Studies on transit and storage methods of lychees[1]

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Abstract Maturity standards, storage temperatures, packaging methods and some chemicals for prolonging the storage life of lychee were studied. Lychee harvested at 7 "fen" or about 70% coloring had an acceptable color and flavor and a storage life of 47 days at 5°C. Similar fruit harvested when fully ripe had a storage life of only 19 days and that harvested at green-mature stage had a storage life of 29 days.

Unwrapped lychee turned into brown completely in 4 days at 20°C and in 8 days at 5°C or 0°C. Lychee packed in polyethylene (PE) bags, boxes or trays extended their storage life substantially. The packed fruit only had a negligible decay in 4 weeks at 0°C. Packages of molded PE trays covered with Magi-film, which had a shinny attractive appearence, seemed promising.

Antisenescencing plant growth regulators (2, 4-D and kinetin), wetting agents (calcium chloride and sodium chloride) and waxing had no effect on prolonging the postharvest life of lychee. Systematic fungicides (Benlate and TBZ) were effective in controlling decay but not in retaining red color. CMC (carboxymethyl cellulose) plus citric acid coating was slightly effective in retarding browning but had no effect on decay control. A postharvest handling flow chart was designed for exporting lychee use.

Lychee (*Litchi chinesis* Sonn.) is a subtropical fruit esteemed as the "king of fruit" in China for thousands of years [(13)]. It is now widely grown in the southern and central parts of Taiwan. Each year, limited quantities of lychee are exported to southeastern Asia countries and Japan. The biggest difficulty of lychee in export trade has been that lychee has a very short harvest season and a very short postharvest life. Soon after harvest it loses the attractive red color and turns into dull brown. After the color change, lychee is very susceptible to fungal decay. Thus, to extend the postharvest life of lychee and to maintain the fruit in good quality during export transit is of great importance.

Desiccation and decay have long been regarded as two vital problems during storage of lychees. Various methods, such as refrigeration [(4,8,17,18)], paper or polymeric film packaging [(9,11,12)], irradiation [(2,3,16)], and chemical treatment [(5,11)] have been tested to control decay and to extend the storage life.

Postharvest diseases caused by *Aspergillus*, *Cylindrocarpon*, *Botryodiplodia*, and *Colletotrichum* have been reported [(20)]. A species of *Peronophythora* has also been found to

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be parasitic on lychees in Taiwan [6]. Decay organisms which caused fermentation and decay of stored lychees have been isolated and turned out to be bacteria, yeast, and other fungi in the proportion of 3 : 96 : 1, respectively [22].

Lychees grown in central Taiwan usually attain their green mature stage in early June. After this stage, they still increase their size and weight accompanying color changes. Fruits turn their green color to red about in 3 weeks. During this period, the acid content changes significantly but total sugar content changes little [10] and the fructose content rises progressively [21]. Lychee at it's "50-70%" coloring has claimed to possess the best quality for canning [10].

This study was to determine the optimum harvesting maturity and storage temperature, usefulness of various packaging methods, and the effectiveness of several chemicals on the prevention of peel browning of lychees. The objective was to develope a practical postharvest handling method which could be applied in lychee transit and storage.

Materials and Methods

This study was conducted in 1980. The fruit used in the experiment was grown in Nantou, Taiwan. and harvested from 10-year-old trees of 'Hak Ip' cultivar. Immediately after harvest by clipping, bunches of the stems of the fruit, were placed in cartons with non-perforate polyethylene (PE) liner and trucked directly to the laboratory. Then the pedicles were clipped and lychees were seperated into individual fruits and sorted into different classes according to the size and color. The mechanically-damaged and off-typed fruits were discarded. Since fruits of the same cluster (inflorescence) did not mature evenly, only those of proper maturity were selected for this experiment. Each class of fruits after sorting was evenly distributed into the test lots to minimize the diversity of the samples.

Lychees harvested on June 10, 15, 20, 25, and 30 corresponded to local farmer's maturity standard of 6, 7, 8, 9, and 10 "fen", respectively. The color of the outside layer of the peel and the inner membrane of the peel were determined with a color and color differential meter (Nippon Denshoku model ND-1010 CD) by using pink and yellow standards [19]. The value of "L" indicated the lightness of color (100 = white and 0 = black); "a" indicated red when the value was positive, gray when zero and green when negative ; "b" indicated yellow when the value was positive, gray when zero and blue when negative.

