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Studies on morpho-biochemical changes of longan [*Euphoria longana* (Lour) Steud.] fruit during fruit growth and development for determination of maturity

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ABSTRACT

Longan fruit is used as fresh as well as preserved as canned due to its sweet juicy and flavoured aril and becomes available when availability of litchi is over. It is a non-climacteric fruit and continues to ripen being attached to the plant. The fully ripened, freshly harvested fruit has a bark like shell, thin and firm, making the fruit easy to peel by squeezing the pulp to out. The seed is small, round, hard and of an enamel like, lacquered black. However, the proper maturity stage is yet to be known as scientific findings on physical and biochemical maturity indices of longan is scare. In the present experiment, the pattern of sequential development and changes in physio-chemical properties of longan fruit after fruit set were investigated in ten plants of 10 to 15 years age group. The experiment was laid under Randomized Block Design considering the stages of harvest (days after fruit set) as treatments and all ten plants as separate replication during the year 2022. Fruit growth based on fruit length, fruit diameter, seed diameter, aril thickness, weight of fruit, weight of seed, followed a smooth sigmoidal curve during the fruit growth and development. A similar trend of changes has also been observed with respect to total soluble solids (TSS), acidity, total sugar and reducing sugar. Both the fruit morphological characters as well as the quality parameters reached to the steady state in between 114 to 128 days after fruit set. Based on the attainment of fruit size, aril quantity and quality aspects, it can be concluded that the optimum stage for harvest of longan is 114-128 days after fruit set.

***Keywords*:** Fruit growth, longan, maturity, morphological changes, quality.

INTRODUCTION

Longan [*Euphoria longana* (Lour) Steud.] is an evergreen subtropical fruit tree species and originated from Southern China and came to India in the year 1978 (Morton *et al*., 1987). This fruit comes under the order Sapindales and family Sapindaceae (soapberry family). In India it is cultivated in very limited pockets of West Bengal and North Bihar. Thus it is considered as one of the minor as well as underutilized fruit in India like other crops (Hazarika and Lalruatsangi, 2016).

The fruits of longan are preferred and consumed as fresh due to its juicy refreshing taste and flavour. Fleshy aril is the edible portion of this fruit which is rich in sugar, vitamins (B-complex and C), minerals (iron, phosphorus, calcium) as well as various antioxidants and bioactive compounds which are reported to be antitumor, antidiabatic, antiallergic activities (Kumar *et al*., 2023, Nath *et al*., 2018). This fruit is considered as one of the important among the all minor and underutilized fruits like jamun, phalsa, Indian olive, latka etc. (Prasad *et al*., 2017; Halder *et al*., 2023). Along with the other underutilized fruit crop species, longan was also studied for its nutritional profiling by many scientists (Wang *et al*., 2011, Marisa, 2006, Jiang *et al*., 2002).

Longan trees usually produce shoot once in a year, although it can produce more than one shoot during summer and autumn that converts into 10-45 cm long panicle once during end of winter. The small flowers contain 5-6 yellow or brown petals in both unisexual and bisexual (hermaphroditic) flowers (Pham *et al*., 2016). The female flowers bear a carpellate ovary and the heart shaped, yellowish or light brown coloured, single seeded

fruits are small drupe of 20-37 mm in diameter and 5-20g in weight. Basically, the seed is orbicular with black or brown colour with a rounded white spot that has the appearance of a dragon's eye (Sun *et al*., 2010). Panicles of longan plants bear upto 350 fruits and take about 140-190 days as per the report of Crane *et al*. (2005). However, the proper maturity stage is not yet reported as scientific findings on the basis of fruit physical and biochemical maturity parameters. In this context, the present experiment has been conducted to study the pattern of sequential development and changes in physio-chemical properties of longan fruit to assess the proper maturity stage.

