THE EFFECT OF HEAT TREATMENT, DIFFERENT PACKAGING METHODS AND STORAGE TEMPERATURES ON SHELF LIFE OF DRAGON FRUIT (*Hylocereus spp.*).

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ABSTRACT.

Dragon fruit (*Hylocereus* spp.) is a recent introduced fruit crop in the State which was cultivated initially by a number of pioneering entrepreneurs in 2001. Since then, it has been shown to thrive well under local biophysical conditions. At present, there is a concentration of commercial plantings of this fruit in the Sibu Division and some smaller plantings in other Divisions of Sarawak.

The high nutritional value of dragon fruit and claims of its medicinal benefits have led people to consider it as a health fruit. Local production of this fruit at present is still not sufficient to meet growing demand and this short fall is met by some imports. The quick returns from dragon fruit plantings together with the favorable prices it commands make it an attractive and profitable fruit crop to invest in. It is anticipated that there will be more plantings and production in the State in future.

To support the development of this fruit, the Agriculture Research Centre of the Department of Agriculture, Sarawak has since 2006 carried out post harvest studies on shelf life of white-fleshed and red-fleshed dragon fruit. The fruit used in the studies were at optimum ripeness and quality which is 8 to 9 days and 5 to 6 days after fruit color change for white-fleshed and red-fleshed types respectively. At ambient, fruit stayed fresh for a few days after which its physical appearance deteriorated and disease infestation set in resulting in spoilage in 6 to 7 days. Fruits however remained fresh and disease-free for 6 days if stored at 10^0C with 90% relative humidity, but started to deteriorate and got spoiled after the 15^{th} day.

Both types of fruit treated in hot water of 55^0C for 15 minutes and bagged in sealed polyethylene plastic bag without holes maintained their physical appearance better with much reduced disease infestation for up to 21 days in chilled storage as compared with those without heat treatment in similar storage conditions. The eating quality of these fruit was maintained. In general, white-fleshed fruit was found to stay fresher than that of the red-fleshed when stored at 10^0C.

Fungal decay on fruit was the main limiting storage factor. The main fungi associated with spoiled fruit were *Colletotrichum* spp., *Helminthosporium* spp and *Fusarium* spp.

The findings on extended shelf life of both types of dragon fruit can be applied in local market to reduce wastage due to spoilage and to enable the marketing of this wonderful fruit to neighboring countries.

INTRODUCTION:

The dragon fruit (*Hylocereus spp.*), which belongs to the cactus family is native to the tropical forest regions of Mexico and Central and South America (Mizrahi et al., 1997). There are a number of species grown commercially namely; white-fleshed, *Hylocereus undatus*; red-fleshed, *H. costaricensis* and *H. polyrhizus* and yellow pitaya, *Selenicereus megalanthus.* It is grown commercially in Vietnam, Taiwan, Southern China, Israel and more recently, in Thailand, Australia, U.S and Malaysia.

In Sarawak, dragon fruit was first introduced by Mr Lee Wung Thai from Kuala Pilah, Negeri Sembilan in the late 2000. Mr Lee conducted a series of talks on this fruit at hotels in major towns of the State then. Subsequently, a number of pioneer entrepreneurs ventured into dragon fruit cultivation in Sarikei, Sibu, Miri and Kuching Divisions (Kueh and Voon, 2003). These early plantings were carried out with technologies adopted from offshore sources. At present, there is a concentration of commercial farms of this fruit, with an estimate of over 70 hectares in Sibu Division alone (Tie, 2007). There are smaller scale plantings in other Divisions and it is anticipated that there will be more plantings of it in the State in future.

Dragon fruit has an attractive color and shape and is rich in fiber, vitamin C and minerals (Morton, 1987). It also has phytoalbumins which are highly valued for their antioxidant properties. It has less sugar content than most popular tropical fruits, and thus is more suitable to diabetics and high blood pressure patients. These attributes have led people to consider it as a health fruit and this is one of the reasons why it commands a premium price. The prevailing prices for locally produced white-fleshed and red-flesh fruits in the domestic market are RM8-9 and RM10-12 per kg respectively. With more plantings coming into production in near future, prices of this fruit are expected to come down to a more affordable level. There are some cheaper imported dragon fruit from Vietnam, however its quality is much inferior as compared to the local ones.

Locally, fruits are sold mainly for fresh consumption. The deterioration of physical appearance and damages due to disease attacks on fruits after keeping for a few days under ambient conditions could render losses in value and spoilage. These losses are costly to retailers for such a high valued fruit. In 2005, a local marketer shipped a consignment of this fruit to Dubai by air. At that time little information on post harvest handling and storage of dragon fruit was available locally. It was through this occasion that the need for proper packing and storage to extend the shelf life of this fruit became obvious, if the export market was to be explored further.