After the color test, fruit juice was extracted for acidity and soluble solids analysis. The total acidity was determined by titrating an aliquot of flesh extracts with standardized sodium hydroxide using phenolphthalin indicator. Total soluble solids was measured with hand refractometer (Bausch & Lomb model 32).

Fruits harvested on June 20 and 4 replications with 15-50 fruits per sample in each treatment were used for stored temperature, packaging, and chemical dipping studies. The color and flavor of the fruit before and after test were evaluated. Numerical scales were used to express the degree of browning : 1 = all red, 2 = browning on tips of tubercles only, 3 = brown spots up to 0.5 cm in diameter, 4 = large brown sports over 0.5 cm in diameter, and 5=all brown. The flavor of the fruit was rated as excellent, good, fair, poor and inedible by a panel test with 7 panelists. All fruits before test were rated as grade 1 in color and excellent in flavor.

Chemicals with fungicidal, antisenescence or wetting properties were screened for their effectiveness in preventing browning and decay and purchased from various companies : kinetin from Sigma Chemical Co., USA ; 2, 4-D (2, 4-dichloroacetic acid) from Tokyo Kasei Chemical Co., Japan ; calcium chloride and sodium chloride from Merck Inc., West German ; TBZ (thiabendazole, 2-(4-thiazolyl) benzimidazole, Mertect) from Merck, Sharp & Dohme International, USA ; Benlate (methyl-(1 butyl carbamoyl)-2-benzimidazole carbamic acid) from Du Pont Co., USA ; CMC (carboxymethyl cellulose) from Nichlin Chemical Co. Japan and Tag® as a generous gift from M. C. W. Co., Israel. Fruits were dipped in aqueous solution at concentrations indicated in Table 6 for four minutes.

Various packaging materials were also tested for their effectiveness in extending storage life. Magi-film®(0.012 m/m thick) made of ethylene vinyl acetate copolymer resin with special antifog treatment is a product of Chiyi Industrial Co., Taiwan. Molded PE meal box (11×7.5×2.5 cm, 0.17 m/m thick) was purchased from local supermarket ; PE tray has the same size as the meal box but without flat cover, was also purchased from local market.

Samples either packed or not were placed in ventilated PE bins (4×30×10cm) which were kept in storage rooms maintained at assigned temperatures and 85-90% relative humidity. Temperature of each storage room was thermostatically controlled with ±0.5°C accuracy.

Results

Maturity test

A maturity description based on color changes of tubercles, the ground of the peel and the inner membrane of the peel was made to code to the presently used but not yet well defined numerical maturity standard "fen" (Table 1). The description covers a range from 5 "fen", at which the fruit was green-mature, to 10 "fen" when the fruit was over ripen.

Table 1. Description of color changes coded to maturity standard of 'Hak Ip' lychee by "fen" unit

Maturity[a]	Color changes in different parts of the peel		
"fen"	Ground	Tubercles	Inner membrance
5	green	green	white
6	yellow first appeared	red on the tip of yellow ground	white
7	1/3 red	1/2 red	white tinted with light red
8	1/3 to all light	1/3 brown on tip	1/2 red
9	red	all brown on tip	red
10	dully red	brown	deep red

a. Maturity expressed with "fen" unit is presently used by Taiwan farmers ; 6 "fen" is about turning stage.

Values of color components, either in outer or inner membrane of the peel changed drastically during fruit ripening (Figure 1). The brightness "L" of the outer peel decreased as the fruit ripened and a sharp decrease occured between 8 and 9 "fen". Red color "a" increased drastically from 6 to 8 "fen", then decreased sharply. Like brightness, the value of yellow "b" decreased as ripening progressed and had a rapid change between 6 and 8 "fen". Changes of color components in inner membrane of the peel followed nearly the same pattern as those of outer peel. The slight differences noticed are that the brightness of inner membrane changed little during ripening ; red color "a" increased as ripening progressed and the most drastic change was observed with one stage delay starting from 7 to 9 "fen".

