Universidad Autónoma de Querétaro

FACULTAD DE QUÍMICA

DEPARTAMENTO DE INVESTIGACION Y POSGRADO EN ALIMENTOS

# FINAL REPORT

"The application of Gamma-Ray Irradiation as a quarantine treatment, and its effects on the quality of different varieties and sizes of mango fruit grown in different regions of Mexico"

**Presented by**

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**For**

**The National Mango Board**

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## 1. EXECUTIVE SUMMARY

Mango fruits of six varieties (‘Tommy Atkins’, ‘Haden, ‘Kent’, ‘Keitt’, ‘Ataulfo’ and ‘Manila’) produced in different regions of Mexico at two maturity stages (¼ and ¾), were irradiated with gamma rays from $_{60}$Co at different ranges (0, 0.15-0.44; 0.50-0.88 and 0.87-1.52 kGy), using an commercial irradiator and then stored a 10 and 20°C for 19 days. At different time periods, the external and internal visual quality as well as the physicochemical quality (firmness, ascorbic acid, acidity titratable, solid soluble content and flesh and skin color) was measured.

The changes in the external and internal quality were the most important factors to evaluate the gamma irradiation effect on mango fruit. On this basis, all varieties in both maturity stages did not show external or internal damages when they were submitted into 0.15 to 0.44 kGy range. However, all varieties showed external and internal damages when they were irradiated at 0.92 to 1.52 kGy

The skin and flesh browning as well as the spongy tissue development were the damages observed. These studies indicated that irradiation should be avoided in fruit at ¼ maturity stage; being more advisable to irradiate fruit at maturity ¾. Under these restrictions, the maximum tolerated dose depended on the variety; the varieties ‘Kent’ and ‘Ataulfo’ were the most tolerant to irradiation which could withstand up to 0.86 kGy, while the varieties ‘Tommy Atkins’, ‘Haden’, ‘Keitt’ and ‘Manila’ were more sensitive, suggesting that these varieties does not should be irradiated above 0.6 kGy.

The fruit storage at 10°C increased the damages caused by the irradiation treatment, these damages were evident when the fruit was transferred at 20°C, indicating that was an additive effect of irradiation stress and the chilling temperature stress.

The analysis of physicochemical data showed that any variable response could be considered an adequate estimator to measure the irradiation dose effect because these responses depended on the variety, maturity stage and the storage conditions of the fruits.

However, when some negative effect of the irradiation dose was observed in some physicochemical factor, generally this was associated with high irradiation doses in addition to ¼ maturity stage. For these reasons it is recommended to process fruit at ¾ maturity and avoid irradiate it above the doses indicated for each variety (0.86 kGy for ‘Kent’ and ‘Ataulfo’ and 0.6 kGy for ‘Tommy Atkins’, ‘Haden’, ‘Manila’ and ‘Kent’).

## 2. PROPOSSED OBJECTIVES:

MAIN OBJECTIVE: Determine the maturity stage effect and irradiation dose on the fruit quality of six mango varieties

SECONDARY 0BJECTIVES

Identify the maturity stage and maximum dose which should be applied to the fruit without alter its quality.

Observe if the size fruit affect the visual and physiological responses of the irradiated fruits

## 3. WORKS DEVELOPMENT:

### 3.1 Experimental design and methodology used.

The experimental design was a full four-factor design with two replicates $4x2^3$, which generated 32 treatments. The irradiation doses (0, 0.15, 0.60 and 1.00 kGy), the maturity stage (¼ and ¾), the fruit size (size 8 or 10 gauge or C8 and C10) and storage temperature (10 and 20°C) were the factors studied. The experimental units in each sampling period were three fruits and the analysis was applied at 192 fruits at each sampling period.

The weight loss, firmness fruit, internal and external color, acidity titratable, ascorbic acid and solid soluble content were the response variables.

The original project did not consider studying the changes in the fruit stored at 10°C and transferred at 20°C; these samples were incorporated after the first sampling of the first variety studied. By the number of factors involved in the experiment, it was necessary to investigate which of them had minor importance into the project purposes. With the first sampling data, a general analysis of variance was performed using the JMP 5.0.1 statistical package and a means comparison test (Tukey 0.05) to determine the significance of each factor. The fruit size factor had less significance in comparison with other factors (Results Section). Therefore, the experimental design applied to the other varieties was a full factorial design 4X2X3; with three factors comprising the irradiation doses (0, 0.15, 0.60 and 1.00 kGy), maturity (¼ and ¾) and storage temperature (10 and 20 ° C and its transfers from 10 to 20°C). A total of 24 treatments were conformed for each variety with two replicates. The experimental unit was composed of three fruits analyzed separately for the same response variables identified.

To reach the central objective of the project respect of radiation dose effect on different mango varieties from two maturity stages and stored at two storage temperatures; the analysis of variance were performed grouping the data of each variable response into each maturity stage and storage temperature and analyzing the radiation dose effect during each period of storage and its interactions. The statistical analysis was performed using the same statistical package mentioned before and the means comparison test was conducted using the Tuckey test at 0.05 as a confidence level. This analysis allowed describing in a specific way the radiation dose effect in all period of storage for each maturity stage and storage temperature.

The weight loss was calculated by the weight difference between the initial weight of the fruits in each treatment and the final weight of the same samples after each sampling period. The weight difference found it was expressed as weight percentage respect of the initial weight.

The firmness fruit was registered trough the compression force of the whole fruit (with skin); using a texture analyzer TA-HD equipped with load cell of 70 Kgf equivalent to 686.5 Newtons (N) and a circular flat probe of 50 mm of diameter and 20 mm of high which descended at 2 mm $s^{-1}$ rate. The fruit was collocated in horizontal position on a flat plate and was compressed to reach 3% deformation respect of the maximum high of the fruit; a second compression was applied to same fruit in the opposite point of the first compression (180° gyros). The maximum force to reach the deformation setting was registered; both values were averaged to register the firmness value of each fruit.

The external color was registered on the epidermis of equatorial zone of the fruit; whereas the flesh color was measured in a longitudinal cut of the fruit following a parallel plane to the seed and located at 5 mm of the peduncles fruit center. On the surface cut, a central zone near the seed was choosing to make the measurement using a spectrophotometer Minolta CM-2002. Both measurements were made using a C illuminant and observer at 2° and registering the a* value of the International Scale of color CIELAB.

The solid soluble content was registered at 20°C on the juice extracted of each fruit through the measurements of °Bx using an Abbe refractometer calibrated with distilled water at that temperature.

The titratable acidity was measured in 10g of sample and 10 mL of distilled water, homogenized during 30 s at 13 500 rpm using a tissue homogenizer ULTRA TURRAX T25; an aliquot of 5 mL was titrated with NaOH 0.1N solution using phenolphthalein as indicator and calculating the percentage of citric acid in according with the procedure indicated by the AOAC (1998).

The ascorbic acid content was quantified following the 43.059 method of the AOAC (1998). One gram of fresh tissue was homogenized with 9 mL of 3% metha phosphoric acid solution; 5 mL of the mix were titrated with 2, 6 dichloride phenol indo phenol previously standardized with an ascorbic acid solution of concentration known.

### 3.2 Origin and harvest fruits

The Annex 1 shows a graphic sequence of the operations following during the experiment from the harvest to irradiation process. The fruit was harvested from certificated orchards to exportation market and brought to the packing facilities of two companies exporters, one of them denominated "El Colibrí" located in Michoacán Mexico and the other denominated "Empacadora Arivania" located in Nayarit Mexico both associated to EMEX A.C. organization. The "El Colibrí" company provided the 'Haden' and 'Tommy Atkins' varieties from "Tierra Caliente and "Nuevo Urecho" Michoacán which were harvested during April and May in 2009; whereas the "Empacadora Arivania" company provided the ' Keitt' variety harvested in Escuinapa Sinaloa and the 'Kent', 'Ataulfo' and ' 'Manila' varieties were harvested in Tecoala Nayarit during June and July of 2009. Technical personal of these companies help us to harvest the fruit and transport them to packing facilities to select them by maturity stage (¼ y ¾). The maturity stage was determined by the filling shoulder and the external appearance of the fruit; some fruits were cut randomly to evaluate the internal color of the flesh and this was compared with color chart of the exporting companies. Fruit in ¼ maturity stage should have a similar minimum flesh color of the fruit designated to the hot water treatment; whereas the fruit in ¾ maturity had a development lightly higher than the green maturity fruits and higher yellow color development of the flesh.

### 3.3 Select, classifying, packaging and fruit transport

After the selection by maturity stage; the fruit were classifying by size and packaging in corrugated cardboard boxes following the same place packing system to exportation market. The boxes were identified by the irradiation treatment and storage condition after the set boxes were palletized, and transported to Sterigenics Company facilities in Tepeji del Rio, Mexico.

In the irradiation facilities, the boxes were separated by treatment and all fruit were marked and weighed and returned to the original box.

### 3.3. Irradiation treatments application

The irradiation treatments were applied in the Sterigenics Co. which has an industrial radiator of 5 million Curies from a $_{60}Co$ source and capacity to process 20 tons of products continuously.

To avoid wide dose heterogeneity into each treatment; previous test were carried out to determine the more appropriated position and exposition time of the boxes to the radiation source, two Alanine dosimeters were placed in each box; one of them placed on the fruit located at the geometrical center of the box and the other on the fruit located at the corner of the same box; after each treatment, the dosimeters were removed and then analyzing in a resonance electronic spin equipment (ESR, Bruker BioSpin's e-scan EPR, EUA) to measure the absorbed dose. The dose distribution for each box and in the box set into the radiation chamber was calculated with the dose absorbed data.

The best position was to place two sets of three boxes in the second floor of the radiation chamber as shown in figure 1.

