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Postharvest quality of Rambutan (*Nephelium lappaceum* L.) associated with packaging and storage conditions

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Abstract

Limited information exists regarding the ideal packaging and storage conditions for optimum quality and storage life of rambutan. In this study, the physicochemical properties of rambutan fruits were monitored during storage. Fruit were packaged in Ventilated LDPE (150 gauge), Ventilated Polypropylene (PP) (100 gauge), Polystyrene tray with cling film wrap, Shrink wrapping and stored under room (30±2˚C and RH 80-85%) or refrigerated (10±2˚C and RH 90-95%) conditions were investigated for their potential to enhance the quality and extend the storage life of the fruit. Rambutan pre-packaged in ventilated polypropylene (PP) reduced weight loss. Refrigerated storage extended storage life of PP packed fruits compared to un-refrigerated fruits up to 14 days. Result of study revealed that Rambutan pre-packaging of rambutan in ventilated polypropylene (PP) reduced weight loss, while refrigerated storage extended storage life of PP packed fruits compared to un-refrigerated fruits up to 14 days. These results provide important information regarding the storage behavior of rambutan fruits and indicate that packaging and storage conditions are effective for reducing moisture loss and extending storage life of fresh rambutan fruit.

Key words: Shelf life, Polypropylene, Polystyrene, Shrink wrap, Refrigeration

Introduction

Fruits and vegetables are highly perishable, as they continue their metabolic processes after harvest and these biological activities deteriorate the quality. The rate of respiration and multiplication of decay organisms is higher at high temperature (Desai *et al.,* 1986). Produce must have less than 3% to 5% water loss to maintain its marketability. Wilting and shrivelling caused by water loss seriously damage the product appearance (Mitchell, 1991).After harvest rambutan fruits rarely stay marketable for more than 2-3 days under ambient conditions (Mendonza *et al*., 1972; Lam *et al*., 1987). The fruit pericarp, consisting of soft spines called spinterns which have more stomata than that of peel or main fruit axis (Pantastico *et al*., 1975). Extreme desiccation leads to browning of entire pericarp Physiological weight loss of a produce decreased horticultural perishables by reducing physical injury during transit and handling (Gast, 1991). even if the pulp or aril is still acceptable or edible. Packaging minimizes the postharvest losses of with increase in thickness of plastic bags (Nainar *et al.,* 1997). Suitable postharvest handling practices can enhance the shelf life by preserving its nutritional quality and there by extending the availability for domestic and distant market. Hence the study on packaging and storage of rambutan was done to extend the shelf life of rambutan with minimum nutritional loss.

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Material and methods

Rambutan fruits of uniform maturity were harvested from the homesteads of Thiruvananthapuram districts and were pre-packaged immediately after ozonization (2 ppm) treatment, with different packages (Plate 1.). Pre-packaged fruits (150g each) were stored under two conditions in three replications. Macro ventilation of 2% was provided for LDPE and PP packages. Effectiveness of packaging materials was analyzed based on physiological and biochemical fruit quality parameters. Observations on PLW was recorded on alternate days whereas biochemical

parameters were taken at an interval of two days till the end of shelf life. Effects of packaging treatments and storage conditions were statistically analyzed, found that treatments differed significantly. The data generated from experiments were statistically analyzed using Completely Randomized Design (CRD).

Pre-packaging treatments

P_1- Ventilated LDPE (150 gauge)

P_2- Ventilated PP (100 gauge)

P_3- Polystyrene tray with cling film wrap

P_4- Shrink wrapping

P_5- Control (without any pre-packaging)

Storage conditions

S_1- Room temperature (30±2˚C and RH 80-85%)

S_2- Refrigerated condition (10±2˚C and RH 90-95%)

Physiological loss in weight (PLW)

For determining physiological loss in weight, sample was weighed accurately after the pre-treatment and weight was taken daily till the end of shelf life and cumulative weight loss was calculated using the formula and expressed as percentage.

$$PLW\ (\%) \frac{Initial\ weight\ -\ Final\ weight}{Initial\ weight} x\ 100$$

Total Soluble Solids:

Total Soluble Solids (TSS) of fruit pulp was recorded with digital refractrometer (Atago - 0 to 53 ^{0}B) and expressed in ^{0}B.

pH: pH of the fruit pulp was measured by using pocket pH tester (HANNA instruments, pHep tester).

Titratable acidity: The titratable acidity was expressed in terms of per cent citric acid (Sadasivam and Manickam, 1992).

Vitamin C: Vitamin C content was estimated by 2,6- dichloro phenol indophenol (DCPIP) dye method (Ranganna, 1986) and expressed as mg/ 100g

Reducing sugar: The titrimetric method of Lane and Eynon (Ranganna, 1986) was adopted for the estimation of reducing sugar and expressed as per cent.

Non reducing sugar: The observations under total sugar and reducing sugar were used for calculating non-reducing sugar (Ranganna, 1986) and expressed as percent on fresh weight basis.

Total sugar: The total sugar content was expressed as per cent in terms of invert sugar (Ranganna, 1986).

Antioxidant activity: Total antioxidant activity of fruit pulp was determined using 2, 2- diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay. The scavenging effect on DPPH free radical was measured (Sharma and Bhat, 2009).

Shelf life: 50% browning of spinterns is considered as the end of shelf life of stored rambutan fruits and expressed in days (O'Hare, 1995).

Results and Discussion

PLW of fruits stored at room temperature was 3.30% and 5.40% after 6 and 8 days of storage respectively whereas it was 2.19% and 3.10% respectively for fruits stored under refrigerated storage. Among the pre-packaging treatments, P_2 (ventilated PP) had the lowest PLW of 2.52% after 8th day of storage and the highest value was noticed in P_5 (without pre-packaging) as 11.47%. When the interaction effects were studied, treatment P_2S_2 (ventilated PP + refrigerated storage) had the lowest PLW of 1.81% and the treatment P_2S_1 (ventilated PP + room temperature) recorded lowest PLW of 3.23% for room temperature storage. The highest PLW of 4.03% was for P_5S_2 (control + refrigerated storage) and 18.91% for P_5S_1 (control + room temperature) after 8 days of storage. Fruits stored under room temperature were discarded due to spoilage after 8th day of storage. The treatment P_2S_2 (ventilated PP + refrigerated storage) recorded the lowest PLW of 2.83% and 3.38% after 12th and 14th day of storage respectively. The highest PLW was recorded in P_5S_2 (control + refrigerated storage) after 12th and 14th days of storage as 7.04% and 9.91% respectively. Physiological loss in weight occurs after the harvest of fruits and is related to shelf life. Weight loss of rambutan is mainly due to respiration process and water loss from the fruit which not only reduce the quantity but also the sensory quality and marketability (Wills *et al.*, 1989). When rambutans were pre-packaged in different packages, 100 gauge ventilated PP recorded the lowest weight loss after 8 days when stored at room temperature (2.52%) and after 14 days of refrigerated storage (3.38%) whereas unpacked fruits recorded highest PLW in both

