greater area exposed to the fungus spores.

Fruit injured by puncture gave the most consistent results and showed a decided varietal difference in susceptibilty. Hamlin oranges were the most susceptible and Marsh grapefruit and Valencia oranges, the least; Pineapple and Parson Brown oranges were intermediate. The results indicate that susceptiblity may be related to rind thickness, the varieties with thicker rind having a lower incidence of decay. The 1-mm. puncture of the thin skinned Hamlin oranges resulted in the same amount of decay as the 2-mm. puncture on the Marsh grapefruit. The greatest difference in decay following the punctures of various depths occurred between 1-mm. and 2-mm. depths, with the exception of Hamlin oranges, which showed more decay following 1-mm. punctures than the other varieties tested.

There was no relation between susceptibility to infection and rate of decay development. Decay rate was as great or greater in grapefruit than in any of the kinds of oranges tested. Later pickings of all varieties decayed more rapidly than the early pickings.

The influence of maturity on susceptibility of Marsh grapefruit to green mold following injury is illustrated in figure 1. The 3-mm. punctures resulted in high (90-100 percent) incidence of decay throughout the season. As the season progressed punctures of lesser depth were followed by an increasingly greater percentage of infection. The slope of the curve for the 2-mm. puncture is similar to that of the seasonal change of solids-to-acid ratio of the juice. (Data not shown.)

Results of the tests on oranges indicate that green mold decay should be rampant on Hamlin oranges, a condition which does not exist commercially. More green mold rot is normally observed during the winter months on midseason oranges of the Pineapple type than with fall or spring varieties. This is due in part to the fact that, while Pineapple oranges may not be the most susceptible to decay following uniform injuries, they have very tender rinds and are easily injured. This greater number of injuries would result in more decay.

The inoculum concentration was high in these experiments. Under natural conditions the spore load in the air would seldom be this high, and would rarely be uniform. During the early fall months the spore load in the air would be low but would increase, from decayed fruit during harvesting and handling of susceptible varieties, until the advent of Valencias which are less susceptible to decay. Temperatures below the optimum for green mold growth (75° F.) do not appear to be an important factor in reducing decay during midseason.

SUMMARY

Oranges and grapefruit were injured mechanically by different methods followed by artificial inoculation with *Penicillium digitatum* (green mold) spores. Oranges with cuts had greater incidence of decay than oranges punctured to the same depth. In all varieties approximately 100 percent decay followed 3-mm. punctures in all tests. Incidence of decay following shallower punctures showed varietal differences in the following descending order: Hamlin, Pineapple, Parson Brown, and Valencia oranges, and Marsh grapefruit. Susceptibility of Marsh grapefruit following puncture increased with maturity.

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EQUILIBRIUM MOISTURE CONTENT OF ORANGE JUICE POWDERS AT LOW RELATIVE HUMIDITIES

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The principal objective of this study was to ascertain the relative humidity that should be maintained during handling and packaging of two specific types of orange juice powders, so that they would not adsorb moisture from the

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air. In addition, information obtained in this study will be useful in future studies on the relationship of moisture content to caking and flavor stability.

A suitable range of data was obtained by subjecting two "Foam-Mat" (3) dried orange juice powder products to six different relative humidities, while stored at four different temperatures. The relative humidities to be approached were 2%, 4%, 8%, 10%, 14%, and 18%. The four constant temperatures of storage were 50°, 70°, 85°, and 100° F.

Isotherms of equilibrium moisture content versus relative humidity for both dried products were obtained. Both types of powders were produced by the "Foam-Mat" process described by Morgan *et al.* (3, 4). In this process orange juice concentrate with a small amount of foam stabilizer is foamed by use of a wire whip. This foam is then applied to a moving Teflon coated fibre-glass belt and dried in a stream of hot air. One orange juice product was stabilized with 0.8% modified soya protein and 0.2% methyl cellulose on a solids basis, while the other contained 1% monoglyceride.

Experimental Methods

Predetermined relative humidities were established in desiccators by evaporating the requisite amount of water into a known weight of dry silica gel. The water was evaporated into the silica gel under the same conditions that were to exist for the experiment. Duplicate samples of the silica gel were taken from the desiccators and weighed into tared aluminum dishes. These were subjected to 162° C. for six hours and weighed again. This furnished a means of calculating the silica gel moisture content. The silica gel moisture content in turn was translated to a relative humidity by interpolation of a plot furnished by data from the silica gel manufacturer (1). This procedure of obtaining the silica gel moisture content and translating it into a relative humidity was repeated at equilibrium to give the final equilibrium relative humidities.

Samples of the product in duplicate were weighed in tared aluminum dishes. These were placed in the desiccators, and the pressure reduced to four millimeters of mercury absolute to favor the exchange (6) of moisture between the orange juice powder and silica gel.