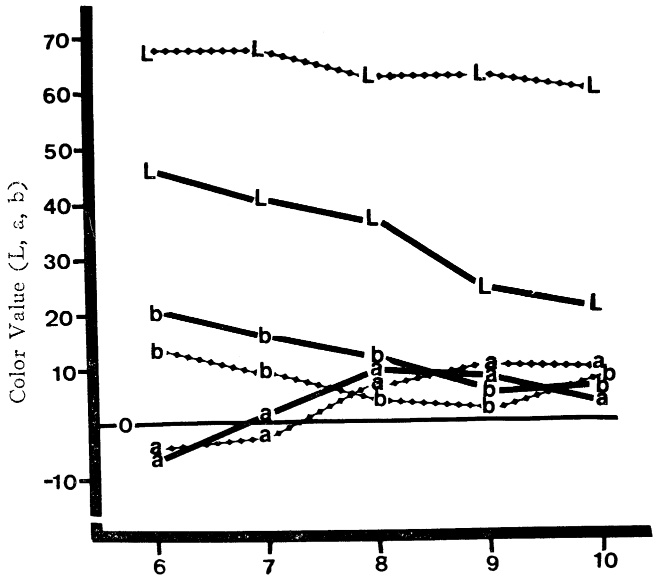

Fig. 1. Changes of color values of outer peel (solid line) and inner membrane (dotted line) at different stages of maturation of lychee. "L" values are : from 100 (white) to 0 (black) ; "a" values are : red (+), gray (0), green (−) ; "b" values are : yellow (+), gray (0), blue (−).

A progressive decrease in acid content and increase in total soluble solid was found during fruit ripening (Table 2). Significant acidity and soluble solid content occured between 6 and 7 "fen" which corresponded to a flavor change from poor to good. Although the flavor at 8 and 9 "fen" was rated as excellent, the storage life of lychee harvested at these stages were very short. The fruit harvest at 7 "fen" had the longest storage life.

Storage temperature vs. browning

The result of storing unpackaged fruit at 0°, 5°, 10°, 15° and 20°C was summarized in Table 4. Under high relative humidity (85-90%) conditions, lychee could retain its freshness and good color for only 2 days at 20°C ; and it attained complete browning in 4 days at this high temperature. The fruit stored at≦5°C did not turn to brown completely before 8 days, however. The fruit had no decay or off-flavor developed but the rind became brittle and very easy to crack as a result of dessication.

Table 2. The quality and storage life of lychee harvested at different stages of matuation

Maturity ("fen")	Acid content as malic acid (%) (x10^{-2})	Total soluble content (Brix)	Flavor	Storage life[a] (days)
6	0.29±3.1	14.0±2.9[b]	poor	29±6
7	0.21±2.6	17.0±1.7	good	47±4
8	0.17±0.8	17.3±2.1	excellent	30±3
9	0.16±1.3	18.1±2.4	excellent	25±4
10	0.13±20	18.0±2.6	good	19±3

a. Storage condition : 0°C, 85–90% R. H. ; storage life was ended when the fruit became inedible.
b. Standard deviation.

Table 3. Temperature effect on the browning rate of lychees stored at 85–90% R. H.

Temperature (0°C)	Cumulative percent of browing			
	2 days	4 days	6 days	8 days
0	0	68	87	100
5	0	75	90	100
10	0	81	100	
15	0	93	100	
20	0	100		

Table 4. Effect of various packaging methods on the prevention of browning of lychee at 0°C, 85–90% R. H.

Packaging	Scores of browning[a]			
	1 week	2 weeks	3 weeks	4 weeks
PE bag (unsealed)	4.86 a[c]	5.00 a	5.00 a	5.00 a
PE bag (sealed)	2.13 cd	2.54 f	3.18 cd	3.81 cd
PE bag (sealed)+paper liner	2.00 cdef	2.24 g	3.09 cde	3.42 cde
PE molded meal box (stapled)	3.53 b	4.20 b	5.00 a	5.00 a
PE molded meal box+moistened pulp[b]	2.11 c	2.88 d	3.24 c	3.85 c
PE molded meal box+moistened sawdust[b]	2.29 c	3.17 c	3.53 b	4.14 b
PE molded meal box+moistened paper liner[b]	1.90 def	2.69 e	3.00 cde	3.57 cde
PE molded tray covered with Magi-film®	1.78 f	2.30 g	2.39 e	3.16 e
Waxing (Tag®)	4.80 a	5.00 a	5.00 a	5.00 a
CK (unwrapped)	5.00 a	5.00 a	5.00 a	5.00 a

a. Rating scale : 1=all red, 2=brown on tips of tubercles, 3=brown spots up to 0.5 cm diameter, 4=large brown spots, 5=all brown.
b. Scotch tape sealed with a pinhole at each end.
c. Means with same letter within a column are not significantly different at 1% level.

