TECHNICAL PROGRESS REPORT 127 DECEMBER 1960

PREVENTING THE DARKENING OF FRESH LYCHEES PREPARED FOR EXPORT

Ernest K. Akamine

HAWAII AGRICULTURAL EXPERIMENT STATION, UNIVERSITY OF HAWAII

CONTENTS

TECHNICAL PROGRESS REPORT 127 DECEMBER 1960

HAWAII AGRICULTURAL EXPERIMENT STATION
University of Hawaii

PREVENTING THE DARKENING OF FRESH LYCHEES PREPARED FOR EXPORT

*By Ernest K. Akamine**

INTRODUCTION

The lychee (*Litchi chinensis* Sonn.) has been in Hawaii since 1873 when the first tree was introduced from South China, where it is considered to be indigenous (*8, 10*). Primarily due to its erratic bearing habit in Hawaii, the commercial growing of lychee in the past did not develop to any great extent.

In recent years, however, the development of cultural methods to induce flowering and fruiting has been an incentive for more extensive growing of the tree (*6, 7*). The development and introduction of new varieties with better quality and higher fruit yield than established varieties (*8*) have been further inducement for more extensive culture of this tree. As a novelty item some fresh lychee fruit has been shipped to the Mainland in the frozen condition. As far as is known to the writer, the lychee is the only commercial fruit in which the edible portion does not break down when frozen and subsequently thawed out. It is believed that the greatest stimulation for still more extensive culture of the lychee in Hawaii is the recent development of a treatment which permits the shipment of fresh fruit to the Mainland under existing quarantine regulations. This treatment, developed in the laboratory of Investigations of Fruit Flies in Hawaii, Entomology Research Division, Agricultural Research Service, U.S.D.A., in cooperation with the Hawaii Agricultural Experiment Station, consists of fumigation with ethylene dibromide(*9*). This treatment produces no detectable injury to the quality or shelf life of the fruit and from the practical standpoint is more feasible than the freezing method.

---

*Assistant Plant Physiologist, Hawaii Agricultural Experiment Station.

While shipment by surface transportation is available, a recent reduction in air freight charges for bulk shipment will probably make even air shipment feasible economically. It is reported that commercial shipments of fresh lychee from the 1960 crop to the Mainland amounting to 5,492 pounds [1] have already been made by surface and air transportation.

The problem of maintaining the quality in transit and on the retailer's shelf is a universal one with all fresh commodities for the export trade. In the fresh lychee, the preservation of the attractive red color on the fruit surface is a major concern to the shipper. The purpose of this report is to present the results of laboratory studies in which attempts were made to prevent the darkening of the pericarp of the lychee fruit.

GENERAL PROCEDURE

During June and July of 1960, fruits from the fields of the Departments of Plant Physiology and Horticulture at the Poamoho Experimental Farm were used in the experiments reported herein. The varieties Brewster (39 tests) and Hak Ip (25 tests) were used mostly because of their readily available supply. Five tests were also conducted with the Kwai Mi variety. Fruits were harvested at the ripe stage and attempts were made to use them on the day of harvest. If, however, the fruits had to be held till the next day, this was done either at room temperature in the laboratory or in a reefer (55° F.). Only carefully selected, apparently normal (unbruised and insect damage-free) fruits were used in tests. Both fumigated and unfumigated fruits were used. For fumigation, fruits were subjected in open containers to ethylene dibromide at a dosage of 1/2 pound per 1,000 cubic feet of space for 2 hours at room temperature. (The approved treatment prescribes a minimum temperature of 70° F. (9).) A total of approximately 9,300 fruits (430 pounds) was used in the tests. For each test more specific procedures are recorded.

PRELIMINARY EXPERIMENTS

As in other fruits, the darkening of the pericarp of the lychee fruit is believed to be due to the formation of the pigment, melanin, as a result of the action of an enzyme polyphenolase on phenolic compounds under aerobic condition. When the pericarp was removed from the fruits of all varieties used and exposed to the air, it turned brown very rapidly. When the excised pericarp was exposed to anaerobic condition (29.5-in. vacuum), no darkening occurred.

---

[1] Information from local federal Plant Quarantine office through courtesy of J. W. Balock.