In the meanwhile, there is growing demand for dragon fruit in nearby countries such as China, Hong Kong and Singapore. It has good potential to be exported to European countries, as its taste is liked by Europeans. The export of some dragon fruit from increased hectarage of plantings will reduce the problem of supply glut which usually results in sharp downturn of prices in the local market. It is with this view in mind that the Post Harvest Centre at ARC Semongok has carried out post harvest handling studies on the shelf life of dragon fruit since 2006. Increasing its shelf life not only reduce spoilage locally but also augers well for marketing it overseas. This paper reports the findings from these studies.

1. MATERIALS AND METHODS

The studies used both white-fleshed and red-fleshed fruits supplied by the Planter Harvest Sdn Bhd in Sibu. Being a non-climacteric fruit, both types of fruits used were at their optimum ripeness and quality. In the case of the former, this is harvested at 8 to 9 days after first sign of fruit color change from green to red. As for the latter, it is 5 to 6 days after the commencement of fruit color change. The average weight of white-fleshed and red-fleshed dragon fruit used was 605g and 526g per fruit respectively.

The studies used a fully randomized replicated design. For each fruit type, the experiment comprised five treatments with five replications. Five fruits per treatment were withdrawn for assessment at weekly intervals for up to four weeks. The five treatments were:

T1 – fruit bagged in polyethylene plastic with holes and stored in chiller at 10^0C
T2 – fruit treated in hot water of 55^0C for 15 minutes, cooled, bagged in polyethylene plastic with holes and stored in chiller at 10^0C.
T3 – same as T2 except fruit was bagged in sealed polyethylene plastic without holes.
T4 – fruit bagged in sealed polyethylene plastic without holes and stored in chiller at 10^0C.
T5 – fruit bagged in polyethylene plastic with holes and stored at ambient (temperature of 25^0C to 30^0C).

The fruits were carefully sorted out to ensure as much uniformity as possible in term of size and color. Then, they were randomly assigned to the different treatments. The hot-water treatment involved emerging fruits in preheated water of 55^0C ± 2^0C for 15 minutes in an electric water bath with thermostat control. The water and fruit core temperatures were monitored separately using thermometers. The fruits were then allowed to cool down, bagged accordingly and placed in paper carton boxes. For chilled storage, the boxes were placed in a chiller room with temperature set at 10^0C± 2^0C and a relative humidity of 90%.

In making assessment of treated fruits at weekly withdrawal, hedonic score was used for determining the state of freshness, presence of wrinkles and disease infestation of fruits. The score is from 1 to 5 with 1 representing fresh or disease-free fruits and increasing score values for deteriorating fruits in term of the three designated physical parameters (see Appendix A for details on scoring).

Differences between treatments were tested using ANOVA. The five treatments have natural groupings, thus enabling orthogonal comparisons between treatments within each natural group to be included in the ANOVA. Some variables were square root transformed to stabilize the variance since the variances of some treatments appear to be proportional to the means.

2. RESULTS

Results in Table F1 and F2 showed the freshness scoring of white-fleshed and red-fleshed dragon fruit respectively at different period of storage. Both types of fruits kept at ambient deteriorated rather quickly as compared to those in chilled storage (Fig.F1& 2).

By the 6th day, there was a highly significant difference between the freshness of chilled and ambient storage ($P<0.001$) in both cases. All T5 fruits of both types of fruit were rejected by the 8th day. As for chilled fruit, freshness of hot-water treated white and red-fleshed fruits was significantly better than that with non hot-water treatment ($P<0.001$). For non hot-water treated fruit, bagging it in sealed polyethylene plastic bag without holes(T4) also contributed significantly toward retaining freshness of white-fleshed ($P<0.001$)and red-fleshed ($P<0.05$) fruits. T3 fruit of white-fleshed type remained in excellent condition after 6 days in chilled storage and was significantly better than that of T1and T2($P<0.001$) and T4($P<0.05$). The same result was obtained for red-fleshed fruit except no difference was detected between it and T2 fruit.

After 15 days of chilled storage, there was a highly significant difference ($P<0.001$) in the freshness of hot-water treated (T2 and T3) and non hot-water treated fruit (T1 and T4) for both cases. The average freshness scores for the former were 1.6(white-fleshed) and 2.4(red-fleshed) while that of the latter were 2.7(white-fleshed) and 3.8(red-fleshed). T4 fruit for both types was again significantly ($P<0.001$) better than that of T1. T3 fruit freshness of white-fleshed type at an average score of 1.4 was the best, even though no statistical difference could be detected with T2 fruit but it was highly significant with T1 or T4 fruit ($P<0.001$). In the case of red-fleshed type, T2 fruit at a mean score of 2.7 was significantly lower than that of T3 ($P<0.05$).