storage conditions. It might be due to the reduced transpiration and respiration rate of the fruits. Perforated bags reduced water and quality loss of rambutan fruits (Paine and Paine, (1992); O'Hare *et al.*, 1994 and Widjanarko *et al.*, 2000). Pre-packaging has the potential to reduce moisture loss, restrict the entrance of oxygen, lower the rate of respiration and retard discoloration (Ahvenainen, 1996) and helps to increase shelf life by creating a modified atmosphere with an increase in concentration of carbon dioxide in the package (Assumi *et al.,* 2009). Storage temperature plays an important role in PLW. Fruits stored under room temperature recorded the lowest PLW of 3.23% after 8 days after storage and also 3.28% under refrigerated condition after 14 days of storage (Fig. 1a and 1b). The lowest PLW was observed for fruits without any pre-packaging at both the storage conditions.

Rambutan fruits stored at room temperature recorded a TSS of 17.16 ^{o}B after 8th day of storage while it was 19.50 ^{o}B for refrigerated storage fruits. Among the pre-packaging treatments, after 8 days of storage, P_2 (ventilated PP) recorded the highest TSS of 18.76 ^{o}B followed by P_1 (ventilated LDPE) (18.64 ^{o}B) while the lowest was in P_5 (without pre-packaging) (17.13 ^{o}B). When the interaction effects were studied, The treatments P_2S_2 (ventilated PP + room temperature) recorded highest TSS of (19.70 ^{o}B) showing no difference with P_1S_2 (ventilated LDPE + room temperature), P_3S_2 (cling film wrap + room temperature), P_4S_2 (shrink wrap + room temperature ranged between 19.53 ^{o}B and 19.63 ^{o}B and the lowest TSS was recorded in P_5S_2 (control + refrigerated storage) as 19.06 ^{o}B after 8 days of storage at refrigerated storage. After 14th day of storage, fruits showed no significant difference in TSS for the pre-packaging treatments (P_1S_2, P_2S_2, P_3S_2, P_4S_2) under refrigerated storage and it ranged from 17.76 ^{o}B to 18.03 ^{o}B (Table 1). Pre-packaging as well as storage temperature influenced the biochemical parameters of rambutan during storage. TSS of all pre-packaged rambutan fruits decreased during the storage irrespective of the storage temperature. Loss of biochemical parameters was greater with increase in storage temperature and duration in fruits (Kays and Paull, (2004) and Onyango, (2010)). The decrease in TSS during storage might be due to rapid utilization of sugar and other metabolites for respiration. This was in agreement with Azene *et al.* (2014) who reported that TSS of papaya was unaltered by pre-packaging and storage at 10ºC. Reduction of TSS observed during room temperature storage could be attributed to accelerate ripening due to high temperature. This could be due to slower conversion of soluble sugar (Tefera *et al*., 2007 and Getenit *et al*., 2008).

pH of rambutan fruits stored at room temperature recorded a pH of as 3.72 after 6 days of storage and 4.02 after 8 days of storage whereas it was 3.49 and 3.58 respectively under refrigerated storage (Table 2). Among the pre-packaging treatments, after 8th day of storage where P_2 (ventilated PP) had lowest pH of 3.73 which showed no difference with P_4 (shrink wrap) and P_1 (ventilated LDPE) while P_5 (without pre-packaging) had maximum pH of 3.93. When interaction effects were studied, After 8th day of storage, treatments P_1S_2, P_2S_2, P_3S_2 and P_4S_2 recorded no significant difference among themselves and highest pH of 3.66 was for P_5S_2 (control + refrigerated storage). Similarly at room temperature storage, lowest pH was noticed in P_1S_1, P_2S_1, P_3S_1 and P_4S_1 showing no significant difference among themselves and the highest pH of 4.26 was for P_5S_1 (control + room temperature). Rambutan fruits stored under room temperature were discarded due to spoilage after 8th day of storage. After 14th day of storage, ventilated PP + refrigerated storage (P_2S_2) recorded the lowest pH of 3.90 having no difference with P_1S_2 (ventilated LDPE + refrigerated storage) and the highest pH was recorded in treatment P_5S_2 (control + refrigerated storage) after 12th and 14th days of storage as 4.06 and 4.23 respectively.

Acidity of fruits stored at room temperature was 0.43% and 0.33% after 6 and 8 days of storage respectively while it was 0.55% and 0.52% respectively under refrigerated storage. Pre-packaging treatments (P_1, P_2, P_3 and P_4) showed no difference while minimum acidity was observed as 0.40% by P_5 (without pre-packaging). When the interaction effects were studied, after 8th day of storage, treatments P_2S_2 (ventilated PP + refrigerated storage) (0.54%), P_1S_2 (ventilated LDPE+ refrigerated storage) (0.54%), P_3S_2 (cling film wrap+ refrigerated storage) (0.52%) and P_4S_2 (shrink wrap + refrigerated storage) (0.52%) did not differ significantly. The treatment P_5S_2 (ventilated PP + room temperature) recorded lowest acidity of

0.50% at refrigerated storage. Pre-packaging treatments (P_1S_1, P_2S_1, P_3S_1 and P_4S_1) showed no significant difference under room temperature and the lowest acidity was recorded for P_5S_1 (control + room temperature) (0.29%) after 8th day of storage. Fruits stored under room temperature were discarded due to spoilage after 8th day of storage. After 14th day of storage, ventilated PP + refrigerated storage (P_2S_2) recorded the highest acidity of 0.44% showed no difference with P_1S_2 (ventilated LDPE + refrigerated storage) (0.39%). The lowest acidity was recorded in treatment P_5S_2 (control + refrigerated storage) after 12th and 14th days of storage as 0.32% and 0.25% respectively (Table 3). pH was found to be increasing during storage of rambutan fruits whereas acidity was decreasing in all the treatments. This might be due to the reason that organic acids present in fruits were utilized during respiration process as substrates. In case of storage temperature, the fruits stored under refrigerated condition recorded highest acidity (0.50%) and lowest pH (3.66). pH and acidity showed no difference among pre-packaging treatments after 8th day of storage. When interaction effect was considered, pre-packaged rambutan stored under room temperature recorded no difference for pH and acidity after 8 days of storage whereas ventilated PP recorded lowest pH (3.90) and highest acidity (0.44%) was noticed for rambutan fruits under refrigerated condition after 14 days of storage. Depletion of organic acids stored at room temperature can be attributed to the faster ripening rate of fruits and respiration (Wills *et al.,* 1989). Pantastico (1995) reported that increase in pH during storage is due to conversion of organic acids in to sugar.

