good texture even after storage at 37°C for three months, demonstrating the importance of inhibiting PG for better texture retention.

Effect of heat

The PG activities in the liquid media of the mold cultures were quite high. To study the differences between them, the culture filtrate was diluted five times with water. Two ml of the diluted enzyme were added to the 36° Brix syrup of each can during canning.

The cans were processed at 100°C (212°F) and 110°C (230°F) respectively for 10 minutes, with PG from *R. stolonifer* added to the cans. Thirty days after canning the fruit showed some softening in samples receiving the enzyme treatment (table 2). After storage for 90 days at 68°F (20°C), the texture of the apricot became even softer.

It appears that raising the sterilization temperature from 100°C (212°F) to 110°C (230°F) affected texture more due to heat effect, but much less to the residual enzyme activity. Statistical analyses of the results indicate that the difference in texture between the control and the PG-treated sample was significant at the 95% level by the sensory texture rating as well as by the shear press readings.

Heat resistance of pectic enzymes was checked. Even at a temperature reaching 215°F (101.7°C) for five minutes, residual PG activity of enzyme from *R. stolonifer* was detected. The PG enzymes produced by *R. arrhizus* and *R. oryzae* were less heat-resistant than that of *R. stolonifer*. The concentration of enzyme other than PG may also be different between the organisms.

TABLE 2. EFFECT OF PROCESSING TEMPERATURE ON TEXTURE OF CANNED APRICOTS

Sample code	Treatment	Heat processing temperature (10 min.) °C	°F	Sensory texture rating* 30 days	90 days	Lee-Kramer Shear Press readings sq. in. 30 days	90 days	Syrup viscosity at 30°C sec. 90 days	pH
B-1	Control	100	212	8.5	6.9	2.07	1.45	48.8	3.70
E-I-1	2 ml diluted PG/can (from R. stolonifer)	100	212	7.5	5.5	1.04	0.44	43.8	3.72
B-2	Control	110	230	6.5	5.3	0.83	0.66	82.0	3.90
E-I-2	2 ml diluted PG/can (R. stolonifer)	110	230	5.0	3.8	0.50	0.58	44.2	3.90

* The panel scored the samples on a 1–10 scale for texture. Excellent, 9–10; Good, 7–8; Fair, 5–6; Poor, 3–4; Very poor (broken completely), 1–2.

Discussion

An important factor in the enzymatic softening problem seems to be intrinsic and/or parasital-originated pectic enzymes. To solve the problem, the food processing industry should work toward control of molds in apricot orchards, and for methods of handling and processing that result in minimum mechanical damage. Prompt handling and canning of the fruit after harvest may also help.

Much remains to be investigated concerning pectin biosynthesis, activation of pectic enzyme systems, the effect of pectic and cellulase enzymes from microorganisms on fruit texture.

B. S. Luh is Food Technologist, Y. K. Liu is Research Assistant, and L. Y. Peupier was a graduate student in the Department of Food Science and Technology, University of California, Davis.

Implication and chemical testing of two rhizopus fungi in softening of canned apricots

J. M. OGAWA
J. RUMSEY • B. T. MANJI
G. TATE • J. TOYODA
E. BOSE • L. DUGGER

EVIDENCE FROM THESE tests showed that a single fruit decayed by *Rhizopus arrhizus*, and placed into a no. 10 can of healthy fruit before canning resulted in total disintegration of healthy fruit during six months' storage at room temperature. Addition of a single *Rhizopus stolonifer* decayed fruit also resulted in significant softening within a six-month period in fruit from one out of three orchards. There was little change in rating of fruit after nine months' storage, but in one treatment 48% of the good Tilton fruit showed initiation of softening, with flesh starting to disintegrate, and soft to the touch.