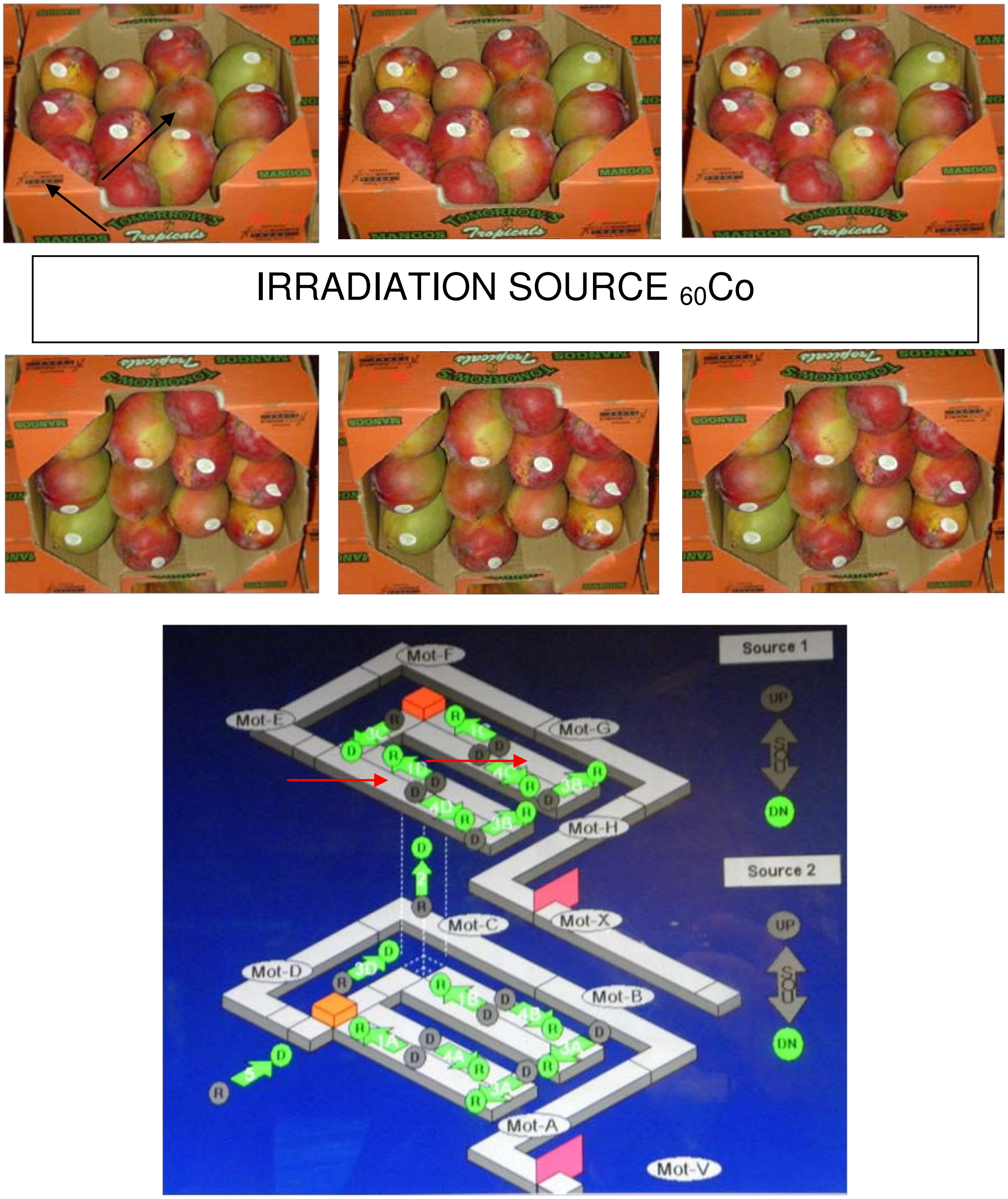



Figure 1 Location of the mango boxes to the irradiation source of $_{60}$Co. The black arrows indicate the fruit where the dosimeters were placed (center and corner of each box). The boxes were placed in the second floor of the irradiation chamber on the track that indicates the red arrows.

### 3.3 Dose applied and distribution

The figure 2 shows the average of minimum, maximum, median and means dose which were applied to fruit of different mango varieties during the experiments; and the Annex 2 collect these data for the fruit located at the center and corner of the boxes. In according with the irradiation technology by gamma rays, the dose did not be uniformly distributed into the boxes; the fruit near the radiation source showed the highest values than the fruit located at the geometric center of these boxes where the minimum values were registered indicating a decrease of dose absorbed from the box surface until the center. The dose range values in all varieties were 0.15 – 0.44; 0.50 – 0.88 y de 0.87 – 1.52 kGy for the proposed dose of 0.15; 0.60 and 1.00 kGy respectively. These data show that the radiation range did not overlap in different varieties and then the effects associated to dose on the fruit quality could be associated to the range dose indicated previously.

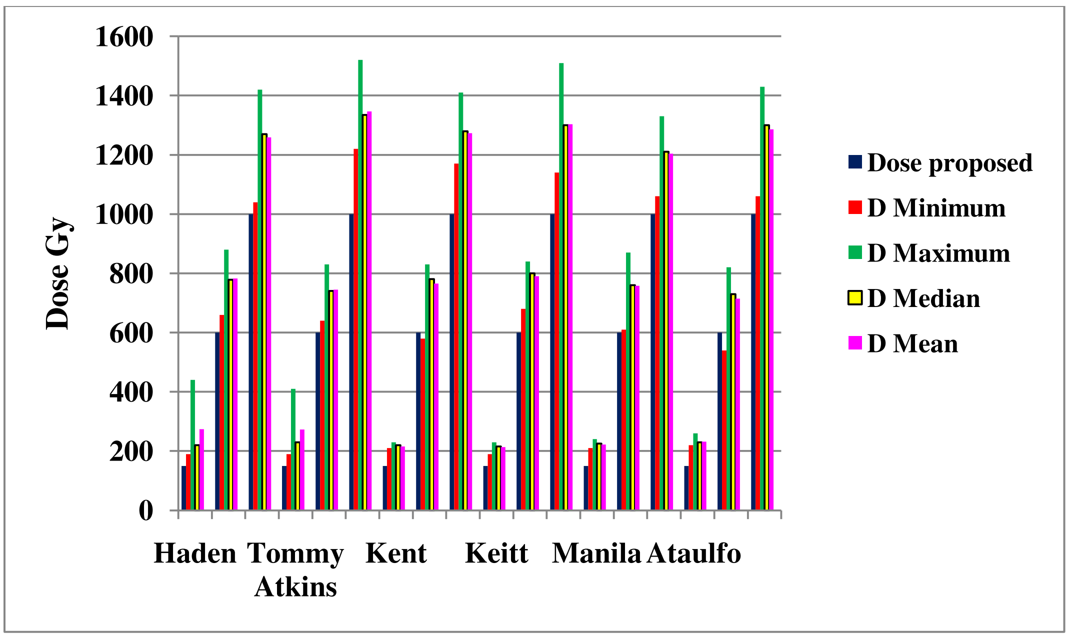



**Figure 2 Comparison of minimum, maximum, median and mean dose applicated to different mango varieties respect of proposed dose in the experiments**

Once finished the radiation treatments, the boxes were placed newly in a pallet, strapping and transported to Universidad Autonoma de Querétaro to storage and analysis.

# 4 RESULTS

## 4.1 Quality changes of the fruit during the storage

### 4.1.1 Size fruit effect.

The initial project considered a full factorial design with four factors at two levels which generated 32 treatment for each mango variety; the factors involved were the maturity stage (¼ and ¾); size fruit (size 8 and 10 or C8 and C10); irradiation treatment (0, 0.15, 0.6 and 1.0 kGy); storage temperature (10 and 20°C) and two repetitions. With the 'Tommy Atkins' variety (first variety studied); the effect of each factor was studied, the Table 1 shows the probability value for each factor. The size factor had less significant effect on the response variables studied and therefore it was decided to eliminate this factor in the other five varieties. However, due to storage at 10°C could interact with the dose received; it was decided to study the transference of fruit from 10 to 20°C; this gave 24 treatments as it was explained in the methodology.

Table 1 Probability values calculated by the means comparison from Analysis variance (Tuckey 0.05)

| Factor | Firmness | Ac Asc | Acidity | %WL | SSC | L* | a* | b* |
|---|---|---|---|---|---|---|---|---|
| Dose | **<.0001** | **<.0001** | **<.0001** | **0.6215** | **<.0001** | **0.3327** | **0.0693** | **0.6312** |
| Temperature | **<.0001** | **<.0001** | **<.0001** | **<.0001** | **<.0001** | **<.0001** | **<.0001** | **<.0001** |
| Maturity | **<.0001** | **0.0012** | **0.3015** | **0.8436** | **<.0001** | **0.6497** | **0.6051** | **0.8140** |
| Size | **0.0303** | **0.0667** | **0.6023** | **0.8936** | **0.0319** | **<.0001** | **<.0001** | **0.1517** |

### 4.1.2 Changes in the external and internal visual quality of mango fruit

The external quality was affected by the dose applied and the response was different in each variety and storage temperature of the fruit.

#### 4.1.2.1 'Tommy Atkins' Variety

The figure 3 shows the final appearance of the mango fruit cv 'Tommy Atkins' after 19 days of storage at 10 and 20°C. At these temperatures, the control fruit and treated at 0.15 kGy (0.16 – 0.41 kGy) showed no abnormal visual changes during the ripening process, showing a slight delay in the color change on the fruit treated at 0.15 kGy and stored at 20°C. However, the fruit treated at 0.6 kGy (0.5 – 0.83 kGy) and 1.0 kGy (0.97-1.52 kGy) and stored at 20°C showed alterations in the external pigmentation of the fruit; the green color areas and those with anthocyanins showed a brown background color which was darker in fruit treated at 1.0 kGy (0.97-1.52 kGy); the percentage of fruit damaged with this damage was 90% approximately and it was visible in both maturity stages. Under continuous storage at 10°C, there was not pigmentation changes (figure 3); but these changes occurred when the fruit was transferred from 10 to 20°C. Figure 4 shows the external appearance of the fruit stored during 13 days at 10°C and transferred 6 days at 20°C; the color alteration was more pronounced (respect of the control) which indicated a synergistic effect of the low storage temperature in addition to the effect given by the irradiation treatment; also the percentage of damaged fruit was 90%.

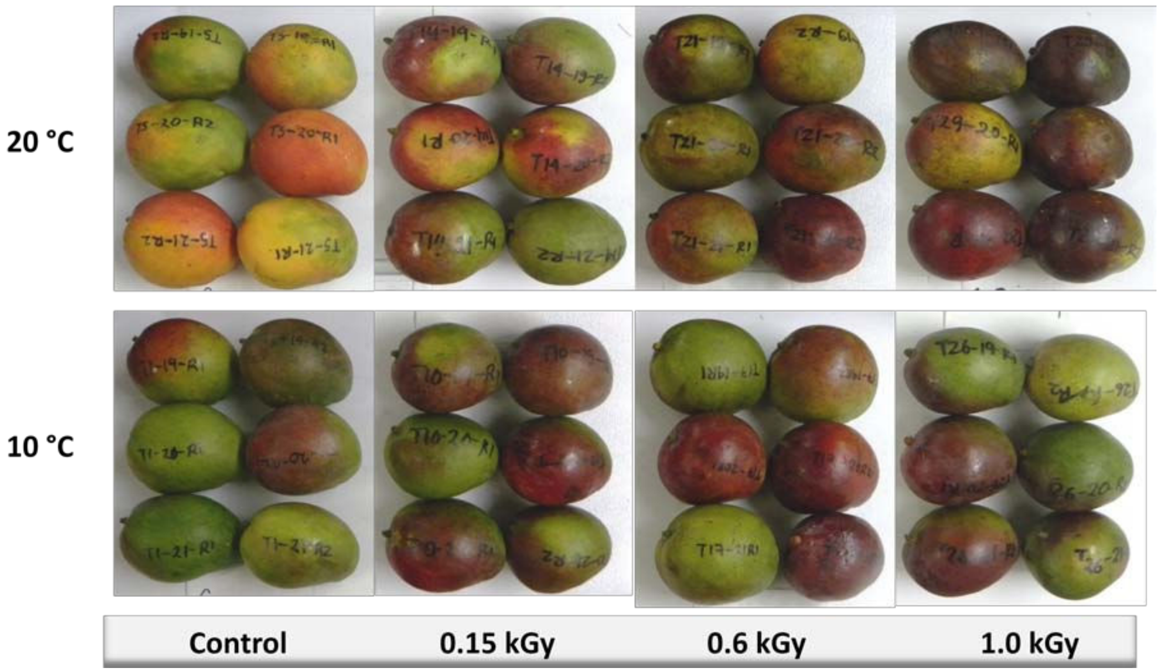



**Figure 3 External appearance of mango fruits cv 'Tommy Atkins' treated at different irradiation dose and stored for 19 days at 10 and 20°C.**


**Figure 4 External appearance of mango fruit cv 'Tommy Atkins' treated at different dose stored during 13 days at 10°C and transferred 6 days at 20°C.**

Into all damaged fruit, the degree damage severity varied within the fruit in each dose applied; this was attributed to different dose absorbed by each fruit because of its location inside the boxes; the fruit that absorbed more dose (those fruit located in the periphery of the boxes) possibly showed more damage severity, although this could not be verified because only two dosimeters were placed in two fruit of each box and these fruit were not monitored after the removal the dosimeters.