The orange juice powder samples were weighed as rapidly as possible in a low relative humidity room (10% or less) at three or four

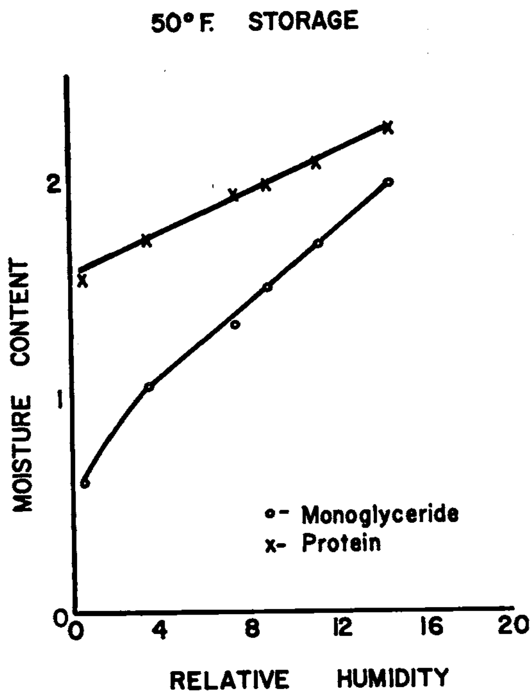

Figure 1. Relationship of Equilibrium moisture content of orange juice powders to relative humidity at 50° F.

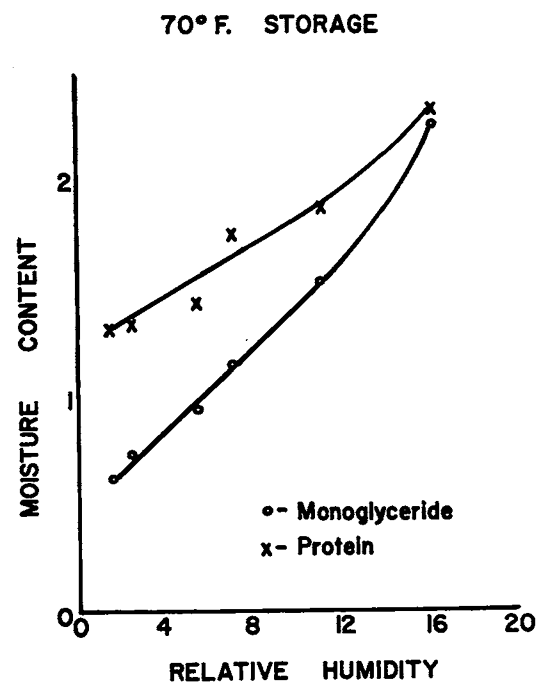

Figure 2. Relationship of Equilibrium moisture content of orange juice powders to relative humidity at 70° F.

TABLE I

Equilibrium moisture contents for "Foam Mat" dried products in 50° F. storage.

Monoglyceride Ave. Exp.E.M.	Ave. V.O.E.M.	E.R.H.	Modified soya protein Ave. Exp.E.M.	Ave. V.O.E.M.
0.61	0.59	0.5	1.56	1.56
1.09	1.05	3.6	1.76	1.73
1.44	1.34	7.5	1.98	1.94
1.59	1.49	9.0	2.06	1.98
1.68	1.70*	11.4	2.02	2.08
1.92	1.98*	14.6	2.18	2.23

Exp.E.M. - Experimental Equilibrium Moisture
V.O.E.M. - Vacuum Oven Equilibrium Moisture
E.R.H. - Equilibrium Relative Humidity
*Adsorption values (others by desorption).

TABLE II.

Equilibrium moisture contents for "Foam-Mat" dried products in 70° F. storage.

Monoglyceride Ave. Exp.E.M.	Ave. V.O.E.M.	E.R.H.	Modified soya protein Ave. Exp.E.M.	Ave. V.O.E.M.
0.62%	0.62%	1.5%	1.40%	1.32%
0.74	0.72	2.4	1.41	1.33
0.95	0.92	5.4	1.56	1.43
1.18	1.16	7.0	1.80	1.74
1.58	1.54	11.0	1.89	1.84
2.25	2.27*	16.3	2.34	- -

*Absorption values (others by desorption).

TABLE III.

Equilibrium moisture contents for "Foam-Mat" dried products in 85° F. storage.

Monoglyceride Ave. Exp.E.M.	Ave. V.O.E.M.	E.R.H.	Modified soya protein Ave. Exp.E.M.	Ave. V.O.E.M.
0.34%	0.44%	1.8%	0.66%	0.66%
0.52	0.59	2.9	0.76	0.72
0.94	0.92	5.6	1.08	0.96
1.04	1.12	7.4	1.14	1.12
1.49	1.50	10.8	1.52	1.45
2.30	2.32*	15.5	2.31	2.14

*Absorption values (others by desorption).