Fruits stored at room temperature recorded vitamin C of 23.49 mg/100g after 6 days of storage and 20.40 mg/100g under room temperature after 8 days of storage whereas it was 26.29 mg/100g and 25.27 mg/100g respectively under refrigerated storage. After 8th day of storage, P_2 (ventilated PP) had highest vitamin C content of 23.87 mg/100g which was non-significant with shrink wrapping (P_4) (23.74 mg/100g) and ventilated LDPE (P_1). Lowest vitamin C was noticed in P_5 (without pre-packaging) as 23.06 mg/100g and 20.85 mg/100g after 6th and 8th day of storage respectively. When the interaction effects were studied, after 8th day of storage P_2S_2 (ventilated PP + refrigerated storage) recorded 26.35 mg/100g with no significant difference with P_4S_2 (shrink wrapping + refrigerated storage). The treatment P_2S_1 (ventilated PP + room temperature) recorded a vitamin C content of 21.43 mg/100g which had no difference with P_4S_1 (shrink wrapping + room temperature) and P_1S_1 (ventilated LDPE + room temperature) under room temperature. The lowest vitamin C content of 23.62 mg/100g was for P_5S_2 (control + refrigerated storage) and 18.07 mg/100g for P_5S_1 (control + room temperature) after 8th day of storage. Fruits stored under room temperature were discarded due to spoilage after 8th day of storage. After 14th day of storage, ventilated PP + refrigerated storage (P_2S_2) recorded the highest vitamin C content of 22.27 mg/100g showed no significant difference with P_4S_2 (shrink wrapping+ refrigerated storage) 21.75 mg/100g.

The lowest vitamin C content was recorded in treatment P_5S_2 (control + refrigerated storage) after 12th and 14th days of storage as 18.44 mg/100g and 16.16 mg/100g respectively. Rambutan pre-packaged in ventilated PP showed highest vitamin C of 23.87 mg/100g and after 8 days of storage at room temperature and (22.27 mg/100g) at the end of shelf life at 14 days of refrigerated storage (Fig. 2a and 2b). Vitamin C is sensitive to oxygen as it is a reducing agent and creation of modified atmosphere around the fruits through packaging prevents reduction of vitamin C. During storage it was found that refrigerated storage retained more vitamin C (25.27 mg/100g) than at room temperature but a slight decrease was observed from initial content which may be due to lower rate of conversion of ascorbic acid to dehydroascorbic acid at low temperature and conversion is hindered by reduced metabolic and enzymatic activity. Similar results were presented by Singh and Rao (2005) where papaya fruits packed with polypropylene had consistently high vitamin C than other pre-packaging treatments after 15 days of storage at low temperature. Reducing sugar of fruits stored at room temperature was 5.68% after 6 days of storage and 4.96% after 8 days of storage while it was 6.64% and 6.25% for fruits after 6th and 8th day respectively for fruits stored under refrigerated storage. After 8 days of storage, P_1 (ventilated LDPE), P_2 (ventilated PP), P_3 (cling film wrap) and P_4 (shrink wrap) showed no significant difference while the P_5 (without pre-packaging) had lowest

Table 1. Effect of pre-packaging on TSS (^oB) of rambutan fruits under different storage conditions

Pre-packaging Treatments	Total Soluble Solids (^oB)																	
	Days after storage																	
	At storage			2			4			6			8			10	12	14
	S_1	S_2	Mean (P)	S_1	S_2	Mean (P)	S_1	S_2	Mean (P)	S_1	S_2	Mean (P)	S_1	S_2	Mean (P)	(*) S_2	S_2	S_2
P_1	20.26	20.26	20.26	20.03	20.23	20.15	19.10	20.03	19.58	18.33	19.63	18.98	17.66	19.63	18.64	19.16	18.33	17.96
P_2	20.26	20.26	20.26	20.06	20.26	20.15	19.13	20.16	19.63	18.36	19.70	19.03	17.83	19.70	18.76	19.23	18.46	18.03
P_3	20.20	20.20	20.20	20.00	20.20	20.10	18.96	20.03	19.50	18.23	19.53	18.88	17.46	19.53	18.50	19.13	18.26	17.76
P_4	20.26	20.26	20.26	20.00	20.23	20.03	18.86	20.06	19.46	18.30	19.60	18.95	17.66	19.60	18.63	19.13	18.26	17.90
P_5	20.26	20.26	20.26	19.90	20.10	20.00	17.43	19.90	18.66	16.13	19.06	17.60	15.20	19.06	17.13	17.63	16.73	15.76
Mean (S)	20.26	20.26		19.88	20.20		18.70	20.04		17.87	19.50		17.16	19.50		18.85	18.00	17.48
CD (0.05)	P- NS S-NS PxS- NS			P-0.094 S-0.059 PxS-NS			P-0.150 S-0.095 PxS-0.212			P-0.147 S-0.093 PxS-0.208			P-0.177 S-0.112 PxS-0.250			0.196	0.470	0.493

* - Rambutan fruits stored under room temperature (S_1) were discarded due to spoilage after 8th day of storage

S_1- Room temperature S_2- Refrigerated storage

P_1- Ventilated LDPE, P_2-Ventilated PP, P_3- Polystyrene tray with cling film wrap, P_4 – Shrink wrap, P_5- Control

Table 2. Effect of pre-packaging on pH of rambutan fruits under different storage conditions