Parts of the surface of fruits of all varieties used were abraded with a knife. Some of the injured fruits were placed immediately in solutions (1.2 gm. per l.) of ascorbic acid for various periods ranging from 10 minutes to 14 hours at room temperature. As long as the fruits were left in the solutions, no darkening occurred. Upon removal from the solutions and exposure to air, the abraded areas darkened immediately. The abraded areas on comparable fruits left in air at room temperature turned brown in a few minutes. Similarly treated fruits placed in water also turned brown but at a slower rate than those exposed to the air. Twenty-five fruits were used for each treatment. The test was repeated and similar results were obtained.

Insect-damaged fruits begin to brown from points of punctured areas. The browning process is slower in cold storage than at room temperature. Normal uninjured fruits also brown when stored in the open condition even in cold storage. In the following experiments, attempts were made to prevent the browning in these normal fruits.

USE OF CHEMICALS

Fruits of the Brewster variety were dipped for 1 to 2-1/2 hours at room temperature in ascorbic acid solutions (.6 to 2.4 gm. per l.), dried, and stored in the open and in polyethylene bags (gauge 0015) at room temperature. The treated lots darkened as rapidly as their respective control lots. Each treatment consisted of 25 fruits. Similar results were obtained in another test with the Hak Ip variety.

Fumigated and unfumigated fruits of the Brewster variety were dipped in .1N and .2N solutions of citric acid at room temperature for 1 hour, dried, bagged in polyethylene bags, and stored at room temperature. The acid treatment was ineffective in preventing the darkening of the fruit. In this test sodium salt of dehydroacetic acid (1.0 and 1.5 percent solutions) was also used as dips. This was detrimental in that the chemical hastened the darkening process in both fumigated and unfumigated fruits. Forty fruits were used for each treatment.

In South Africa, it is claimed that the color of the lychee fruit of the variety Mauritius can be preserved by "sulphuring" the fruit after harvest, the beneficial effect presumably being due to the action of the sulfur dioxide fumes interfering with the oxidative system involved in the darkening of the fruit (*5*).

In a series of 4 tests, fumigated and unfumigated fruits of the Brewster and Hak Ip varieties were subjected to sulfur dioxide fumes and dips. Fruits were placed in air tight gallon jars and subjected to fumes from a 6 percent SO_2 solution placed in the bottom of the jars. Varying quantities (1 to 10 cc.) of SO_2 solution were used in combination with varying exposures ranging from 5 to 45 minutes. The treatments were ineffective in preventing or retarding the darkening process of both the fumigated and unfumigated fruits of the two varieties when stored open at room temperature. Likewise, dipping in SO_2 solutions (1 to 3 percent) for varying periods (5 to 30 minutes) were ineffective. The higher concentrations and longer exposures bleached the fruits, and lower concentrations and shorter exposures did not retard the browning process as compared with that of the untreated when stored open at room temperature. Each treatment consisted of 15 fruits for all tests.

Fruits of the Brewster and Hak Ip varieties were coated with sulfur dust (wettable insecticide) and stored open at room temperature along with untreated lots. The treatment did not affect the darkening rate of fumigated and unfumigated fruits of the two varieties. Fifteen fruits each were used for the treated and untreated lots of the two varieties. Another test produced similar results.

EFFECT OF WAXING

A commercial fruit wax (Sta-Fresh Wax # 920) was found to be ineffective in preserving the normal color of fumigated and unfumigated Brewster and Hak Ip lychees in 9 tests in which 10 to 40 fruits were used for each treatment. Concentrations of the wax ranging from 3 to 50 percent had no effect on the darkening rate of fruits stored in the open at room temperature. When used full strength, the wax preparation scalded the surface of the fruit.

A vinyl resin plastic (Good-rite VR 600, 50.5 percent) was also employed to wax unfumigated fruits of Brewster, Kwai Mi, and Hak Ip. In 3 tests in which 20 fruits were employed per treatment, dilutions ranging from 1/16 to 1/2 of the original concentration of the plastic proved ineffective in preventing the darkening of the fruit of all varieties in open storage at room temperature.

EFFECT OF HEAT

Excised pericarp of fruits of unfumigated Brewster and Hak Ip was dipped in hot water at temperatures ranging from 56° C. to boiling for short periods (1/4 to 2 minutes), then exposed to air at room temperature. Temperatures above 77.2° C. (15-second exposure) prevented the normal darkening but bleached (extraction of anthocyanin pigment) the pericarp. Lower temperatures than this failed to prevent the darkening. The bleached pericarp turned light brown instead of the normal dark brown upon exposure to air. Treatment of whole fruits of Brewster (15 fruits each treatment) with hot water produced similar results in 3 tests.

