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LONGANS
postharvest handling and storage

A report for the Rural Industries Research and Development Corporation

by Dr James Drinnan

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Foreword

This project was initiated to develop a post harvest handling strategy for Longan suitable for both export and domestic marketing. Little information exists on optimum storage temperatures, packaging and humidity for the most commonly grown longan varieties in Australia. Also much of the industry relies on SO_2 fumigation for post harvest handling. While SO_2 works very well there are health and safety concerns about its use, which may see its removal. At the Australian longan industry strategic review and priority workshop improved post harvest handling skills and an investigation of alternative strategies to SO_2 were seen as high priority.

The project results provide information, which is currently lacking - optimal storage temperature and humidity for the Australian grown varieties as well as an alternative treatment to SO_2, which can be used to extend the shelf life.

This project was funded by the Queensland Department of Primary Industries, the Australian Longan Growers Association and the RIRDC Core Funds, which are provided by the Australian Government.

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Simon Hearn
Managing Director
Rural Industries Research and Development Corporation

Acknowledgments

I wish to acknowledge the contribution of the Australian Longan Growers towards the success of this project and the post harvest horticultural staff at our Cairns office.

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Executive Summary

Background

Longan production is relatively new in Australia but has increased rapidly over the last 5 years. Production has now reached 1500 tonnes, worth over $6M. As production levels have increased and the potential for export, so has the need for definitive information on post harvest storage and handling of longans. Limited information is available from overseas literature and most is not applicable to our conditions or varieties grown; or relates to sulphur dioxide fumigation of fruit. Being a tropical fruit longans have high rates of respiration so that if they are not stored carefully they can have a very short shelf life, deteriorating easily and quickly within a few days at room temperature (25^{C}).

Longan fruit are difficult to store in good condition (appearance and taste) even for short periods of time. This is because fruit discolour (darken go brown from yellow) easily from disease, dehydration or chilling injury. When fruit are stored at high humidity's to avoid dehydration and high temperatures to avoid chilling injury disease is a major problem and develops quickly. When fruit are stored at low humidity's and temperatures to reduce disease problems, dehydration and/or chilling damage is a problem.

Sulphur Dioxide (SO_2) fumigation of longan fruit has been used successfully overseas and now here by most of the industry to overcome many of these post harvest problems. However, SO_2 fumigation is facing increasing consumer and regulatory resistance to its use. Without the use of SO_2 major problems are expected from the lack of control of storage quality and disease in the fruit by a large part of the industry. Current post harvest handling recommendations for longan are incomplete and need to be refined for our varieties and handling practices to improve the effectiveness of storage facilities especially in the absence of SO_2.

There is some confusion in the literature about the effects of storage conditions on longans, probably due to the lack of official grades or international standards for longan. Most indicators of the performance of longan in storage do not specify how the various cultivars rate. In Australia, cultivars of commercial importance are Kohala, Homestead, Fuhko, Biew Kiew, Chompoo, Dang and Haew. The time of harvest for each variety varies, as does the region and the market preference, making it important for post harvest recommendations to cultivar specific.

The Australian Longan Growers Association at their industry strategic review identified post harvest issues and alternatives to SO_2 fumigation as one of their key priority areas in their 5 year strategic plan. This project was developed in conjunction with the industry to address these concerns.

Objectives

The project aimed to develop a post harvest handling strategy suitable for both export and domestic marketing. Alternative strategies to SO_2 fumigation and the potential of pre-storage treatments to reduce chilling injury sensitivity were also assessed.

1. Determine optimal storage temperatures and packaging requirements for longan.
2. Develop alternative post harvest strategies to sulphur dioxide fumigation.

Methodology

The research work for this project was conducted in the field on growers' properties and in the laboratory and cold rooms at Mareeba and Cairns Departments of Primary Industries. Most of the work was conducted on the varieties Kohala and Biew Kiew, as they are the two most important commercial varieties, with some information collected on the other varieties also grown. The work was completed over three harvest seasons.

Assessment of the fruit from the treatments in each of the experiments was conducted with the aim of determining the quality of the fruit. Visual quality was determined by using a rating scale for the level of skin brownness, presence of disease, skin and flesh dehydration, chilling injury and market acceptability. For the level of skin browning a scale with a rating from 1 to 10 was developed for each cultivar.

Assessments were completed on control fruit immediately after harvest and on the stored fruit at regular intervals (1-14 days) until fruit reached unacceptable quality (up to 10 weeks).

Results

The results from this project have provided some valuable information on the post harvest storage aspects of longan. This has enabled a better understanding by growers of the factors involved in determining the shelf life of fruit.

The temperature and humidity trials indicate that the best compromise for storage is to store at the lowest possible temperature that fruit can be stored without suffering chilling damage and in packaging which keeps the fruit skin from dehydrating but doesn't allow it to become wet. The critical temperatures at which chilling injury became a problem were 10^0C for Biew Kiew, 7.5^0Cfor Kohala; 6.5-7.5^0C for Homestead, 10^0C for Fuhko and 7-8^0C for Chompoo. The best packaging was vita film, modified interactive plastic bags and vegi bags. In this type of packaging reasonable skin colour can be retained for 2-4 weeks.

Alternative strategies such as spraying fruit in the field with wettable sulphur prior to harvest, increasing the nutrient status of the tree prior to harvest, coating the fruit with light oils, using paper towelling in high humidity packaging to reduce humidity or wetting the fruit and packing with leaves in low humidity packaging to increase the humidity, dipping fruit in various disinfectants or hot water, or pre-conditioning fruit in progressively lower temperatures, did not prove effective in significantly increasing the shelf life of the fruit or preventing chilling injury. The only treatment, which showed promise in aiding storage life of longan, was dipping the fruit in hydrochloric acid. By dipping fruit in the correct concentration (5%) and for the correct length of time (20 minutes) the skin colour of longan could be slightly improved and fruit did not discolour easily from dehydration or chilling damage which allowed fruit to be stored at low humidity's and cool temperatures which greatly extended the shelf life over control fruit for up to 40-60 days.