Pre-packaging Treatments	pH																	
	Days after storage																	
	At storage			2			4			6			8			10	12	14
	S_1	S_2	Mean (P)	S_1	S_2	Mean (P)	S_1	S_2	Mean (P)	S_1	S_2	Mean (P)	S_1	S_2	Mean (P)	(*) S_2	S_2	S_2
P_1	3.43	3.43	3.43	3.43	3.43	3.43	3.46	3.43	3.45	3.66	3.46	3.56	4.00	3.60	3.76	3.76	3.83	3.93
P_2	3.43	3.43	3.43	3.33	3.33	3.33	3.33	3.33	3.33	3.63	3.43	3.53	3.93	3.53	3.73	3.60	3.76	3.90
P_3	3.46	3.46	3.46	3.50	3.43	3.46	3.50	3.43	3.46	3.76	3.53	3.65	3.96	3.60	3.78	3.83	3.96	4.13
P_4	3.43	3.43	3.43	3.46	3.43	3.45	3.53	3.43	3.48	3.76	3.50	3.63	3.96	3.53	3.80	3.80	3.93	4.06
P_5	3.43	3.43	3.43	3.50	3.46	3.48	3.53	3.46	3.50	3.76	3.53	3.65	4.26	3.66	3.93	3.86	4.06	4.23
Mean (S)	3.44	3.44		3.44	3.42		3.48	3.42		3.72	3.49		4.02	3.58		3.77	3.90	4.05
CD (0.05)	P- NS S- NS PxS- NS			P-0.106 S-0.066 PxS-0.148			P-0.137 S-0.073 PxS-0.164			P-0.086 S-0.054 PxS-0.120			P-0.089 S-0.0526 PxS-0.125			0.110	0.100	0.145

S_1- Room temperature S_2- Refrigerated storage

* - Rambutan fruits stored under room temperature (S_1) were discarded due to spoilage after 8th day of storage

P_1- Ventilated LDPE, P_2-Ventilated PP, P_3- Polystyrene tray with cling film wrap, P_4 – Shrink wrap, P_5- Control

Table 3. Effect of pre-packaging on acidity (%) of rambutan fruits under different storage conditions

Pre-packaging Treatments	Acidity (%)																	
	Days after storage																	
	At storage			2			4			6			8			10	12	14
	S_1	S_2	Mean (P)	S_1	S_2	Mean (P)	S_1	S_2	Mean (P)	S_1	S_2	Mean (P)	S_1	S_2	Mean (P)	(*) S_2	S_2	S_2
P_1	0.58	0.58	0.58	0.57	0.59	0.58	0.54	0.58	0.56	0.44	0.55	0.49	0.34	0.54	0.44	0.49	0.44	0.39
P_2	0.59	0.59	0.59	0.58	0.59	0.59	0.54	0.59	0.56	0.45	0.56	0.50	0.35	0.54	0.44	0.58	0.50	0.44
P_3	0.59	0.59	0.59	0.57	0.58	0.57	0.52	0.58	0.55	0.42	0.55	0.48	0.33	0.52	0.42	0.47	0.41	0.35
P_4	0.58	0.58	0.58	0.57	0.58	0.58	0.52	0.58	0.55	0.42	0.55	0.48	0.32	0.52	0.42	0.47	0.41	0.35
P_5	0.59	0.59	0.59	0.58	0.58	0.58	0.50	0.58	0.54	0.39	0.55	0.47	0.29	0.50	0.40	0.44	0.32	0.25
Mean (S)	0.58	0.58		0.57	0.58		0.52	0.58		0.43	0.55		0.33	0.52		0.49	0.41	0.35
CD (0.05)	P- NS S- NS PxS- NS			P-NS S-NS PxS-NS			P-0.037 S-0.024 PxS-0.052			P-0.039 S-0.025 PxS-0.056			P-0.032 S-0.020 PxS-0.043			0.078	0.044	0.056

S_1- Room temperature S_2- Refrigerated storage

* - Rambutan fruits stored under room temperature (S_1) were discarded due to spoilage after 8th day of storage

P_1- Ventilated LDPE, P_2-Ventilated PP, P_3- Polystyrene tray with cling film wrap, P_4 – Shrink wrap, P_5- Control

Table 4. Effect of pre-packaging on total sugar (%) of rambutan fruits under different storage conditions

Pre-packaging Treatments	Total sugar (%)																	
	Days after storage																	
	At storage			2			4			6			8			10	12	14
	S_1	S_2	Mean (P)	S_1	S_2	Mean (P)	S_1	S_2	Mean (P)	S_1	S_2	Mean (P)	S_1	S_2	Mean (P)	(*) S_2	S_2	S_2
P_1	19.27	19.27	19.27	18.38	18.56	18.47	18.01	18.49	18.25	16.44	17.23	16.84	15.17	16.98	16.17	16.28	15.11	14.13
P_2	19.14	19.14	19.14	18.90	19.08	18.96	18.78	18.94	18.86	16.88	17.49	17.18	15.70	17.33	16.51	18.54	17.62	15.45
P_3	19.21	19.21	19.21	18.40	18.94	18.74	18.32	18.58	18.45	16.65	17.32	16.99	15.10	16.81	16.05	16.25	15.03	14.11
P_4	19.27	19.27	19.27	18.54	19.02	18.81	18.67	18.88	18.77	16.80	17.47	17.13	15.51	17.11	16.31	16.43	15.37	14.22
P_5	19.21	19.21	19.21	18.12	18.60	18.36	17.88	18.30	17.94	14.65	16.60	15.62	12.47	15.58	14.02	14.22	13.19	11.74
Mean (S)	19.22	19.23		18.48	18.84		18.33	18.45		16.29	17.22		14.87	16.76		16.34	15.26	13.93
CD (0.05)	P- NS S- NS PxS- NS			P-0.467 S-0.298 PxS-0.661			P-0.496 S-0.316 PxS-0.700			P-0.619 S-0.391 PxS-0.769			P-0.589 S-0.372 PxS-0.623			0.588	0.613	0.744

S_1- Room temperature S_2- Refrigerated storage

* - Rambutan fruits stored under room temperature (S_1) were discarded due to spoilage after 8th day of storage

P_1- Ventilated LDPE, P_2-Ventilated PP, P_3- Polystyrene tray with cling film wrap, P_4 – Shrink wrap, P_5- Control

