Effects of hot air treatment on postharvest quality of 'cat Hoa loc' mangoes

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Effects of hot air treatment on postharvest quality of 'cat Hoa loc' mangoes.

Abstract — Introduction. Vietnam is among the world's top 20 mango producing countries. In this country, the 'cat Hoa loc' variety is predominant, with 17 692 ha under cultivation with an annual production of 58 471 t; it is considered to be the best mango variety in the Mekong delta. Ripening of the fruit is typically expressed by a skin colour change from green to bright yellow. This variety is highly prized by local and foreign consumers, but subject to different disorders, especially fruit fly infestations. Heat treatment is a safe alternative to chemical treatments. It can impair mould development and control fruit infestation by destroying fruit fly eggs and larvae. It may have a greater or lesser effect on fruit physiology. If the treatment temperature and duration are incorrectly handled, skin burns may result and the internal quality of the fruit may be affected. **Materials and methods**. 'Cat Hoa loc' mangoes at the commercially mature stage were subjected to hot air treatment (47 °C and 90% RH) of different durations [(0, 20, 40, 60, 90, 120 and 180) min from the fruit core attaining the temperature]. After treatment, the fruits were stored at 25 °C and quality parameters evaluated (weight loss, peel and flesh colour, percentages of fruit with burns and rots, burn index, ripening percentage, firmness, TSS, TA, vitamin C content, pH, reducing and total sugars, and taste test). **Results and discussion**. For the 'cat Hoa loc' variety, heat treatment accelerated ripening of the fruit in the initial storage period and colour changes occurred more quickly. However, after 7 days' storage, the difference in Hue value between the treated and control fruits disappeared. Hot air treatment at 47 °C of different durations [(20 to180) min] did not affect the internal coloration changes of 'cat Hoa loc' mangoes, but did affect the flesh firmness. We found that, after 3 d, hot air treatment at 47 °C led to significantly faster weight loss than control fruits but this difference disappeared after 7 d. Total sugar content was not affected by the treatment, but titratable acidity decreased more quickly in treated fruits.

Vietnam / *Mangifera indica* / fruits / postharvest control / heat treatment / quality

Effets du traitement thermique sur la qualité post-récolte de mangues 'cat Hoa loc'.

Résumé — Introduction. Le Vietnam est parmi les 20 premiers pays producteurs de mangues au monde. Dans ce pays, la variété 'cat Hoa loc' est prédominante (17 692 ha cultivés et production annuelle de 58 471 t) ; elle est considérée comme la meilleure variété de mangue dans le delta du Mékong. La maturation du fruit s'exprime généralement par un changement de couleur de la peau qui vire du vert au jaune vif. Cette variété est très appréciée par les consommateurs locaux et étrangers, mais elle est sujette à divers troubles, notamment à des infestations par la mouche des fruits. Le traitement thermique est une bonne alternative aux traitements chimiques. Il peut altérer le développement des moisissures et contrôler l'infestation des fruits par la destruction des œufs et des larves de la mouche des fruits. Il peut avoir un effet plus ou moins marqué sur la physiologie des fruits. Si la température de traitement et la durée ne sont pas correctement ajustées, il peut se produire des brûlures de la peau et la qualité interne des fruits peut être affectée. **Matériel et méthodes**. Des mangues 'cat Hoa loc' au stade de maturité commerciale ont été soumises à un traitement thermique (47 °C et 90% d'humidité relative) pendant différents temps [(0, 20, 40, 60, 90, 120 et 180) min après obtention de la température voulue au cœur du fruit]. Après traitement, les fruits ont été conservés à 25 °C et certains paramètres de qualité ont été évalués (perte de poids, couleur de la peau et de la chair, pourcentage de fruits avec brûlures et pourriture, indice de brûlure, pourcentage de maturation, fermeté, SST, AT, teneur en vitamine C, pH, sucres réducteurs et totaux, tests gustatifs). **Résultats et discussion**. Pour la variété 'cat Hoa loc', le traitement thermique a accéléré la maturation des fruits au début de la période de stockage et des changements de couleur se sont produits plus rapidement. Toutefois, après 7 j de stockage, la différence de valeur Hue entre les fruits traités et les témoins a disparu. Le traitement thermique à 47 °C pendant (20 à 180) min n'a pas eu d'incidence sur les changements de coloration interne des mangues 'cat Hoa loc ', mais il a affecté la fermeté de la chair. Nous avons constaté que, après 3 j, le traitement thermique à 47 °C a induit une diminution de poids significativement plus rapide que celle des fruits témoins, mais cette différence a disparu après 7 j. La teneur totale en sucre n'a pas été affectée par le traitement, mais l'acidité titrable a diminué plus rapidement dans les fruits traités.