Effect of packaging on browning

Browning was delayed by packaging lychee in PE bag, molded PE boxes or trays (Table 4) . Packaged fruit retained its color at least 2 to 4 times longer than unpackaged fruit. Waxing the fruit or keeping the fruit in unsealed PE bags had little effect on preventing fruit browning. The fruit kept in PE bags and in molded meal boxes turned brown more slowly than the unwrapped one. The fruit in PE tray covered with Magi-film turned brown most slowly. Moistened pulp and moistened paper liner had a better ability to maintain moisture in the package than moistend sawdust.

Chemicals vs. browning and decay

Systematic fungicides, TBZ and Benlate, had a good effect in decay control but had no effect in delaying browning (Table 5). Antisenscence plant growth regulators, 2, 4-D and kinetin, had no effect either in retarding peel browning or decay control. Wetting agents, 4% calcium chloride or 5% sodium chloride damaged the fruit osmotically and, hence, accelerated browning. CMC coating was slight effective in preventing browning when lychee stored for 12 days but not effective in controlling decay.

Table 5. Effect of chemicals on the control of decay and browning of lychee in perforated PE bag stored at 10°C, 85-90% R. H.

Chemicals	scores of browning and percent of decay			
	3 days	6 days	12 days	12 days
	Browning[a]	Browning	Browning	Decay (%)
TBZ 1000 ppm	2.60 bc[b]	3.40 bc	5.00 a	0.00 c
Benlate 1000 ppm	2.45 bcd	3.20 cd	5.00 a	0.00 c
Benlate 1000 ppm+2% $CaCl_2$	2.50 bcd	3.20 cd	4.80 ab	0.00 c
4% $CaCl_2$	4.10 a	5.00 a	5.00 a	13.50 ab
5% $NaCl_2$	4.50 a	5.00 a	5.00 a	16.50 a
1% CMC+0.05% citric acid	2.05 d	2.85 d	4.50 b	11.00 b
2, 4-D 50ppm	2.75 b	3.75 b	5.00 a	14.50 ab
kinetin 25ppm	2.35 bcd	3.25 cd	5.00 a	14.00 ab
CK_1 (untreated)	2.50 bcd	3.75 b	5.00 a	14.50
CK_2 (water)	2.75 b	3.30 cd	5.00 a	13.50 ab

a. Brown rating scale : 1=all red, 2=brown on tips of tubercles, 3=brown spots up to 0.5 cm diameter, 4=large brown spots, 5=all brown.

b. Means with same letter within a column are not significantly different at 1% level.

Discussion and Conclusion

This experiment confirmed previous reports [24,25,26] on that while the flesh quality of lychee could be maintained for several weeks by proper refrigeration and packaging. External discoloration was difficult to prevent. The fruit harvested at 7-8 "fen", shortly before full ripe, had two to three times longer storage life than that harvest at fully ripe.

The fruit may be harvested even earlier if requires a long distance, but at some sacrifice of quality for exchange of durability. This study revealed that using color development of inner membrane of the peel was more dependable and easier than using ground color of the peel or the color of tubercles [10] in judging maturity since little change of brightness and red color component increased during fruit ripening was found in the inner membrane of peel.

Keeping lychee under low but unfrozen temperature is essential in delaying fruit browning [9,18]. This study confirmed that quick browning would occur when the storage temperature was higher than 10°C, Therefore a prompt precooling to remove field heat of the fruit should be a good practice. Few information on chilling injury of lychee is available yet. However, there was some indication that lychee might suffer some extent of chilling injury during a period of cold storage since the fruit after storage turned to brown quickly at room temperature. The symptom of browning developed after cold storage was the same as that caused by desiccation.