Table 5. Effect of pre-packaging on reducing sugar (%) of rambutan fruits under different storage conditions

Pre-packaging Treatments	Reducing sugar (%)																	
	Days after storage																	
	At storage			2			4			6			8			10	12	14
	S_1	S_2	Mean (P)	S_1	S_2	Mean (P)	S_1	S_2	Mean (P)	S_1	S_2	Mean (P)	S_1	S_2	Mean (P)	(*) S_2	S_2	S_2
P_1	6.96	6.96	6.96	6.40	6.80	6.60	6.53	6.96	6.66	6.04	6.73	6.38	5.15	6.41	5.78	5.93	5.50	5.14
P_2	6.80	6.80	6.80	6.53	6.96	6.75	6.61	6.80	6.78	6.58	6.80	6.69	5.24	6.41	5.83	5.98	5.55	5.22
P_3	6.59	6.59	6.59	6.14	6.59	6.37	6.11	6.59	6.35	5.87	6.59	6.08	5.02	6.27	5.69	5.75	5.21	4.89
P_4	6.96	6.96	6.96	6.33	6.96	6.65	6.47	6.96	6.71	5.90	6.80	6.35	5.29	6.37	5.83	5.87	5.39	4.96
P_5	6.59	6.59	6.59	6.17	6.59	6.38	5.98	6.59	6.28	5.06	6.30	5.68	4.09	5.89	4.99	4.83	4.16	3.59
Mean (S)	6.78	6.78		6.31	6.78		6.34	6.78		5.68	6.64		4.96	6.25		5.67	5.16	4.76
CD (0.05)	P- NS S- NS PxS- NS			P-NS S-NS PxS-NS			P-0.513 S-0.327 PxS-0.725			P-0.406 S-0.257 PxS-0.669			P-0.332 S-0.210 PxS-0.467			0.413	0.459	0.401

S_1- Room temperature S_2- Refrigerated storage

* - Rambutan fruits stored under room temperature (S_1) were discarded due to spoilage after 8th day of storage

P_1- Ventilated LDPE, P_2-Ventilated PP, P_3- Polystyrene tray with cling film wrap, P_4 – Shrink wrap, P_5- Control

Table 6. Effect of pre-packaging on non reducing sugar (%) of rambutan fruits under different storage conditions

Pre-packaging Treatments	Non reducing sugar (%)																	
	Days after storage																	
	At storage			2			4			6			8			10	12	14
	S_1	S_2	Mean (P)	S_1	S_2	Mean (P)	S_1	S_2	Mean (P)	S_1	S_2	Mean (P)	S_1	S_2	Mean (P)	(*) S_2	S_2	S_2
P_1	11.68	11.68	11.68	11.84	11.59	11.71	12.17	11.52	11.84	10.60	10.43	10.51	10.40	10.56	10.48	10.44	9.87	9.08
P_2	12.34	12.34	12.34	12.08	12.22	12.15	11.70	12.14	11.92	10.77	10.73	10.75	10.45	10.91	10.68	10.60	10.06	9.22
P_3	12.61	12.61	12.61	12.39	12.34	12.37	12.19	12.18	12.18	11.07	10.73	10.90	10.49	10.64	10.56	10.49	9.81	9.22
P_4	12.30	12.30	12.30	12.56	12.11	12.34	12.20	11.98	12.09	10.98	10.69	10.83	10.16	10.74	10.45	10.40	9.72	9.17
P_5	12.06	12.06	12.06	10.95	12.01	11.48	10.89	12.01	11.45	9.59	10.30	9.94	8.37	9.69	9.03	8.51	7.92	7.15
Mean (S)	12.20	12.20		11.67	12.06		11.92	11.97		10.60	10.57		9.97	10.51		10.08	9.47	8.76
CD (0.05)	P- NS S- NS PxS- NS			P-0.755 S-0.477 PxS-1.068			P-0.809 S-0.513 PxS-1.145			P-0.780 S-0.494 PxS-1.103			P-0.634 S-0.401 PxS-0.890			0.413	0.559	0.601

S_1- Room temperature S_2- Refrigerated storage

* - Rambutan fruits stored under room temperature (S_1) were discarded due to spoilage after 8th day of storage

P_1- Ventilated LDPE, P_2-Ventilated PP, P_3- Polystyrene tray with cling film wrap, P_4 – Shrink wrap, P_5- Control

Table 7. Effect of pre-packaging on antioxidant activity (%) of rambutan fruits under different storage conditions

Pre-packaging Treatments	Antioxidant activity (%)																	
	Days after storage																	
	At storage			2			4			6			8			10	12	14
	S_1	S_2	Mean (P)	S_1	S_2	Mean (P)	S_1	S_2	Mean (P)	S_1	S_2	Mean (P)	S_1	S_2	Mean (P)	(*) S_2	S_2	S_2
P_1	88.15	88.15	88.15	82.73	85.84	84.18	79.48	82.73	81.10	73.03	79.48	76.26	64.72	74.92	69.82	70.77	67.62	61.89
P_2	88.09	88.09	88.09	83.88	86.57	85.22	79.96	83.88	81.92	74.04	80.29	77.17	66.34	76.66	71.50	72.30	69.13	64.23
P_3	88.29	88.29	88.29	81.00	84.10	82.55	75.85	81.00	78.42	70.20	75.85	73.02	63.88	73.23	68.54	69.85	64.45	59.69
P_4	88.11	88.11	88.11	80.47	85.64	83.15	76.67	80.47	78.57	69.85	76.67	73.26	62.59	74.29	68.44	69.87	62.59	56.73
P_5	88.50	88.50	88.50	79.04	83.86	81.45	71.25	79.04	75.15	64.02	71.25	67.64	55.12	64.21	59.67	59.69	53.76	46.57
Mean (S)	88.03	88.03		81.42	85.20		76.64	81.42		70.23	76.71		62.53	72.66		68.49	63.51	57.822
CD (0.05)	P- NS S- NS PxS- NS			P-0.635 S-0.402 PxS-0.898			P-0.720 S-0.455 PxS-1.018			P-1.006 S-0.636 PxS-1.412			P-0.971 S-0.614 PxS-1.364			1.659	1.375	1.685

S_1- Room temperature S_2- Refrigerated storage

* - Rambutan fruits stored under room temperature (S_1) were discarded due to spoilage after 8th day of storage

