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STUDIES ON THE DEVELOPMENT OF DEHYDRATED SALAD VEGETABLES

by

Stephen J. Wallner

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Studies were made on the development of dehydrated salad vegetables using chemical treatments such as glycerol, polycerols, and gums. Results indicate that locust bean gum is a viable alternative to glycerol for use in the preparation of dehydrated celery slices. In future work, a uniform source of the gum should be found and the optimum concentration determined. In additon, various combinations of locust bean gum and glycerol should be tested.		

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PREFACE

The work described in this report represents a continuation of the US Army NARADCOM effort to develop a dehydrated vegetable salad. While previous success has been obtained with celery slices, improvements can be made and progress must be extended to include tomatoes and other salad components. This report contains results obtained in tests of glycerol and other water-displacing agents, comparisons of tomato cultivars, and the effect of calcium chloride on rehydrated tomato slice texture.

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TABLE OF CONTENTS

	<u>Page NO.</u>
List of Figures	10
List of Tables	14
Introduction	5
Experimental Procedures	6
Results and Discussion	7
Conclusions	15

LIST OF FIGURES

<u>Figure No.</u>		<u>Page No.</u>
1	Dehydrated and rehydrated slices of fresh market and processing type tomatoes	10
2	Scanning electron micrographs of untreated, glycerol-pretreated, and glycerol plus CaCl_2 -pretreated tomato slices.	14

LIST OF TABLES

1	Effect of glycerol and polyglycerol pretreatment on the quality of reconstituted celery slices.	8
2	Weight and water content of pretreated, dehydrated celery slices.	8
3	Effect of glycerol and natural gum pretreatments on the quality of reconstituted celery slices.	9
4	Tomato breeding programs visited (1974).	11
5	Apparent shear modulus of fresh and glycerated, rehydrated tomato slices.	12
6	Effect of CaCl_2 on Instron-measured textural properties of reconstituted tomato slices.	15

STUDIES ON THE DEVELOPMENT OF DEHYDRATED SALAD VEGETABLES

INTRODUCTION

The dehydration of high moisture produce items such as celery and tomatoes is accompanied by an unacceptable degree of tissue damage. In the case of freeze-drying, the texture changes that occur are at least partially due to ice crystal formation. However, the loss of bound water can result in mechanical damage in the absence of ice formation. Chemical additives can be used to protect against tissue damage caused by this type of dehydration. Substantial progress was made in this area by Shipman, et al. (1972)¹, who described the use of a glycerol pretreatment to retain the texture of celery after rehydration from the dried (4% moisture) state. Although the texture of this product is acceptable, the loss of fresh celery flavor may be a problem.

The development of techniques for the successful dehydration of salad vegetables continues to be one of the goals of food research for the Armed Forces. The National Research Council (ABMPS, Committee on Fruit and Vegetable Products, 1975)² has recommended that the effectiveness of other water displacing agents (polyglycerols, gums, other polysaccharides, etc.) be evaluated. The same committee also stressed the importance of raw product characteristics in the study of tomato dehydration. Factors such as cultivar differences, stage of ripeness, enzymatic softening, etc. were particularly emphasized.

This report describes the relative effectiveness of glycerol, polyglycerol, and natural gum pretreatments in maintaining fresh-like quality in reconstituted salad vegetables, tomato cultivar differences, and the effect of CaCl_2 on tomato texture retention.

¹Shipman, J.W., A.R. Rahman, R.A. Segars, J.G. Kapsalis, and D.E. Westcott. 1972. Improvement of the Texture of Dehydrated Celery by Glycerol Treatment. *Journal of Food Science*. 37:568-571.

²Advisory Board on Military Personnel Supplies. Report No. 59, Committee on Fruit and Vegetable Products. January, 1975.