The figure 5 shows the internal visual appearance of the mango fruit cv 'Tommy Atkins' stored during 19 days at 10 and 20°C and figure 6 shows the internal changes in fruits stored 13 days at 10°C and transferred 6 days at 20°C. The control fruit and irradiated at 0.15 kGy (0.16 – 0.41 kGy) did not show important changes in the internal tissue after 19 days of storage at 20°C; whereas the fruit irradiated at 0.6 kGy (0.50 – 1.52 kGy) developed internal browning. The fruit stored at 10°C during the same period and irradiated at 1.00 kGy (0.97 – 1.52 kGy) showed spongy tissue development. Fruit transferred from 10 to 20°C (figure 5) also showed spongy tissue development after being stored for 13 days at 10°C and transferred 6 days at 20°C.

According to these observations, it may indicate that the 'Tommy Atkins' variety is susceptible to high radiation dose and therefore would not be advisable to reach these doses as phyto sanitary treatment.

Since there was no damage at low dose (range from 0.16 to 0.41 kGy), it is possible to say that the maximum dose recommended for this variety is in the range of 0.50 -0.60 kGy.


**Figure 5 Internal appearance of mango fruit cv 'Tommy Atkins' irradiated at different doses and stored at 10 and 20°C for 19 days.**

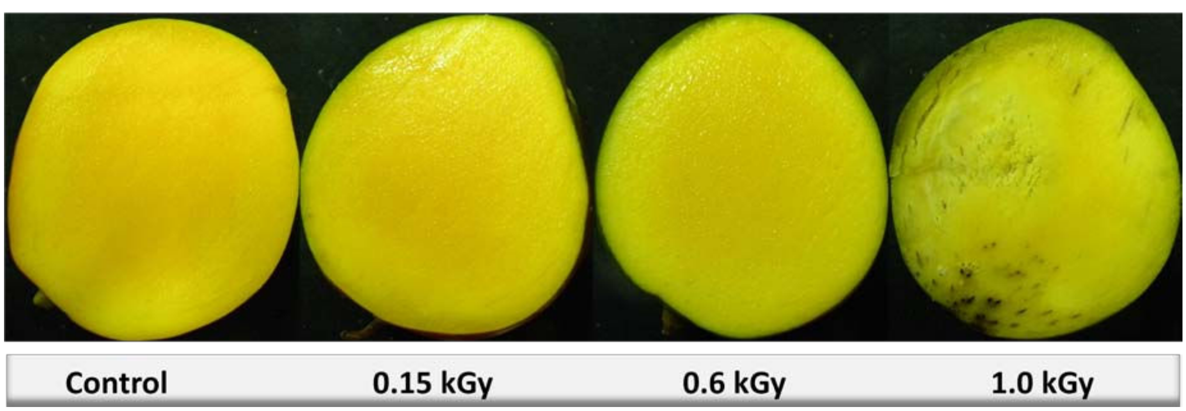



**Figure 6 Internal appearance of mango fruit cv 'Tommy Atkins' irradiated at different doses and stored 13 days at 10°C and transferred 6 days at 20°C.**

#### 4.1.2.2 'Haden' Variety

Figures 7 and 8 show the external appearance of mango fruit cv 'Haden' submitted to the irradiation and storage conditions described before. During its storage at 10 and 20°C; the control fruit and treated at 0.15 kGy (0.16 to 0.44 kGy) did not showed pigmentation alterations during the ripening; although they showed a slight delay in the color change in the irradiated fruit. At dose of 0.6 kGy (0.56 0.88 Kgy), the pigmentation changes were slight and more evident in the fruit exposed at 1.00 kGy (0.92 to 1.42 kGy). In the fruit stored continuously at 10°C the changes was not perceptible (figure 7); however, in fruit irradiated into the range of 0.56 to 0.88 kGy and 0.92 – 1.42 kGy and transferred from 10 to 20°C (figure 8), a superficial browning was observed. As the photographs shows, the changes observed in this variety were less severe than the observed in the ‘Tommy Atkins’ variety

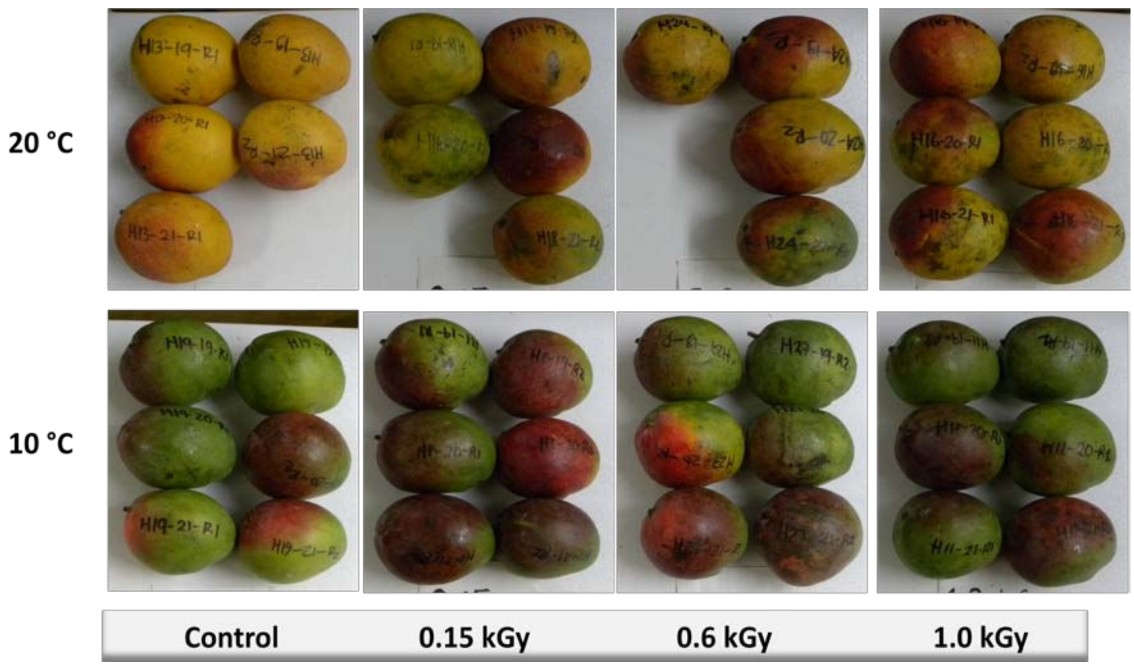



**Figure 7 Visual appearance of mango fruit cv ‘Haden’ treated at different doses and stored for 19 days and stored for 19 days at 10 and 20°C. Marks on the fruit represent the treatment codes.**


**Figure 8 External appearance of mango fruit cv ‘Haden’ treated at different irradiation doses stored for 13 days at 10°C and transferred 6 days at 20°C.**

The fact that the fruit transferred from 10 to 20°C showed a higher damage incidence, suggesting that the damage caused by the radiation stress is enhanced when the fruits were stored at refrigeration temperatures.

Figures 9 and 10 shows the internal appearance of fruit tissue at the same conditions of storage, the internal browning was significantly lower compared with the 'Tommy Atkins' variety, although the fruit irradiated into the range of 0.92 to 1.42 kGy and after transferred at 20°C also showed spongy tissue development (figure 10).


**Figure 9 Internal appearances of mango fruit cv 'Haden' submitted at different doses of gamma irradiation and stored 19 days at 10 and 20°C.**


**Figure 10 Internal appearances of mango fruit cv 'Haden' submitted at different irradiation doses, stored 13 days at 10°C and transferred 6 days at 20°C. Note the spongy tissue development in fruits exposed at 1.00 kGy.**

Although this variety showed lower incidence of internal damage, the damage shown in the skin seem to indicate that the maximum dose recommended for this variety could be in the 0,50 to 0.60 kGy range as the 'Tommy Atkins' variety.

Although it was noted that the skin of these two varieties had color alterations associated to the irradiation doses applied, the skin microscopic observation showed differences between both varieties (figure 11); the 'Haden' variety showed necrosis around the lenticels became more wide as increased the irradiation dose, while in the cultivar 'Tommy Atkins' the lenticels damage was minor but there was brown color development in the green color areas. It is possible that the origin of these color changes is different in both varieties, while in 'Tommy Atkins' seems to be due to an internal biochemical change caused by the irradiation; in the cultivar 'Haden' appears to be another cause and could be associated with the disease development because the damage was similar to anthracnose development suggesting that the radiation could cause weakness in the tissue and facilitate the development of this disease; although this aspect could not be confirmed in the research.

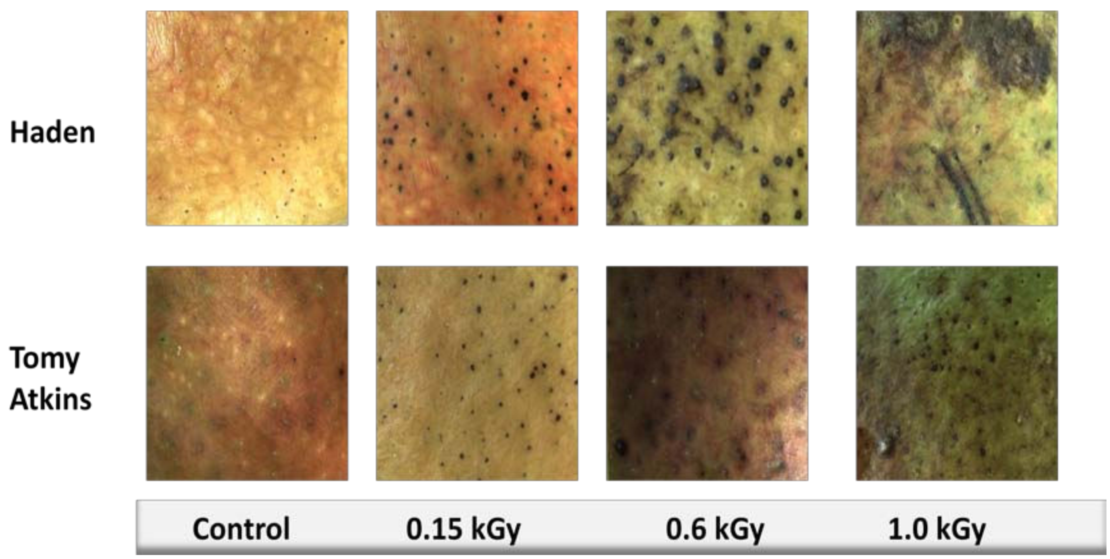



**Figure 11 Microscopic observations in the skin of mangos 'Haden' and 'Tommy Atkins' varieties submitted at different irradiation doses and stored 19 days at 10°C.**

#### 4.1.2.3 ´Kent' Variety

On external visual quality point of view, this variety appeared to show higher tolerance to irradiation because the damages in the skin were lower but also a brownish background pigmentation was observed in the fruit treated with 1.00 kGy and storage during 19 days at 20°C; however, the damage was evident in the maturity stage ¼ since 13 days of storage at 20°C (figure 12); while the fruit of maturity ¾ did not show changes during this period of storage for that irradiation dose. The fruit of maturity ¼ and stored at 10°C did not show changes in the pigmentation during those 13 days.