The best storage and packaging strategy for longan depends on the length of storage that is required and where and how it is being transported. With the requirement that fruit must have good skin colour and taste and free from disease the following strategies are recommended

A Few Days	Fruit should be protected from dehydration with medium to high humidity packaging (poly bag, vita film) and kept between 15-20^{0}C.
A week	Fruit should be protected from dehydration with medium humidity packaging (vita film, veggie bag or MIP packaging) and kept at 10-15^{0}C.
2-4 weeks	Fruit should be protected from dehydration with medium humidity packaging (vita film, vegi bag, MIP packaging) and kept just above the critical temperature for chilling injury 10^{0}C for Biew Kiew, 7.5^{0}C for Kohala.
Over 3 weeks	For long-term storage fruit have to be kept at low temperatures 5^{0}C or even less and kept reasonably dry in order to prevent disease developing. To achieve this fruit must be either treated with SO_2 or dipped in HCl. Both these treatments allow fruit to be stored relatively dry (crispy bag or MIP packaging) and at 5^{0}C without discolouring from dehydration or chilling injury. This can allow fruit to be stored in good condition for up to 60 days. The SO_2 treated fruit is probably the preferred method while it is still able to be used as it results in a more uniform consistent and attractive colour, however should SO_2 be withdrawn from use, HCl would provide a slightly inferior alternative.

1. Introduction

Longan *(Dimocarpus longan)* a member of the Sapindaceae family, is a subtropical evergreen fruit tree native to northeastern India, Burma and southern China. Longan fruit are non-climacteric (hence will not continue to ripen once harvested) with a thin greeny-yellow, pliable skin and a translucent, white edible flesh surrounding a single seed. They are sweet, crisp and juicy with a unique musky flavour. Harvest is judged by eating quality, size and appearance in colour. Longan production is relatively new in Australia but has increased rapidly over the last 5 years. Surveys by the Queensland Department of Primary Industries indicate that there are presently around 70,000 commercial trees with around 50 growers spread along the coast between North Queensland and northern New South Wales. Production has reached 1500 tonnes worth over $6M in the last couple of years.

Longans are relatively unknown on the domestic market but are highly sought after by people with Asian backgrounds. As production levels have increased and the potential for export, so has the need for definitive information on post harvest storage and handling of longans. Limited information is available from overseas literature and most is not applicable to our conditions or varieties grown; or relates to sulphur dioxide fumigation of fruit. Being a tropical fruit longans have high rates of respiration so that if they are not stored carefully they can have a very short shelf life, deteriorating easily and quickly within a few days at room temperature (25^0C) (Reed, 1986; Paull and Chen, 1987).

The major factors reducing the storage life and marketability of longan fruit are microbial decay and skin browning, both of which detract from the appearance and can impart off-flavours to the flesh. In many crops if the fruit is stored at low temperatures these problems can be reduced however in longan the skin is very prone to chilling damage so that they cannot be stored at low temperatures. Also low humidity storage can be used in some crops to reduce the incidence of disease during storage but in longan this causes dehydration of the skin causing it to go brown.

Sulphur Dioxide (SO_2) fumigation of longan fruit has been used successfully overseas and now here by most of the industry to overcome many of these post harvest problems. The SO_2 works by bleaching and disinfecting the skin, resulting in a uniform yellow colour and protecting it from microbial decay. The yellow skin colour remains even when fruit is stored at low temperatures and low humidity's because the fruit doesn't suffer from chilling injuring or discolouration from dehydration. Both of these factors add significantly to the shelf life and appearance of longan.

However, SO_2 fumigation is facing increasing consumer and regulatory resistance to its use. Recently it has had strict guidelines placed over its use by the Australian and New Zealand Food Authority (ANZFA) because of concerns over health risks to workers and consumers. So the Longan industry is under threat of its removal in the future. Without the use of SO_2 major problems are expected from the lack of control of storage quality and disease in the fruit by a large part of the industry. The removal of SO_2 could have a significantly detrimental effect on the longan industries ability to maintain current domestic and export markets as well as take advantage of new export opportunities. This is largely due to the lack of knowledge on the post harvest aspects of longan storage.

Current post harvest handling recommendations for longan are incomplete and need to be refined for our varieties and handling practices to improve the effectiveness of storage facilities especially in the absence of SO_2. Optimum storage temperatures and packaging conditions have only been superficially examined. While longans appear to be a chilling sensitive product little work has been conducted to examine the potential of pre-conditioning strategies to reduce the susceptibility of low temperature injury. Most of the post harvest work here and overseas has been done into SO_2 fumigation technology so that very little exists on alternatives to SO_2 fumigation. A few reports exist on post harvest physiology, storage and packaging of longan fruit, but none have been published in recent years (Tongdee, 1977, 1994; Mantasathian, 1981; Buangsuwon *et al*., 1981). Post harvest aspects for longans were included in a recent review (Tongdee, 1997). There is some confusion in the literature about the effects of storage conditions on longans, probably due to the lack of official grades or international standards for longan. Most indicators of the performance of longan in storage do not specify how the various cultivars rate. In Australia, cultivars of commercial importance are Kohala, Homestead, Fuhko, Biew Kiew, Chompoo, Dang and Haew. The time of harvest for each variety varies, as does the region in which they are grown and the market preference, making it important for post harvest recommendations to be cultivar specific. Menzel *et al.* (1989) reported that longan fruit store longer than lychee at room temperature or under refrigeration with little dehydration, loss of colour or rotting of the flesh. Fruit maintain acceptable eating quality for five weeks, at 5 to 7^{o}C and 90% relative humidity, with a rapid loss of eating quality at lower temperatures. Batten (1986) reported a shelf-life of about six days, and Tongdee (1997) gave a shelf-live of only two or three days at room temperature. O'Hare and Prasad (1989) showed that a storage temperature of 10^{0}C was optimum, and that the temperature at which longans should be stored is dependant on the period of storage. However, in this work broad temperature ranges (5^{0}C) were used and further work is necessary to determine specific temperature optima for different storage periods and different varieties.

Wong (1992) working with the variety Chompoo found storage life increased with decreasing temperature. Fruit lasted 2 weeks at 15^{0}C and up to 5 weeks at 5-7½^{0}C. Tongdee *et al.* (1982) found chilling injury occurred around 5-7^{0}C but did not specify variety. Jrang *et al. (*2002) reported storage temperature of 1-5^{0}C are best to reduce fungal decay but may lead to chilling injury, none of the varieties listed are grown in Australia. It was stated that the chilling sensitivity varies with varieties and is not available for Biew Kiew or Kohala.