Viet Nam / *Mangifera indica* / fruits / lutte après récolte / traitement thermique / qualité

1. Introduction

Vietnam is among the world's top 20 mango producing countries. In 2004, Vietnam's mango production was around 314 000 t, from 79 000 ha. Mango cultivation is concentrated in the southern part of the country, especially in the Mekong delta and the South-east provinces. The 'cat Hoa loc' variety is predominant, with 17 692 ha under cultivation and an annual production of 58 471 t.

The 'cat Hoa loc' mango is considered the best mango variety in the Mekong delta [1]. The fruit of this variety weighs between 400 g and 500 g, with a fine, firm and sweet flesh (19–22 °Brix), and a high edible proportion (77%). Ripening of the fruit is typically expressed by a skin colour change from green to bright yellow. This variety is highly prized by local and foreign consumers.

Heat treatment is a method increasingly used in postharvest handling of fruits; it is a safe alternative to chemical treatments as it can impair mould development [2, 3]. The application of a heat treatment to control fruit diseases was reported for the first time in 1922 [4]. At present, to meet the requirements of demanding importer countries, such as the USA, Japan and New Zealand, heat treatment is the most commonly used treatment for mangoes, papaya and citrus, for example, since it is able to destroy fruit fly eggs or larvae [5–12].

Heat treatment may have a greater or lesser effect on fruit physiology. It causes a significant increase in respiration rate and greater weight loss after treatment. The firmness and titratable acidity of the fruit are reduced, and the Brix degree is higher than in untreated fruits ([13], Do Minh Hien *et al.*, unpublished results). Pal *et al.* [14] found that 'Baneshan' variety mangoes treated with hot air produced a more attractive skin colour than the controls, making it possible to increase the fruit's export potential. If the treatment temperature and duration are incorrectly handled, skin burns may result, with the internal quality of the fruit being affected [15, 16].

Hot water treatment of 'cat Hoa loc' mangoes (55 °C, 5–10 min) did not affect fruit quality, but reduced anthracnose development during storage at 12 °C. However, this treatment duration was not sufficient as an insect elimination treatment. Furthermore, if the duration is increased, adverse effects are observed in quality, with the appearance of skin burn symptoms, and abnormal or completely impeded ripening (Do Minh Hien *et al.*, unpublished results).

This work describes the effects of hot air treatment on the various physiological processes of the 'cat Hoa loc' mango. This study will lead to the selection of a time/temperature combination that can maintain mango quality during storage, as well as being an effective fruit fly treatment.

2. Materials and methods

2.1. Fruit

Mango fruit (cv. 'cat Hoa loc') were sourced from an orchard located in Tien Giang Province, in South Vietnam, at the commercial maturity stage; the average weight of fruit was (507 ± 61) g. After harvest, the fruit were rapidly transported to the postharvest laboratory at SOFRI (Southern Fruit Research Institute, Vietnam) the same day, weighed and held at 25 °C for 24 h before being treated.

2.2. Experimental design and heat treatment

The treatment consisted of heating fruit to a core temperature of 47 °C for periods of (20, 40, 60, 120 or 180) min. Non-heated fruit were included as a control.

The treatments were applied as six separate runs in an experimental heat treatment Sure Fruit Unit (0.3 m^3) constructed by HortResearch. The chamber in each run contained six baskets each holding 16 fruit: 15 fruit for assessment, plus a single fruit of similar weight to the others in the basket for logging fruit temperature response. The probe fruit contained two PT100 thermister probes, one inserted into the core, the other immediately below the skin surface (~2 mm deep).

Run conditions for the lower temperature treatment comprised heating the chamber from (35 to 47.8) °C over 180 min at 90% RH. This temperature was maintained for 60 min, and then decreased (over 5 min) and held at 47.5 °C until the core temperature in the respective probe fruits reached their target of 47 °C. After the specified duration at the target temperature (based on the fruit temperature of the probe fruit for each individual basket), fruit were removed and hydro-cooled in a water shower for 90 min with ambient temperature water (~30 °C). After completion of heat treatment and hydro-cooling, all fruit were air-dried and stored at 25 °C.