**Figure 12 External appearance of mango fruit cv 'Kent' irradiated at different doses and stored during 13 days at 10 and 20°C.**

In fruit of maturity ¼, irradiated at 1.00 kGy (0.93 – 1.41 kGy), stored during 7 or 13 days at 10°C and transferred 6 days at 20°C, showed brownish pigmentation in the skin (figure 13). The fruit of maturity ¾ did not show pigmentation changes into the same observation period. These observations indicated newly, that there was an effect of the high radiation doses (0.93 – 1.41 kGy) in the fruit physiology that it was incremented by storing them at 10°C; this suggest that the stress suffered by the irradiation was added the chilling stress which lead an increased damage.

The internal visual appearance of the fruit of this variety in both maturity stages and stored at 10 and 20°, did not appear significantly altered (figure 14); suggesting that the flesh of this variety was more tolerant to irradiation and refrigeration temperatures. However, in fruit of maturity ¼ irradiated at 1.00 kGy (0.93 – 1.41 kGy) and stored at 10°C during 7 or 13 days and transferred for 6 days at 20°C developed spongy tissue (figure 15)

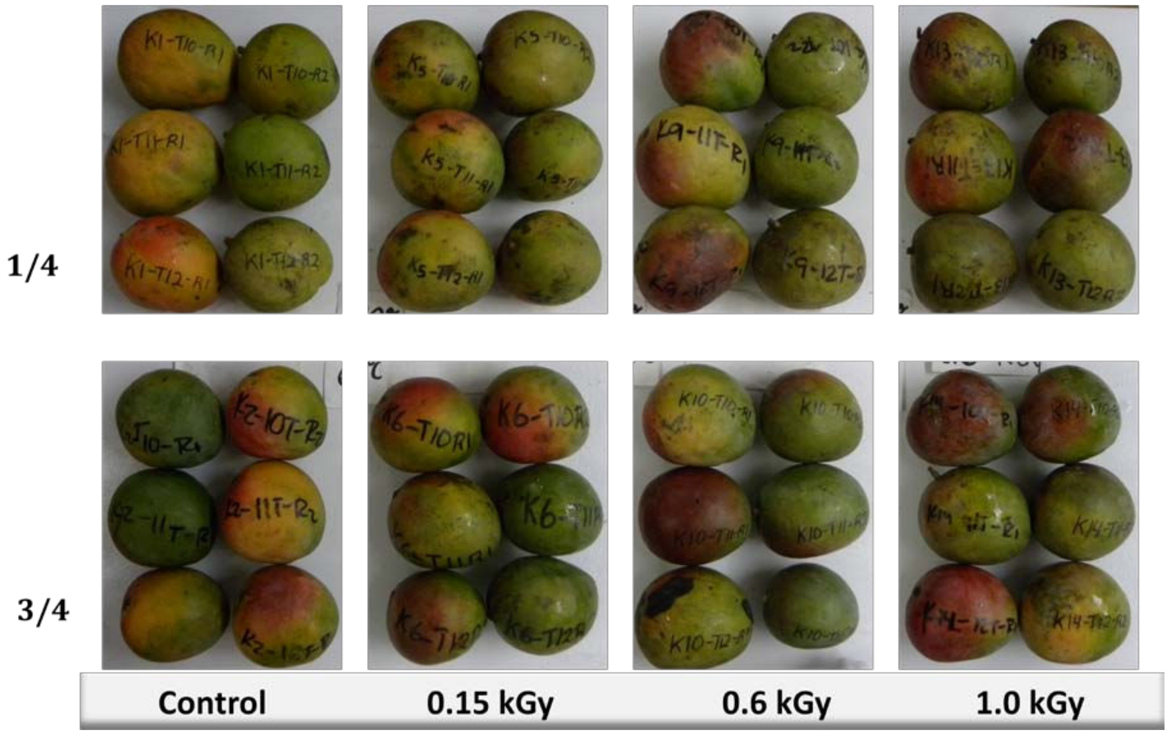



**Figure 13 External appearance of mango fruit cv 'Kent' of different maturity stages irradiated at different doses and stored 13 days at 10°C and transferred 6 days at 20°C.**


**Figure 14 Internal appearance of mango fruit cv 'Kent' irradiated at different doses and stored 13 days at 10 and 20°C.**

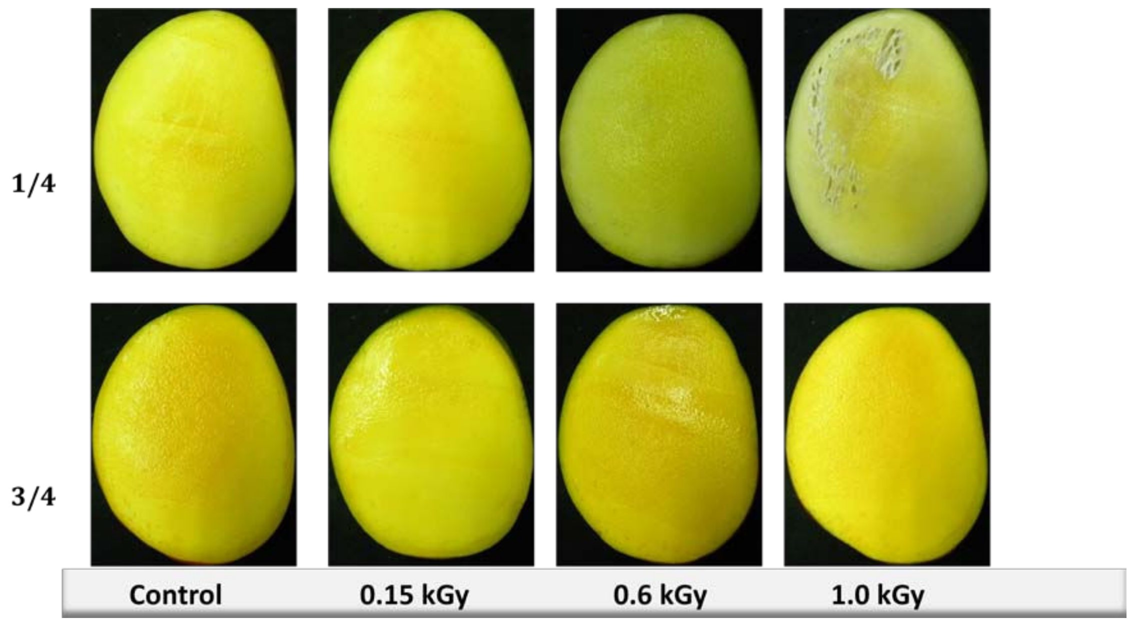



**Figure 15 Internal appearance of mango fruit cv 'Kent' in different maturity stages, irradiated at different doses and stored 13 days at 10°C and transferred during 6 days at 20°C. Note the spongy tissue development in fruit of maturity ¼ irradiated at 1.00 kGy.**

According to previous data, this variety tolerated irradiation doses into the range from 0.16 to 0.83 kGy in both maturity stages analyzed; but high doses should not be apply because of the risk of spongy tissue development in the maturity stage ¼ when it is stored at 10°C.

#### 4.1.2.4 'Keitt' Variety

After 7 and 13 days of continuous storage, the skin of control fruit and irradiated at different doses did not show important changes. However, the fruit exposed at 0.60 and 1.00 kGy (0.54 – 0.84 and 0.87 -1.51 kGy respectively) stored for 19 days developed internal browning and more susceptibility to pathogenic disease (figure 16); although this symptoms were observed in both maturity stages, a higher susceptibility was observed in the fruit of maturity ¼. Fruit stored at 10°C did not show these changes (figure 16), whereas fruit irradiated at 0.60 and 1.00 kGy stored for 13 days at 10°C and transferred 6 days at 20°C showed superficial browning development in both maturity stages (figure 17). These data indicated that this variety was also susceptible to high irradiation doses.

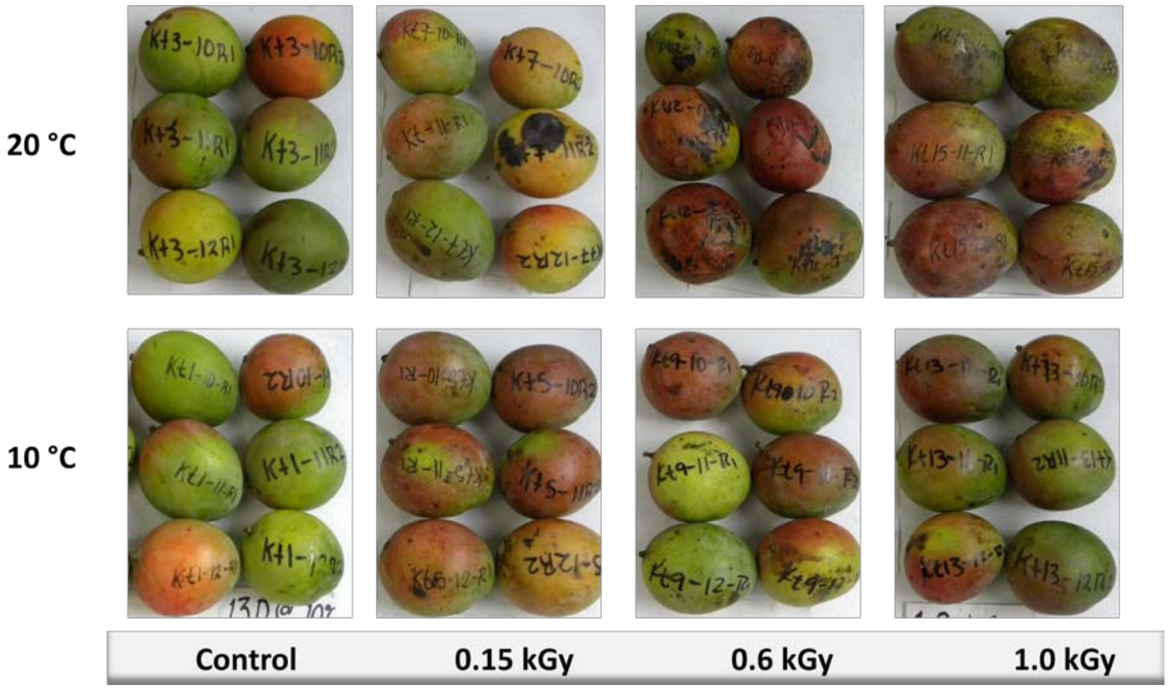



**Figure 16 Internal appearance of mango fruit cv 'Keitt' irradiated at different doses and stored 19 days at 10 and 20°C.**