P_1- LDPE, P_2-PP, P_3- Polystyrene tray with cling film wrap, P_4 – Shrink wrap, P_5- Control

reducing sugar of 4.99%. Pre-packaging treatments (P_1S_2, P_2S_2, P_3S_2, P_4S_2) noticed no significant difference and ranged from 6.27% to 6.41% and lowest reducing sugar was recorded in P_5S_2 (control + refrigerated storage) as 5.89% after 8 days of storage under refrigerated condition similar fashion was observed in room temperature with insignificant difference among pre-packaging treatments (P_1S_1, P_2S_1, P_3S_1, P_4S_1) and lowest reducing sugar content was recorded by P_5S_1 (control + room temperature) as 4.09%. Pre-packaged fruits stored under room temperature were discarded due to spoilage after 8th day of storage. After 14th day of storage, rambutan fruits showed no significant difference in reducing sugar for the pre-packaging treatments (P_1S_2, P_2S_2, P_3S_2, P_4S_2) at refrigerated storage and ranged from 4.89% to 5.22% while the lowest reducing sugar was recorded by P_5S_2 (control + refrigerated storage) as 3.59% (Table 5).Non-reducing sugar of fruits stored at room temperature was 10.60% and 10.57% at refrigerated condition with no significant difference after 6 days of storage whereas it was 9.97% and 10.51% for fruits stored under room temperature and refrigerated storage respectively after 8 days of storage. All the pre-packaging treatments showed no significant difference between themselves and lowest non-reducing sugar content was recorded in P_5 (without pre-packaging) as 9.03%. When the interaction effects were studied, all the pre-packaging treatments (P_2S_2, P_4S_2, P_3S_2 and P_1S_2) showed no significant difference. Lowest non-reducing sugar was noticed in P_5S_2 (control + refrigerated storage) (9.69%) after 8 days of storage under refrigerated condition. At room temperature P_1S_1, P_2S_1, P_3S_1 and P_4S_1 showed no difference. The lowest non-reducing sugar of 8.37% was for P_5S_1 (control + room temperature). Pre-packaged rambutan fruits stored under room temperature were discarded due to spoilage after 8th day of storage. After 14th day of storage, rambutan fruits showed no significant difference in non-reducing sugar for the pre-packaging treatments (P_1S_2, P_2S_2, P_3S_2, P_4S_2) at refrigerated storage and ranged from 9.08% to 9.22%. The lowest non-reducing sugar content was recorded in treatment P_5S_2 (control + refrigerated storage) after 12th and 14th days of storage as 7.92% and 7.15% respectively (Table 6). Reducing and non-reducing sugar of rambutan fruits decreased with storage and reduction was highest in room temperature than refrigerated storage. Fruits without packaging recorded lowest reducing and non-reducing sugar during the whole storage period whereas all pre-packaging treatments helped in better retention. This result had synchronization with Tefera *et al.* (2007) in mango. Higher reduction in non-reducing sugar stored at room temperature as compared to refrigerated storage might be due to the low temperature and relative humidity compared to the ambient storage (Seyoum, 2002).Total sugar of fruits stored at room temperature was recorded as 16.29% and 14.87% respectively after 6 and 8 days of storage whereas it was 17.22% and 16.76% respectively under refrigerated storage. Among the pre-packaging treatments, highest total sugar of 17.18% and 16.51% was recorded for P_2 (ventilated PP) after 6th and 8th day of storage respectively which did not differ significantly with shrink wrapping (P_4) for both storage days and the lowest was recorded by P_5 (without pre-packaging) as 15.62% and 14.02% after 6 and 8 days of storage respectively. When the interaction effects were studied, after 8th day of storage also no significant difference was noticed among the pre-packaging treatments P_1S_2, P_2S_2, P_3S_2 and P_4S_2 under refrigerated storage. P_2S_1 (ventilated PP + room temperature) showed highest retention of total sugar (15.70%) and showed no difference with P_4S_1 (shrink wrapping + room temperature) under room temperature. Fruits without pre-packaging (control) recorded the lowest total sugar of 15.58% and 12.47% under refrigerated and room temperature storage respectively. After 14th day of storage, ventilated PP + refrigerated storage (P_2S_2) recorded the highest total sugar of 15.45% followed by P_4S_2 (shrink wrapping+ refrigerated storage) 14.22% (Table 4). The lowest total sugar of 13.19% and 11.74% was recorded in P_5S_2 (control + refrigerated storage) after 12th and 14th day of storage respectively. Total sugar content of rambutan fruits ranged between 19.14% and 19.27% at the time of storage. Rambutan stored under refrigerated condition retained the highest total sugar (15.45%) even after 14 days of storage and the fruits stored at room temperature recorded highest reduction in total sugar content. The decrease in total sugar at room temperature could be due to higher rates of metabolic activity and respiration resulting in quick