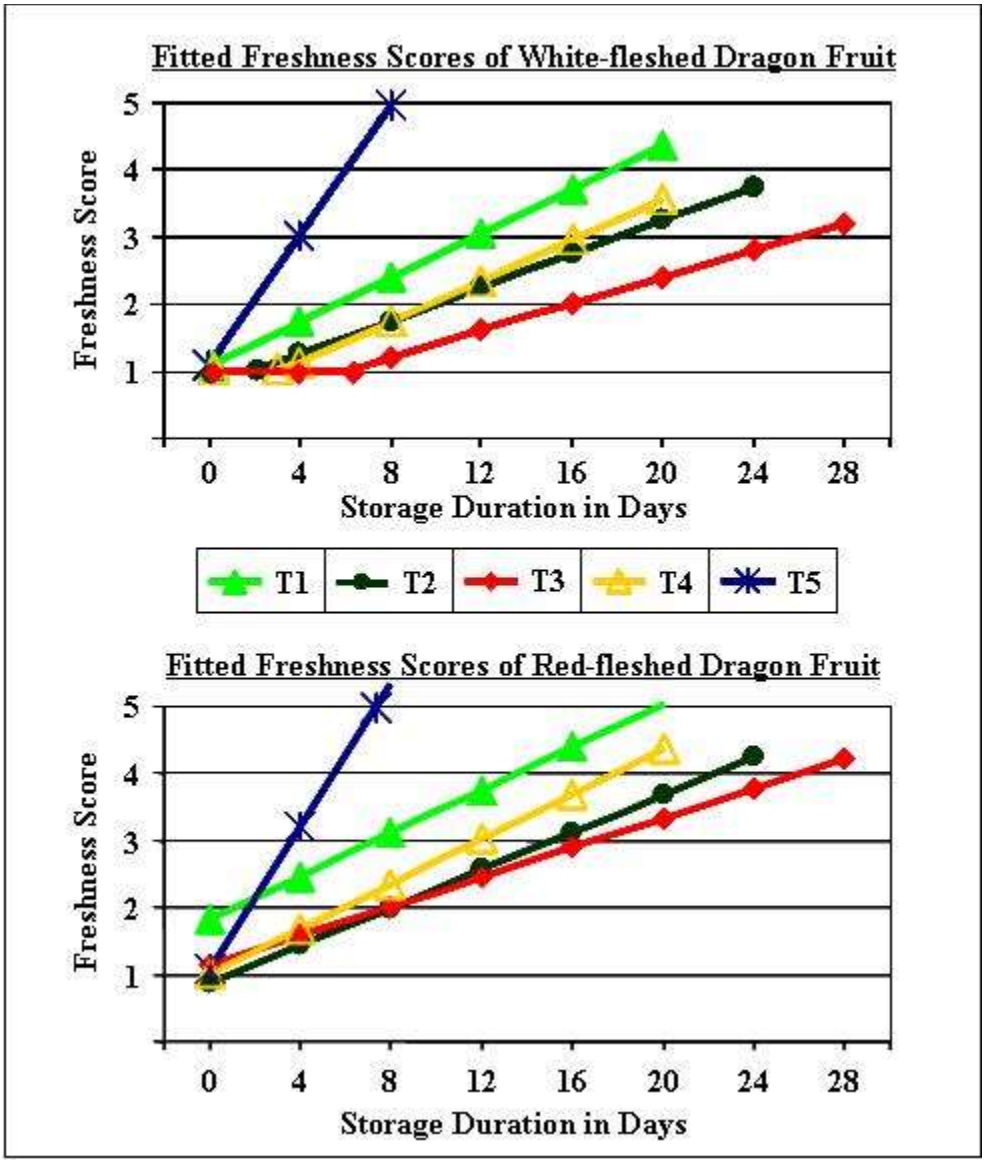
After 20 days of chilled storage, freshness differences were only detected between the average effect of hot water treated fruit (white-fleshed = 2.85; red-fleshed = 3.6) and untreated fruit (white-fleshed= 4.4 and red-fleshed= 4.8). After 24 days, T3 fruit of white-fleshed type was significantly better than that of T2 at $P<0.05$ and there was no significant difference between them in the case of red-fleshed fruit.

TableF1: WHITE-FLESHED FRUIT FRESHNESS SCORES AFTER STORAGE

TREATMENT	Storage Time (Day)				
	6th	**15th**	**20th**	**24th**	**After 24th**
T1: Fruit in poly'ne plastic bag with holes, stored @ 10° C.	2.30	3.40	4.70		All rejected by 21/3/2007
T2: Hot water (55° C_15 min.) treated fruit + T1	1.40	1.87	3.20	4.50	All rejected by 25/3/2007
T3: Hot water (55° C_15 min.) treated fruit + T4	1.00	1.40	2.50	3.60	3.6 with 1 fruit rejected on 27/3/07
T4: Fruit bagged in poly'ne plastic without holes, stored 10°C	1.30	2.10	4.10		All rejected by 23/3/2007
T5: Fruit bagged in poly'ne plastic with holes, stored @ ambient	4.00	All rejected by 9/3/2007			
S.E. Diff. (mean)	0.161	0.359	0.442	0.313	
C.V %	13	24	19	10	