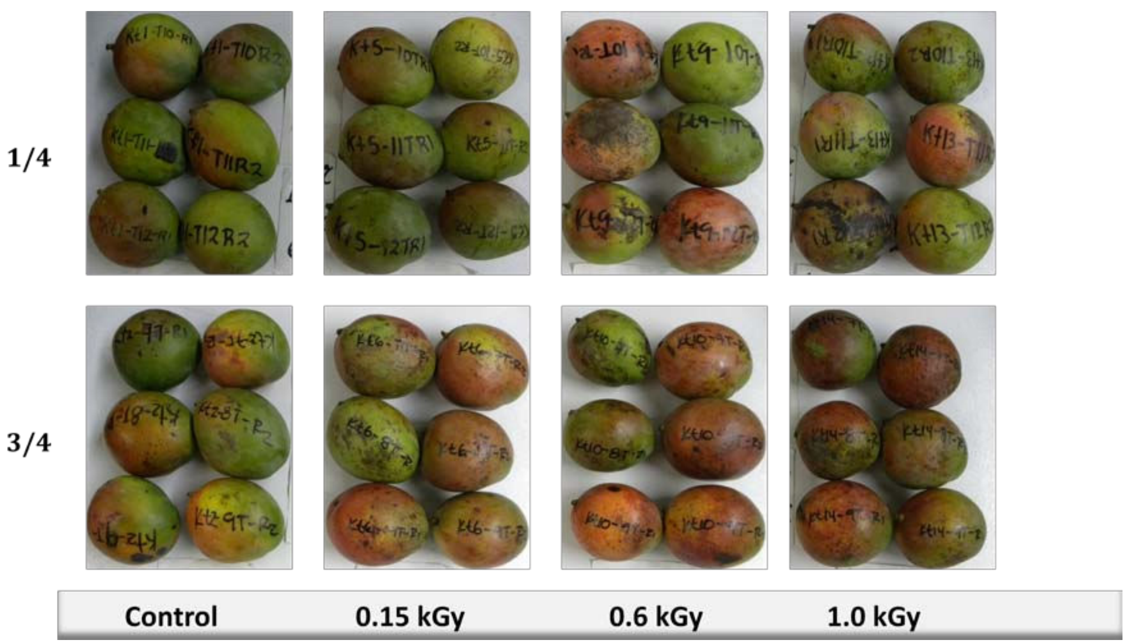



**Figure 17 External appearance of mango fruit cv 'Keitt' in different maturity stage (¼ and ¾), irradiated at different doses, stored 13 days at 10°C and transferred 6 days at 20°C..**

A high susceptibility to spongy tissue development (figures 18 and 19) was observed on internal tissue in fruit of maturity ¼ irradiated at 1.00 kGy (0.87 – 1.51 kGy) and stored at 10 and 20°C during 13 days and its transferences from 10 to 20°C.

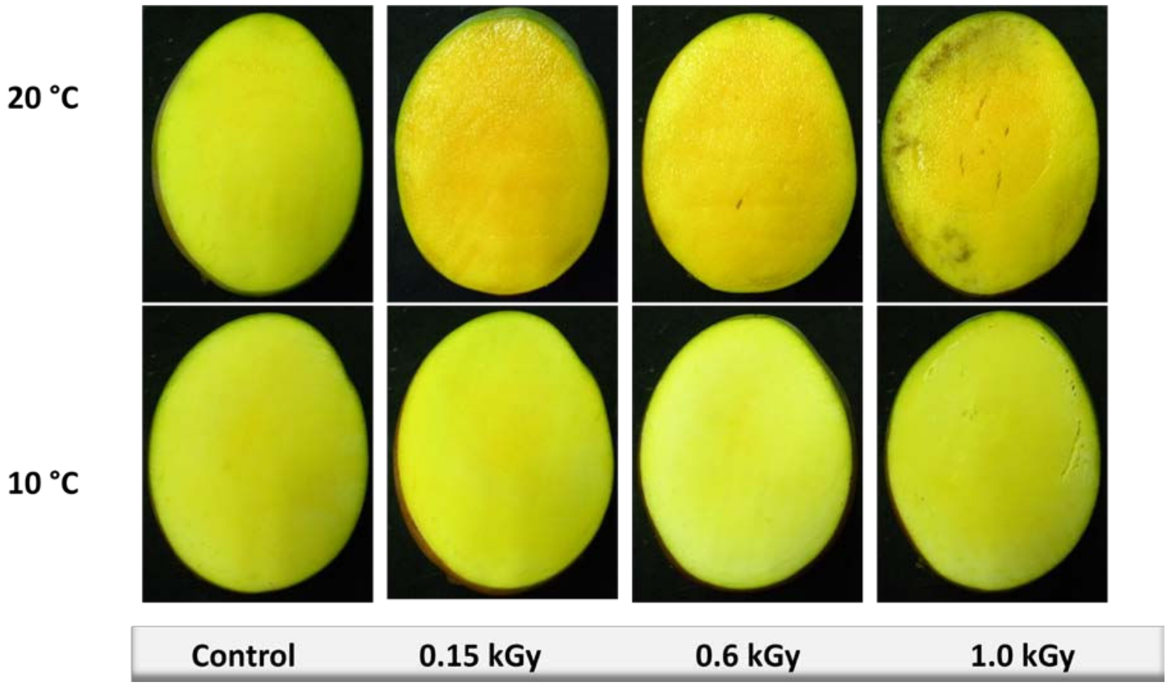



**Figure 18 Internal appearance of mango fruit cv 'Keitt' irradiated at different doses and stored for 19 days at 10 and 20°C.**

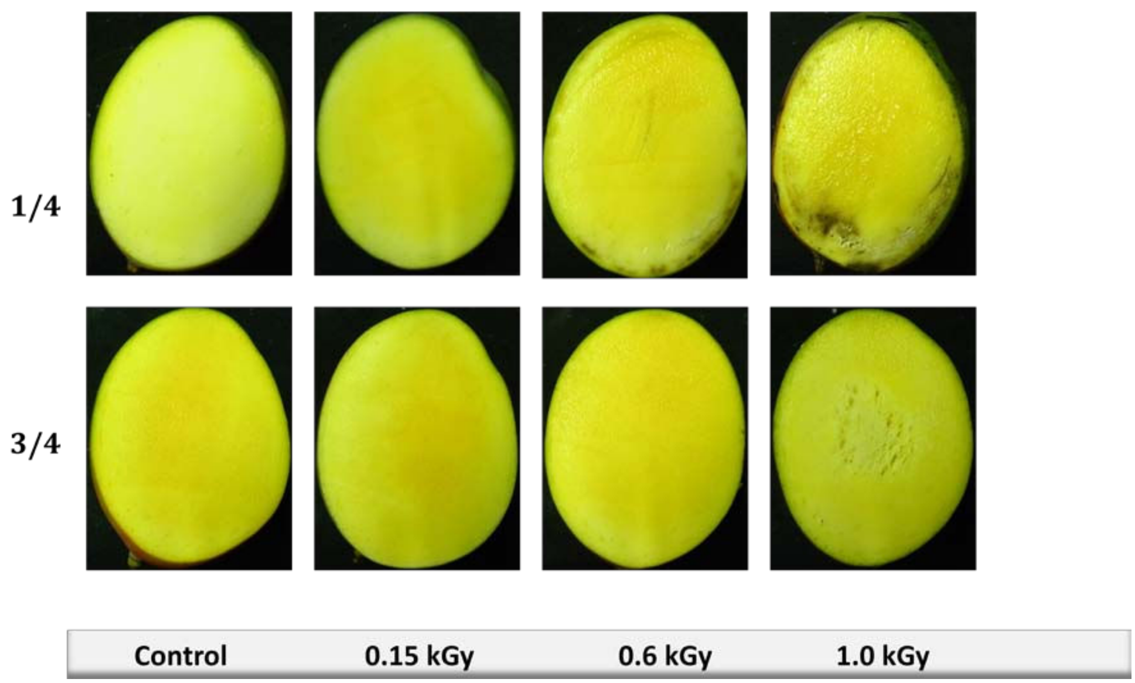



**Figure 19 Internal appearance of mango fruit cv 'Keitt' from different maturity stages irradiated at different doses and stored 13 days at 10°C and transferred 6 days at 20°C.**

Fruit of both maturity stages irradiated at 1.00 kGy showed internal browning as well as spongy tissue development after 19 days of continuous storage in both temperatures (figure 18).

Fruit in both maturity stages and stored 13 days at 10°C and transferred at 20°C showed high susceptibility to spongy tissue development (figure 19). These data indicated also that this variety in maturity stage ¼ should not be irradiated between 0.54 and 1.51 kGy doses. However, if the maturity stage is ¾ the range between 0.87 – 1.51 kGy should be avoided.

Therefore to irradiate the fruit of this variety should be taken into account the maturity stage of the fruit, recommending processing those fruit whose maturity stage is ¾.

#### 4.1.2.5 'Ataulfo' Variety

Under continuous storage at 10 and 20°C, the fruit of this variety seems to show higher tolerance to irradiation doses applied. Figure 20 shows the fruit in both maturity stage stored 19 days at 10 and 20°C; this figure shows that the storage at 10°C had a notable effect to delay the ripening process without important effects of irradiation doses.

However, when the fruit of both maturity stages were transferred from 10 to 20°C, those fruits irradiated at 1.00 kGy (0.95 – 1.43 kGy) and stored for 7 or 13 days at 10°C developed a black discoloration on its surface (figure 21), this discoloration could be associated to chilling injury which was enhanced by the high irradiation doses application.