Desiccation, which causes fruit browning, should be avoided during handling, storage and transit of lychee [15]. Anatomical studies (data not shown) revealed that natural wax covering epidemical cells of lychee was thin and discontinuous. Very few or no wax found around the tip of tubercle. The thin-layered epidemal cells on the tip of tubercle were easy to break during fruit ripening and, therefore, the parenchyma cells would then be exposed to the air. This might be the reason why full ripe fruit was more prone to desiccate than partially ripen.

Waxing was not effective in preventing browning in test confirmed previous works [1,14] but was contray to the other [11]. The tips of tubercles could not easily be covered by wax during the waxing process may be the reason. Fruit treated with CMC plus citric acid slightly delayed browning. The explaination is that CMC hydrated within the break of tubercles, preventing the desiccation and oxidation [7].

Prevention of browning by packaging lychee in various PE material seemed to be due to the effect of maintaining high humidity and low oxygen atmosphere in the package. Magi-film® is considered to be a good consumer packaging material because it has a shinny appearance, adequate permeable to air and an ability to prevent condensation of water vapor on the film.

Browning was not a result of peel senescence because neither 2, 4-D or kinetin could alleviate it. Systematic fungicides TBZ and Benlate, was very effective in controlling decay and somewhat effective in preventing browning. The effect of preventing browning might to their fungicidal effect instead of growth regulatory effect [23].

The above findings suggested that prevention of desiccation is of prime importance in order to prevent browning of lychee. However, a practical device to prevent desiccation should not create an anaerobic condition of the fruit. Consumer-pack made of PE bags, molded PE boxes, and molded PE trays covered with Magi-film are useful for lychees. Although coating with CMC and citric acid was slightly preventing browning in the test, it is not worth to be recommend in practical use since effect of packaging is far better than chemical treatment in preventing browning.

Lychee for export should be harvested at 7-8 "fen" or about 70% ripe (coloring) and should be held at a temperature below 5°C during handling, shipping and marketing. If the importer's quarantine requirement includes disinfestation of Oriental fruit fly, fumigation treatment is necessary. A portharvest handling flow chart shown as Fig. 2 is designed for exporting lychees.

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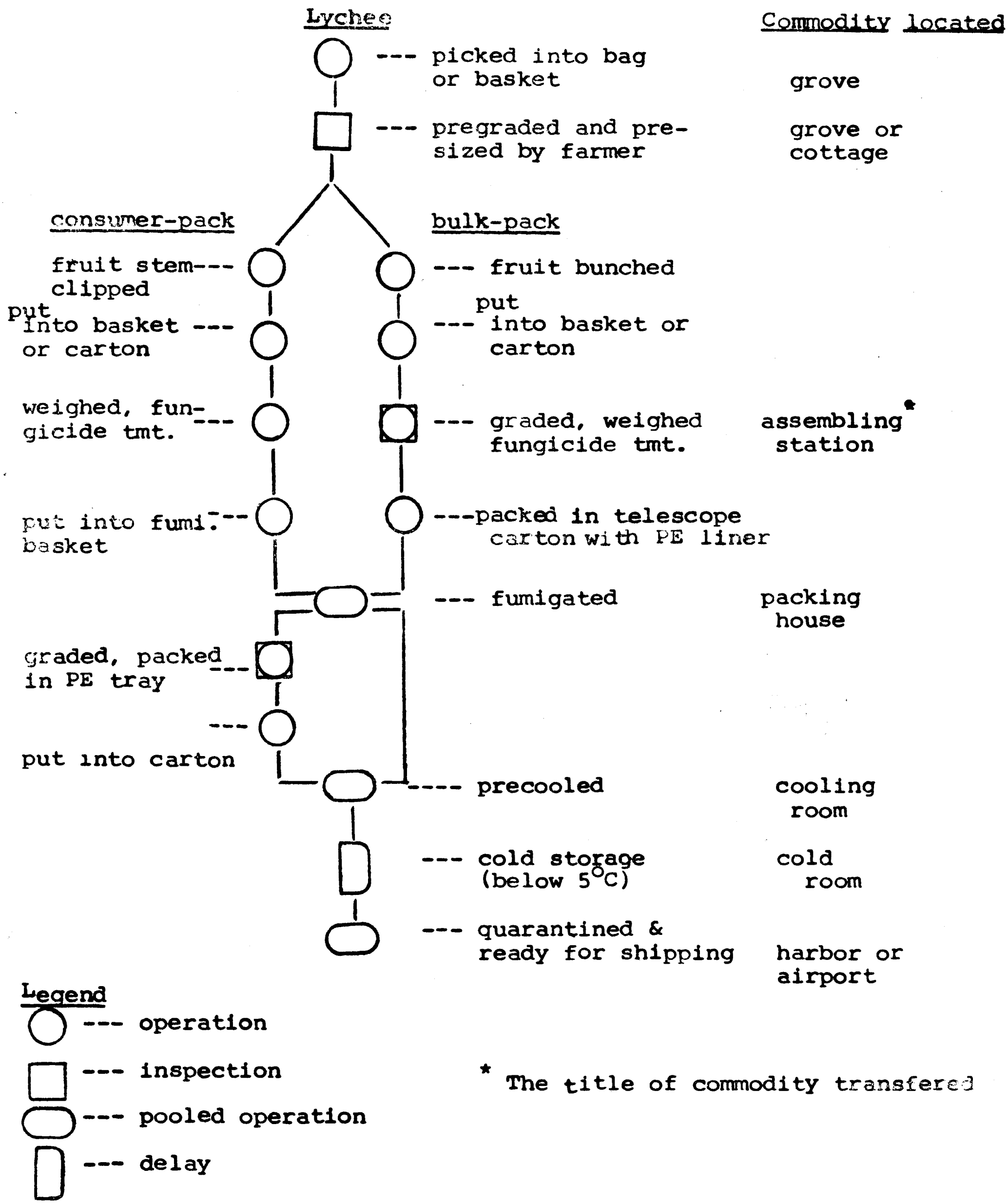