EXPERIMENTAL PROCEDURES

Polyglycerols were provided by Capital City Products Company, Columbus, Ohio. These included triglycerol, hexaglycerol, and decaglycerol, of molecular weight 240, 462, and 758, respectively. They were synthesized by heating glycerol in the presence of an alkaline catalyst. Natural gums were kindly supplied by Dr. E. T. Reese, FSL; those used in this study (to treat celery slices) were gum arabic, carageenan, gum ghatti, and locust bean gum. Calcium chloride was reagent grade obtained from Baker Chemical Company.

Fresh California celery was locally procured and used immediately. Stalks of uniform size and appearance were sliced into 3.0 mm cross-cut pieces. Several tomato cultivars, including both fresh market and processing types, were obtained from the sources shown in Table 4. On the basis of preliminary experiments, tomatoes were used at the pink stage (USDA, 1975)³ of ripeness. The results of initial experiments also indicated that a transverse slice (6 to 7 mm thick) was the most suitable for dehydration.

Using a procedure similar to that of Shipman, et al. (see reference 1), tissue slices were soaked for 3 to 5 hours (at room temperature) in aqueous solutions of the compounds to be tested. Following pretreatment, the tissue slices were drained on paper towels and transferred to a bin drier with blowing air at 40°-42°C for 16 hours. Rehydration was accomplished by placing the air-dried (3 to 5% moisture) samples in a large excess of distilled water at room temperature for 3 to 4 hours; the water was changed twice.

The quality of reconstituted celery slices was tested by sensory evaluation using a nine-point scale for appearance, color, texture, and flavor. The panel was composed of eleven screened and trained members. The six samples in each session were coded and served to each member in random order. Each serving was four slices of celery; water and unsalted crackers were used to reduce flavor carryover.

The extent of tomato slice reconstitution was determined by measuring textural properties with the Instron Universal Testing Apparatus. Measurements of maximum shear stress and apparent shear modulus (both in newtons/cm²) were obtained from force of compression recordings which were made as a shear punch penetrated the outer pericarp tissue.

³U.S.D.A. 1975. U.S. Standards for Grades for Fresh Tomatoes. Sec. 51.860 (40F.R.2791).

In addition, certain cellular aspects of tomato slice treatments were examined using scanning electron microscopy (SEM). Samples were 6 x 6 mm pieces of outer pericarp tissue which were fixed in 2.5% glutaraldehyde in borate buffer (pH 7.1) and dehydrated using an alcohol series from 30% to 100% ethanol. Samples were then frozen in liquid nitrogen, freeze-fractured, and subjected to critical point drying using carbon dioxide. For SEM observation, tissue pieces were attached to specimen stubs and coated with gold:palladium.

RESULTS AND DISCUSSION

The results of pretreating celery slices with glycerol and polyglycerols prior to dehydration are shown in Table 1. Untreated slices of fresh celery were included as a control and to assist panel evaluation. The most pronounced change observed in the treated samples was the loss of fresh flavor. None of the polyglycerols resulted in a product with better flavor than that obtained with glycerol itself. Furthermore, treatment with triglycerol and decaglycerol yielded celery slices which, upon rehydration, were not significantly different from glycerol-treated slices in any of the measured parameters. The appearance and color of these slices compared very favorably with the fresh, untreated controls. However, the color, appearance, and texture of the hexaglycerol-treated celery was significantly inferior to all of the other treatments.

It is noteworthy that the dry weight of the dehydrated celery was slightly less with increasing molecular weight of the glycerol compound used to displace water (Table 2). These differences were clearly not due to water content, since it was highest (4.3%) in the decaglycerol-treated slices. Since the dehydrated weight includes any residual glycerol compound, it appears that the extent to which the compounds penetrated the tissue was inversely related to their molecular weight. Since reduced weight is of critical importance in a dehydrated product, molecular weight may be a factor to consider in selecting a protective, water-displacing agent.

However, it is obvious from the data of Table 1 that none of the polyglycerols tested would be more suitable for the preparation of intermediate moisture celery than glycerol. This is especially true when one considers the relative availability of these compounds.