This data suggest that this variety could resist high irradiation doses if the fruit is stored at 13°C as suggest the mango preservation protocols.
(http://postharvest.ucdavis.edu/Produce/ProduceFacts/Espanol/Mango.shtml )

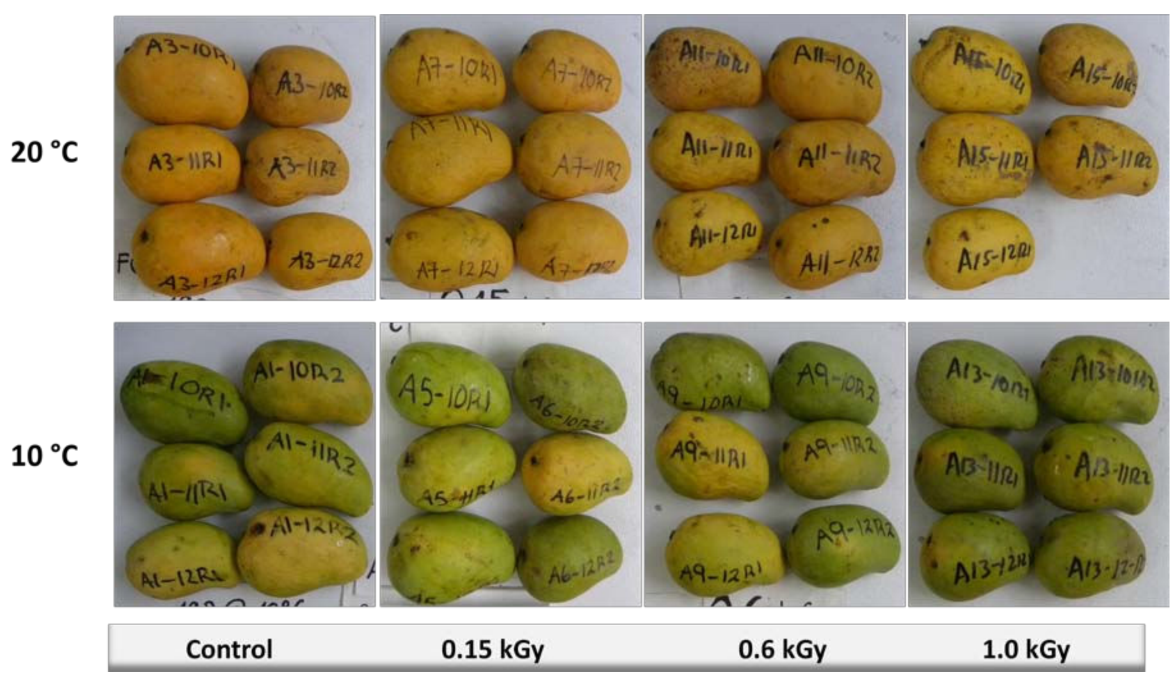



**Figure 20 External appearance of mango fruit cv 'Ataulfo' irradiated at different doses and stored for 19 days at 10 and 20°C.**

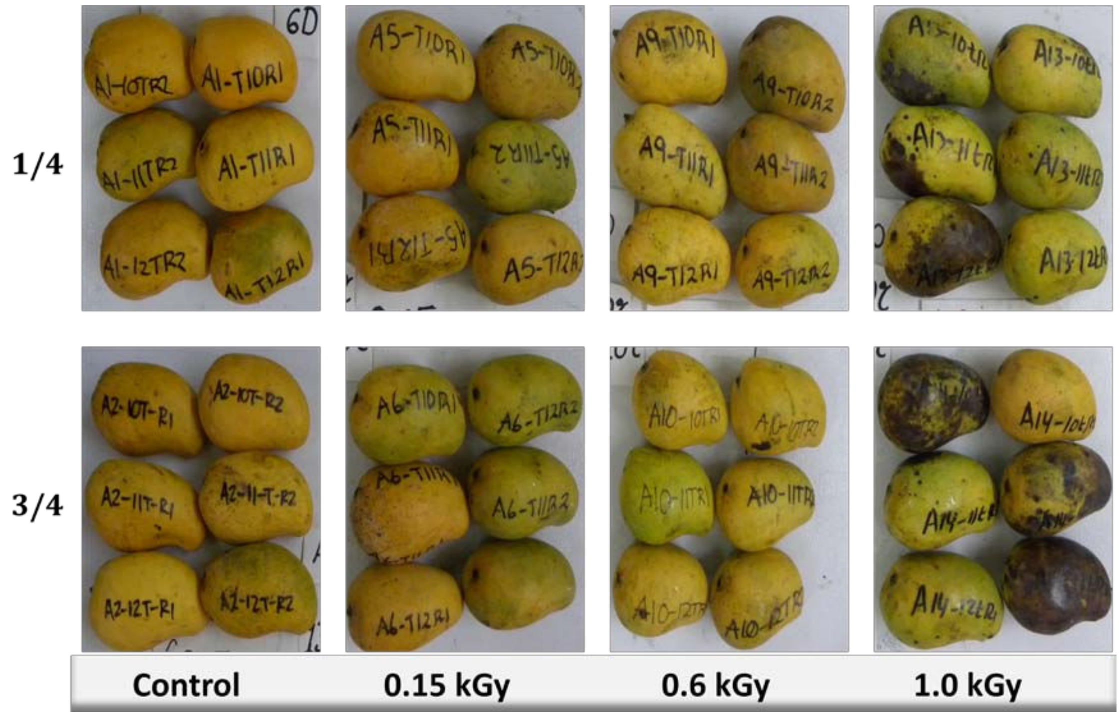



**Figure 21 External appearance of mango fruit cv 'Ataulfo' in different maturity stages, irradiated at different doses, stored for 13 days and transferred 6 days at 20°C.**

The internal observations of the fruis stored 19 days at 10 and 20°C (figure 22) indicated that the fruits irradiated at 1.00 kGy (0.95 – 1.43 kGy) and stored at 20°C developed flesh browning while those stored at 10°C developed spongy tissue which also indicated that the exposure to these irradiation doses should be avoided in this variety.


**Figure 22 Internal appearance of mango fruit cv 'Ataulfo' irradiated at different doses and stored for 19 days at 10 and 20°C.**

The observations of the internal tissue of fruits irradiated at 1.00 kGy (0.95 – 1.43 kGy) stored at 10 and transferred at 20°C showed a severe spongy tissue development in both maturity stages; this damage was evident after 7 or 13 days of storage at 10°C and transferred at 20°C for 6 days (figure 23). Fruit in maturity stage ¼ and irradiated at 0.60 kGy (0.54 – 0.82 kGy) also showed spongy tissue development.

The above observations indicate that this variety can resist up to 0.82 kGy dose if it is harvested at ¾ maturity stage and after stored at temperatures above 10°C. It is possible to recommend the fruit irradiation to 0.6 kGy in both maturity stages but it would be advisable to be careful to store them at temperatures above 10°C.

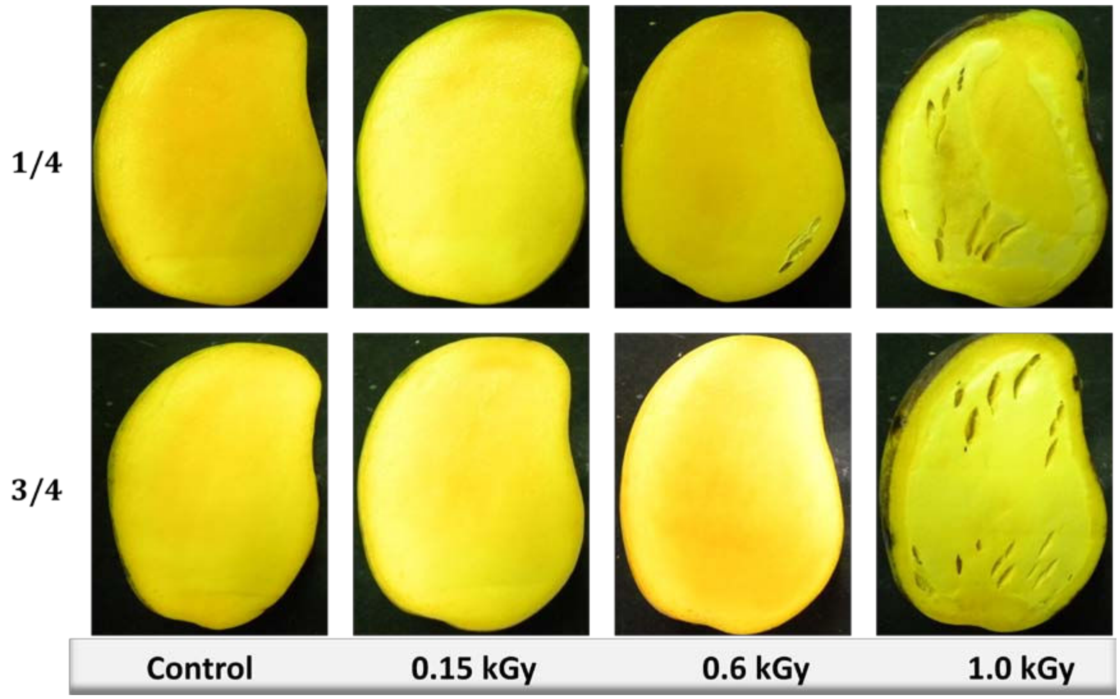



**Figure 23 Internal appearance of mango fruit cv 'Ataulfo' of different maturity stages irradiated at different doses stored during 13 days at 10°C and transferred for 6 days at 20°C. Observe the spongy tissue development at 1.00 kGy.**

#### 4.1.2.6 'Manila' Variety

This variety showed high dehydration rate which limited their shelf life at 20°C at 13 days only. Like the 'Ataulfo' variety, the continuous storage at 10°C showed ripeness delayed in comparison the fruit stored at 20°C (figure 24). The comparison of irradiated fruit with their respective controls showed that the irradiation delayed the skin color change and high doses caused slight skin browning but without clear distinctions between the different doses.

Fruit of maturity ¼ irradiated with 1.00 kGy (0.96 – 1.33 kGy) and stored at 10°C showed spongy tissue development which indicated their susceptibility to these irradiation doses (figure 25).