MATERIALS AND METHODS

The present experiment was conducted during the year 2021 and 2022 selecting ten longan plants under age group of fifteen to twenty years at various village locations (viz. Bahadurpur, Binuria, Raipur, Deuli, Supur, Ballavpur, Baganpara, Lohagar, Surul and Jambuni) of Bolpur Sriniketan Block, Birbhum, West Bengal. Twenty five branches of each plants bearing panicles have been randomly selected and tagged before the anthesis for recording various observations on fruit growth and development. Longan plants started bearing during mid-February to mid-March. After tagging of selected branchlets (panicles) recording of observations were started from the fifty one (51) days after fruit set at seven days interval upto thirteen different stages of fruit growth was taken for identifying the optimum maturity stage of longan. Thirteen different stages of fruit growth were considered as different treatments and ten different plants were considered as replications following Randomized Block Design with thirteen treatments and ten replications. Thirteen (13) different stages of fruit growth that considered were fifty one (51), fifty eight (58), sixty five (65), seventy two (72), seventy nine (79), eighty six (86), ninety three (93), hundred (100), hundred seven(107), hundred fourteen (114), hundred twenty one (121), hundred twenty eight (128) and hundred thirty five(135) days after fruit set. As the aril development of longan fruits was started only after 50 days of fruit set (Prasad *et al*., 2017), thus all the observations has been recorded only after 50 days of fruit set. Various observations on fruit physical parameters like average length of the fruit, diameter of the fruit, seed diameter, aril thickness, weight of the fruit (g) and seed weight (g) have been recorded as per following procedure:

Fruit physical parameters: The length of ten fruits from each replication was measured from the distal end to the proximal end of the fruit with the help of a digital vernier caliper (Mitutoyo, Japan) and the mean was worked out and expressed in millimetres. The fruit diameter of ten fruits per replication was recorded at the widest point of the fruit using a a digital vernier caliper and the mean value was expressed in millimetres. Data on seed diameter was recorded from three randomly selected seeds from each replication using a vernier caliper at the widest point and their mean value was expressed in millimetres. Aril thickness of ten fruits from each replication was measured with the help of a digital vernier caliper and the mean was calculated out and expressed in millimetres. Ten randomly selected fruits from each replication were used for measuring the fruit weight. The weight was measured on a pan balance and the average fruit weight was calculated and expressed in grams. Seed weight was measured on a simple pan balance and their mean weight was recorded and expressed in grams.

Fruit biochemical parameters: Total Soluble Solids of the juice of ten longan fruits from each treatment were recorded using a pocket digital refractometer (Atago, Model PAL-1, Japan) and expressed in °Brix. The titration method using the fruit juice against 0.1 N NaOH and phenolphthalein as indicator were used to determine the titrable acidity (Rangana, 1986). Total sugars was determined following the method as described by Rangana, (1986) by hydrolysis of juice with 1 or 2 drops of concentrated hydrochloric acid and neutralized by adding 1N sodium hydroxide solution followed by titration against standard Fehling's solution mixture A and B (1:1) using methylene blue indicator in a heated environment until brick red colour precipitated. Reducing sugars were determined by adopting the method given by Lane and Eynon (1923) taking prepared sample up to zero, and then it was titrated against combination of Fehling's solutions in a heated environment until brick red colour precipitated.

Statistical analysis of the data on different observations has been carried out using SPSS

(Version 18.0.2) considering thirteen different stages of fruit growth as treatments and ten different plants as replications. The analysis of observations of both the years (i.e. 2021 and 2022) is cited in the tables separately as well as pooled value for easy comprehension.

RESULTS AND DISCUSSION

The statistical analysis of data pertaining to the fruit physical parameters and biochemical parameters has been presented in Table 1 and 2 as separate analyses of both the years as well as pooled value for all the observations. However, after homogeneity test of data on all parameters, it was clear that both the years as well as pooled data has shown similar trend of variation. In the present experiment the observations on different physical and quality aspects of longan fruits has been recorded at thirteen different stages of fruit growth according to days after fruit set. The results on the basis of pooled value showed the significant variation in physical and biochemical parameters of longan fruits under different stages of fruit growth as follows:

Fruit length: Longan fruits have shown double sigmoid growth pattern in both the years as well as in pooled value, with respect to fruit length, as presented in Table 1 and Fig. 1. It has started to increase from 8.93mm at 51 days after fruit set and reached a steady state at 121 days after fruit set as 20.37mm as observed in pooled value. Although, at steady state the fruit attained a length of 20.82 mm at 135 days after fruit set after passing through double sigmoid pattern.