In experiments conducted separately, technical panel analyses of fresh and glycerol-treated celery yielded consistent results (Tables 1 and 2). These data also agree well with the corresponding values presented by Shipman, et al. in 1972 (see reference 1).

Table 1. Effect of glycerol and polyglycerol pretreatment on the quality of reconstituted celery slices.

Water Displacing Agent*	Technical Panel Analysis**			
	Appearance	Color	Texture	Flavor
None (fresh control)	6.9 ^a	6.9 ^a	7.8 ^a	7.1 ^a
Glycerol	6.5 ^a	6.3 ^a	6.6 ^b	4.8 ^b
Triglycerol	6.7 ^a	6.6 ^a	6.4 ^b	5.2 ^b
Hexaglycerol	5.5 ^b	5.2 ^b	5.9 ^c	4.3 ^b
Decaglycerol	6.4 ^a	6.4 ^a	6.5 ^b	4.6 ^b

*All compounds were prepared as a 40% (w/v) solution and used as described in the text.

**1-extremely poor; 2-very poor; 3-poor; 4-below fair; above poor; 5-fair; 6-below good; above fair; 7-good; 8-very good; 9-excellent.

Means for a measurement bearing the same letter do not differ significantly at 5% level or probability by Duncan's Multiple Range Test.

Table 2. Weight and water content of pretreated, dehydrated celery slices.

Water Displacing Agent	Weight* (g)	Water Content (%)
Glycerol	17.1	2.3
Triglycerol	12.0	2.8
Hexaglycerol	11.8	2.9
Decaglycerol	10.4	4.3

*Original celery fresh weight was 50 g.

Table 3 shows the results of tests to determine the potential usefulness of a series of gums relative to that of glycerol. Fresh, untreated celery slices were again included as a control and to assist panel evaluation. For celery which was pretreated with glycerol or locust bean gum, the appearance of the rehydrated slices was not significantly different from the untreated controls. Slices treated with the other gums rehydrated to a product of poorer general appearance. However, this diminished appearance was not due to a loss of color. All rehydrated slices retained color that compared favorably with that of the fresh control. Texture retention was much greater with locust bean gum than any of the others used in this study. Slices rehydrated following treatment with locust bean gum and air drying could not be distinguished from fresh untreated controls on the basis of texture. However, the effect on flavor retention is perhaps the most striking aspect of treating celery slices with locust bean gum prior to dehydration. Although full flavor is not retained, it is significantly better than the flavor of slices pretreated with glycerol or the other gums. This is an important observation since the loss of fresh flavor is a drawback to the use of the glycerol pretreatment in preparing dehydrated celery. The results of this study are promising; the use of locust bean gum as a protective water-displacing agent should be given further consideration and study.

Table 3. Effect of glycerol and natural gum pretreatments on the quality of reconstituted celery slices.

Water Displacing Agent*	Technical Panel Analysis**			
	Appearance	Color	Texture	Flavor
None (fresh control)	6.7 ^a	6.6 ^a	7.5 ^a	7.3 ^a
Glycerol	6.5 ^{ab}	6.4 ^a	6.8 ^a	5.0 ^b
Gum Arabic	5.5 ^c	5.9 ^a	6.0 ^b	4.8 ^b
Carageenan	5.9 ^{bc}	6.2 ^a	6.0 ^b	4.5 ^b
Gum Ghatti	5.5 ^c	6.2 ^a	5.6 ^b	4.8 ^b
Locust Bean Gum	6.2 ^{ab}	6.2 ^a	7.1 ^a	6.1 ^c

*Glycerol was used as 40% (w/v) solution; natural gums were prepared as 1% (w/v) solutions.

**Quality scale as shown for Table 1.

Means for a measurement bearing the same letter do not differ significantly at 5% level of probability as determined by Duncan's Multiple Range Test.