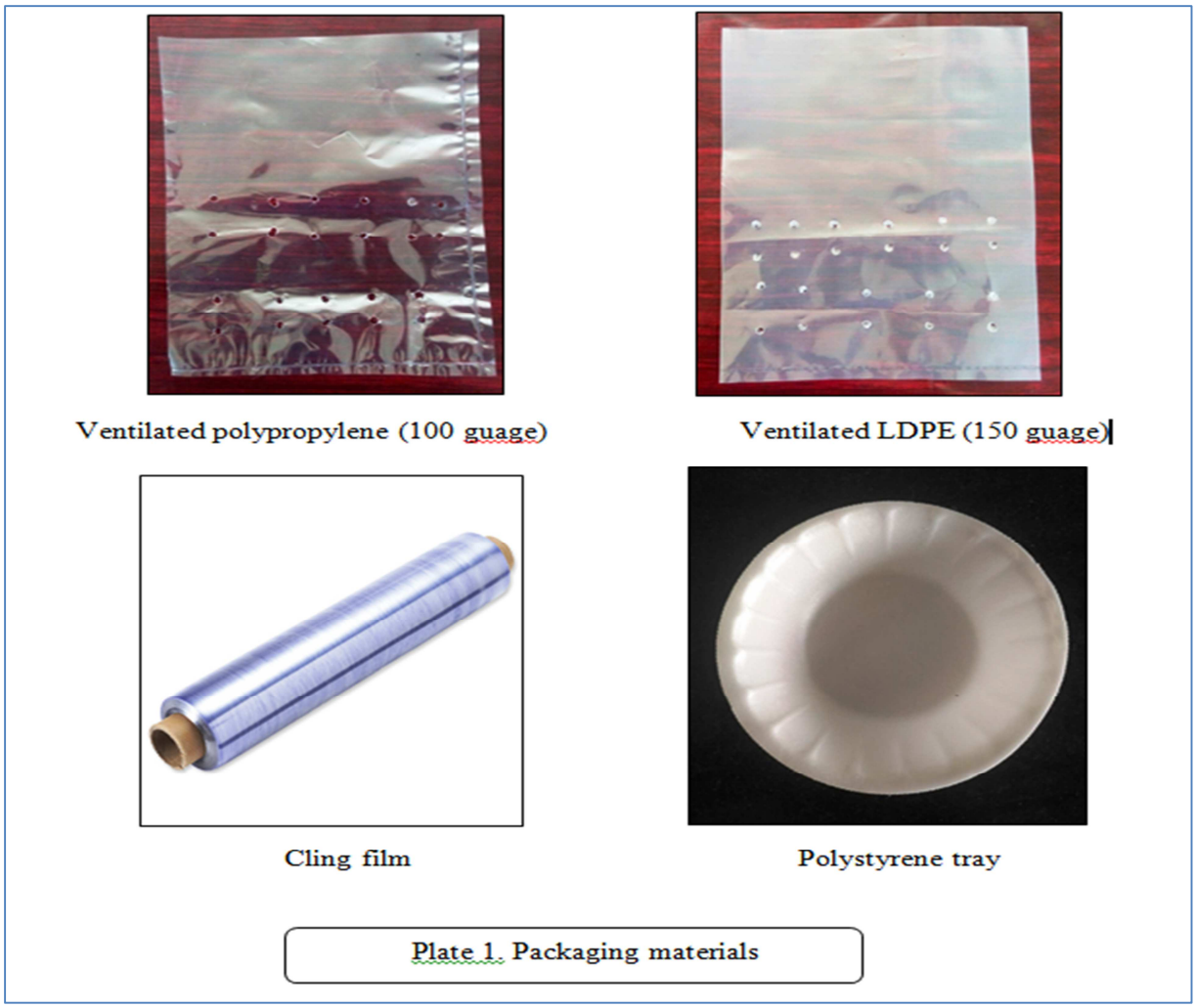

Plate 1. Packaging materials

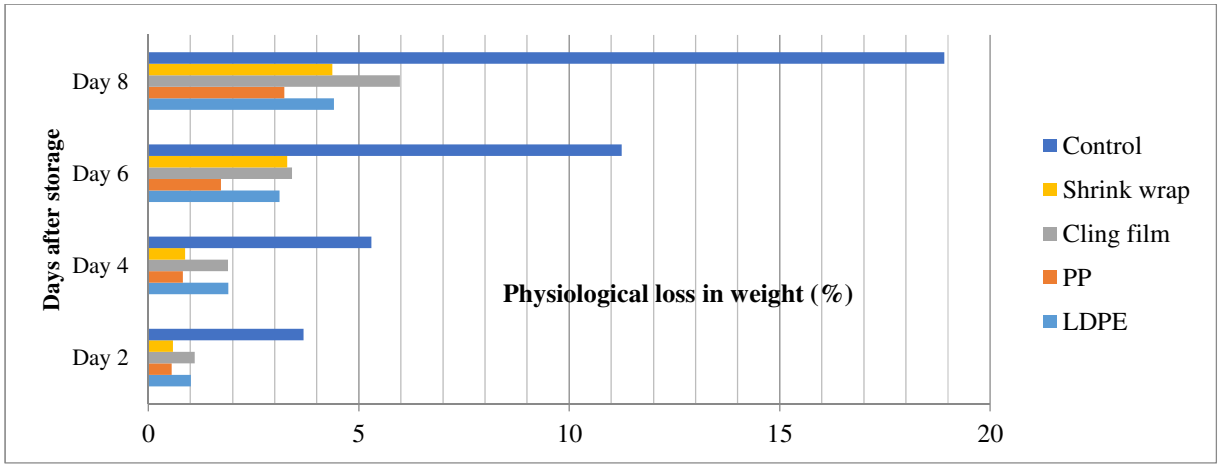

Fig 1a. Effect of pre-packaging on PLW (%) of rambutan fruits under room temperature

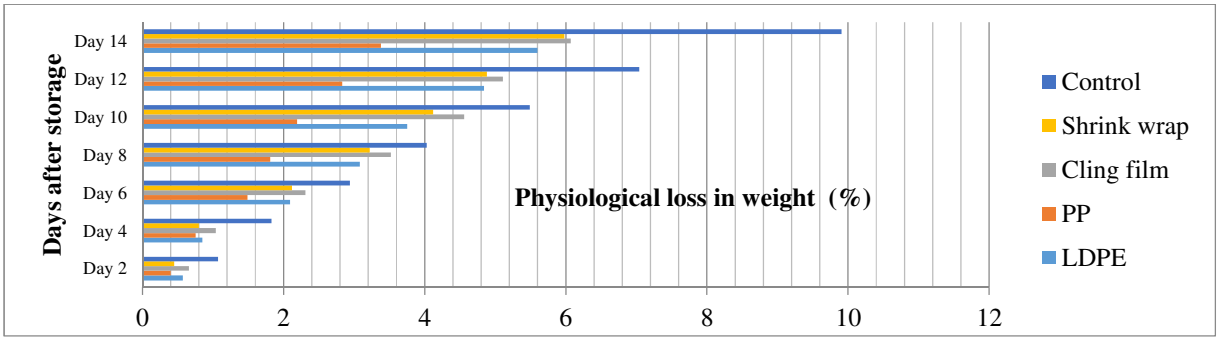

Fig 1b. Effect of pre-packaging PLW (%) of rambutan fruits under refrigerated storage