The addition of Botran (2,6-dichloro-4-nitroaniline) when the fruit was canned did not reduce softening although in one test there was a significant increase in good fruit. There was no correlation between pH and *Rhizopus*-associated softening. Similar results from addition of *R. stolonifer* to canned apricots have been reported from Australia. *R. arrhizus* is also present in Australia but tests with this fungus were not reported. The 1973 California studies showed that pre- and postharvest Botran applications did not control *R. arrhizus* on apricots. Previous studies also have shown that *R. arrhizus* is present in orchards throughout California and that Botran failed to control it.

Chemicals

Chemicals tested were 75% Botran (2, 6-dichloro-4-nitroaniline) and 70% Topsin M (1,2-bis(3-methyoxy-carbonyl-2-thioureido)-benzene-thiophanate methyl). Botran was applied at the rate of 1⅓ lb per 100 gallons of water as a field spray and as a postharvest dip. Definite amounts of Botran in acetone were added to empty cans and acetone-evaporated before filling with fruit. Only 4.08 mg of proprietary 75% Botran was added to each can, giving one ppm of active ingredient on a weight-for-weight basis. Topsin M was applied only as a field spray at the rate of 0.5 lb per 100 gallons of water. Field sprays were applied with a hand gun sprayer on June 13 and July 2, 1973, at the rate of about 6 gal per tree.

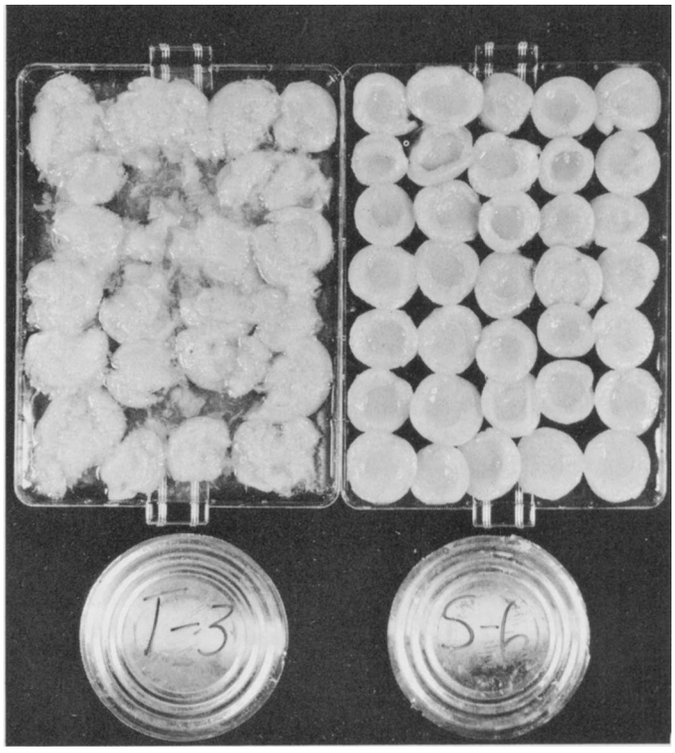
EFFECT OF **RHIZOPUS** FUNGI ON SOFTENING OF BLENHEIM AND TILTON APRICOTS IN CANS AND HELD FOR 6 AND 9 MONTHS

	Six month storage			Nine month storage		
Check	91.2a[4]	7.2	1.6	82.2a	16.1	1.7
R. stolonifer decayed fruit	90.0a	8.2	1.8	75.7a	16.9	7.4
R. arrhizus decayed fruit Orchard D (pH not taken)	28.4b	8.9	62.7	0.0b	0.0	100.0
Check	99.6a	0.4	0.0	97.6a	2.4	0.0
R. stolonifer decayed fruit	90.1b	7.0	2.9	no data		
R. arrhizus decayed fruit	0.0c	1.5	98.5	0.0c	0.3	99.7
R. stolonifer decayed fruit plus Botran	86.1b	6.8	7.1	65.5b	30.2	4.3
R. arrhizus decayed fruit plus Botran	3.4c	19.4	77.2	0.0c	0.0	100.0
Botran added	98.9a	1.1	0.0	93.4a	6.6	0.0
LOTS—Orchard B (pH 3.87)						
Check	92.1a	7.7	0.2	91.9ab	6.8	1.3
R. stolonifer decayed fruit plus Botran	93.1a	5.3	1.6	97.2a[5]	0.0	2.8
R. arrhizus decayed fruit plus Botran	0.0b	0.0	100.0	0.0c	0.0	100.0
Botran added	89.9a	9.2	0.9	84.5b	15.5	0.0

3.8–4.2, and orchard B 4.0–4.2.