TableF2: RED-FLESHED FRUIT FRESHNESS SCORES AFTER CHILLED STORAGE

TREATMENT	Storage Time (Day)				
	6th	**15th**	**20th**	**24th**	**After 24th**
T1: Fruit in poly'ne plastic bag with holes, stored @ 10° C.	3.00	4.50	5.00		All rejected by 21/3/2007
T2: Hot water (55° C_15 min.) treated fruit + T1	2.00	2.00	4.00	4.83	5.00 (Only 1 fruit)
T3: Hot water (55° C_15 min.) treated fruit + T4	1.80	2.70	3.10	4.50	4.75 (Only 2 fruit)
T4: Fruit bagged in poly'ne plastic without holes, stored 10°C	2.20	3.10	4.50		All rejected by 22/3/2007
T5: Fruit bagged in poly'ne plastic with holes, stored @ ambient	4.60				All rejected by 8/3/2007
S.E. Diff. (mean)	0.310	0.316	0.333	0.279	
C.V %	18	16	11	8	



Wrinkles on fruit appeared on T5 fruit for both white and red-fleshed types by day 6 with mean scores of 2.5 and 2.83 respectively (Tables W1 and W2). After 15 days in chilled storage, only T2 and T3 fruit of white-fleshed type were wrinkle free. In the case of red-fleshed type, T3 fruit has significantly lower wrinkle score than T1, T2 and T4 fruit ($P<0.05$).

By the 20th and 24th day, fruits of all treatments for both types have same or similar wrinkle scores. Fig W1 and W2 show the rates of wrinkle development of fruit for the different treatments during storage.