2.3. Fruit quality assessments

Fruit weight loss (OHAUS CS 5000 balance, USA) was calculated with regard to the initial mass of the fruit and expressed as a percentage. Ripening percentage was assessed by numbering ripe fruits at the time of observation with regard to the initial number of fruits. Number of fruits with rots at the time of observation with regard to the initial number of fruits gave the rot percentage and number of fruits with burns at the time of observation with regard to the initial number of fruits gave the burn percentage.

The burn index was calculated according to the degree of burn from 0 to 4 (0: without burn, 1: total burned surface < 5%, 2: total burned surface between (5 and 10)%, 3: total burned surface between (11 and 20)%; and 4: total burned surface > 20% of the surface of the fruit) with: burn index = Σ[(Number of fruits burned at each level × level of burn) / total number of fruits].

Flesh firmness was measured four times around the equator using a FT 327 penetrometer (Italy) (0–15 N, 8 mm diameter head). Peel and flesh colours (L, a^*, b^*) were measured four times around the equator for the peel and twice per part when the fruit was cut, using a Minolta chromameter (CR300 with a D65 light source; Minolta Camera Co., Osaka, Japan). pH was obtained by pH meter (WTW pH, Inolab Level 1, Germany), titratable acidity was expressed by citric acid equivalents by titration with 0.1 N NaOH, and total soluble solids was measured with an Atago refractometer (0–32%).

Vitamin C content was assessed by titration with 0.1% 2, 6-dichloroindophenol, reducing and total sugars by Lane and Eynon's method (these measurements were made on juice expressed from flesh of the whole fruit filtered through nylon cloth), and taste by a five-point hedonic scale.

2.4. Data analysis

All the data obtained were submitted to analysis of variance (ANOVA) and comparisons were made by Duncan's method ($P = 0.05$) using the statistics software STAGRAPHIC version 7.0.

3. Results and discussions

3.1. Peel colour

The L^* value of mango peel colour increased during ripening, and this increase was affected by heat treatment. We found that, 3 d after treatment, the L^* value of treated fruits was between 60.17 and 63.07, whereas, for the control fruits, it was 59.91. This difference was significant after 7 d (*table I*).

The two fruit skin values a^* and b^* also increased during storage at 25 °C. Three days after treatment, a significant difference was found between the treated and control fruit in the a^* value. However, this difference disappeared after 7 d (*table I*).

The Hue angle decreased as the fruit ripened, which explains the change from green to yellow of the 'cat Hoa loc' mango skin. After 3 days' treatment, there was a significant visible difference in the Hue value between the treated fruit (114.81–115.99) and control fruit (118.61). This may be explained by the effect of heat treatment, which can accelerate fruit ripening in the initial storage period. However, after 7 d no differences between the lots were noted for Hue angle (*table I*).

Table I.
Effect of hot air treatment on peel and flesh colour changes of 'cat Hoa loc' mangos after 3 d and 7 d at 25 °C.

Duration of heat treatments at 47 °C (min)	Peel, 3 d after treatment				Peel, 7 d after treatment				Flesh, 7 d after treatment			
	L*	a*	b*	Hue value	L*	a*	b*	Hue value	L*	a*	b*	Hue value
Control	59.91	– 18.77 c	34.32	118.61 a	62.20 d	– 13.22	41.59 c	106.97	70.73	1.33	66.55	88.93
20	62.39	– 17.39 b	35.73	115.99 b	64.18 ab	– 9.02	44.00 ab	101.64	70.05	1.60	66.82	88.67
40	63.07	– 16.78 b	36.03	114.93 b	65.00 a	– 10.58	44.28 a	103.51	72.13	1.28	66.60	88.93
60	62.07	– 17.23 b	36.10	115.55 b	64.39 ab	– 10.15	44.57 a	102.85	70.68	0.61	64.62	89.50
90	60.17	– 16.22 a	35.10	114.81 b	62.97 cd	– 11.07	42.10 c	104.70	68.88	1.35	65.37	88.90
120	62.43	– 17.20 b	36.54	115.19 b	63.59 bc	– 11.92	42.84 bc	106.06	69.74	1.07	65.17	89.17
180	61.21	– 17.25 b	37.82	115.71 b	63.21 bcd	– 12.24	42.16 c	106.39	71.45	0.27	64.02	89.80

Means followed by the same letter in a column are not significantly different (Duncan's test. $P < 0.05$).