Fig. 2. Proposed Poteharvese handling flow chart for exporting lychees.

Literature cited

1. Akamine, E. K. 1960 Preventing the darkening of fresh lychees prepared for export. Hawaii Agri. Exp. Stat. Tech. Progress Report 127, 18pp.
2. Beyers, M. and A. C. Thomas. 1979. Gamma irradiation of subtropical fruits. 4. Changes incertain nutrients present in mangoes, papays and litchis during canning freezing and gamma irradiation. J. Agri Food Chem. 27 (1) : 48-51.
3. Beyers, M., Thomas, A. C. C. and A. J. Tonder Van. 1979. Gamma irradiation of subtropical fruits. 1. Composition tables of mango, papaya, strawberry, and litchi fruit at edible-ripe stage. J. of Agri. Food Chem. 27 (1) : 37-42.
4. Campbell C. W. 1959. Storage behavior of fresh 'Brewster' and 'Bengal' lychees. Proc. Fla. Stat. Hort. Soc. 72 : 356-360.
5. Chang, K. P. 1969. Application of fungicides on the cold storage of litchi fruit. Taiwan Agriculture 5 (2) : 79-83.
6. Chen, C. C. 1961. A species of *Peronophythora*, Gen. Nov. parasitic on litchi fruit in Taiwan. College of Agri. Natl. Taiwan Uinv., Special Publication No. 10 : 1-42.
7. Daniel R. 1973. Fruit and vegetable coating. In "Edible coating and soluble packaging". Food Tech. Rev. 3., Noyes Data Co. Park Ridge, N. J., USA.
8. Dennison R. A. and C. B. Hall. 1975. Studies on the handing of fresh lychees. Fla. Lychee Growers Assoc. Yearbook 3 : 31-33.
9. Deullin T. and F. Trupin. 1965. Sea transport of litchis. Fruit Outremer 20 : 341-3., cited *in* : Hort. Abstract 35 : 634.
10. Fang, T. T. and Y. C. Huang. 1970. A study on the picking maturity of lychee. J. Hort. Soc. China 16 (5) : 63-77.
11. Gaur, G. S. and P. N. Bajpai. 1978 Postharvest Physiology of litchi fruits. Progressive Horticulture 10 (3) : 63-77.
12. Hatton, T. T, Reeder, W. F. and J. Kaufman. 1966. Maintaining market quality of fresh lychees during storage and transport. Agri. Res. Serv, USDA, Marketing Res. Report No. 770, 9pp.
13. Huang. B. T. 1979. Litchi. In "Fruit growing in Taiuan", N. N. Liang ed.), Vol. II. Harvest Farm Magazine, Taipei, Taiwan 312pp.
14. Huang, B. T. and S. W. Wong. 1966. Cold storage test of litchi fruit. Hroticulture 1 : 5.
15. Joubert, A. J., and L. J. Lelyreld Van. 1975. An investigation of preharvest browning of litchi. peel. Phytophylactica 7 (1) : 9-13.
16. Kramer, M. S. and G. D. Kuhn, 1965. The effect of radiation on fresh lychees. Proc. Fla. Stat. Hort. Soc. 77 : 436-438.
17. Lutz, J. M. and R. E. Hardenburg. 1968. The commercial storage of fruits vegetable and florist and nursery stocks. USDA Agri. Handbook 66, 94pp.
18. Mukerjee, P. K. 1975. Prevention of natural color in litchi and cold storage. Sci. and Cult. 23 : 101 -103.
19. Nippon Denshoku color calculatting system. Nippon Denshoku Ine., Japan.
20. Prasad, S. S. and R. S. Bilgrami. 1974. Investigations on diseases of litchi : VI. Postharvest diseases of fruit in India. Plant Disease Reporter 58 (12) : 1134-1136.
21. Prasad, U. S. and O. P. Jha. 1979 Variation in the level of oxygen uptake, fructose and pyruvate in fruit avil of *Litchi chinesis* Sonn. during maturation and ripening. Indian J. Plant Physiol. 22 (22) : 163-165.