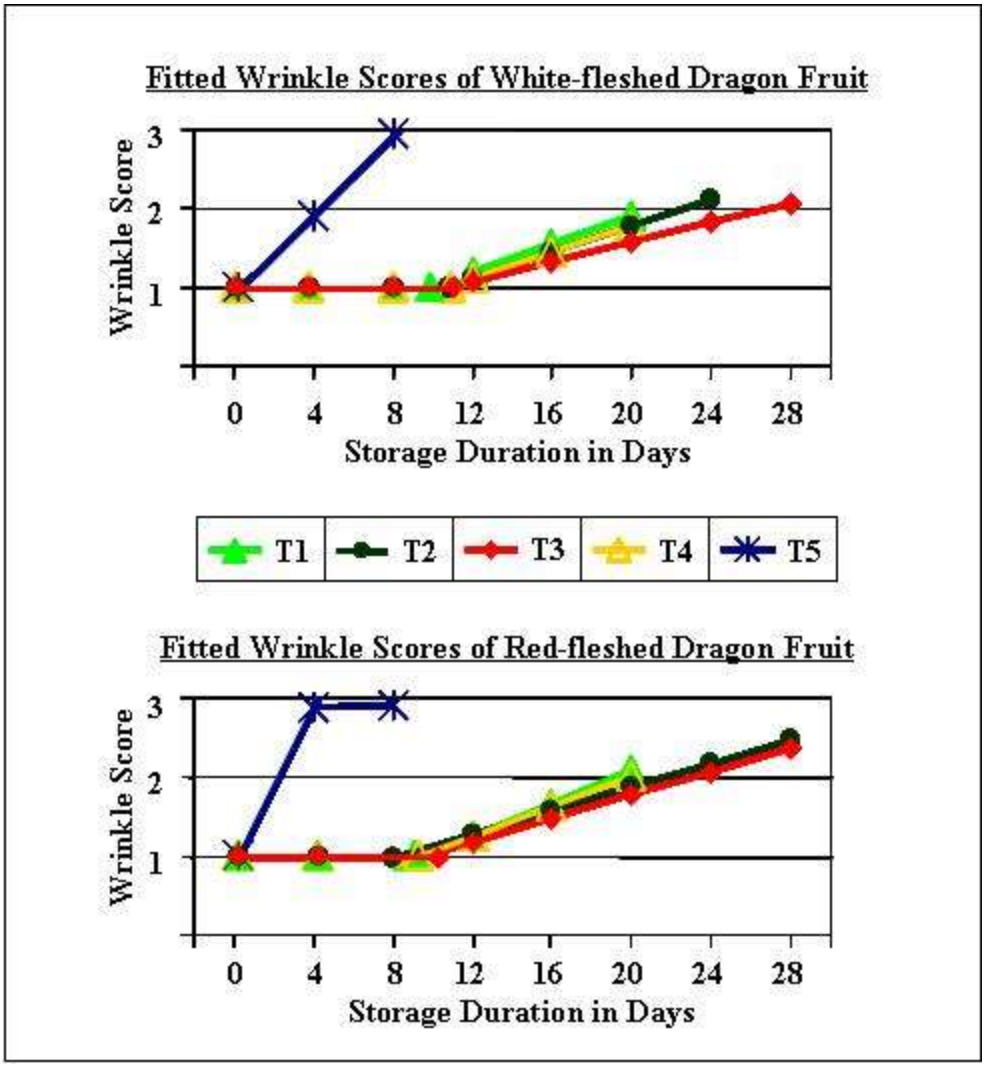
TABLE W1:- WHITE-FLESHED FRUIT WRINKLENESS SCORES AFTER CSTORAGE

TREATMENT	Storage Time (Day)				
	6th	**15th**	**20th**	**24th**	**After 24th**
T1: Fruit in poly'ne plastic bag with holes, stored @ 10° C.	1.00	1.30	2.00		All rejected by 21/3/2007
T2: Hot water (55° C_15 min.) treated fruit + T1	1.00	1.00	2.00	2.00	All rejected by 25/3/2007
T3: Hot water (55° C_15 min.) treated fruit + T4	1.00	1.00	1.90	2.00	2.00
T4: Fruit bagged in poly'ne plastic without holes, stored 10°C	1.00	1.10	1.90		All rejected by 23/3/2007
T5: Fruit bagged in poly'ne plastic with holes, stored @ ambient	2.50	All rejected by 9/3/2007			
S.E. Diff. (mean)	No ANOVA	0.123	0.100	No ANOVA	
C.V %		17	8		

TABLE W2:- RED-FLESHED FRUIT WRINKLENESS SCORES AFTER STORAGE

TREATMENT	Storage Time (Day)				
	6th	**15th**	**20th**	**24th**	**After 24th**
T1: Fruit in poly'ne plastic bag with holes, stored @ 10° C.	1.00	1.50	2.00	All rejected by 21/3/2007	All rejected by 21/3/2007
T2: Hot water (55° C_15 min.) treated fruit + T1	1.00	1.50	2.00	2.17	2.00 (Only 1 fruit)
T3: Hot water (55° C_15 min.) treated fruit + T4	1.00	1.30	2.00	2.12	2.25 (Only 2 fruit)
T4: Fruit bagged in poly'ne plastic without holes, stored 10°C	1.00	1.50	2.00	All rejected by 21/3/2007	All rejected by 22/3/2007
T5: Fruit bagged in poly'ne plastic with holes, stored @ ambient	2.83	All rejected by 8/3/2007	All rejected by 8/3/2007	All rejected by 8/3/2007	All rejected by 8/3/2007
S.E. Diff. (mean)	No ANOVA	0.087	No ANOVA	0.203	

C.V %		9		12	



Diseases attack on fruit was the main cause of spoilage. Fruit was rejected once it reached a disease score of over 4. By day six, disease score for T5 fruit of both types have reached over 4, while fruits kept in chilled storage were disease-free except for T1 fruit of red-fleshed type (Tables D1 and D2).

After 15 days, hot-water treated fruit (T2 and T3) of red-fleshed type has a significantly lower disease infestation as compared to that of non hot-water treatment (T1 and T4) at $P<0.001$ while no such difference was found in white-fleshed type, which recorded relatively low infestation for all four treatments. However, at 20 days, hot-water treated fruit for both types were significantly less affected by diseases than that of non hot-water treatment ($P<0.001$). In the case of white-fleshed type, T3 fruit was also significantly better than T2 fruit ($P<0.05$). Although all T2 and T3 fruits were fairly infested with

diseases (scores < 4) by the 24th day, the infestation was mainly confined to the skin and not affecting the flesh portion.

The rates of development of diseases on fruit during storage are shown in Fig D1 and D2.