One of the most important problems in marketing longans is skin browning (Xu *et al.* 1998, Wu *et al.* 1999). Although usually only a cosmetic symptom with little effect on flavour, colour deterioration results in lower prices. Browning can be associated with dehydration, heat stress, senescence, chilling injury or disease, (Pan, 1994). Browning has been attributed to the enzymatic oxidation of phenolics by polyphenol oxidase (PPO) Jian 1999, Liu 1999; Tian *et al.* 2002. Some work has been done on skin coatings to extend shelf life. Shi (1990) used two waxes and was able to extend shelf life, however this was done on varieties not grown in Australia. Little work has been done on packaging. In Asia fruit is mostly sold in open baskets. Plastic bags have been useful in reducing moisture loss (Su and Yang 1996) and led to the longest shelf life Zhou *et al.* (1997a). Rapid moisture loss from the skin during storage was reduced at 85-95% humidity. Under low relative humidity visual appearance declined to unacceptable levels due to skin dehydration and browning. Under higher relative humidity the skin suffered water soaking and disease (Hong *et al.,* 1984).

Recent information is notably lacking on the effects of a range of different temperatures and humidity's on the storage capabilities of the fruit of the varieties grown in Australia.

The Australian Longan Growers' Association at their industry strategic review identified post harvest issues and alternatives to SO_2 fumigation as one of their key priority areas in their 5-year strategic plan. This project was developed in conjunction with the industry to address these concerns.

2. Objectives

The project aimed to develop a post harvest handling strategy suitable for both export and domestic marketing. In achieving this goal a documented series of post harvest recommendations for longan, covering optimum storage temperatures, packaging and handling of the fruit was developed. Alternative strategies to Sulphur Dioxide (SO_2) fumigation and the potential of pre-storage treatments to reduce chilling injury sensitivity were also assessed. Grower participation facilitated a greater awareness of developed technologies and provided hands-on experience of correct post harvest procedure. Project results were discussed with the industry through their association meetings and newsletter.

The specific objectives were:

1. Expand the current information on longan post harvest handling.
2. Develop alternative post harvest strategies to sulphur dioxide fumigation.
3. Determine optimal storage temperatures and packaging requirements for longan.
4. Improve the knowledge base of longan growers on post harvest aspects.

3. Methodology

The research work for this project was conducted in the field on growers' properties and in the laboratory and cold rooms at Mareeba and Cairns Department of Primary Industries. Most of the work was conducted on the varieties Kohala and Biew Kiew, as they are the two most important commercial varieties grown in Australia, some information was collected on the other varieties also grown. The work was completed over three harvest seasons. The specific experiments conducted were decided upon in collaboration with the industry at the start of the project. Experimental details are given below.

3.1 Temperature and Packaging Trials

These experiments were designed to determine the optimal storage temperature and packaging (humidity) for the storage of longan. Because relative humidity could not be easily adjusted in the cold rooms and growers would also have difficulty achieving a specific humidity either in storage or throughout the supply chain thus it was decided that packaging was a better way to influence the humidity, gas exchange and level of condensation around the fruit. Cold rooms were set at a range of temperatures from 5-25^{0}C (5, 7½, 10, 12½, 15 & 25^{0}C). Fruit (≈ ½ kg) was packaged in a range of materials and placed at each of the temperatures.

Packaging assessed during the project included;

1. Open netting (onion bag)
2. Oven bag (cellophane)
3. Plastic poly bag
4. Lychee bag (light plastic with holes in)
5. Paper bag
6. Glad wrap
7. Vitafilm
8. Crispy bag (used in lychee industry – lots of fine holes)
9. Plastic container (Chinese)
10. MIP bag (modified interactive packaging - Bantec international)
11. MIP container (modified interactive packaging - Bantec international)
12. Veggie bag

Some of the high humidity packaging was stored with and without paper towels to help absorb excess moisture from condensation in the packaging. Some fruit were wetted before storage and some samples were packaged with leaves to help increase the humidity. A few samples were also stored with a cardboard block soaked in tea tree oil with the aim of reducing fungal rots and some fruit were coated with a fine oil to help reduce dehydration.

Fruit from all treatments were assessed for storage life (colour and disease) and sensitivity to chilling damage.

3.2 Pre-Conditioning

Samples of fruit (≈ 1kg in plastic poly bags) were pre-conditioned in progressively lower temperatures (15°C → 10°C) before placing in low temperature storage (5°C) to see if chilling sensitivity could be reduced. Pre-storage treatments associated with low temperature disinfestation research have shown significant potential in alleviating chilling injuries and disease development in other crops (eg. lemons, avocadoes).

Fruit were assessed for storage life and sensitivity to chilling damage.

3.3 Pre-storage treatments

Sulphur pre-treatments prior to harvest were investigated. Panicles of fruit from varieties Kohala and Biew Kiew were sprayed with wettable foliar sulphur (2g/ l), 1, 1 and 2, 1, 2 and 4 weeks prior to harvest to see if the sulphur had any effect on storage life. Samples of fruit were harvested and then stored in a range of packaging types (open nets, plastic container, MIP Bags) and temperatures (5, 7½, 10, 12½°C). Fruit were assessed for storage life and sensitivity to chilling damage.

3.4 Nutritional Status of Tree

Samples of fruit were collected from trees with low and high nitrogen status (leaf N). Fruit was then placed in different packaging types (open nets and MIP punnets) and temperatures (5, 10 and 14°C) and assessed for storage life and sensitivity to chilling injury.

3.5 Alternatives to Sulphur Dioxide fumigation (SO_2)

A range of products aimed at disinfecting or bleaching the skin of longan were investigated as potential alternatives to SO_2 fumigation. Samples of fruit were dipped or sprayed with various concentrations of these products and then stored at two temperatures (5°C and 10°C) and in two types of packaging (open nets, plastic containers). The treatments used in this experiment were hot water dips 45-90^{0}C, Chlorine Dioxide (Castle Wash), Sani Chlor, Soda Ash, Mango Wash, Semperfresh, polyshine, NaOH and various acids (Hydrochloric, Acetic & phosphoric). Fruit from all treatments were assessed for storage life and sensitivity to chilling damage.

3.6 Acid Dipping

Following on from the trial work done on alternatives to SO_2 fumigation, the potential for using Hydrochloric Acid (HCl) dipping as a post harvest treatment for increasing the shelf life of longan was investigated. Samples of fruit were dipped in HCl of various concentrations (0.5 - 4.5%) and pH (0-1) for various lengths of time (3-60 min) and then stored at different temperatures (5, 10, 15°C) and in different packaging types (open nets, MIP bags, plastic poly bags).

Fruit from all treatments were assessed for storage life and sensitivity to chilling damage.

3.7 Fruit Samples

For all experiments samples of fruit were harvested as panicles from growers' trees and taken back to the laboratory. Whole panicles were cut up into smaller pieces (sub panicles) of 6-10 fruit to remove some of the main wood from the panicle. Fruit were left attached to small twigs. This procedure copies that used by the growers packing for market. Any damaged, blemished or uneven coloured fruit was discarded and then samples of approximately 500 g (30-40 fruit) were used for each of the treatments. In some of the experiments samples of SO_2 fumigated fruit were also used where they were available from the grower.