22. Roth, G. 1963. Postharvest decay of litchi fruit. S. Africa Dept. Agr. Tech. Serv., Tech. Commum. 11, 16pp,

23. Thomas, T. H. 1973. Growth regulatory effect of three benimidazole fungicides on the germination of celery seeds. Ann. Biol. 74 : 233-238.

24. Thompson, B. D. 1955. The effect of prepackaging and cold storage on the quality of fresh lychees. Fla. Lychee Growers Assoc Yearbook 1 : 22-25.

25. Thompson, B. D. 1965. A progress report on handling and storage of fresh lychees., Fea. Lychee Growers Assoc. Yearbook 2 : 27-28.

26. Wang, J. C. 1970. The effect of loss weight and qualities on lychee fruit during storage. Rural Taiwan 6 (6) : 19-20.

荔枝果實貯運方法之研究[1]

林學正 江慧鈴[2]

摘要

荔枝於採收後極易變色失味，貯運能力深受限制，本實驗就果實成熟度、包裝方法、貯運溫度與保鮮藥劑加以研究，期能尋求一適合內外銷之處理貯運方法，提供業者參考。

黑葉荔枝在七分熟時最耐貯運，在 0°C 時可貯存達 47 天之久，過熟（十分）及綠熟（五分）皆不耐貯運，各爲 19及 27 天。以兩端各留一針孔之密封 PE 盒或 PE 盤覆以 EVA 膜，皆可顯著延長貯運壽命，在 0°C 貯藏達四星期而不失色變味，尤以後者因透明不霧化，清潔美觀，適合用於小包裝。果實塗臘、浸漬抗老化植物生長素 2.4-D (50 ppm) 或 Kinetin (25 ppm) 及濕潤劑一食鹽水（5％）或氯化鈣水（4％），對果實變色或腐爛皆無抑制作用。食品黏糊劑 CMC (1%) 加枸櫞酸（0.05％）水溶液處理果實，對防止果實變色稍具效果但無防止腐爛之效果。殺菌劑一霉敵或萬力 (1,000 ppm)，能有效防止果實腐爛兼稍具防止果實褐變之功效。果實在 20°C 下貯存四天即完全褐化，在 5°C 以貯存可延至第八天始完全褐化，故果實採收燻蒸後，應迅速預冷於 5°C 下貯運。應用上述試驗結果，設計一荔枝採收後之處理流程圖建議在外銷作業上使用。

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