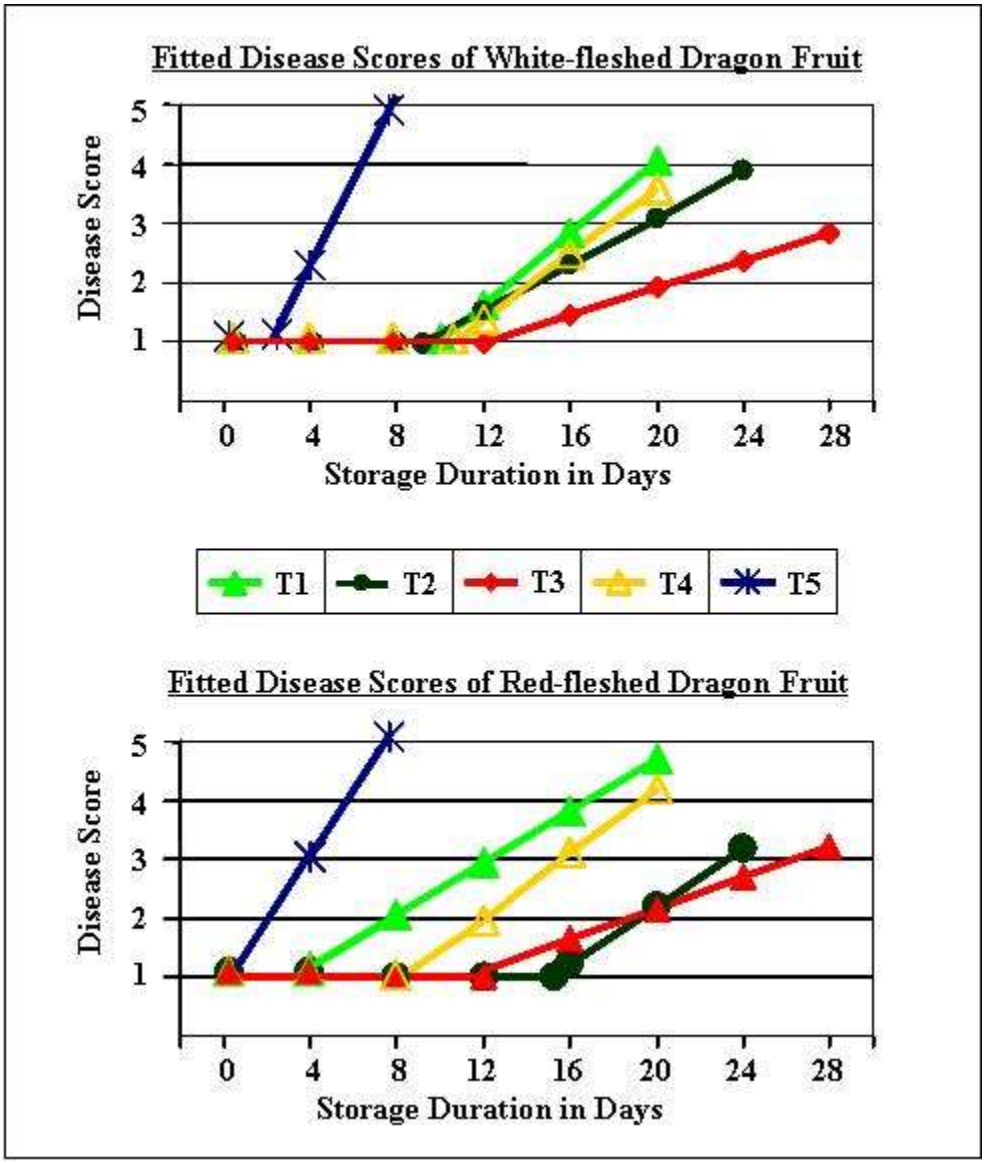
TABLE D1:- WHITE-FLESHED FRUIT DISEASE SCORES AFTER STORAGE

TREATMENT	Storage Time (Day)				
	6th	**15th**	**20th**	**24th**	**After 24th**
T1: Fruit in poly'ne plastic bag with holes, stored @ 10° C.	1.00	1.70	4.50		All rejected by 21/3/2007
T2: Hot water (55° C_15 min.) treated fruit + T1	1.00	1.25	2.90	4.00	All rejected by 25/3/2007
T3: Hot water (55° C_15 min.) treated fruit + T4	1.00	1.00	1.70	3.20	2.88
T4: Fruit bagged in poly'ne plastic without holes, stored 10°C	1.00	1.30	3.90		All rejected by 23/3/2007
T5: Fruit bagged in poly'ne plastic with holes, stored @ ambient	4.50	All rejected by 9/3/2007			
S.E. Diff. (mean)	No ANOVA	0.401	0.529	0.729	
C.V %		45	26	25	

TableD2: RED-FLESHED DISEASE SCORES AFTER STORAGE.

TREATMENT	Storage Time (Day)				
	6th	**15th**	**20th**	**24th**	**After 24th**
T1: Fruit in poly'ne plastic bag with holes, stored @ 10° C.	1.30	3.20	5.00	All rejected by 21/3/2007	All rejected by 21/3/2007
T2: Hot water (55° C_15 min.) treated fruit + T1	(1.00)	1.00	1.70	3.67	3 (only 1 fruit)
T3: Hot water (55° C_15 min.) treated fruit + T4	1.00	1.30	1.50	3.62	3(2 fruit)

T4: Fruit bagged in poly'ne plastic without holes, stored 10°C	(1.00)	2.70	4.12	All rejected by 22/3/2007	All rejected by 22/3/2007
T5: Fruit bagged in poly'ne plastic with holes, stored @ ambient	4.30			All rejected by 8/3/2007	
S.E. Diff. (mean)	0.204	0.557	0.378	0.577	
C.V %	26	43	19	21	



Finally, results in Table V1 showed that white-fleshed fruit was significantly fresher than the red-fleshed fruit at all the four assessment times. And in relationship to presence of wrinkle and disease infestation, white-fleshed fruit was only significantly better than red-fleshed fruit at 15th days of chilled storage (P<0.001). At 20th and 24th day, there was no difference in these two parameters between the two types of dragon fruit tested.