The development of a dehydrated salad requires that similar techniques be applied to other vegetable items. The tomato, for example, is an important salad ingredient. However, fundamental anatomical and physiological differences between the celery petiole and tomato fruit present certain problems. Celery contains many well-developed bundles of xylem, a conductive tissue which consists primarily of cells which have massive, secondarily-thickened walls. In addition, celery does not normally undergo extensive postharvest physiological deterioration. The tomato fruit, on the other hand, consists largely of parenchyma (thin-walled cells) which undergo degradative changes as a normal part of fruit development. Polygalacturonase and other enzymes act during ripening to greatly weaken tomato cell walls. Tomato cultivars vary considerably in both internal anatomy and the degree of fruit softening; those grown for processing typically have less locular space (higher flesh content) and remain firmer throughout ripening than do the fresh market types.

Cultivar differences can thus be expected to influence the quality of dehydrated tomato slices; this effect is illustrated in Figure 1.

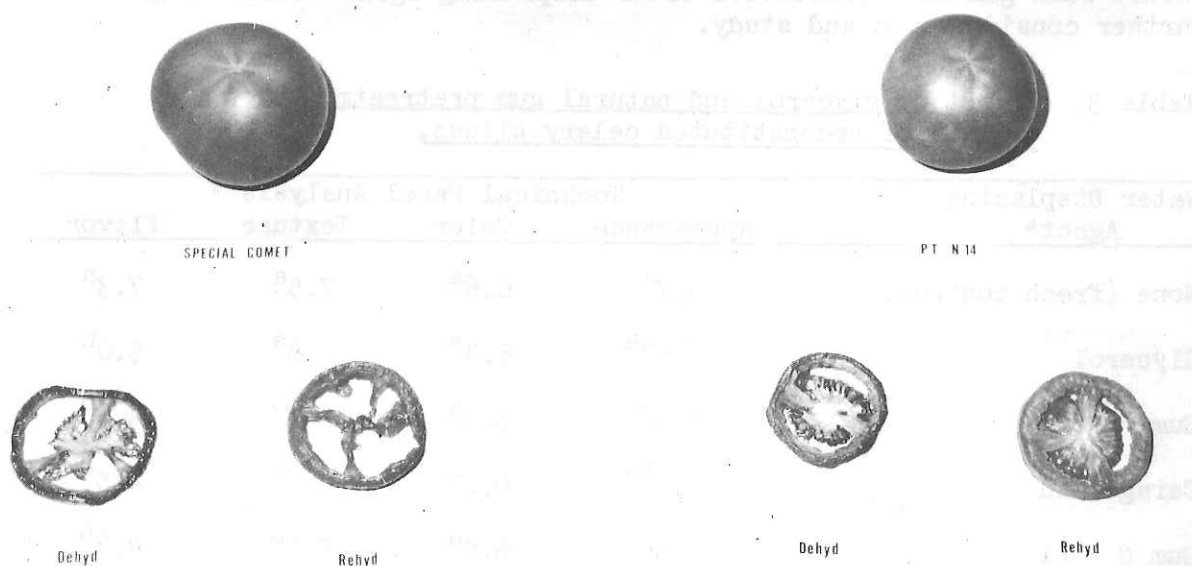


Figure 1. Dehydrated and rehydrated slices of Special Comet and PT N 14 (UC105J) tomatoes. Slices were pretreated with 40% glycerol and air-dried. Rehydration was in distilled water.