Heat treatment increased the peel colour change of 'Carabao' variety mangoes harvested at the green stage [17]; and the colour of treated mangoes was more attractive than for untreated fruits [17, 14]. For the 'cat Hoa loc' variety, heat treatment accelerated ripening of the fruit in the initial storage period, and coloration appeared more quickly. However, after 7 days' storage, the difference in Hue angle between the treated and control fruits disappeared.

3.2. Flesh colour

After 7 days' storage at 25 °C, the coloration values of mango pulp subjected to heat treatment were no different from the control fruit values (*table I*). This demonstrates that hot air treatment at 47 °C of different durations (20–180 min) does not affect the internal coloration change of 'cat Hoa loc' mangoes.

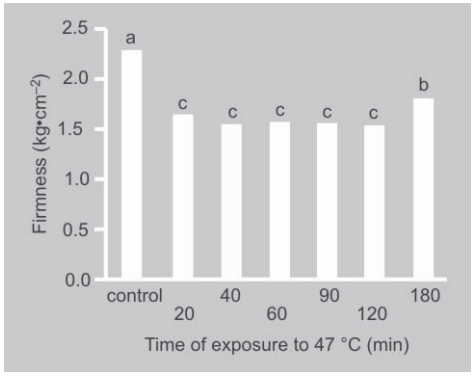

Figure 1.
Effect of different times of exposure of 'cat Hoa loc' mangoes to heat treatment (47 °C) on the flesh firmness after 7 d at 25 °C.

3.3. Weight loss

Weight loss is a natural process observed in the postharvest stage, whatever the fruit in question. However, the speed of this process is dependent on several factors, such as the ambient conditions (temperature and relative humidity), the condition of the product when harvested (ripeness, wounds, bruising) and the postharvest treatments used (heat treatment), etc. Heat treatment increased weight loss in Kensington variety mangoes [18, 19].

For our study, we found that hot air treatment at 47 °C led to significantly faster weight loss than the control after 3 d (data not shown), but that this difference disappeared after 7 d (*table II*); the longer the treatment time, the greater the weight loss. After 7 d at 25 °C, the 47 °C / 180-min treatment resulted in the highest weight loss (13.45%), while the control was the lowest (10.57%).

3.4. Flesh firmness

We found that flesh firmness was affected by heat treatment. The control fruits had the highest firmness value (2.28 kg·cm^{-2}), while the treated fruit firmness values varied between (1.56 and 1.81) kg·cm^{-2} (*figure 1*).

Table II.
Effect of hot air heat treatment on external quality and weight loss changes of 'cat Hoa loc' mangoes after 7 d at 25 °C.

Duration of heat treatments at 47 °C (min)	Weight loss %	Ripening %	Burn %	Rot %	Burn index
Control	10.6	73.3 b	0.0 b	43.3 a	0.0 b
20	10.8	100.0 a	0.0 b	0.0 b	0.0 b
40	10.8	100.0 a	80.0 a	0.0 b	0.9 a
60	11.1	100.0 a	73.3 a	6.7 b	1.0 a
90	11.5	86.7 ab	93.3 a	6.7 b	1.3 a
120	12.3	86.7 ab	73.3 a	10.0 b	1.0 a
180	13.4	80.0 b	100.0 a	10.0 b	1.1 a

Means followed by the same letter in a column are not significantly different (Duncan's test. $P < 0.05$).

In another study on 'Carabao' variety mangoes subjected to hot air treatment, Cabahug also observed decreased firmness in treated fruits [20]. The same results were found for Kensington variety mangoes subjected to hot air treatment at 47 °C for 15 min [18, 19].