3.8 Fruit Assessment

Assessment of the fruit from the treatments in each of the experiments was conducted with the aim of determining the quality of the fruit. Visual quality was determined by using a rating scale for the level of skin brownness, presence of disease, skin and flesh dehydration, chilling injury and market acceptability. For the level of skin browning a scale with a rating from 1 to 10 was developed for each cultivar. Ten fruit with slightly increasing levels of skin brownness from perfect colour (no browning) (1) to completely dark brown in colour (10) were photographed. These scales were then used for all fruit colour assessments. For the level of disease the fruit samples were given a rating from 0-10 depending on the percentage of fruit affected by disease the, (0) - no disease, (5) -50% of the fruit affected by disease and (10) - 100% of the fruit affected by disease. Internal quality was determined by taste with the aim to detect any 'off' flavours, which may have developed as a consequence of storage treatment.

Assessments were completed on control fruit immediately after harvest and on the stored fruit at regular intervals (1-14 days) until fruit reached unacceptable quality (up to 10 weeks).

4. Results and Discussion

4.1 Temperature and Packaging Experiment

4.1.1 Temperature

Disease development was least and slowest to develop at 5^0C and greatest and fastest to develop at 25^0C. At 25^0C fruit became diseased within 4-8 days and 2-6 days, compared with 65 and 50 days at 5^0C in low humidity packaging for Biew Kiew and Kohala respectively (see Table 1, Figure 1). Disease development was also accelerated if the skin became wet for example in the high humidity packaging (Figure 1) and if condensation was a problem (see packaging). Table 1 shows when disease is first observed and Figure 1 shows how quickly the disease then develops.

Table 1. Approximate number of day's fruit can be stored at different temperatures before disease development starts. Fruit were stored in high (H), middle (M) and low (L) humidity packaging.

Temperature	**Biew Kiew**			**Kohala**		
	H	**M**	**L**	**H**	**M**	**L**
5°C	35*	40*	65	28*	36*	50
7.5°C	27*	33*	45	26*	28*	35
10°C	18*	23*	35	16	18	25
12.5°C	13	17	27	7	9	15
25°C	4-8	4-8	4-8	2-6	2-6	2-6

(*) Chilling damage

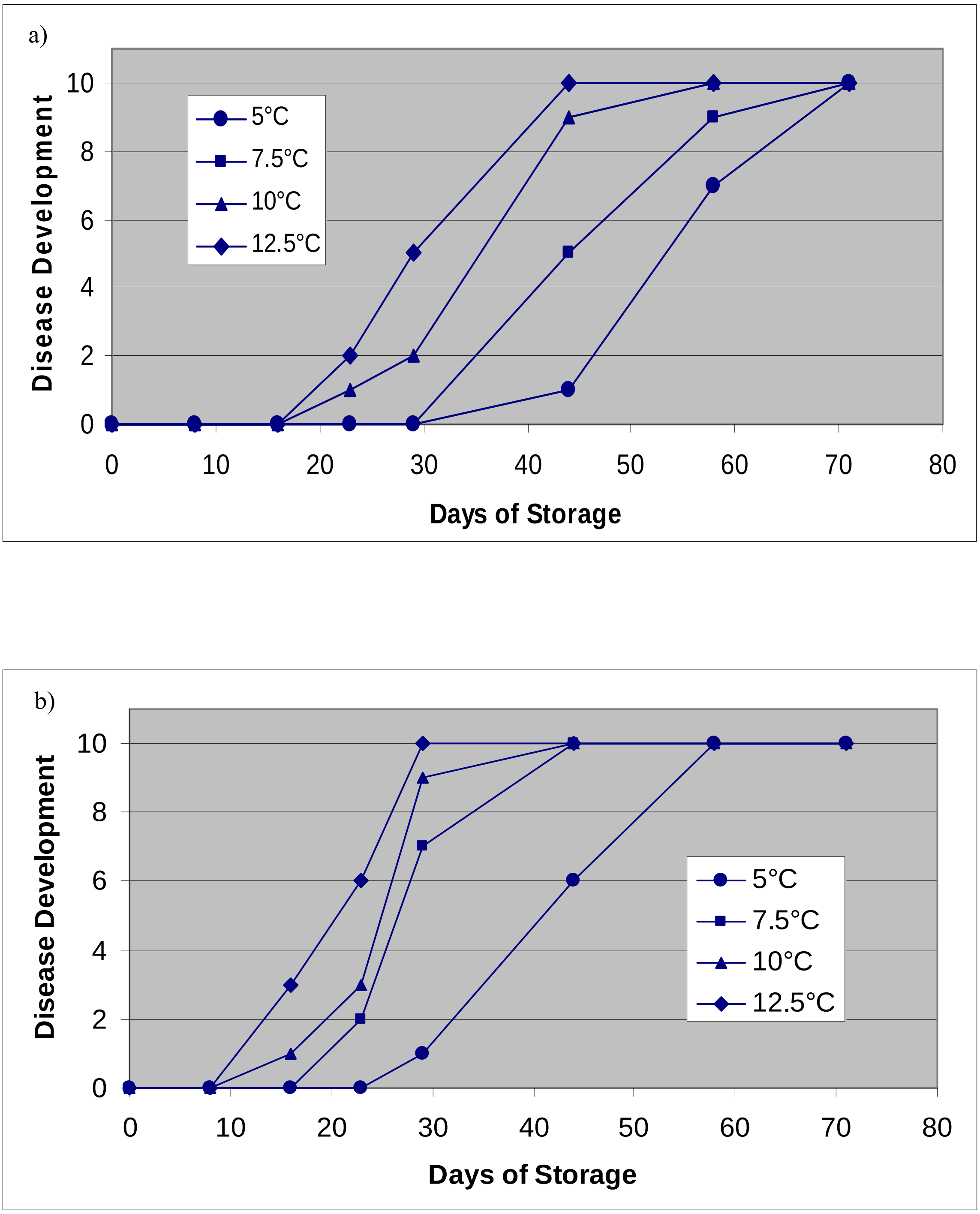

Figure 1 *The effect of storage temperature on disease development on fruit (variety Biew Kiew) stored in a) MIP bags (medium humidity) and b) poly bags (high humidity). (0) = 0% diseased fruit, (5) = 50% diseased fruit, (10) = 10% diseased fruit.*

The amount of dehydration of the flesh and skin and skin colour was a reflection of the type of packaging (hence humidity) rather than the storage temperature. However, the storage temperature did influence skin colour by affecting the speed of disease development (Figure 1) and causing chilling damage.