Slices of Special Comet (a fresh market cultivar) and PT N14 (a processing type) were soaked in 40% (w/v) glycerol and air-dried. The slices of Special Comet deteriorated badly while those of PT N14 rehydrated to a near normal appearance. However, the texture of the rehydrated PT N14 slices was very poor; they lacked firmness and came apart during normal handling. For this reason, other processing cultivars were tested in an effort to find those which would respond more favorably to this treatment. Cultivar selection was based on consultation with individuals actively involved in the development of tomato cultivars with improved processing characteristics. The breeding programs visited and from which tomatoes were obtained are shown in Table 4. In Table 5, the firmness (apparent shear modulus) of fresh, untreated slices is compared to that of slices that were rehydrated after glycerol treatment and air-drying. A limited number of these, e.g. Md 118 and Red Rock, reconstituted especially well. However, most showed a soft, watery consistency upon rehydration. Thus, although processing cultivars generally respond more favorably than fresh market types (Figure 1), the texture obtained with the 40% glycerol procedure is usually unacceptable. The wide range of values shown in Table 5 may be partially due to several factors: the tomatoes were grown under a variety of conditions; postharvest handling may have differed; and variations in maturity probably occurred. It should also be pointed out that the firmness of untreated fruit tissue was no indication of how well the glycerated slices would rehydrate.

Table 4. Tomato breeding programs visited (1974).

<u>Director</u>	<u>Location</u>
R. Young	Suburban Experiment Station Waltham, Massachusetts
E. L. Moore	Southern Tomato Exchange Program Starkville, Mississippi
M. Sayeed	H. J. Heinz Bowling Green, Ohio
L. Balics	Contadina Foods (Carnation) Woodland, California
M. A. Stevens	Vegetable Crops Dept., Univ. of California Davis, California
E. V. Wann	Vegetable Breeding Laboratory (USDA) Charleston, South Carolina

Table 5. Apparent shear modulus of fresh and of glycerated, rehydrated tomato slices.*

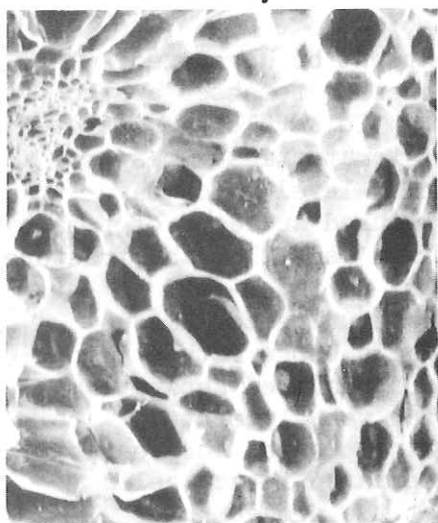
<u>Cultivar</u>	<u>Breeding Program</u>	Apparent Shear Modulus (Newtons/cm ² X10 ²)	
		<u>Fresh (LR)</u>	<u>Treated (P)</u>
Md 118	U. Maryland	4.1	3.6
Md 121	U. Maryland	3.8	2.1
M32N	U. Calif., Davis	3.6	1.3
UC105	U. Calif., Davis	4.3	2.9
UC105J	U. Calif., Davis	4.2	2.4
UC122	U. Calif., Davis	3.1	0.8
VF134	U. Calif., Davis	2.9	0.7
PR-65	U. Calif., Davis	3.6	1.8
C-28	Campbell Soup	3.2	3.0
1159-5	Ferry-Morse	4.6	2.0
H-1706	H. J. Heinz	4.4	1.0
Skinny	Peto Seed	3.7	1.8
Cal-J	Peto Seed	2.9	0.9
Red Rock	USDA, Beltsville	4.9	4.1
71B12	USDA, Beltsville	4.1	3.0
Chico III	Texas AES	5.2	1.4

*Slices were 6 mm thick. The untreated (fresh) slices were from light red (LR) fruits; treated (40% glycerol, air-dried, rehydrated) slices were from pink (P) fruits.

It is necessary that a more effective pretreatment be developed, especially if normal commercial supplies of processing tomatoes are to be suitable for production of dehydrated slices. To develop an improved procedure, more information was needed regarding tomato tissue response to dehydration. To examine changes at the cellular level which may influence tissue texture, we examined freeze-fractured surfaces of tomato pericarp using scanning electron microscopy. It was felt that the fracture plane might reflect some textural property related to inter- and intracellular wall strength. When samples of fresh untreated tissue were freeze-fractured, the walls of individual cells broke rather than the connections between cells; intercellular bonds resisted separation (Figure 2a). However, in the case of tissue which was glycerated, air-dried, and rehydrated, the bonds between cells appeared to present the least resistance, since freeze-fracturing separated intact cells (Figure 2b). This finding clearly indicated that the process of dehydration in some way decreased intercellular adhesion. In other systems, chelating agents macerate plant tissue, possibly by removing calcium from intercellular binding sites.