MODIFIED ATMOSPHERE STORAGE

The effect of atmosphere modified by the respiration of the lychee fruit in sealed polyethylene bags on the maintenance of color was determined in several experiments. The gas in the bag was analyzed for CO_2 and O_2 concentration with the Gas Analysis Apparatus – Orsat Type (Arthur H. Thomas Co., Philadelphia, Pennsylvania). In a representative test fumigated and unfumigated fruits of the variety Kwai Mi were sealed in 4-pound polyethylene bags and stored at room temperature. Corresponding control lots were stored open. Twenty-four selected fruits were used for each treatment. The results are recorded in table 1.

Judging from the accumulation of CO_2 in the polyethylene bags, the fumigated fruits probably respired slightly more than the unfumigated fruits (table 1). In both lots, the CO_2 concentration decreased and the oxygen concentration correspondingly increased with storage time after the first day. This indicated the pervious nature of the bag which is not absolutely airtight. Furthermore, the sharp ridges of the exocarp of the fruit readily punctured the bag, thus rendering it all the more pervious. The pressure increase in the bag caused by the accumulation of CO_2 forced some of this gas out through the pores of the bag and was replaced by normal air entering the bag.

TABLE 1. Effect of polyethylene bags on the preservation of color in Kwai Mi lychee at room temperature (74°– 83° F.)

Treatment	Days in Storage				
	1	2	3	4	6
EDB,* bagged	15.6% CO_2 5.4% O_2 0% browned†	10.7% CO_2 10.3% O_2 12% browned	7.4% CO_2 13.6% O_2 12% browned	12% browned	45% browned‡
EDB, open	0% browned	50% browned	88% browned	100% browned	
No EDB, bagged	14.8% CO_2 6.2% O_2 0% browned	7.0% CO_2 14.0% O_2 12% browned	5.5% CO_2 15.5% O_2 12% browned	12% browned	50% browned‡
No EDB, open	0% browned	50% browned	88% browned	100% browned	

*Ethylene dibromide fumigation.

†Average degree of browning of 24 individual fruits.

‡Unbrowned fruits fairly good in flavor.

After 4 days at room temperature, both the fumigated and unfumigated fruits stored in the open were completely browned, whereas those in the polyethylene bags were only about 50 percent browned after 6 days (table 1).

In another test fumigated and unfumigated fruits of the variety Brewster were similarly stored in polyethylene bags and in the open at room temperature. Each treatment consisted of 60 fruits. The results as shown in table 2 again indicated that the fumigated fruits respired more than the unfumigated ones. The decrease in CO_2 content with corresponding increase in O_2 content with storage time was again manifested. As in the case of the Kwai Mi variety (table 1), bagging significantly increased the retention of the color of the Brewster variety (table 2).

TABLE 2. Effect of polyethylene bags on the preservation of color in Brewster lychee at room temperature ($74^{\circ}-83^{\circ}$ F.)

Treatment	Days in Storage				
	1	2	3	5	6
EDB,* bagged	16.2% CO_2 4.8% O_2 0% browned†	0% browned	9.6% CO_2 11.4% O_2 0 % browned	0% browned	12% browned‡
EDB, open	0% browned	12% browned	50% browned	88% browned	100% browned
No EDB, bagged	8.8% CO_2 12.2% O_2 0% browned	0% browned	5.8% CO_2 15.2% O_2 0% browned	0% browned	12% browned‡
No EDB, open	0% browned	12% browned	50% browned	88% browned	100% browned

*Ethylene dibromide fumigation.

†Average degree of browning of 60 individual fruits.

‡Flavor good.

The effect of storage temperature on the accumulation of CO_2 in polyethylene bags was shown in a test in which 20 unfumigated fruits of the Brewster variety were used for each treatment. The results as recorded in table 3 indicate the expected influence of temperature on respiration.