Chilling injury damages the cells in the skin resulting in brown blotches, which penetrate right through the skin to the fruit flesh. The inside of the skin affected by chilling damage is covered with brown blotches rather than being shiny white. This damage to the skin then imparts 'off' flavours to the flesh, which is aggravated if the skin remains wet. Initially (7-14 days) chilling damage results in a stale, mouldy, unfresh taste, probably associated with skin breakdown, but as storage time increases the damaged skin allows microbial attack which spreads to the flesh resulting in fruit rots. A rapid loss of eating quality at low temperatures (5^0C) has also been found by Menzel *et al.* 1989, Batten 1986, O'Hare and Prasad 1989.

Where the skin of the fruit dried out (low humidity packaging) or in SO_2 fumigated fruit chilling injury did not occur and so storage life was greatly extended. In Biew Kiew the first signs of chilling injury were observed around 10^0C and in the variety Kohala around 7.5^0C (Table 3). At these temperatures it took approximately 6-8 days for symptoms to develop compared with 4-6 days at 5^0C and only a few hours at 1^0C. The chilling damage threshold for some other varieties studied during the project was $6.5\text{-}7.5^0$C for Homestead, 10.0^0C for Fuhko and $7.0\text{-}8.0^0$C for Chompoo. Variation in the chilling damage threshold has also been found by Jiang 1999b, Shi 1990, Hong *et al.* 1984 and Pan *et al.* 1996. O'Hare & Prasad (1989) found the optimum storage temperature was 10^0C for the variety Kohala while Tongdee *et al*. 1982 found chilling damage at $5\text{-}7^0$C but did not specify the variety.

4.1.1.1 Pre-Conditioning

The pre-conditioning experiments where fruit was stored at progressively lower temperatures to try and avoid chilling injury symptoms developing were not successful. Fruit was stored in plastic poly bags (high humidity) in which chilling damage is particularly bad. These samples were then stored at 15^0C, $12½^0$C & 10^0C for 24 hours each and then placed at 5^0C. Within 2-4 days at 5.0^0C the symptoms of chilling damage had developed. Although this experiment was not successful the need for low temperatures for long-term storage of longans warrants further work on pre-conditioning experiments to try and prevent chilling injury developing. There has been some success in other crops in this area (McLauchlan *et al.*, 1997).

Table 1 indicates that Kohala generally has a shorter shelf life than Biew Kiew. This is thought to be related to the thinner, more pliable and more easily damaged skin. The skin of longan plays a vital role in protecting the flesh in an airtight sterile environment. While the skin remains undamaged and in good condition so the flesh remains good also. Hence the excellent storage life of the longans packed in the low humidity packaging at 5°C.

4.1.2 Packaging

The types of packaging used in this experiment allowed for a range in relative humidity's, airflows and degree of condensation. The packing used could be split into the following humidity categories (Table 2).

Table 2 - Humidity around the fruit stored in various types of packaging.

Dry		**Moist**		**Wet**
- low humidity - high airflow - no condensation	→	- medium humidity - medium airflow - some condensation	→	- high humidity - low airflow - condensation
open net paper bag crispy bag lychee bag veggie bag Mip bag vitafilm glad wrap Mip punnet plastic container poly bag oven bag				

4.1.2.1 Low Humidity Packaging

In the fruit kept at low humidity's, eg open net, paper bag, crispy bag, the skin dried out and became brown and crisp over 3-4 days (see Table 3, Figure 2). Storing the fruit with leaves and wetting the fruit prior to storage, delayed dehydration only by a day or so. Also coating the fruit with a light vegetable oil slowed dehydration marginally but unfortunately also discoloured the skin. The inclusion of some foliage within the packaging and wetting the fruit before packing delayed dehydration by only a few days. In these low humidity packaging, the flesh also dehydrated although very slowly; 2-4 weeks in Kohala and 4-6 weeks in Biew Kiew (due to the thicker skin) and disease development was very slow compared to high humidity packaging (Table 1, Figure 3). In this packaging fruit deteriorated due to the flesh going rotten rather than skin disease developing; this occurred quickly (2-8 days) at 25^0C but very slowly (50-65 days) at 5^0C (Table 1, Figure 3). At these low temperatures eating quality remained good up until flesh started to decay. Due to the crisp dry brown skin in this type of packaging chilling injury was not a problem and the fruit retained the best taste however, the appearance of the fruit deteriorated very quickly.

Table 3 Number of days in storage before fruit skin colour reaches unacceptable levels (rating 4 – 5). Fruit were stored in high (H), medium (M) and low (L) humidity packaging.

Temperature	**Biew Kiew**			**Kohala**		
	H	**M**	**L**	**H**	**M**	**L**
5^0C	4*	4*	4	4*	6*	3
7½^{0}C	6*	7*	4	6*	8*	3
10^0C	8*	12*	4	18	28	3
12.5^0C	16	26	4	16	26	3
25^0C	8	8	4	8	6	3

