, 0.04% and 0.10% BS indicate these levels of sodium benzoate and potassium sorbate).

samples without, suggesting ethanol was produced by the yeast.

Some samples were stored for 3 weeks at 5°C followed by 4 weeks at 10°C to simulate temperature abuse. Compared with samples stored for 7 weeks at 5°C, for all samples, the ethanol contents after storage at 10°C (data not shown) were virtually the same as they were after storage at 5°C (Fig. 3). In contrast, only those samples containing preservatives (at either level, 0.04% or 0.1%) had microbial populations about the same after storage at 10°C (data not shown) as they were after storage at 5°C (Fig. 2), namely about 3 cfu/g. For samples without preservatives the cfu/g values after 10°C storage were 2.2×10^7 and 14×10^7 for irradiated and non-irradiated, respectively, the bags were swollen, and the samples smelled like vinegar. The reason why the microbial populations, but not the ethanol contents, were relatively higher at 10°C than at 5°C may have been that some of the alcohol produced by yeast metabolism was oxidized to acetic acid, despite the low oxygen permeance of the bags.

Fruit salad stored for 180 days at 5°C appeared to be edible. No deterioration was apparent. Thus, the pectic enzymes used for peeling did not seem to prevent use of enzyme-peeled fruit in products intended for long-term storage in syrup.

There was no significant change in Brix, acid, Brix-acid ratio or pH for samples with preservatives when stored at 5°C for up to 180 days. Mean Brix was 14.8 ± 0.1°, acid (as citric) was 0.82 ± 0.01%, ratio was 18.0 ± 0.2 and pH was 3.70 ± 0.03 (data not shown). For samples without preservatives there was, however, 0.05% reduction in the acidity (0.2 increase in pH) after storage for 49 days.

In conclusion, irradiation of fruit salad did not replace the addition of chemical preservatives, and in general did not seem to contribute to the quality of the fruit salads. Enzyme-peeled citrus did not noticeably deteriorate during long-term storage, and plastic bags seem a suitable packaging material for fruit salad in syrup.

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