TABLE 3. Effect of temperature on CO_2 accumulation in 1 day in polyethylene bags containing 20 unfumigated fruits of the variety Brewster

Storage temperature (°F.)	CO_2 (%)	O_2 (%)
74–83 (room)	8.3	12.7
55	4.7	16.3
45	2.6	18.4
35	2.0	19.0

The effect of airtight storage on the retention of color by lychee was investigated in 3 tests in which 60 Brewster fruits were used for each treatment. As expected, the CO_2 accumulated to a greater amount in the airtight container than in the polyethylene bags. In some cases, the storage atmosphere analyzed more than 30 percent CO_2 after 1 day in storage at room temperature. In these tests, it was observed that in some cases, the fruits in the airtight container were bleached. In other tests to be discussed later, fruits subjected to 35 to 45 percent CO_2 in CO_2 - air mixtures at room temperature failed to bleach. Therefore, it seemed unlikely that the bleaching was caused by the accumulation of CO_2 in the fruit container.

On the assumption that the bleaching was caused by reduction in the amount of oxygen available to the fruits in airtight storage, an experiment was installed in which varying amounts of fruit were placed in airtight gallon jars and stored at room temperature. Unfumigated Brewster and Hak Ip varieties were used. The results are recorded in table 4.

Although the varieties differed in their rates of response to the storage condition, it is clearly seen that in both varieties the rate of bleaching was determined by the amount of oxygen available to the fruits in storage, i.e., the greater the volume (weight and number) of fruit per unit space, the less the amount of oxygen available per unit weight of fruit and thus the more rapid the bleaching, and vice versa (table 4). With the reduction of available oxygen, the fruits bleached. Anaerobic condition was evidenced by alcoholic fermentation at the end of the experiment. The anthocyanin pigment was extracted, and the bleached fruits turned light brown upon exposure to normal air.

That the bleaching was not caused by the accumulation of volatile emanations from the fruits themselves was apparently demonstrated when known sources of ethylene —fading *Vanda* blossoms (*2*) and ripening Cavendish bananas (*3*) sealed with Brewster and Hak Ip fruits — failed to cause bleaching. However, apparent emanations from the lychee fruits faded normal *Vanda* blossoms.

TABLE 4. Effect of ratio of air space to amount of fruit on bleaching of unfumigated lychee in storage in airtight gallon jars at room temperature

Variety	Fruit wt. (lb.)	No. of fruits	Percent average degree of bleaching in individual fruits after indicated days of storage						
			2	3	4	5	6	7	8
Brewster	1	20	0	0	10	50	90	100	
	2	40	0	0	10	90	100		
	4	80	0	10	100				
Hak Ip	1	30	0	0	0	0	10	90	100
	2	60	0	0	0	10	90	100	
	4	120	0	0	10	90	100		

Having determined that oxygen was required for the preservation of color in the lychee, attempts were then made to determine whether the modified atmosphere created by the fruits packaged in polyethylene bags was the effective factor that prevented the loss of color. This was done by storing the fruits in atmosphere containing known concentrations of CO_2.

Three tests were conducted with lychees in storage in CO_2 - air mixtures. Desired CO_2 concentrations were obtained by mixing together proper proportions of CO_2 and air as previously described (*1*). The mixed air was passed over the fruits in glass jars at constant rate at atmospheric pressure at room temperature. In 1 test fumigated and unfumigated fruits of the variety Brewster stored in 25 percent CO_2 did not maintain their color any better than their corresponding controls stored in normal air in similar glass jars. Normal treated and untreated fruits (not damaged by fruit flies and other insects) in both the modified atmosphere and in air maintained their color for approximately 7 days. The quality of these fruits was maintained to the end of the experiment. Two hundred fruits were used for each treatment in this test.

In the other 2 experiments, unfumigated fruits of the variety Hak Ip were similarly subjected to 8, 16, 35, and 45 percent CO_2. Fruits in both the modified atmosphere and normal air maintained their color and quality for 6 days at room temperature. In these tests each treatment consisted of 150 fruits. In all jars used in these experiments, moisture in the compressed air condensed on the inner walls and provided a high humidity condition for the stored lychees. Since the fruits in normal air retained their color just as well as those subjected to CO_2 - modified air, the effect of desiccation in the promotion of darkening was next investigated.

EFFECT OF DESICCATION

Attempts were made to demonstrate that exposure of the fruit to drying conditions caused darkening of the pericarp. In the first experiment, 5 holding boxes (10" × 15" × 4¾" with mosquito screening at the bottom) with 15 unfumigated fruits in each were stacked and stored at room temperature. The effect of the degree of exposure upon the rate of darkening of Brewster lychee is clearly seen in the data presented in table 5, which indicate that the fruits most exposed to the air (uppermost box) turned brown first, followed successively by the fruits in the lower boxes, with those in the bottom box darkening the last. In the second test, the variety Hak Ip (25 unfumigated fruits per treatment) reacted similarly to identical conditions of storage.