(*) Chilling injury

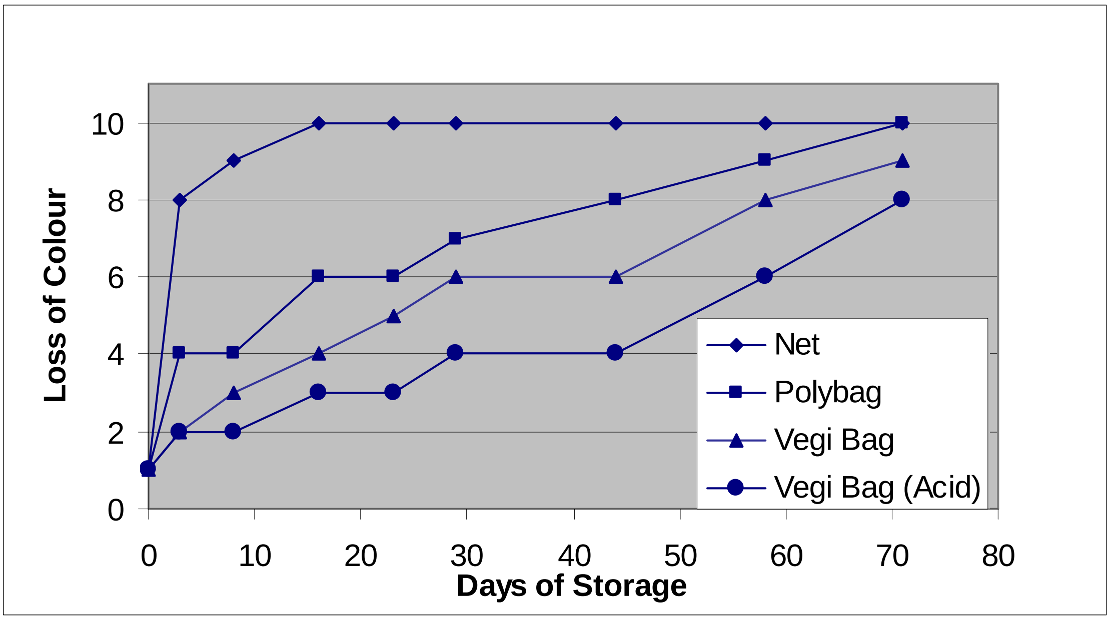

Figure 2 The effect of packaging type and acid dipping on skin colour deterioration of fruit (variety Kohala) stored at 10°C. (1) = perfect colour, (5) = light brown, (10) = dark brown. A rating of 4 or above is considered unacceptable.

4.1.2.2 High Humidity Packaging

In the fruit kept at very high humidity's (free moisture and condensation) eg oven bag, poly bag, plastic container, fruit deteriorated quite quickly compared with low humidity packaging, with skin rots at high temperatures and chilling injury at low temperatures (Table 1, Figure 3). At these temperatures fruit rapidly became mouldy and stale tasting. However, skin colour remained good until disease set in or chilling injury became apparent (Table 3, Figure 2). At 10-12.5^{0}C good skin colour could be maintained for about 2-3 weeks (Table 3, Figure 2). The high moisture content and condensation of this type of packaging may be able to be reduced by limiting the temperature fluctuations during storage and transport, reducing the air volume in the package and pre-cooling fruit before packaging. Trials using paper towel inside the packaging to reduce the free moisture and condensation and using tea tree oil vapour to reduce fungal attack did not work. Better results were achieved however by reducing the humidity of the packaging.

4.1.2.3 Intermediate Humidity Packaging

In the intermediate packaging types (glad wrap, vitafilm, veggie bag, modified interactive packaging (bag and punnet)) skin colour and flesh firmness were retained due to the relatively high humidity, but the skins remained surface dry so that skin diseases and chilling injury were slower to develop than in the high humidity packaging (Table 3, Figure 2 and 3). In this type of packaging fruit could be kept in reasonably good condition (appearance and eating quality) for 3-4 weeks at around 10^{0}C (Table 1 and 3, Figure 2 and 3). At high temperatures 25^{0}C the shelf life is as short in this type of packaging as any other.

SO_2 fumigated fruit retained very good skin colour in all packaging. The skin is not susceptible to chilling injury and does not discolour due to dehydration. At high temperature and high humidity's the fruit is still very prone to fungal attack so fruit should be stored at low temperatures. During the experiments it was observed that SO_2 fumigated fruit are also very prone to dehydration (presumably because the cellular structure of the skin has been damaged by the fumigation) so that the fruit must be protected from drying out. Therefore the medium humidity packaging (vitafilm, glad wrap, MIP bags) is recommended for SO_2 treated fruit.

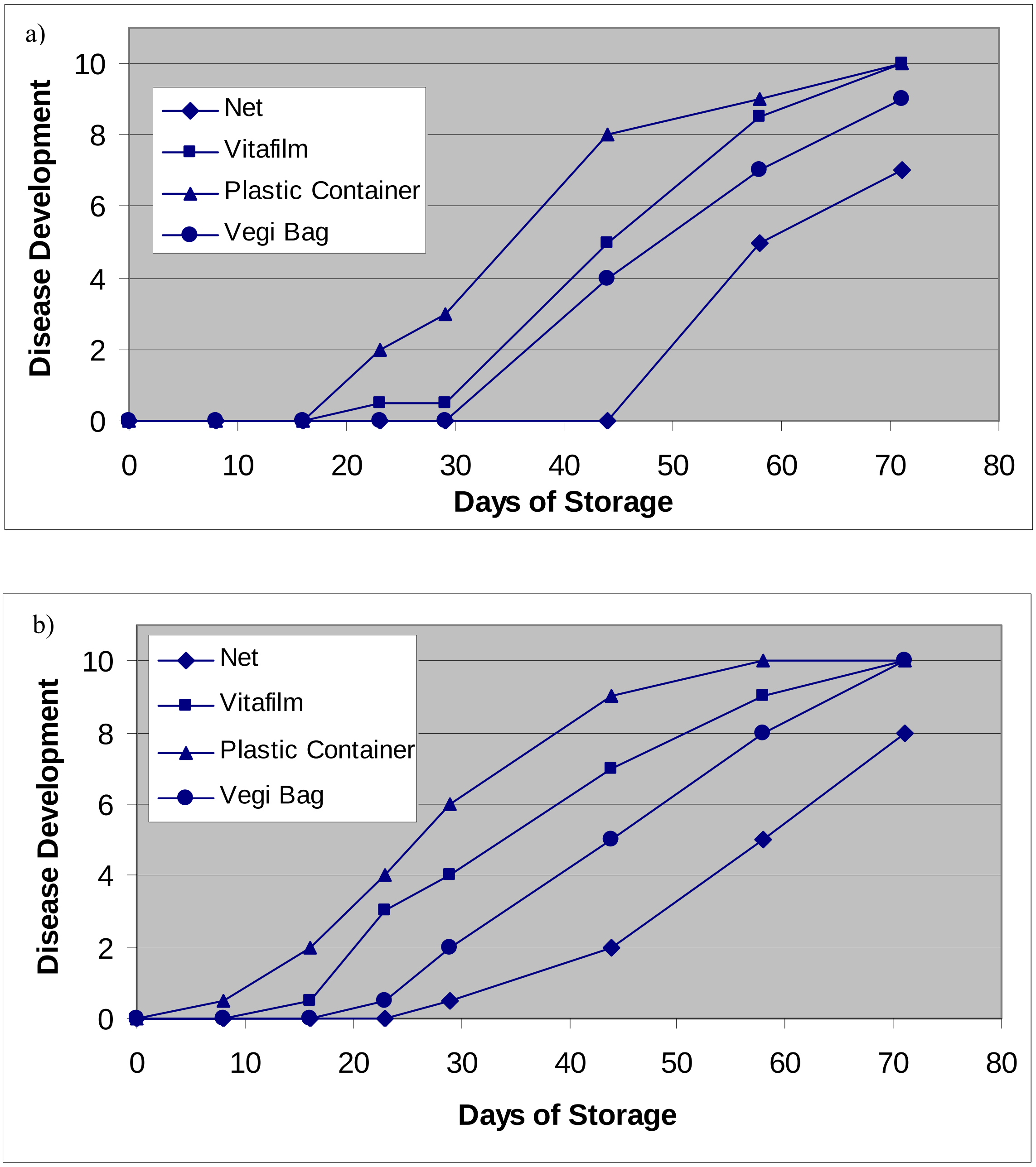

Figure 3 The effect of packaging type on disease development in fruit (variety Biew Kiew) stored at a) 7.5 °C and b) 12.5 °C.