3.5. Ripening percentage

Heat treatment affected the ripening percentage after 3 d (data not shown) and 7 days' storage at 25 °C. The duration of treatment, between (20 and 40) min at 47 °C, significantly accelerated fruit ripening in comparison with the other treatments (*table II*). The fruit from two treatments [(120 and 180) min] were not ripe after 3 days' storage, nor were the control fruits. This may be explained by inhibition of the activity of -amylase, which hydrolyses starch during fruit ripening [21]. After 7 days' storage, the (20- to 120-) min treatments exhibited no significant difference in terms of percentage ripening from the 180-min treatment and untreated control *(table II)*.

3.6. Burn percentage and rot percentage index

The percentage of burned fruit in all the treatments from (40 to 180) min was high (73.33–100.00%) after 7 days' storage at 25 °C. The main symptom was the appearance of brown spots on the mango surface. Brown spotting was more pronounced and appeared more quickly with the 180-min treatment (1 day after treatment); with the other treatments, the symptoms appeared more slowly. A treatment duration of 20 min was deemed to be optimal, posing the least risk of undesirable quality changes in the 'cat Hoa loc' variety (*table II*).

The burn index was higher (0.93–1.33) and not significantly different for the (40- to 180-) min heat treatments (*table II*).

After 7 d, the highest rot percentage was 43.3% for the untreated control. It was significantly different from the hot air treatments (*table II*). This demonstrates the effectiveness of heat treatment in limiting postharvest mould development, particularly anthracnose, in mangoes.

In previous studies, hot water treatment of 'cat Hoa loc' mangoes caused the appearance of skin burns on the fruit, but also limited fungal development (Do Minh Hien *et al.*,unpubl. results). Coates *et al.* found that steam treatment of Kensington variety mangoes at 46.5 °C for 10 min from the fruit core attaining the temperature effectively controlled *Dothiorella dominicana* fungi, responsible for mango stem-end rot [22].

3.7. Biochemical changes

The °Brix of the fruit of all the heat treatments was higher (19.60–22.20%) than for the untreated control (19.00%) after 7 d at 25 °C. However, there was no significant

Table III.
Effect of hot air treatment on the chemical composition of 'cat Hoa loc' mangoes after 7 d at 25 °C.

Duration of heat treatments at 47 °C (min)	Soluble sugar content (°Brix)	Titratable acidity (%)	pH	Vitamin C (mg·100 g^{-1})	Reducing sugar (%)	Total sugar (%)
Control	19.00 a	0.20 a	4.93 bc	31.80 a	0.82 c	5.65 a
20	20.80 a	0.16 bc	5.10 b	30.33 a	1.37 a	4.03 a
40	19.60 a	0.17 bc	5.60 a	29.63 a	0.85 bc	4.77 a
60	20.60 a	0.15 c	5.10 b	29.35 a	1.17 a	4.25 a
90	20.40 a	0.18 ab	4.83 c	30.23 a	1.41 a	5.24 a
120	22.20 a	0.19 a	5.10 b	25.49 b	1.14 ab	5.61 a
180	20.20 a	0.15 c	5.07 b	24.06 b	1.23 a	6.35 a

Means followed by the same letter in a column are not significantly different (Duncan's test. $P < 0.05$)

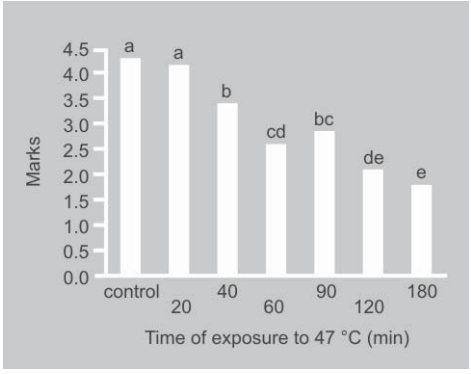

Figure 2.
Effect of different times of exposure of 'cat Hoa loc' mangoes to heat treatment (47 °C) on the organoleptic quality of mango after 7 d at 25 °C.

difference between the heat treatments. Titratable acidity decreased quicker in heat-treated fruits. This reflects faster ripening of treated fruits than of control fruits.

Extended treatment duration (120–180 min) significantly reduced the vitamin C content of mango pulp after 7 days' storage (24.06–25.49 mg·100 g^{-1}) compared with the controls, which had the highest content (31.80 mg·100 g^{-1}). The total sugar content was not affected by hot air treatment (*table III*).

Jacobi *et al.* [18] and Nyanjage *et al.* [23] also demonstrated that heat treatment for mangoes had the effect of increasing the °Brix and that the acid content was lower than in controls [18].