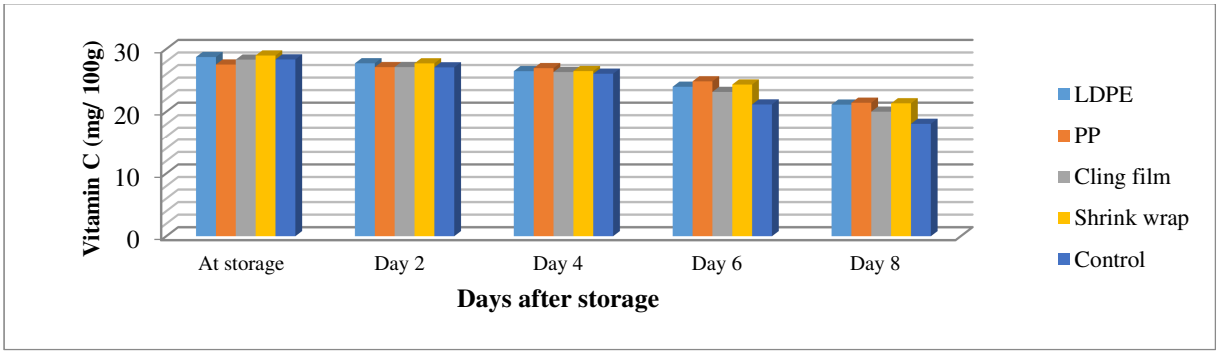

Fig 2a. Effect of pre-packaging on vitamin C (mg/ 100g) of rambutan fruits under room temperature

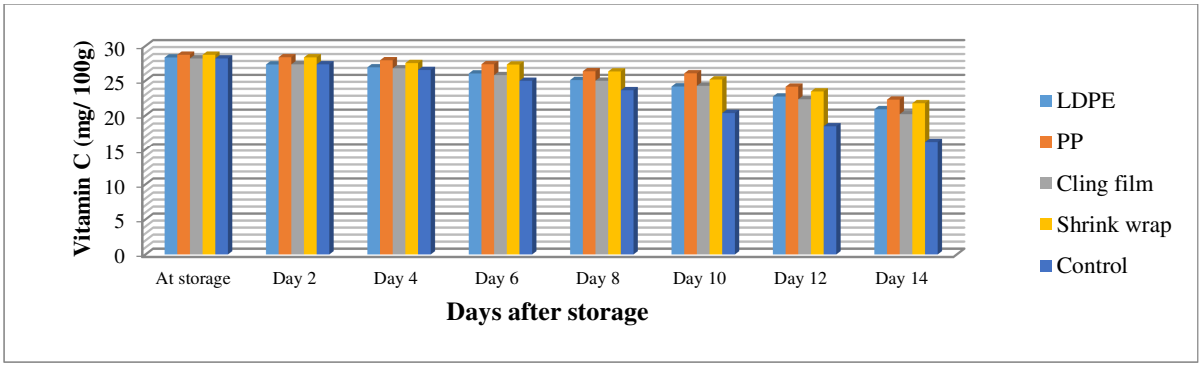

Fig 2b. Effect of pre-packaging on vitamin C (mg/ 100g) of rambutan fruits under refrigerated storage

hydrolysis of sugar (Gomez *et al*., 2002). Pre-packaging of rambutan in ventilated PP stored at room temperature retained maximum total sugar of 15.70% after 8th day of storage.When fruits were packed with pre-packaging materials it created modified atmosphere where consumption of respiratory substrates like sugar are retarded (Chachin *et al*., 2002). Antioxidant activity of fruits recorded 70.23% at room temperature after 6 days of storage and 62.53% after 8 days of storage while it was 76.71% and 72.66% respectively under refrigerated storage. Among the pre-packaging treatments, P_2 (ventilated PP) had (ventilated PP) had highest antioxidant activity of 81.92%, 77.17% and 71.50% followed by P_1 (ventilated LDPE) with 81.10%, 76.26%, 69.82% after 4th, 6th and 8th days of storage and the lowest value was noticed in P_5 (without pre-packaging) as 75.15%, 67.64% and 59.67% respectively. When the interaction effects were studied, after 8th day of storage, treatment P_2S_2 (ventilated PP + refrigerated storage) had the highest antioxidant activity of 76.66% followed by

P_1S_2 (ventilated LDPE + refrigerated storage) (64.72%) and the treatment P_2S_1 (ventilated PP + room temperature) recorded the antioxidant activity of 66.34% followed by P_1S_1 (ventilated LDPE + room temperature) (64.72%) for room temperature storage. The lowest antioxidant activity of 64.21% was for P_5S_2 (control + refrigerated storage) and 55.12% for P_5S_1 (control + room temperature). Rambutan fruits stored under room temperature were discarded due to spoilage after 8th day of storage. The treatment P_2S_2 (ventilated PP + refrigerated storage) recorded the highest antioxidant activity of 69.13% and 64.23% after 12th and 14th day of storage respectively. The lowest antioxidant activity was recorded in treatment P_5S_2 (control + refrigerated storage) after 12th and 14th days of storage as 53.76% and 46.57% respectively (Table 7). Reduction of antioxidant activity of fruits in storage was attributed to the reduction in total phenol content and vitamin C.

On analyzing PLW, and biochemical parameters ventilated PP was found acceptable up to 8 days at room temperature and 14 days at refrigerated condition while untreated fruits had shelf life of only five days under both the storage conditions. The fruits stored without any pre-packaging recorded shelf life of 5 days at room temperature and refrigerated condition whereas fruits pre-packaged in ventilated PP stored under room temperature exhibited a shelf life of 8 days and 14 days under refrigerated condition. This result is in accordance with Widjanarko *et al.* (2000) in rambutan fruits packaged with polypropylene at low temperature (10±1 ^{o}C) extended shelf life up to 12 days. The extension of shelf life at low temperature was due to reduction in metabolism of fruits (Latifah *et al.*, 2009; Julianti *et al.*, 2012; Shao *et al.*, 2013). Intensity of spoilage of pre-packaged rambutan fruits stored at room temperature was high as compared to refrigerated condition. Thus shelf life of rambutan fruit was influenced by pre-packaging treatments and storage temperature.

Conclusion

Pre-packaging as well as storage temperature influenced the biochemical parameters of rambutan during storage. Loss of biochemical parameters was greater with increase in storage temperature and duration. Under refrigerated storage, ventilated PP was ideal as it registered the lowest PLW and excellent biochemical parameters after 14 days of storage. Rambutan fruits without any postharvest treatments had limited shelf life of only 3 days with diminished nutritional and organoleptic qualities. Pre-packaging in ventilated polypropylene (100 guage) could extend the shelf life of fruits up to fourteen days when stored under refrigerated condition and eight days under room temperature storage with minimum nutritional loss.

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