TABLE 5. Effect of exposure on the rate of browning in unfumigated Brewster lychee in storage in stacked boxes at room temperature

Position of box in stack*	Percent average degree of browning of individual fruits after indicated days of storage						
	2	3	5	6	7	8	9
1	100						
2	25	75	100				
3	0	12	88	100			
4	0	0	38	50	95	100	
5	0	0	25	45	75	95	100

*1 is uppermost box, followed successively by 2, 3, 4, and 5 (lowest box).

In another test, some unfumigated fruits of the Brewster variety were placed in the holding box with the stem end up (50 fruits) and others with the blossom end up (50 fruits) in a single layer. After storage for 4 days at room temperature, the exposed (upper) ends of the fruits were darkened regardless of whether it was the stem or blossom end which was up, but the unexposed (lower) ends still retained their color.

Twenty unfumigated fruits of Hak Ip were fanned with an electric fan for 5 hours at room temperature. Three hours after fanning, the fruits were nearly completely darkened, whereas 20 comparable unfanned fruits were darkened in 2 days. Similar results were obtained with the Brewster variety.

In 4 tests, various portions (stem end, blossom end, central portion, whole surface, etc.) of the pericarp were coated with melted paraffin (120° F.) and the fruits stored at room temperature. Each treatment consisted of 10 fruits. In all cases, after 2 days of storage, darkening occurred only in the exposed areas of the pericarp. The varieties Brewster and Hak Ip produced similar results. In 2 additional tests scotch tape was also employed to cover the fruits (10 Brewster and 10 Hak Ip fruits per treatment) and similar results were obtained.

PACKAGING MATERIALS

In a test, polyethylene bags were compared with other packaging materials (Saran wrap, cellophane, and wax paper). Unfumigated fruits of the varieties Brewster and Hak Ip were packaged in these containers and stored at room temperature for a week. Fifteen fruits were used for each treatment. Moisture condensation on the inner surface of the package was obvious in the case of cellophane, polyethylene, and Saran, this being the decreasing order of the amount of condensation. Moisture condensation was not visible in the case of the wax paper, however. At the end of the storage period, those fruits stored in cellophane, polyethylene bags, or Saran wrap were normal in appearance and flavor. Those stored in the wax paper desiccated to some extent and were approximately 58 percent darkened at the end of the storage period.

STORAGE TEMPERATURES

Storage life of waxed (15 percent Sta-Fresh Wax #920) fruits and those stored in polyethylene bags was compared with that of fruits in open storage at room temperature (74° – 83° F.), 55°, 45°, and 35° F. Twenty fumigated Brewster lychees were used for each treatment. The results are shown in table 6.

That waxing was ineffective in preventing the browning of the pericarp at room temperature storage was again demonstrated. Even at 55° F., the rate of browning of waxed fruit was the same as that of the normal fruit in open storage. At 35° and 45° F. the waxed fruit browned only slightly less rapidly than unwaxed fruit. Whereas, the normal fruits in open storage completely browned in approximately 4 days at room temperature, those in low temperatures required 7 days to brown completely. Depending on the storage temperatures, fruits packaged in polyethylene bags retained their color at least 2 to 4 times longer than those stored in the open. The effect of temperature in this respect is striking. Bagged fruits retained their color for at least 8, 15, 25, and 32 days at room temperature, 55°, 45°, and 35° F., respectively. Although the storage test was discontinued when insect-damaged fruits darkened and became infected with decay organisms, uninjured fruits retained their color and flavor up to this point (table 6).