3.8. Taste test

Extending the treatment duration had adverse effects on ripe mango quality. Fruit treated for between (60 and 180) min had overripe flesh, with little natural aroma and a fermented taste. Therefore, the marks for these treatments were low, below the acceptable mark (< 3). For the two treatments of (20 and 40) min, the marks were higher, especially for the fruits from the 20-min lot (4.20), a mark equivalent to the control fruit (4.33) (*figure 2*).

4. Conclusions and prospects

Hot air treatment of 'cat Hoa loc' mangoes (47 °C) with RH 90% for 20 min does not affect the ripening process, biochemical composition or organoleptic quality of the fruit. This treatment does not cause any skin burns, and limits postharvest mould development in the mangoes. 'Cat Hoa Loc' mangoes are thus a suitable candidate for fruit fly disinfestation by hot air. However, it has to be shown that this treatment is effective against fruit fly, because treatments found in the literature were longer: for example, Miller *et al.* [24] found the best results on 'Tommy Atkins' mangoes at 51.5 °C for 125 min, while Mitcham and Mc Donald [25] found a temperature of 46 °C for 3-4 h for 'Keitt' and 'Tommy Atkins' fruits to be optimum. Depending on the country of origin, mango fruit may be infested by one or more species of fruit flies, and any disinfestation treatment must meet a prescribed degree of statistical probability of death of over

99.9968% to be accepted by quarantine authorities. We must now prove the efficiency of the treatment in disinfestation.

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Efectos del tratamiento térmico en la calidad post-cosecha de mangos 'cat Hoa loc'.

Resumen — Introducción. Vietnam se encuentra entre los 20 primeros países del mundo productores de mango. En este país predomina la variedad 'cat Hoa loc ' (17 692 ha cultivadas y producción anual de 58 471 t); se considera como la mejor variedad de mangos en el delta del Mekong. La mutación del fruto se expresa generalmente mediante un cambio de color de la piel que va del verde al amarillo vivo. Dicha variedad se aprecia mucho por los consumidores locales y extranjeros, pero está sujeta a diversos problemas, sobre todo a las infestaciones por la mosca de los frutos. El tratamiento térmico es una buena alternativa en lugar de los tratamientos químicos. Puede alterar el desarrollo de moho y controlar la infestación de los frutos mediante destrucción de los huevos y de las larvas de las moscas de los frutos. Puede tener un efecto más o menos marcado en la fisiología de los frutos. Si la temperatura de tratamiento y la duración no se ajustan correctamente, pueden producirse quemaduras de la piel y la calidad interna de los frutos puede verse afectada. **Material y métodos**. Se sometieron a un tratamiento térmico (47 °C y el 90% de humedad relativa) durante tiempos diferentes [(0, 20, 40, 60, 90, 120 y 180) min después de obtención de la temperatura deseada en el corazón del fruto] unos mangos 'cat Hoa loc' en el estadio de madurez comercial. Después de tratamiento, los frutos se conservaron a 25 °C y ciertos parámetros de calidad se evaluaron (pérdida de peso, color de la piel y de la pulpa, porcentaje de frutos con quemaduras y podredumbre, indicio de quemadura, porcentaje de maduración, firmeza, SST, AT, contenido en vitamina C, pH, azúcares reductores y totales, testeos gustativos). **Resultados y discusión**. Para la variedad 'cat Hoa loc', el tratamiento térmico aceleró la maduración de los frutos al principio del periodo de almacenamiento y se produjeron cambios de color más rápidamente. Sin embargo, tras 7 días de almacenamiento, desapareció la diferencia de valor Hue entre los frutos tratados y los testigos. El tratamiento térmico a 47 °C durante (20 a 180) min no tuvo incidencia en los cambios de coloración interna de los mangos 'cat Hoa loc', pero afectó la firmeza de la pulpa. Constatamos que, después de 3 días, el tratamiento térmico a 47 °C indujo una disminución de peso significativamente más rápida que la de los frutos testigo, pero esta diferencia desapareció tras 7 días. El contenido total en azúcar no se vio afectado por el tratamiento, pero la acidez valorable disminuyó más rápidamente en los frutos tratados.

Vietnam / *Mangifera indica* / frutas / control de postcosecha / tratamiento térmico / calidad