Fruit diameter: In the present study the changes in diameter of longan fruits in both the years as well as in pooled value have been presented in Table 1 and Fig. 1. The perusal of data of pooled of two years on fruit diameter shows a gradual increase starting from first day of observation (i.e. 51 days after fruit set) as 8.47mm and increased upto 19.93mm as on 121 days after fruit set after reaching at the steady state. Thus the growth pattern of the longan fruit with respect to fruit diameter was also double sigmoid.

Seed diameter: Critical review of the data on seed diameter of longan fruits in both the years as well as in pooled value (Table 1 and Fig. 1) revealed that it changed significantly with advancement of fruit growth and maturity. It is evident from the data of pooled value of both the years, at the initial stage of observation at 51 days after fruit set, the seed diameter was recorded as 2.01mm which ultimately attained the final plateau on 128 days after fruit set as 13.85mm. Although a little shrinkage of seed size was observed which was statistically non-significant.

Weight of fruit: With regard to the average fruit weight of longan (Table 1) with advancement of fruit growth, development and maturity in both the years as well as in pooled value, again double sigmoid curve have been observed (in pooled value) starting from 0.35g at 51 days after fruit set and attained the steady state of gaining weight at 114 days after fruit set as 5.08g which ultimately reached to 5.28g as on 135 days after fruit set, but such increment was within the steady state (i.e. the change was statistically non significant).

Seed weight: In the present experiment the statistical analysis of data on seed weight of longan fruits (Table 1) in both the years as well as in pooled value have shown increasing trend as starting from (in pooled value) 0.04g as on 51 days after fruit set to 1.63g as on 107 days after fruit set. The seed weight has been increased upto 1.80g which was non-significant. However, the seed weight of the longan fruit has shown double sigmoid growing habit.

Total Soluble Solids (TSS): The perusal of statistically analyzed data on changes in total soluble solids of longan fruit juice in the 2021 and 2022 as well as pooled value have directed the increasing trend in two phases (Table 2 and Fig. 2). It is clear from the pooled data of both the years that the TSS was started to increase from 3.51^0Brix at 51 days after fruit set in the first phase to 8.81^0Brix at 93 days after fruit set. Again in second phase the TSS of the longan fruits has increased from 10.22^0Brix at 100 days after fruit set to 16.29^0Brix at 135 days after fruit set. However, the highest TSS of longan fruits (16.46^0Brix) was observed at 128 days after fruit set after which it was gradually decreased.

Acidity: The observations on acidity of juice of longan fruits (Table 2) have increased significantly with the advancement of fruit growth and maturity as observed in both the years as well

Table 1: Changes in fruit physical parameters of longan with advancement of fruit growth towards maturity.