4.2 Pre-storage Treatment

Fruit from this experiment were stored at 5, 7½, 10 and 12½°C in three types of packaging (open nets, plastic containers and MIP bags) to give a range in humidity's. No discernible differences in skin colour of the fruit were detected on the trees in either variety for any of the sulphur treatments. Also storage trials demonstrated that there was no improvement in shelf life of any of the treatments over the control fruit. The storage life of fruit in this trial was comparable to those obtained in the temperature and packaging experiment for the varieties Biew Kiew and Kohala.

4.3 Nutritional Status of Tree

Fruit from high and low nitrogen status trees (variety Biew Kiew) were stored in open nets and modified interactive packaging (MIP) punnets (to simulate low and medium humidity storage) at three temperatures 5, 10 and 14°C. Fruit were observed every 2–4 days for skin colour and disease development. The results (See Table 4) indicated that the tree nutritional status had no significant effect on the disease development or skin colour of the fruit. Fruit showed the first signs of disease within 14 – 50 days and skin colour reached unacceptable levels within 4 – 22 days of storage depending on the storage temperature and the type of packaging. These results are similar to those obtained in the temperature and packaging experiments for the variety Biew Kiew.

Table 4 The number of days in storage until fruit showed the first sign of disease or reached an unacceptable skin colour (Variety Biew Kiew).

Tree Nutritional Status	Low				High			
Packaging	**Open Net**		**MIP Punnet**		**Open Net**		**MIP Punnet**	
Temperature of Storage	**Disease**	**Colour**	**Disease**	**Colour**	**Disease**	**Colour**	**Disease**	**Colour**
5°C	**50**	**4**	**29**	**7***	**50**	**4**	**29**	**7***
10°C	**29**	**4**	**22**	**14**	**29**	**4**	**14**	**14**
14°C	**14**	**4**	**14**	**22**	**14**	**4**	**14**	**22**

(*) Chilling injury

4.4 Alternatives to SO_2 fumigation

Possible alternatives to SO_2 fumigation were investigated to enhance the appearance (skin colour) and/or shelf life of longan fruit over control fruit. Fruit were dipped and sprayed with various concentrations and for varying lengths of time. The products were chosen (disinfectants, bleaching agents, high and low pH), for their possible affect at inactivating the browning enzyme in the skin a possible treatment to prevent chilling injury, and as bleaching agents to colour the skin.

4.4.1 Hot Water

Longan fruit (Biew Kiew and Kohala) were dipped in hot water baths of 45^0, 60^0, 80^0 and 90^0C for 5-60 seconds. Fruit was then packaged (open nets, plastic containers) and stored at 5^0C and 10^0C. None of the hot water treatments improved shelf life or appearance of the fruit. The skin of the fruit was damaged (burnt-scolded) at anything above 50^0C even for very short periods of time and became dry looking. The hot water dips also seem to make the fruit more susceptible to chilling injury.

4.4.2 Chlorine Dioxide (Castle Wash)

Chlorine Dioxide was used at two concentrations one to act as a disinfectant (5 ppm) and the other as a bleaching agent (5%). Appearance (skin colour) and shelf life was improved slightly over control fruit but the result was not significant and no further trial work was carried out.

4.4.3 Sani Chlor

Sani Chlor at high concentration (10%) bleached the surface of the skin however, this tended to enhance the natural blemishes in the skin so that the appearance was slightly worse than the controls. Shelf life was marginally better than controls. Fruit were still prone to going brown and suffered chilling damage. Used as a disinfectant (100 ppm) Sani Chlor did not improve shelf life.

4.4.4 Soda Ash

Soda Ash (0.02% & 0.3%) burnt the skin of the fruit so appearance and the shelf life were reduced.

4.4.5 Polyshine

Polyshine is used in the citrus industry as a post harvest treatment to improve the appearance and reduce dehydration of the fruit. Unfortunately the polyshine resulted in a darker skin colour and there was no improvement in shelf life over controls.

4.4.6 Mango Wash & Semperfresh & NaOH

Mango Wash (½%), Semperfresh (1%) and NaOH (½%) had no effect on the appearance or shelf life of fruit. Fruit still suffered from browning due to dehydration and chilling injury.

4.4.7 Acid

The acid dipping treatments were designed to copy some of the technology being developed for the post harvest treatment of lychee.

In lychee the acid ruptures the colour glands of the skin, which gives the fruit a uniform red colour, which is long lasting even under adverse storage conditions. Longan fruit was dipped in various concentrations of Hydrochloric, Acetic and Phosphoric Acid. The acetic acid burnt the skin of the fruit. The other two acids - phosphoric (1%) and Hydrochloric (2%) did improve the skin colour (hence appearance) of the fruit and there was an improvement in shelf life. The Hydrochloric Acid (HCl) was more effective than phosphoric acid so trial work continued in this area.

Treatment with HCl results in a reasonably uniform golden yellow skin colour and small blemishes were masked. Also following treatment the skin colour was long lasting and did not go brown through dehydration and fruit did not suffer chilling injury. With the skin remaining in good condition shelf life was improved.

Although some of these products improved the shelf life and appearance of the fruit slightly, the only treatment, which gave significant improvement, was the HCl dipping. Therefore, all trial work concentrated on determining the best rates, timing and details of storage of HCl treated fruit as an alternative to SO_2 fumigation.

4.5 Acid Treatments

Experiments were conducted to determine the best rates and timing of HCl acid dipping to give the best appearance. Samples of fruit from 250 g - 2000 g were dipped for 1-60 minutes in HCl acid dips ranging from 1.7 - 15% (300 g/ 1 HCl) PH (0.1 - 1.0). Fruit were then stored at 5, 10 and 15^0C in three types of packaging (open nets, MIP bags and poly bags). The results indicated that concentrations greater than 6% were too strong and damaged the skin leading to cracking and off flavours. While concentrations less than 4% were too weak and did not improve skin colour significantly. Dipping times needed to be in excess of 15 minutes or the acid did not have time to colour the skin. A concentration of 5% (300 g/l HCl (pH 0.3 - 0.4) and a dipping time of 20 minutes was determined as the optimum. In lychee 3% HC1 (O pH) is used for 15 minutes Qubo *et al.* 1997.