TABLE IV.

Equilibrium moisture contents for "Foam-Mat" dried products in 100° F. storage.

Monoglyceride Ave. Exp.E.M.	Ave. V.O.E.M.	E.R.H.	Modified soya protein Ave. Exp.E.M.	Ave. V.O.E.M.
0.40%	-	2.5%	0.27%	-
0.60	-	4.6	0.46	-
0.89	1.17%	7.0	0.78	1.04%
1.04	1.34	8.4	0.95	1.23
1.36	1.62	10.9	1.28	1.50
1.75	2.00*	14.1	1.69	1.88

*Absorption values (others by desorption).

day intervals until constant weight indicated equilibrium had been reached. This is a modification of Wink's equilibrium weight method (7) by which the equilibrium moisture content of a powder is calculated from the known original moisture content and the loss or gain in weight during equilibration. Both initial and final moisture content of the powders were determined by vacuum oven drying (2) (60° C. at 10 mm absolute pressure for 16 hours). Final moisture content at equilibrium was used to verify experimental (weight change) values. All moisture content values for the orange juice powder are on a wet-weight basis, although the work with silica gel was based on dry weight.

Results and Discussion

Results as tabulated in the tables give both the calculated experimental equilibrium moisture values and the vacuum oven values for the orange juice powder samples. In the middle column of each table the values of the final equilibrium relative humidity are shown for each desiccator. Comparisons of the calculated experimental equilibrium moisture values with the vacuum oven values for each *product in* tables I, II, and III show very close agreement. The vacuum oven values are considered more accurate in each case. In table IV the calculated values are all lower than the vacuum oven values. This seems to be caused by some discrepancy in technique which overshadowed the equilibrium points.

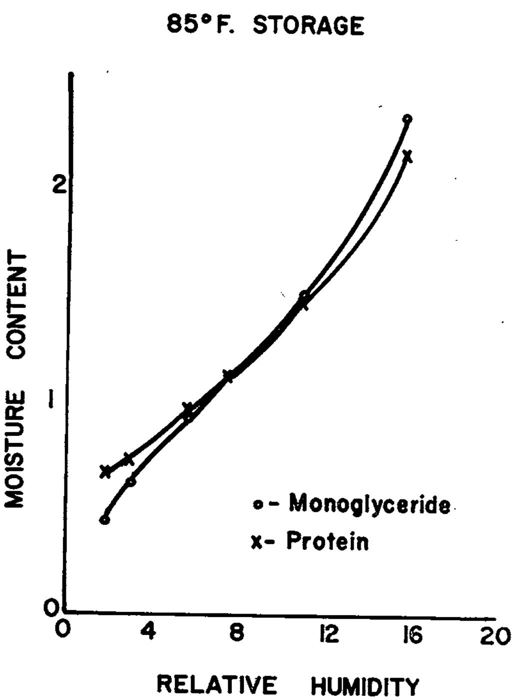

Figure 3. Relationship of equilibrium moisture content of orange juice powders to relative humidity at 85° F.

Plotting the vacuum oven values of equilibrium moisture versus relative humidity for each product gives the particular curve for each storage temperature. Comparisons of the curves of the two products show that the monoglyceride product contained less moisture at 50° and 70° F. than the modified soya protein product. This trend changed at 85° F., and the equilibrium moisture contents of the two products were equal at a relative humidity of 7.4. Above this relative humidity the monoglyceride product contained more moisture. In 100° F. storage all the monoglyceride samples contained a higher percentage of water than the modified soya protein samples.

Temperature influenced the equilibrium values in some cases and not in others. Nearly identical moisture-relative humidity relationships were observed for monoglyceride samples at 70°, 85°, and 100°F., but higher moisture contents were observed at 50°F. Modified soya protein stabilized samples showed similar moisture equilibrium values at 85° and 100°F., somewhat higher moisture values at 70°F. and still higher moisture values at 50°F.

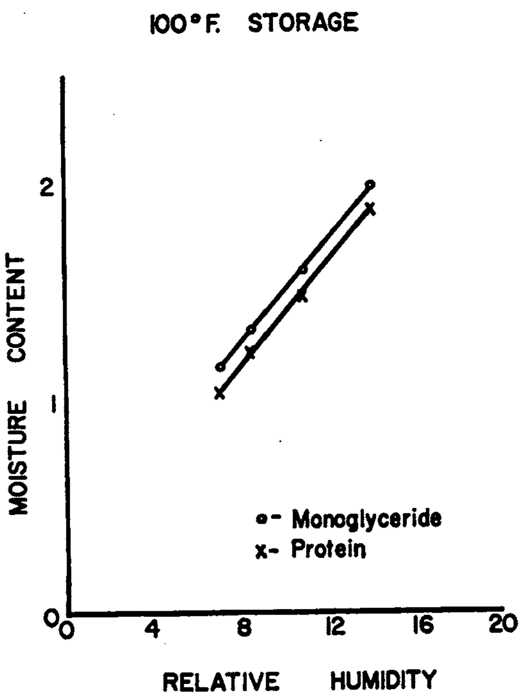

Figure 4. Relationship of equilibrium moisture content of orange juice powders to relative humidity at 100° F.