Days after fruit set	Fruit length (mm)			Fruit diameter (mm)			Seed diameter (mm)			Weight of fruit (g)			Seed weight (g)		
	2021	**2022**	**Pooled**	**2021**	**2022**	**Pooled**	**2021**	**2022**	**Pooled**	**2021**	**2022**	**Pooled**	**2021**	**2022**	**Pooled**
51 days	8.46	9.40	8.93	8.29	8.65	8.47	1.93	2.09	2.01	0.31	0.39	0.35	0.03	0.05	0.04
58 days	12.05	11.79	11.92	10.84	10.71	10.77	4.05	3.93	3.99	0.79	0.70	0.74	0.18	0.12	0.15
65 days	12.42	12.01	12.21	11.69	11.39	11.54	6.52	6.18	6.35	1.02	0.92	0.97	0.19	0.15	0.17
72 days	12.78	13.12	12.95	12.68	13.02	12.85	7.03	7.39	7.21	1.46	1.68	1.57	0.24	0.32	0.28
79 days	14.65	15.07	14.86	14.35	14.89	14.62	9.20	9.70	9.45	1.98	2.20	2.09	0.55	0.65	0.60
86 days	15.94	15.36	15.65	15.14	14.71	14.92	10.83	10.47	10.65	2.33	2.15	2.24	0.85	0.77	0.81
93 days	16.72	16.06	16.39	15.52	15.20	15.36	11.10	10.84	10.97	3.08	2.86	2.97	1.28	1.23	1.26
100 days	17.63	18.19	17.91	17.02	17.34	17.18	11.13	11.39	11.26	3.35	3.51	3.43	1.28	1.33	1.30
107 days	18.35	18.07	18.21	17.90	17.52	17.71	11.69	11.47	11.58	4.26	4.08	4.17	1.66	1.60	1.63
114 days	19.24	19.78	19.51	18.85	19.26	19.05	11.72	12.14	11.93	5.01	5.15	5.08	1.66	1.69	1.67
121 days	20.03	20.71	20.37	19.72	20.14	19.93	11.76	12.02	11.89	5.02	5.26	5.14	1.70	1.76	1.73
128 days	20.47	20.99	20.73	20.03	20.41	20.22	13.69	14.01	13.85	5.17	5.39	5.28	1.74	1.86	1.80
135 days	21.02	20.62	20.82	20.41	20.09	20.25	13.92	13.76	13.84	5.34	5.22	5.28	1.84	1.76	1.80
SE±m	0.21	0.23	**0.24**	0.21	0.18	**0.17**	0.23	0.19	**0.17**	0.13	0.14	**0.11**	0.07	0.08	**0.06**
CD 5%	0.66	0.71	**0.75**	0.62	0.55	**0.54**	0.69	0.58	**0.52**	0.39	0.41	**0.32**	0.22	0.24	**0.20**

Table 2: Changes in biochemical parameters of longan with advancement of fruit growth towards maturity.

Days after fruit set	TSS (^{0}Brix)			Acidity (%)			TSS: Acidity (%)			Total Sugar			Reducing Sugar (%)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
51 days	3.43	3.59	3.51	0.015	0.017	0.016	228.66	211.17	219.37	5.01	5.47	5.24	3.29	3.67	3.48
58 days	4.06	3.98	4.02	0.019	0.018	0.017	213.68	259.25	236.47	7.43	7.31	7.37	4.58	3.94	4.26
65 days	4.71	4.81	4.76	0.015	0.019	0.017	314.02	246.22	280.12	8.12	8.41	8.26	4.06	4.28	4.17
72 days	6.60	6.44	6.52	0.019	0.017	0.018	388.23	336.25	362.24	9.94	9.11	9.52	5.41	5.17	5.29
79 days	7.92	8.14	8.03	0.019	0.021	0.020	416.84	356.31	386.52	11.46	12.48	11.97	6.22	6.52	6.37
86 days	8.35	8.21	8.28	0.022	0.020	0.021	379.54	409.06	394.28	13.64	13.54	13.59	7.05	6.83	6.94
93 days	8.70	8.92	8.81	0.022	0.024	0.023	395.45	408.63	402.04	13.78	1.92	13.85	7.05	7.51	7.28
100 days	10.11	10.33	10.22	0.022	0.024	0.023	459.54	429.16	444.34	14.36	15.02	14.69	8.17	8.45	8.31
107 days	11.37	11.19	11.28	0.025	0.024	0.024	454.82	485.26	470.04	15.03	14.43	14.73	9.42	9.04	9.23
114 days	12.16	12.34	12.25	0.025	0.024	0.025	486.43	493.85	490.14	15.20	15.36	15.28	10.59	11.09	10.84
121 days	15.64	16.08	15.86	0.025	0.027	0.026	579.25	641.30	610.27	16.28	16.59	16.43	12.48	12.76	12.62
128 days	16.72	16.98	16.85	0.026	0.027	0.026	619.25	676.84	648.07	16.77	16.15	16.46	12.53	13.05	12.79
135 days	16.55	16.41	16.48	0.025	0.024	0.024	662.51	710.84	686.68	16.57	16.02	16.29	12.76	12.42	12.59
SE±m	0.15	0.13	**0.14**	0.001	0.01	**0.001**	9.08	8.60	**7.01**	0.31	0.32	**0.29**	0.12	0.12	**0.23**
CD 5%	0.46	0.49	**0.42**	0.003	0.04	**0.003**	27.21	25.73	**20.98**	0.94	0.96	**0.86**	0.35	0.36	**0.31**