Table V1: Varietal effect on physical parameters of fruit at different storage periods

TREATMENT	Storage Time (Day)											
	6th day			**15th day**			**20th day**			**24th day**		
	F	W	D	F	W	D	F	W	D	F	W	D
White	2.00	1.07	1.70	2.19	1.10	1.31	3.63	1.95	3.25	3.86	2.00	3.43
Red-flesh	2.72	1.20	1.72	3.08	1.45	2.05	4.15	2.00	3.08	4.64	2.14	3.64
S.E. Diff. (mean)	0.110	-	-	0.164	0.051	0.239	0.190	0.037	0.225	0.197	0.1	0.436
C.V. %	16	-	-	19	13	45	15	6	22	9.0	9	2

Note: F - Freshness, W - Presence of wrinkles and D - Disease infestation

3. DISCUSSION

Since its introduction in 2000, dragon fruit has brought a sense of excitement and renewed interests in fruit cultivation firstly, amongst entrepreneurs and more recently, fruit smallholders in the State. Initial plantings by a number of entrepreneurs and field trials carried out by ARC, Semongok showed that dragon fruit thrived under local biophysical conditions. It can be grown on most soil types provided the area is not waterlogged.

Dragon fruit plant commences production about 8 months after field planting. Records from 4 years old red-fleshed dragon fruit stands at the Rampangi Station of Department of Agriculture in Kuching Division showed that fresh fruit yield of 15 to 20 mt per hectare was achievable. Raveh et al. (1997) reported an estimated 16 tons per hectare of *H. polyrhizus* plants in the second year after planting in Israel. In Vietnam, Mizrahi et al. (1997) reported production of 30 tons of fruit per hectare with mature orchards.

The quick returns from dragon fruit plantings and the premium that its fruit fetches at present make it an attractive and profitable new fruit crop to investors and farmers. With its growing popularity, local plantings and production of this fruit is anticipated to increase substantially in the near future. As domestic market is limited, efforts should be made now to explore and market the expected increase production overseas to avoid a possible supply glut of it locally. Furthermore, local dragon fruit production is almost all year round which facilitates more regular supply, and this makes it a good fruit crop candidate to develop for export market. Although this fruit has good prospects for development but recent outbreak of serious disease attacks on pseudo stems and fruit in a number of farms in Sarikei and Sibu Divisions is a major concern. To this day, there is no solution to this problem.

Presently, fresh dragon fruit is marketed with little or nil post harvest handling consideration along the local supply chain. In ambient conditions, fruit stays fresh for a few days after which its appearance deteriorates, resulting in down grading of value. Invariably disease infestation set in and fruit is spoiled in 6 to 7 days. However, results from the studies showed that if fruit was stored at 10^0C and in relative humidity of 90%, it stayed fresh and disease-free for 6 days but after the 15th day, spoilage caused by diseases set in. These results were in contrast to report that fruit would keep for 2 to 3 months in a cool room at 7-10^0C and 90-98% relative humidity (Luders, L. 1999). However, Nerd (1999) reported that *Hylocereus undatus* fruit harvested at 28 to 30 days after flowering at full color development could maintain their quality for at least two weeks when stored at 14^0C.

The banning of chemicals in post harvest treatment of fruits contributes towards the use of alternative methods such as hot water or hot air treatments. These heat treatments have the advantage that they are also effective against fruit fly in fruit (Merino et al., 1985). Dragon fruit are a fruit fly host. Studies showed that it could withstand water temperature of 55^0C for 30 minutes. During this time, the core temperature of fruit reaches above 41^0C for 15 minutes (figure 4) which is enough to kill off any fruit fly egg on the fruit.

Results from the studies showed that heat treatment substantially slow down the physical deterioration and disease infestation of fruit in chilled storage for up to 21 days. Fungal decay on fruit was the major factor limiting storage. The main fungi found on diseased spots in this studies were *Colletotrichum* spp*, Fusarium* spp *and Helminthosporium* sp*p*. Brown soft spots usually developed from both ends of the fruit while white spots developed over the fruit. Barbeau (1990) reported bacterial (*Xanthomonas campestris*) and *Dothiorella* spp. diseases on dragon fruit and in addition, post harvest disease has been associated with *Fusarium lateritium, Aspergillus riger, and Aspergillus flavus* (Le et al., 2000a). Spalding and Reeder (1986) working on heat treatment of mangoes, found it effective in reducing anthracnose and stem-end rot in cv. 'Keitt'.