The results show the conditions under which the powdered orange juices could be held or handled without adsorbing moisture. In general it was indicated that a relative humidity of about 6% would be satisfactory to handle monoglyceride powders of 1% moisture content, while even lower humidities would be required for modified soya protein stabilized powders. Both types of powders with 2% moisture content could be handled in 15% relative humidity, except modified soya protein stabilized material at 50° F. which would require a lower humidity. A 10% relative humidity was adopted for the handling of these powders, as this provides a margin of safety to cover such adverse conditions as dehumidifying equipment failures for brief periods, or overloading of this equipment because of excessively high humidities in the surrounding atmosphere. Both orange juice powder products have a tendency to cake when adsorbing moisture. From observations in processing this tendency increases as moisture content increases.

The equilibrium moisture contents of the "Foam-Mat" dried products used in this study at 70° F. were lower than those of orange juice powders puff dried in a previous study (5) by Notter, Taylor, and Downes. These differences in equilibrium moisture content between the two products investigated in this study and the puff dried product indicate that the monoglyceride and modified soya protein stabilizers have a direct influence on the moisture exchange mechanism associated with orange juice powders.

Summary

The equilibrium moisture contents of the two "Foam-Mat" dried orange juice powder products were obtained in the lower range of relative humidity for 50° F., 70° F., 85° F., and 100° F. storage. This information showed a 10% relative humidity would give a safe atmosphere for handling and packaging these hygroscopic powders if the temperature was 70° F., or above. As an example a "Foam-Mat" dried orange juice powder product with a moisture content above 1.50% in 85° F. and a relative humidity of 10% would not adsorb moisture. At 50° F. orange powder with monoglyceride stabilizer could be handled safely at 10% relative humidity, but powder with soya bean stabilizer is more hygroscopic and exposure to these conditions should be limited. Both temperature and relative humidity

influenced the moisture capacity of the products. Monoglyceride products in equilibrium at 50° and 70° F. retained less moisture than those containing modified soya protein. This was also true at relative humidities below 7.4% in 85° F. storage. However, as relative humidity increased at this temperature the difference in equilibrium moisture content of the two powders decreased and became equal at a relative humidity of 7.4%. At relative humidities above 7.4% in 85° F. storage the equilibrated modified soya protein products contained less moisture. Monoglyceride products contained more moisture than modified soya protein products throughout the range of relative humidities studied under 100° F. storage.

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TECHNIQUES IN THE ISOLATION OF VOLATILE MATERIALS FROM CELERY AND THE IDENTIFICATION OF SOME COMPOUNDS WITH ACIDIC PROPERTIES

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Celery, in common with other crops which are sold primarily in the fresh state, is extremely sensitive to the vagaries of the market. In 1959, for example, 82,500,000 pounds of celery—about 48% of the Arizona crop and 15% of that of Florida—were not even marketed (1). Because of this sensitivity, the need for a more dependable outlet, which means a processing outlet, has been receiving increased attention.

The feasibility of processing celery and blending it with other vegetables has been well demonstrated in the home, in industry, and in the laboratory (2, 3). Celery products could conceivably be processed and stored until the summer months when processors in other areas are manufacturing juice blends, soups, baby foods, and the like. Because celery is used in these products for the unique flavor that it imparts, the nature of this flavor has been a matter of active interest. Qualitative observations have been made concerning celery flavor by Hall (8, 9), and a bitterness factor sometimes associated with celery has been under investigation (9, 13). No information is available, however, concerning the chemical composition of the natural flavor of celery. Such information is necessary for the proper study of processing methods and the intelligent selection of raw materials. It is essential for the development of the objective methods for estimating quality and total flavoring capacity that would enable the standardization of celery products by industry.

Guenther, in his comprehensive work, *The Essential Oils* (6), lists what is known concerning the composition of celery seed oil, but says, ". . . the content of oil in the parts other than seed is so small that the cost of distillation is almost prohibitive." Indeed, the compounds responsible for the flavor and odor of celery are present in the juice in a total concentration of from 0.5 to 1 ppm, necessitating the use of large amounts of starting material, the development of new techniques and the refinement of existing ones. It is the purpose of this paper to describe some of these techniques and report on the results thus far obtained.

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