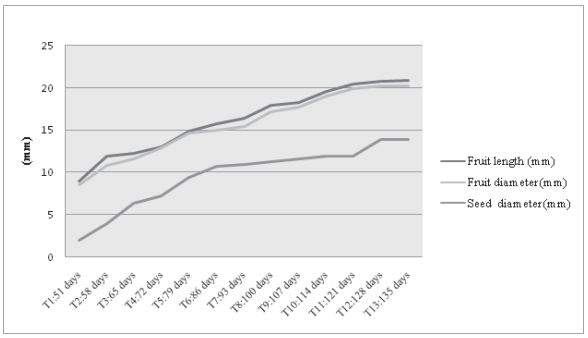

Fig. 1 : Changes in fruit size of longan with advancement of fruit growth

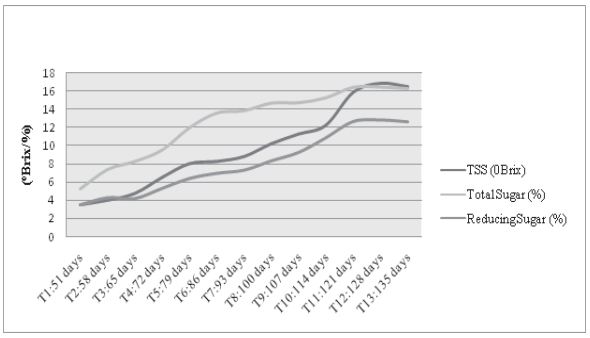

Fig. 2 : Changes in quality parameters of longan fruits with advancement of fruit growth

as in pooled value. The initial pooled value of acidity of longan fruit was only 0.016% at 51 days after fruit set which has attained to 0.023% at 93 days after fruit set as higher level. Although a highest level of acidity of longan fruit juice was recorded as 0.026% at 121 days after fruit set which remained same upto 128 days after fruit set after which it has reduced to 0.025% at 135 days after fruit set.

TSS-Acidity ratio: A drastic increase in TSS-acidity ratio of juice of longan fruits has been observed in the present experiment with advancement of fruit growth and maturity of longan in the 2021 and 2022 as well as pooled value (Table 2). The pooled initial ratio was recorded as 219.37 at 51 days after fruit set which has increased to 402.04 at 93 days after fruit set during the first phase of fruit growth. On the other hand the TSS-acidity ratio was started to increase from 402.04 at 100 days after fruit set to 686.68 at 135 days after fruit set of longan. Thus a double sigmoid nature of fruit growth and development with respect to TSS-acidity ratio was recorded in can of fruit development of longan upto fruit maturity.

Total sugar: The total sugar content of longan fruits have shown an increasing pattern with advancement of growth and attaining maturity into two distinct phases (Table 2 and Fig. 2). At the beginning the total sugar content of longan fruit juice was recorded as 5.24% at 51 days after fruit set which was increased to 11.97% at 79 days after fruit set which is clear from the pooled data of both the years. Again during second phase of fruit growth of longan, the total sugar content has increased from 13.59% at 86 days after fruit set to 16.46% as highest at 128 days after fruit set after which reduced to 16.29% at 135 days after fruit set. It was thus clear that the longan fruit also has shown double sigmoid pattern of growth with respect to total sugar content of fruit juice.