TABLE 6. Effect of waxing (15 percent Sta-Fresh Wax #920), polyethylene bags, and open storage on the rate of browning in unfumigated Brewster lychee in storage at various temperatures

Storage temperature (° F.)	Storage method	Percent average degree of browning of individual fruits after indicated days of storage												
		1	2	4	7	8	11	12	15	18	21	25	28	32
74–83 (room)	Waxed, open	0	0	100										
	Polyethylene bag	0	0	0	0	0*								
	Open	0	0	100										
55	Waxed, open	0	0	62	100									
	Polyethylene bag	0	0	0	0	0	0	0	0*					
	Open	0	0	75	100									
45	Waxed, open	0	0	62	88	100								
	Polyethylene bag	0	0	0	0	0	0	0	0	0	0	0*		
	Open	0	38	75	100									
35	Waxed, open	0	0	70	88	100								
	Polyethylene bag	0	0	0	0	0	0	0	0	0	0	0	0	0*
	Open	0	38	70	100									

*Normal fruits. Fruits injured by insect stings prematurely darkened and molded, causing termination of test. Organisms identified on decaying fruits at room temperature included species of *Penicillium, Aspergillus, Verticillium, Monilia, Trichoderma,* and *Nigrospora.*

In 2 other tests, fumigated and unfumigated fruits of the varieties Hak Ip and Brewster were packaged in polyethylene bags and stored at various temperatures. The two varieties reacted similarly to the various storage temperatures, and there was no difference in response between fumigated and unfumigated lots in these two varieties. In one test 70 fumigated and 70 unfumigated Brewster fruits in polyethylene bags on the average retained their color and edible quality for approximately 8, 18, 33, and 40 days at room temperature, 55°, 45°, and 35° F., respectively.

The feasibility of packaging lychees in polyethylene bags in quantities which might possibly be commercial in volume for shipment out of Hawaii was investigated. Twelve pounds (240 fruits) of unfumigated Brewster lychees were packaged in large polyethylene bags which were then twist-closed and placed in cardboard cartons. A sealed carton was stored at each of three levels of temperature. At 55°, 45°, and 35° F., the fruits remained in a salable condition for about 17, 25, and 32 days, respectively.

DISCUSSION

Studies on the prevention of darkening in the lychee fruit presented above indicate that darkening is due to some enzyme activity, presumably one involving an aerobic oxidative polyphenolase system. Evidence for the system's aerobic requirement was shown when sections of the pericarp failed to darken when subjected to vacuum (29.5 in.). Pericarp in ascorbic acid solutions failed to darken. The acid in its capacity as a reducing agent prevented the accumulation of some oxidized phenolic compound which leads to the formation of melanin, the dark pigment. Therefore, as long as the pericarp was in the ascorbic acid solution, no darkening occurred. This principle is commercially employed in the canning process. The thermolabile nature of the enzyme was indicated when heated pericarp failed to darken in air.

Studies conducted on the effect of varying the exposure of the fruits to air by differential covering with melted paraffin and Scotch tape, by fanning, and by placing the fruits in holding boxes so as to differently expose them to the air indicated that degree of desiccation is related to the darkening process since the rate of darkening was related to the degree of exposure to the air; i.e., the greater the exposure the more rapid the darkening process. Thus, the prevention of darkening of fruit by polyethylene bags and other similar materials seems to be due to the prevention of desiccation of the fruit. No attempts were made to determine the minimum oxygen requirement for the storage of lychee, but as long as anaerobic condition did not prevail, the fruit could be stored even in airtight containers that prevented desiccation of the fruit. It is believed that in effect desiccation is similar to mechanical injury to the pericarp. In either case, the tissues are exposed to oxygen, and the darkening process proceeds.

Thus, it follows that from the practical standpoint, the method to be used for the prevention of darkening in exported lychee must be one in which the fruit is not subjected to either desiccating or anaerobic condition. Packaging made of polyethylene or some similar porous material meets this requirement. Polyethylene is naturally pervious to gases and, in practice, the punctures caused by the sharp protuberances of the pericarp increase the porosity of the membrane. Further aeration is obtained by merely twist-sealing the package or by using perforated material (*5*). The high humidity created by the condensation of moisture in the air on the inner surface of these materials prevents the desiccation of the fruits.

SUGGESTIONS FOR PACKAGING

In view of the above findings and since there is no special recommended method of packaging the lychee here and elsewhere in the United States (*4*), the following considerations are presented as suggestions for shippers of this fruit.

It is believed that rapid discoloration of the pericarp may occur if the fruit is wet with dew when harvested (*4*). This possibility was not tested here, but it is conceivable that excessive moisture may contribute to the prevalence of decay organisms in storage. Since there is sufficient moisture in the air to condense within the package to develop a high humidity condition, fruits to be packaged should be free of excessive moisture on the surface.