Bagging fruit in sealed polyethylene plastic without holes appeared to slow down dehydration of fruit and thus retaining it freshness better. This was evidence on the bracts that remained greenish or turgid of over a week in chilled storage. A similar study by Le (2000b) showed that fruit harvested 28 to 30 days after flowering and stored in a modified atmosphere bag could be held for 35 days at 10^0C versus 14 days for air controls.

4. CONCLUSION

In the short time since it's introduction into the State, dragon fruit has gained popularity amongst entrepreneurs, fruit growers and consumers. The growing demand for it and premium prices it commands in domestic market make it a profitable fruit crop to invest in. Although recent outbreak of a serious disease at some commercial farms is of great concern, more plantings and production of this fruit is expected in future.

Studies carried out by the Research Branch of Department of Agriculture, Sarawak have shown that heat treatment of fruit at 55^0C for 15 minutes and then, bagging it in polyethylene plastic bag could extended its shelf life for up to 21 days when stored at 10^0C. The heat treatment is a standard procedure against fruit fly of which dragon fruit is a host to it. Fruit kept at ambient last about 6 to 7 days.
The findings on extended shelf life of locally grown dragon fruit can be applied by marketers and retailers in domestic market to reduce wastage due to spoilage and the downgrading of the quality of fruit to a lower priced market. Furthermore, it should help in the export of this wonderful fruit to neighboring countries.

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REFERENCES

Barbeau, G. 1990.La pitahaya rouge, an nouveau fruit exotique. Fruits 45: 141-147.

Kueh, K.H. and Voon, B.H. 2003. Pitaya (Hylocereus and Selenicereus sp.) cultivation in Sarawak. Proceedings of the in-house seminar on New Crops with potential for commercialization. 7^{th}-8^{th} August 2003. Department of Agriculture, Sarawak.

Le, V.T., N. Nguyen, D.D. Nguyen, K.t. Dang, T.N.C. Nguyen, M.V.H. Dang, N.H. Chau and N.L. Trink. 2000a. Quality assurance system for dragon fruit. ACIAR Proceedings 100:101-114.

Le, V.T., D. Nguyen, N. Nguyen, K.T. Dang, T.N.C. Nguyen, M.V.H. Dang, N.H. Chau and N.L. Trink. 2000b. The effects of harvesting time, use of plant growth regulators and modified atmosphere packages on storage-life and the quality of dragon fruit grown in Vietnam. Intl. Symp. Trop. Subtrop. Fruits, Cairns, Australia.

Luders, L. 1999. The Pitaya or Dragon Fruit. Agnote No. 778 D42. Australian department of primary Industry and Fisheries.

Merino, S.R., Eugenio, M.M., Ramos, A.W. and Hermandez, S.T. 1985. Fruit fly Disinfection of mangoes by Vapour Heat Treatment. Bureau of Plant Industry, Ministry of Agriculture and Food, Manila. 89pp.

Mizrahi, Y. and A. Nerd and P.S. Nobel. 1997. Cacti as crops. Hort. Rev. 18:291-319.

Morton, J. 1987. Strawberry Pear. In: Fruits of warm climates, P.347-348.

Nerd, A., F. Gutman, and Y. Mizrahi. 1999. Ripening and Post harvest Behavior of Fruits of Two Hylocereus species (Cactaceae). Postharvest Biology and Technology. 17;39-45.

Raveh, E., A. Nerd, and Y. Mizrahi. 1997. Responses of Two Hemiepiphytic Fruit Crop Cacti to Different Degrees of Shade. Scientia Horticulturae. 73:151-164.

Spalding, D.H. and Reeder, W.F. 1986. Decay and acceptability of mangoes treated with combination of hot water, imazalil and *r*-radiation. Plant Diseases 70, 1149-1150.

Tie, C.P. 2007. A proposal paper on the operation of a Post Harvest Handling Centre for fruit and vegetables by Rejang Agronomics Corporation Bhd. 26th March 2007.

Appendix A: Scoring descriptions of dragon fruit physical parameters.

Score	***Freshness***	***Presence of Wrinkles***	***Disease infestation***
1	Bracts are firm, mostly green in color with less than 10% of them yellowing.	No wrinkles on fruit. Glossy skin surface.	Disease-free fruit
2	Bracts are firm with over 10% to 20% of them yellowing.	Slight wrinkling at the posterior end of fruit (less than 5%).	Brown spot of not more than 0.5cm diameter and not more than 2 spots.
3	Bracts going flaccid with over 20% to 50% of them yellowing.	Wrinkles at posterior end of fruit(over 5% to 20%).	Brown spot of less than 1cm and covers less than 5% of fruit.
4	Bracts more flaccid, slightly dried up with over 50% to 70% of them yellowing.	Wrinkles of over 20% to 30% of fruit. Dull looking	Spots or diseased surface of over 5% to 10%. Fruit is rejected with score over 4.
5	Bracts dried up and turn brown or black	Wrinkles of over 30% of fruit.	Diseased area of over 10% of fruit.