Reducing sugar: A gradual increase of reducing sugar content of longan fruit juice have been observed in the present investigation while experimenting the biochemical changes pattern of longan fruits with advancement of fruit growth towards maturity (Table 2 and Fig. 2). The statistical analysis of data on both the years as in pooled data indicated 3.48% of reducing sugar content in juice in longan fruits at 51 days after fruit set while it has been reached to a steady state after attaining reducing sugar content of 12.62% at 121 days after fruit set. Although, a little increase of reducing sugar has also been observed upto 12.79% at 128 days after fruit set which has reduced to 12.59% at 135 days after fruit set of longan.

In the present experiment the fruit growth and development took place in two different phases after fruit set. First stage of fruit growth was from fruit set to 93 days after fruit set i.e. 14 week age of the fruit. On the other hand, the second phase of fruit growth was observed from 100 days after fruit set to 128 days after fruit set with respect to most of all fruit physical and biochemical parameters. As per the findings of various workers on phonological studies of longan fruit that the fruit development can be divided into two main growth stages (Chen *et al.*, 1995; Xu *et al*., 1997).

In the first stage, pericarp and aril development started and the seed coat, embryo and endosperm can be observed with the naked eye. The second stage is characterized by the embryo filling the seed

cavity, hardening of the seed coat, thinning of the pericarp, development of the fleshy aril and the maturation process. Two waves of fruit maturation in longan fruits in China was observed by Zee *et al*. (1998). The first cycle occurred 43-70 days after fruit set, and the second 80-120 days before harvest. In southern Spain, the first sigmoid curve appears 8 weeks after anthesis (Davenport and Stern, 2005). Thus the findings of the present experiment have conformity with findings of above mentioned scientists.

The fruits are ready for harvest when the pericarp is thin, smooth, tough and leathery, and its color changes from green yellow to yellow-brown (Subhadrabandhu and Stern, 2005). The same applies for fruit maturity that in present experiment occurred at 121 to 128 days after fruit set and similar maturity stage has been reported in China in July-September (Wong, 1991), in Thailand in June-August (Stern, 2005; Wong, 2000), in Queensland from January/February to March/April (Stern, 2005; Wong, 2000), in Florida in August-September (Jonathan *et al*., 2013), and in northern Vietnam from July to August (FAO, 2004). This little variability of fruit growth, development and maturity of longan fruits around the world may be due to the differences in growing conditions and genotypic variability of the plants.

REFERENCES :

Chen, Q.X., Liao, J.S. and Hu, Y.L. 1995. The growth curve of longan fruit and the correlative analysis of its tissues. *J. Fujian Acad. Agric. Sci*., **24**:19-22.

Crane, J.H., Balerdi, C.F., Sargent, S.A. and Maguire, I. 2005. Longan Growing in the Florida Home Landscape; Institute of Food and Agricultural Sciences, University of Florida: Gainesville, FL, USA. (https://edis.ifas.ufl.edu/publication/MG049)

Davenport, T.L. and Stern, R.A. 2005. Flowering. *In*: Menzel, C.M., Waite, G.K. (Eds.), Litchi and Longan: Botany, Production and Uses. CABI International, Wallingford, UK, pp. 87-113.

FAO, 2004. Fruits of Vietnam. Food and Agricultural Organization of the United Nations, Regional Office for Asia and the Pacific, Bangkok, Thailand. http://www.fao.org/docrep/008/ad523e/ad523e00.htm.

Halder, A., Mukherjee, P. K. Gonmei, G. and Deb, P. 2023. Effect of seed treatments on seed germination and seedling growth of Indian Olive (*Elaeocarpus floribundus*), *Int. J. Minor Fruits, Med. Arom. Plants*, **9**(1): 77-81

Jiang, Y.M., Zhang, Z.Q., Joyce, D.C. and Ketsa, S. 2002. Postharvest biology and handling of longan fruit (*Dimocarpus longan* Lour), *Posthar. Biol. Technol*., **26**: 241- 252.

Jonathan, H.C., Carlos, F.B., Steven, A.S. and Ian, M. 2013. Longan growing in the Florida home landscape, Fact Sheet HS-49. Institute of Food and Agricultural Sciences, University of Florida, pp**.**11.