Only ripe, freshly harvested, insect damage-free fruits should be used for the export trade. Fruit flies are destroyed by the fumigation, but insect punctures invariably develop into darkened loci where decay organisms multiply. The higher the temperature of storage, the more rapidly and severely this occurs.

After the required fumigation treatment, all visibly defective fruits (insect-punctured, bruised, and overripe) should be rogued. The apparently normal fruits should be placed in polyethylene bags and lightly twist-sealed. Bags up to a size large enough to hold 15 pounds may be used. Weights of fruit greater than this may result in bruising the fruit in transit. The bagged fruits should be placed in paper cartons similar to those used in shipping fresh papayas. Quarantine regulations require the sealing of the cartons which, however, are not airtight. In order to facilitate the cooling of the fruits, only an amount of packing material sufficient to prevent injury to the fruits in transit should be used in the carton. If it is necessary to hold the packed fruits before shipping, the cartons should be stored at approximately 35° F. until shipping time.

If air transportation is economically feasible, this is preferable to surface transportation. No refrigeration is required by air carriage, but the saving in transit time which results in an increase in the shelf life of the fruit is the greatest advantage incurred by this method. For surface transportation by freighters, the lychees should be shipped at 35° F.

Upon arrival on the West Coast, the fruit should be stored under refrigeration and preferably at temperatures as close as possible to 35° F. but not below when in the hands of the wholesaler and retailer. Allowing about 6 days for preparation for shipping and shipping time by boat under normal conditions, the fruits will have approximately 3 weeks of shelf life. If shipped by air, an additional period of about 1 week may be gained.

SUMMARY

Studies were conducted to determine the nature of the darkening process in the pericarp of the ripe lychee fruit. Attempts were made to prevent this undesirable feature, which is a major problem in the shipment of fresh fruit to the mainland market. A practical solution to this dilemma was developed and recommended to shippers.

LITERATURE CITED

1. Akamine, E. K. 1959. Effects of carbon dioxide on quality and shelf life of papaya. Hawaii Agric. Expt. Sta. Tech. Progress Report 120. 15 pp.

2. ——— and H. I. Sakamoto. 1951. Brominated charcoal to prevent fading of *Vanda* orchid flowers. Amer. Orchid Soc. Bul. 20: 149–152.

3. Biale, J. B., R. E. Young, and A. J. Olmstead. 1954. Fruit respiration and ethylene production. Pl. Physiol. 29: 168–174.

4. Cobin, M. 1954. The lychee in Florida. Florida Agric. Expt. Sta. Bul. 546 (Revised). 35 pp.

5. Marloth, R. H. 1949. The litchi in South Africa. Bul. 286 (2nd revised edition). 16 pp.

6. Nakata, S. 1953. Girdling as a means of inducing flower-bud initiation in *Litchi.* Hawaii Agric. Expt. Sta. Progress Notes 95. 4 pp. (Mimeo.)

7. ———. 1955. Floral initiation and fruit-set in lychee, with special reference to the effect of sodium naphthaleneacetate. Bot. Ga. 117: 126–134.

8. Storey, W. B., R. A. Hamilton, and H. Y. Nakasone. 1953. Groff—a new variety of lychee. Hawaii Agric. Expt. Sta. Cir. 39. 8 pp.

9. U.S.D.A. Agricultural Research Service Plant Quarantine Div., Territorial Quarantine Notices Part 318, Sec. 318.13-4b. Dec. 29, 1959.

10. Yee, W. 1957. The lychee in Hawaii. Hawaii Agric. Ext. Cir. 366. 13 pp.

ACKNOWLEDGMENT

Grateful acknowledgment is made to the laboratory of Investigations of Fruit Flies in Hawaii, Entomology Research Division, Agricultural Research Service, U.S.D.A. for assistance in the fumigation of lychee fruits and the loan of the gas analyzer. The identification of the decay organisms in stored fruits by Mamoru Ishii, Hawaii Agricultural Experiment Station, is acknowledged with thanks. Appreciation is also extended to the Horticulture Department of this station for the supply of Hak Ip and Kwai Mi varieties of lychees used in these investigations and to Edward Ross of this station for the donation of Sta-Fresh Wax #920.

UNIVERSITY OF HAWAII
COLLEGE OF TROPICAL AGRICULTURE
HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII

LAURENCE H. SNYDER
President of the University

MORTON M. ROSENBERG
Dean of the College and
Director of the Experiment Station