[2] One **Rhizopus**-rotted fruit added to each no. 10 can of healthy fruit.

[3] Ratings of softening: "good" is sound fruit; "moderate" is fruit that can be picked up, epidermis is sound, flesh is partially disintegrated; "bad" is disintegrated fruit that cannot be picked up with fingers. Evaluations were made under the supervision of L. L. Claypool.



Condition of apricot halves after 6-months storage, with one **Rhizopus arrhizus** (T-3) or **Rhizopus stolonifer** (S-6) decayed fruit added to each can. After 9 months, initial softening was also evident in S-6. No maceration was evident in control fruit after 9-months storage.

Apricots were canned by commercial canning procedures at the California Canners and Growers plant #4, Sunnyvale. Fruits were picked at the beginning of normal harvest from five orchards, two of which had fruits classified as suspect for non-enzymatic softening, based on fruit pH equal or lower than 3.7. Fruits were harvested in 50 lb wooden cannery lug boxes on July 3, three days before canning. Some lots were treated and others left untreated and all were held at 36°F. Enough fruits were harvested to provide eight replications of no. 10 cans. Fruits were halved by hand or by machine.

Variations from normal maturity were as follows: Fruits from orchard A were slightly greener than those from orchard B; those from orchard C had more overripes; and fruits from orchard D varied considerably from green to ripe, with a few of the fruit showing brown rot (*Monilinia laxa*). *Rhizopus* decayed fruits added to the cans were prepared by inoculation of Blenheim apricots with known isolates of *Rhizopus stolonifer* (RS 140) or *Rhizopus arrhizus* (RX 149). Before inoculation the fruits were surface-sterilized for three minutes with 400 ppm chlorine prepared from commercial Purex. The cooking time of the cans was 23 minutes with a maximum temperature of about 209°F. This was sufficient to kill fungal pathogens added to the cans.

Canned fruits were stored for six months at room temperature in Sunnyvale, then transported to the University of California, Davis by car and three cans of each treatment were inspected on January 7, 1974. The remaining cans have been held at 55° F. Three more cans from each treatment were evaluated on April 15, 1974, after an additional three months. The remaining cans will be opened after a total holding period of 12 months.

Blenheim and Tilton varieties were equally susceptible to softening (see table). *Rhizopus arrhizus* induced softening quicker than *Rhizopus stolonifer*, as indicated by data taken after six months of storage. Even after nine months' storage, lots with added *R. stolonifer* had some good fruits, but the fruit flesh texture had deteriorated indicating that complete disintegration was likely with time. In all treatments, percent of good fruit was less after nine months, except in the *R. stolonifer* plus Botran lot of Tilton fruit from orchard B. This exception is the result of placing in the good category, fruit that had started softening but was not severe enough to score. Thus the amount of softening was directly correlated with time in storage.

There was no indication that the addition of Botran reduced softening caused by *Rhizopus*. This result was expected because placing cans in the cooker almost immediately after adding decayed fruit killed the fungus within a short time. The pH of the fruit, and the acidity range of individual cans showed a slight increase from initial readings because of dilution; acidity remained constant thereafter. No differences in acidity were noted after addition of *Rhizopus* decayed fruit or Botran. Within the pH range of 3.6 to 4.2 the amount of softening in the checks or the treatments remained about the same irrespective of fruit source.

J. M. Ogawa is Plant Pathologist, B. T. Manji and E. Bose are staff Research Associates, C. Tate is Research Assistant, and L. Dugger is Laboratory Helper, Department of Plant Pathology, University of California, Davis. J. Rumsey is Manager and J. Toyoda is Assistant, Field Research, California Canners and Growers.