Kumar, A., Gupta, A., Kanth, N. and Yadav, S. 2023. Genetic Variability Studies Based on Morphological and Physicochemical Characteristics Among Different Longan (*Dimocarpus longan* Lour.) Genotypes Under North Bihar Conditions, *J. Hort*., **9**(4): 1-5. http;//doi: 10.21203/rs.3.rs-3316454/v1.

Marisa, M.W. 2006. Ascorbic acid and mineral composition of longan (*Dimocarpus longan*), lychee (*Litchi chinensis*) and rambutan (*Nephelium lappaceum*) cultivars grown in Hawaii. *J. Food Compost. Anal*. **19**: 655 – 663.

Morton, J. 1987. Longan. *In*: Fruits of warm climates. Julia F. Morton, Miami, Floorida. pp. 259-262.

Nath, V., Gupta, A.K., Marboh, E., Srivastava, K., Kumar, V. and Singh, M.2018. Gandaki Longan 1: first longan variety. *Ind. J. Hort*., **1**:3-4.

Pham, V.T., Herrero, M. and Hormaza, J. I. 2016. Fruiting pattern in longan, *Dimocarpus longan*: from pollination to aril development. *Annals Applied Biol*. **169**(3) : 357-368.

Prasad, K., Pallavi, N., Lal, M.K. and Gaurav, A. K. 2017. Longan (*Dimocarpus longan* Lour) Processing: A Review. *Int. J. Curr. Microbiol. App.Sci.*, **6**(8) : 38-44.

Stern, R.A. 2005. Fruit Set, Development and Maturation: Longan. *In*: Litchi and Longan: Botany, Production and Uses, Menzel, C.M.,

Waite, G.K. (Eds.), CABI International, Wallingford, UK, pp. 138-140.

Subhadrabandhu, S. and Stern, R.A. 2005. Taxonomy, Botany and Plant Development. *In*: Menzel, C.M., Waite, G.K. (Eds.), Litchi and Longan: Botany, Production and Uses. CABI International, Wallingford, UK, pp. 25-34.

Sun, J., Zhang, E., Xu, L., Li, Z., Wang, Z. and Li, C. 2010. Comparison on characterization of longan (*Dimocarpus longan* Lour.) polyphenoloxidase using endogenous and exogenous substrates. *J. Agric. Food. Chem.* **58**(18):10195-10201.

Wang, K., Ying Liang, Ye Zhang, Xianghui Yi, Hengshan Wang, Yingming P. 2011. Antioxidant Activity of Longan (*Dimocarpus longan* L.) (Chapter 83) Seed Extract, *In*: Nuts and Seeds in Health and Disease Prevention, Editor(s): Victor R. Preedy, Ronald Ross Watson, Vinood B. Patel, Academic Press, pp: 705-710.

Wong, K.C. 2000. Longan Production in Asia. Food and Agricultural Organization of the United Nations, Bangkok, Thailand, pp**.** 44.

Wong, K.C. and Ketsa, S. 1991. *Dimocarpus longan* Lour. *In*: Plant Resources of South-East Asia: Edible fruits and nuts., Verheij, E.W.M., Coronel, R.E. (Eds.), Pudoc, Wageningen, the Netherlands, pp. 146-151.

Xu, X.D., Zheng, S.Q., Huang, J.S., Xu, J.H., Lin, Y.Q. and Liu, H.Y. 1997. Studies on fruit development of extremely late maturing species of longan - Dynamic changes of fresh and dry weight, the requirement and distribution of moisture and solute content in fruits. *J. Fujian Acad. Agric. Sci*. **12**: 19–23.

Zee, F.T.P., Chan, H.T.Jr. and Yen, C.R. 1998. Lychee, longan, rambutan and pulasan. *In*: Shaw, P.E., Chan, H.T.Jr. and Nagy, S. (Eds.), Tropical and Subtropical Fruits, Agscience, Auburndale, Florida , pp. 290–335.