The acid seems to have slow penetration into the skin, which could not be improved by hot water dips prior to acid treatment. Also the acid appears to work as a bleaching agent rather than release of colour from colour glands as in lychee. Due to HCl working better than the other acids it was thought that this was due to the chlorine in the acid doing the bleaching. Samples were taken from the acid dipping solutions during the project to see if the pH or the level of free chlorine was changing during dipping. It was found that the pH increased slightly but the level of free chlorine remained about the same.

Temperature and packaging trials with acid dipped fruit indicated that the fruit did not discolour from dehydration or chilling injury. This therefore allowed fruit to be stored at low relative humidity's and at low temperatures without reducing the appearance or eating quality of the fruit. These storage conditions inhibit disease development, which greatly improves shelf life allowing fruit to be stored for 40-60 days (see temperature and packaging experiment).

The acid treatments seemed to work best on slightly immature fruit freshly harvested and with thick skins (Biew Kiew, Chompoo vs Kohala). The skin should be surface dried after dipping and kept dry. If the skin does get wet or is stored in high humidity for long periods following treatment it tends to discolour. The inside of the skin of acid treated fruit stays in very good condition (shiny white), which helps to maintain the flesh in an airtight sterile environment preserving flesh freshness. Also the skin of HCl treated fruit does not dry out like SO_2 treated fruit so flesh dehydration is not a great problem and there are no 'off' flavours associated with the HCl that there can be with SO_2 fumigation.

5. Implications

The results from this project have provided some valuable information on the post harvest storage aspects of longan. This has enabled a better understanding by growers of the factors involved in determining the shelf life of fruit.

Longan fruit are difficult to store in good condition (appearance and taste) even for short periods of time. This is because fruit discolour (darken, go brown from yellow) easily from disease, dehydration or chilling injury. When fruit are stored at high humidity's to avoid dehydration and high temperatures to avoid chilling injury, disease is a major problem and develops quickly. When fruit are stored at low humidity's and temperatures to reduce disease problems, dehydration and/or chilling damage is a problem. The temperature and humidity trials indicate that the best compromise for storage is to store at the lowest possible temperature that fruit can be stored without suffering chilling damage and in packaging which keeps the fruit skin from dehydrating but doesn't allow it to become wet. The critical temperatures at which chilling injury became a problem were 10^0C for Biew Kiew, 7.5^0Cfor Kohala; 6.5-7.5^0C for Homestead, 10^0C for Fuhko and 7-8^0C for Chompoo. The best packaging was vita film, modified interactive plastic bags and veggie bags. In this type of packaging reasonable skin colour can be retained for 2-4 weeks.

Alternative strategies such as spraying fruit in the field with wettable sulphur prior to harvest, increasing the nutrient status of the tree prior to harvest, coating the fruit with light oils, using paper towelling in high humidity packaging to reduce humidity or wetting the fruit and packing with leaves in low humidity packaging to increase the humidity, dipping fruit in various disinfectants or hot water, or pre-conditioning fruit in progressively lower temperatures, did not prove effective in significantly increasing the shelf life of the fruit or preventing chilling injury. The only treatment, which showed promise in aiding storage life of longan, was dipping the fruit in hydrochloric acid. By dipping fruit in the correct concentration (5%) and for the correct length of time (20 minutes) the skin colour of longan could be improved slightly and the skin did not discolour easily from dehydration or chilling damage during storage, allowing fruit to be stored at low humidity's and cool temperatures greatly extending shelf life over control fruit. Acid treated fruit could be stored in good condition for 40-60 days. The acid treated fruit did not have as good skin colour as that achieved with SO_2 fumigation and while this option is available it does result in the best shelf life. The trials indicated even with SO_2 fumigation fruit has to be stored carefully to get the maximum shelf life. SO_2 treated fruit are very prone to dehydration at low humidity and fruit rots at high temperatures. Therefore fruit must be stored at low temperatures and in medium humidity. If SO_2 fumigation is restricted then acid dipping could be used in its place with similar but slightly inferior results.

The results from this project have allowed growers to understand how their field, shed, packing and transport practices affect the shelf life of longan. The ideal conditions for short, medium and long term storage have been documented and growers can use this information to modify their post harvest practices to improve the quality of fruit at the market which will hopefully lead to higher prices.

6. Recommendations

The best storage and packaging strategy for longan depends on the length of storage that is required and where and how it is being transported. For example someone exporting fruit by sea will need to store longans for 3-6 weeks, whereas someone airfreighting fruit to Sydney Market may only need fruit to store for a week. With the requirement that fruit must have good skin colour and taste and be free from disease, the following strategies are recommended. These are aimed at maintaining the skin in perfect condition, which provides a barrier to disease and off flavours.

A few Days	Fruit should be protected from dehydration with medium to high humidity packaging (poly bag, vita film) and kept between 15-20^{0}C.
A week	Fruit should be protected from dehydration with medium humidity packaging (vita film, veggie bag or MIP packaging) and kept at 10-15^{0}C.
2-4 weeks	Fruit should be protected from dehydration with medium humidity packaging (vita film, veggie bag, MIP packaging) and kept just above the critical temperature for chilling injury 10^{0}C for Biew Kiew, 7.5^{0}C for Kohala.
Over 3 weeks	For long-term storage fruit have to be kept at low temperatures 5^{0}C or even less and kept reasonably dry in order to prevent disease developing. To achieve this fruit must be either treated with SO_2 or dipped in HCl. Both these treatments allow fruit to be stored relatively dry (crispy bag or MIP packaging) and at 5^{0}C without discolouring from dehydration or chilling injury. This can allow fruit to be stored in good condition for up to 60 days. The SO_2 treated fruit is probably the preferred method while it is still able to be used as it results in a more uniform consistent and attractive colour, however should SO_2 be withdrawn from use, HCl would provide a slightly inferior alternative.

The recommended HCl dip would be 5% solution (300 g/l HCl) for 20 minutes. Fruit should then be surface dried following treatment and stored at 5^{0}C and in medium humidity packaging.

Results from this project were used to help develop an in store pamphlet for retailers and consumers on handling and storing longans. Information was also presented to the industry at Australian Longan Growers Association meetings, in newsletters and during trial work on growers' properties.

Further work on skin coatings (waxes, oils) to reduce dehydration and browning, and on pre-conditioning of fruit to prevent chilling damage are recommended.

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