Accordingly, experiments were initiated to test the effect of calcium on the texture of reconstituted tomato slices. When calcium ($0.2M \text{ CaCl}_2$) was provided in the pretreatment solution of 40% glycerol, the effect shown in Figure 2b was not seen. Slices that were pretreated with calcium in addition to glycerol behaved more like the fresh control. The freeze-fracture plane in calcium-pretreated, rehydrated samples occurred through, rather than between, individual cells (Figure 2c). The addition of calcium appeared to greatly strengthen the intercellular binding which may directly influence texture.

The effect of calcium on the texture of rehydrated tomato slices is further documented in Table 6. The poor texture of slices pretreated with glycerol alone is shown by the very low values for maximum shear stress and apparent shear modulus. Slices pretreated with only CaCl_2 did not reconstitute enough to allow texture measurement. However, when glycerol and CaCl_2 were used together, the firmness of the rehydrated product was greatly increased. In fact, these slices were much firmer than untreated controls; this was most likely due to the toughness which developed upon rehydration. Lower concentration of CaCl_2 should be tested; in this study, $0.05M$ was essentially as effective as $0.2M$, indicating that the threshold concentration for this effect is $0.05M$ or less.

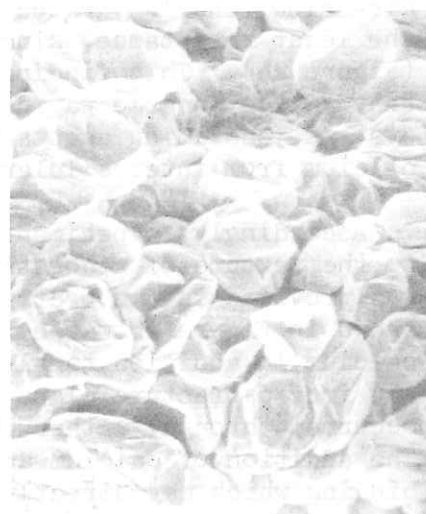


A. Fresh, untreated.



C. Glycerol and CaCl_2 -pretreated, air-dried, and rehydrated.

Figure 2. SEM (320x) of tomato pericarp tissue.



B. Glycerol-pretreated, air dried, and rehydrated.

Table 6. The effect of CaCl_2 on Instron-measured textural properties* of reconstituted tomato slices** (Cv UC 105J).

Water Displacing Solution	Maximum Shear Stress	Apparent Shear Modulus (10^2)
None (fresh control)	6.2	6.0
Glycerol	0.5	1.0
Glycerol & .05 M CaCl_2	12.3	12.0
Glycerol & .20 M CaCl_2	15.9	13.1

*Both properties are expressed as Newton/cm².

**Slices were prepared as described in text; glycerol was used at 40% (w/v).

CONCLUSIONS

Locust bean gum is a suitable alternative to glycerol for use in the preparation of dehydrated celery slices. In future work, a reliable source of the gum should be found and the optimum concentration determined. In addition, various combinations of locust bean gum and glycerol should be tested on celery, cucumber, and tomatoes.

Processing tomatoes reconstituted far better than typical fresh market cultivars. However, the texture of rehydrated slices which were pretreated with glycerol was generally poor for both tomato types.

The addition of CaCl_2 to the pretreatment solution overcame this problem; the lowest CaCl_2 concentration tested (0.05M) resulted in a firm but tough reconstituted slice. It may be that the optimum CaCl_2 concentration is considerably less than 0.05M.