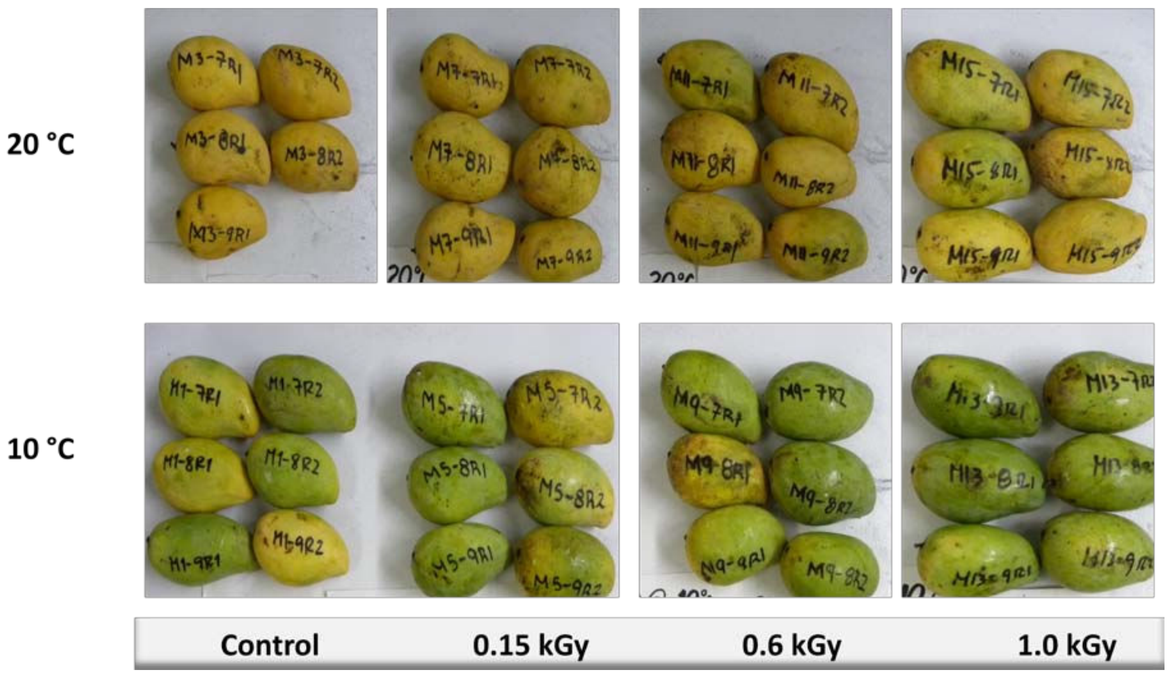



**Figure 24 External appearances of mango fruit cv 'Manila' irradiated at different doses and stored for 13 days at 10 and 20°C.**


**Figure 25 Internal appearance of mango fruit cv 'Manila' irradiated at different doses and stored 13 days at 10 and 20°C. Note the spongy tissue development in fruit treated at 1.00 kGy.**

Fruit of both maturity stages stored at 10°C and transferred from 10 to 20°C showed superficial alterations development (figure 26) which were more higher in fruit irradiated at 0.6 and 1.00 kGy (0.57 – 0.87 and 0.96 – 1.33 kGy range respectively). The internal tissue observation (figure 27) revealed that at 1.00 kGy dose there was spongy tissue development as well as the presence of white tissue which indicated a more severe alteration of ripeness process

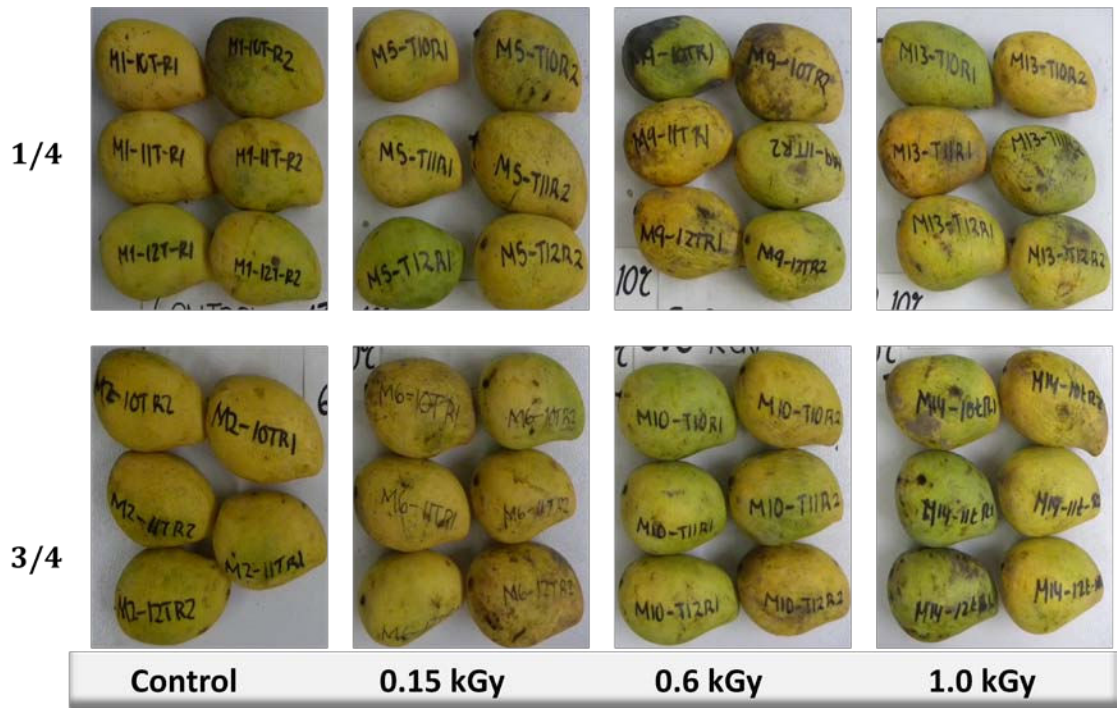



**Figure 26 External appearance of mango fruit cv 'Manila' in different maturity stages irradiated at different doses and stored for 13 days at 10°C and transferred 6 days at 20°C.**


**Figure 27 Internal appearance of mango fruit cv 'Manila' in different maturity stages irradiated at different doses and stored during 13 days at 10°C and transferred for 6 days at 20°C.**

The above observations indicate that this variety can be irradiated at 0.6 kGy in both maturity stages because the high doses induce the skin browning and spongy tissue development.

#### 4.1.2.7 General considerations about the visual external and internal quality.

The results of the irradiation effects in the different varieties and maturity stages gave some general comments and recommendations. The external and internal damages are important factors that it should be taken into account to evaluate the effect of irradiation process in mango, such damages were skin and flesh browning as well as the spongy tissue development. Taking into account these observations it is possible to indicate that all varieties in both maturity stages did not show external and internal damages when they were submitted to irradiation ranges of 0.15 to 0.44 kGy. In a similar way, all varieties showed damages when they were exposed to irradiation doses 0f 0.92 to 1.52 kGy. Also in general way, the studies showed that it is necessary to avoid the irradiation of fruit in maturity ¼ and recommending the irradiation of fruit in ¾ maturity. Under the recommendations before noted, the maximum dose tolerated depended of the variety; the 'Kent' and 'Ataulfo' varieties were more tolerant to irradiation which resisted up to 0.86 kGy; whereas 'Tommy Atkins', 'Haden',' Manila' and 'Keitt' varieties were the most sensitive and therefore is not recommended to subject them to radiation above 0.60 kGy.

The fruit storage at 10°C increased the irradiation damages which were evident when the fruit were transferred at 20°C; this indicated that to the radiation stress was added the low temperature stress.

### 4.1.3 Changes in physicochemical factors.

The physicochemical characteristics of the varieties were different between them, and the statistical comparison lost interest. However, it was more important to establish how these characteristics of each variety were affected by the irradiation treatment applied.

Annex 3 compiles the statistical probability values of ANOVA performed for each variety taking into account the dose effect, storage temperature, maturity stage, storage time and their simple interactions. Due to climacteric behavior and the temperature effect on the ripening process; all response variables tested changed during the storage depending on the temperature; therefore the storage time and temperature as well as their interactions showed a highly significant effect in all varieties.

Although the Annex 3 compiles the results of general statistical analysis described above and indicate the effect of each factor under study. Its usefulness to find specific conclusions does not good because in the analysis of each factor are other factors confounded. That is, when the radiation dose effect is analyzed in general form; the statistical software includes all the data of each radiation dose without separating the maturity stage, the storage temperature or the storage days. Thus the overall analysis does not allow indicating if the maturity stage gave different responses, or if the storage temperature had effects respect of irradiation dose applied or if the response changed during the storage. The same happens when the others factors are considered. Therefore, it was made more specific analysis grouping the data by maturity stage and storage temperature and analyzing the irradiation effect during the storage and their correspondent interactions between both factors as stated in 3.1 Section.

The dose effect and its interactions with the others factors varied among varieties and between the responses analyzed. Therefore, the interpretation of all of them into each variety is showed.

Also in order to simplify the results presentation, the figures that describe the behavior of the response variable analyzed in each variety are added at the end of each variety; which also include the maturity stage and radiation dose applied as well as for the storage temperature of the fruit.

Again, we draw the attention that the proposed radiation dose or nominal, 0.15, 0.60 y 1.00 kGy, does not refer to exact dose because the fruit boxes position into irradiator does not allow an uniform distribution dose into each box. So it is more appropriated to indicate the irradiation doses ranges (obtained from the dosimeters reading) which were actually submitted the fruits. To facilitate the writing and reading of this report, the use of these nominal doses is maintained, it is being understood that these numbers express the following ranges which include the values of all varieties: The values 0.15, 0.60 and 1.00 kGy refer to 0.15 - 0.44; 0.52 – 0.88 and 0.93 – 1.55 kGy ranges respectively. Under these headings, when the nominal doses it is expressed it is talking about these ranges. However, the specific values range in each variety analyzed is indicated which are slightly different from those mentioned above.

#### 4.1.3.1 Physicochemical quality changes in mango 'Tommy Atkins'

Firmness. Firmness values registered one day after the irradiation treatments allowed to grouping varieties in two groups. Those varieties whose firmness values ranged between 85 and 185 N which included 'Tommy Atkins', 'Haden', 'Kent' and 'Keitt', while 'Ataulfo' and 'Manila' varieties formed the group with lower firmness which ranged between 37 to 74 N in 'Ataulfo' mangoes and 14 to 45 N for 'Manila' Mangoes (figures

28A, 32A, 36A, 40A, 44A and 48A and Annexes 4, 5, 6, 7, 8 and 9). These data indicated natural differences between varieties since the beginning of storage.

Figure 28A shows the changes of this factor during the fruit storage in both maturity stages and at two temperatures considered. During the first seven days of storage, the application of 0.6 and 1.00 Kgy showed a statistically lower firmness (Annex 4) respect to control fruit and irradiated at 0.15 kGy. After that period, the fruit of both maturity stages stored at 10°C did not show differences between treatments. However, at 20°C it was also observed that the fruit irradiated at 0.6 and 1.00 kGy showed lower firmness.

The fruit transferred from 10 to 20°C, did not show significant effects of the different irradiation doses at each sampling period (figure 28A). Likewise, no difference was found among this fruit group compared with fruit stored at 20°C continuously. In a logical way, also the comparison with the fruit stored at 10°C showed that the fruit transferred to 20°C had lower firmness (figure 28A). These data showed that the doses applied and the storage at 10°C did not change the softening process of the fruit after their transfer at 20°C.

Ascorbic acid. The statistical analysis (Annex 4) showed statistically significant effects of the irradiation dose in fruit of both maturity stages stored at 10°C; those fruit that were irradiated at 0.6 and 1.00 Kgy showed lower ascorbic acid contents (figure 28B), whereas there were no clear statistical differences at 20°C and all fruit decreased its ascorbic acid content (figure 28B) in all treatments.

The fruits in maturity ¾ transferred from 10 to 20°C did not show significant differences between irradiation treatments or with the fruits stored at 20°C

Titratable acidity. During the first 13 days of storage, the fruit of both maturity stages and stored at 10°C did not show clear effects of irradiation doses or the storage period (figure 29A and Annex 4); on the 19 day, the samples irradiated at 0.60 and 1.00 kGy showed lower values (0.6 to 1.0%). In fruit stored at 20°C, there were no significant effects of irradiation treatments and the differences registered were due to the analysis date; the lowest values (0.1 to 0.3%) were determined on 19 day.

The fruit transferred from 10 to 20°C only showed changes due to the storage date and they were similar to the fruit stored at 20°C. There were no effects registered due to the irradiation doses applied.

Weight loss. Fruit stored at 10°C lost less weight compared to those stored at 20°C (figure 29B and Annex 4). In both maturity stages and temperature condition, no significant differences associated to the irradiation dose were observed. The fruit transferred from 10 to 20°C did not show significant differences due to the irradiation doses and also they had similar values to control fruit stored at 20°C.

Solid soluble content. Like the weight loss variable, the solid soluble content did no was affected by the irradiation treatment applied. In both maturity stages and storage temperatures, there were no significant effects of the irradiation doses (figure 30A and Annex 4), only there were differences related to date analysis , although the fruit stored at 10°C showed minor changes respect of that fruit stored at 20°C.

At 20°C, both maturity stages showed significant increases since day 1 and 7 which continued until 13 and 19 days where the statistical comparison did not show differences between the different irradiation treatments. The fruit stored at 10°C and transferred to 20°C did not show significant differences between the different irradiation treatments and they were similar to the changes followed by the fruit stored at 20°C continuously.

Flesh color. The statistical analysis of the flesh color changes of the fruit of this variety did not show significant differences between irradiation doses applied (figure 30B and Annex 4) neither between date analysis and storage temperatures. However, it is was noteworthy that the color changes in the samples stored at 10°C were significantly lower compared with those measured at 20°C, which showed the highest a* values (figure 30B).

The transfer of fruits from 10 to 20°C slightly favored the fruit color changes without finding irradiation doses effect; however the values showed by this group of fruit were not comparable to values registered by the fruit stored at 20°C continuously. These data showed a significant effect of the 10°C temperature in the flesh color development so it is advisable to store the fruit at 13°C instead of 10°C as it is recommended by the University of California at Davis (http://postharvest.ucdavis.edu/).

Skin color. Fruit stored at 10°C delayed their color changes during the storage and they did not show any effect of irradiation doses and neither by sampling date (Annex 4 and figure 31); fruits stored at 20°C showed external color changes during the storage period but these changes did not be affected by the irradiation doses applied.

The fact that the objective color measurements did not show statistical differences between doses while visual observation showed significant changes in the fruit pigmentation called our attention. It is possible that this apparent discrepancy in the results was due to visual observation evaluated the external fruit appearance in whole fruit while the objective color measurement was performed in a circular area of 1 cm in diameter where it was not possible to observe all the fruit.

According with the previous data; the response variables of weight loss, total solid soluble content, and flesh and skin color did not show changes due to irradiation doses. However, the firmness, the ascorbic acid content and titritable acidity responses showed that 0.60 and 1.00 kGy doses decreased the firmness fruit as well as the ascorbic acid content and the acidity. This confirms the external visual quality observations and showed that this variety should be not irradiated above of 0.60 kGy; additionally and due to the higher susceptibility of fruit in ¼ maturity stage and for that it is advised does not to irradiate fruit in that maturity stage

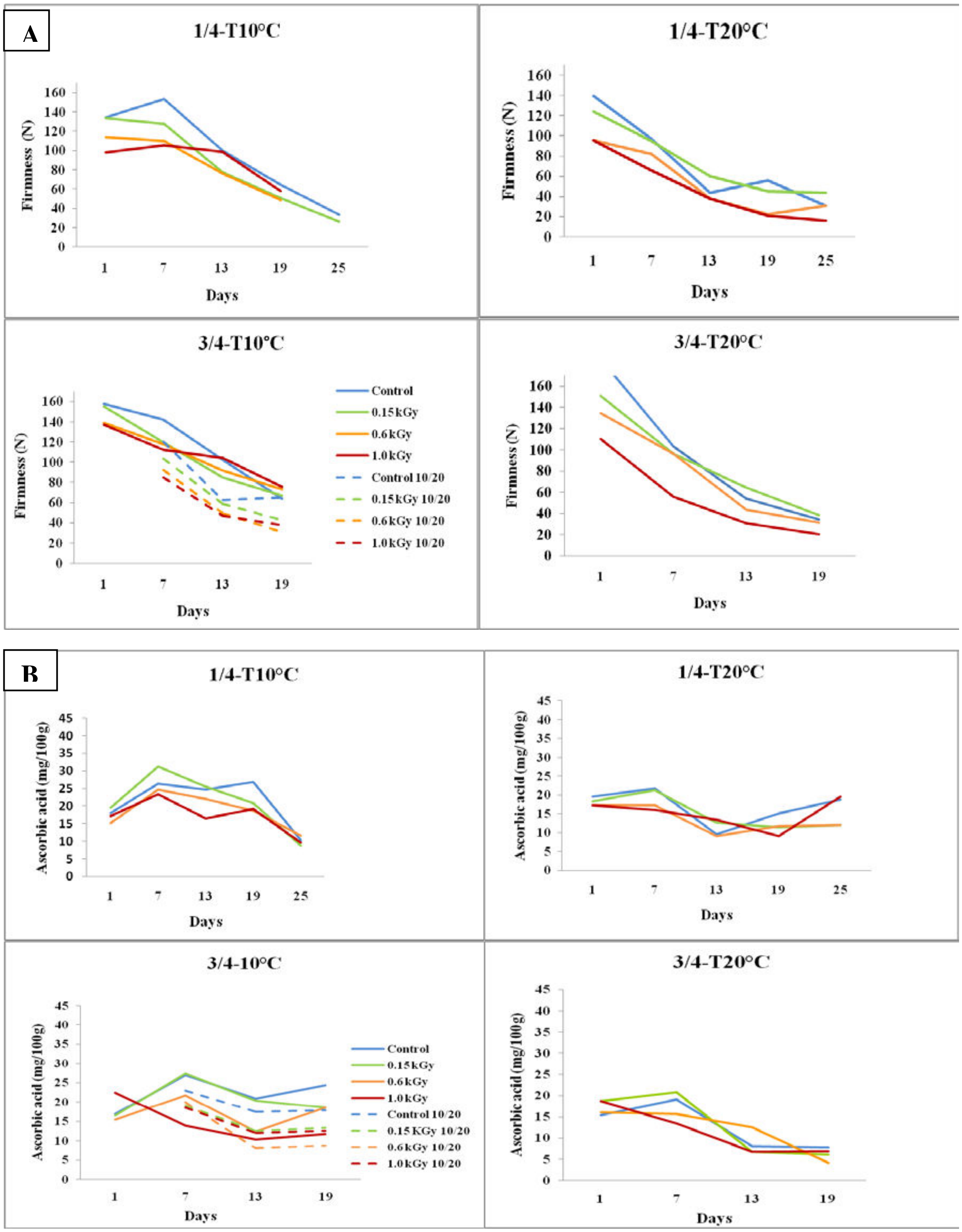



Figure 28 Changes in firmness (A) and ascorbic acid (B) in mango fruits cv 'Tommy Atkins' at different maturity stages (¼ and ¾), irradiated at different doses and stored at 10 and 20°C. Dotted lines indicate the transfer of fruits from 10 to 20

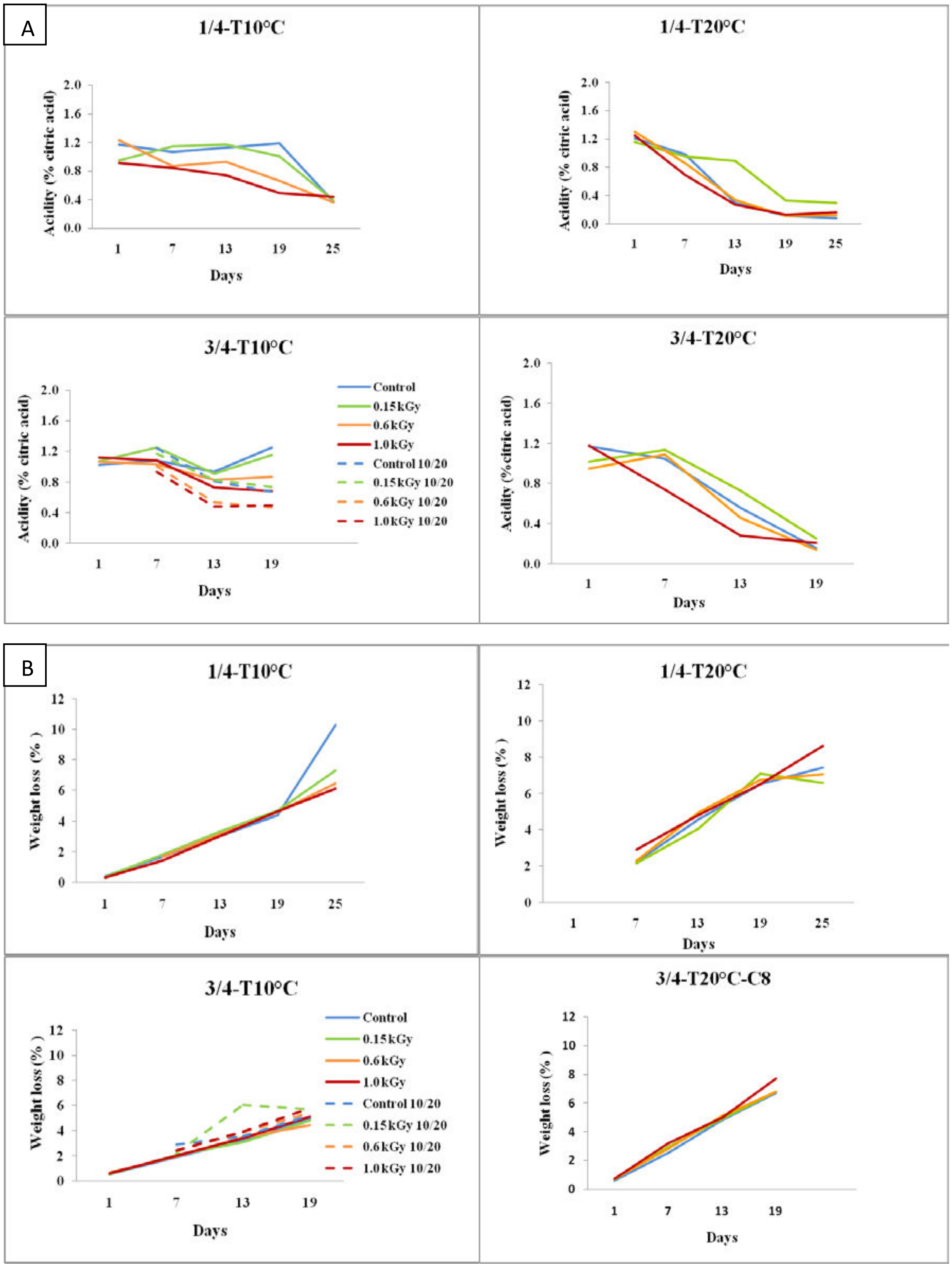



Figure 29 Changes in acidity (A) and weight loss (B) of mango fruits cv 'Tommy Atkins' at different maturity stages (¼ and ¾), irradiated at different doses with gamma rays and stored at 10 and 20°C. Dotted lines indicate the fruit transferred from 10 to 20°C.

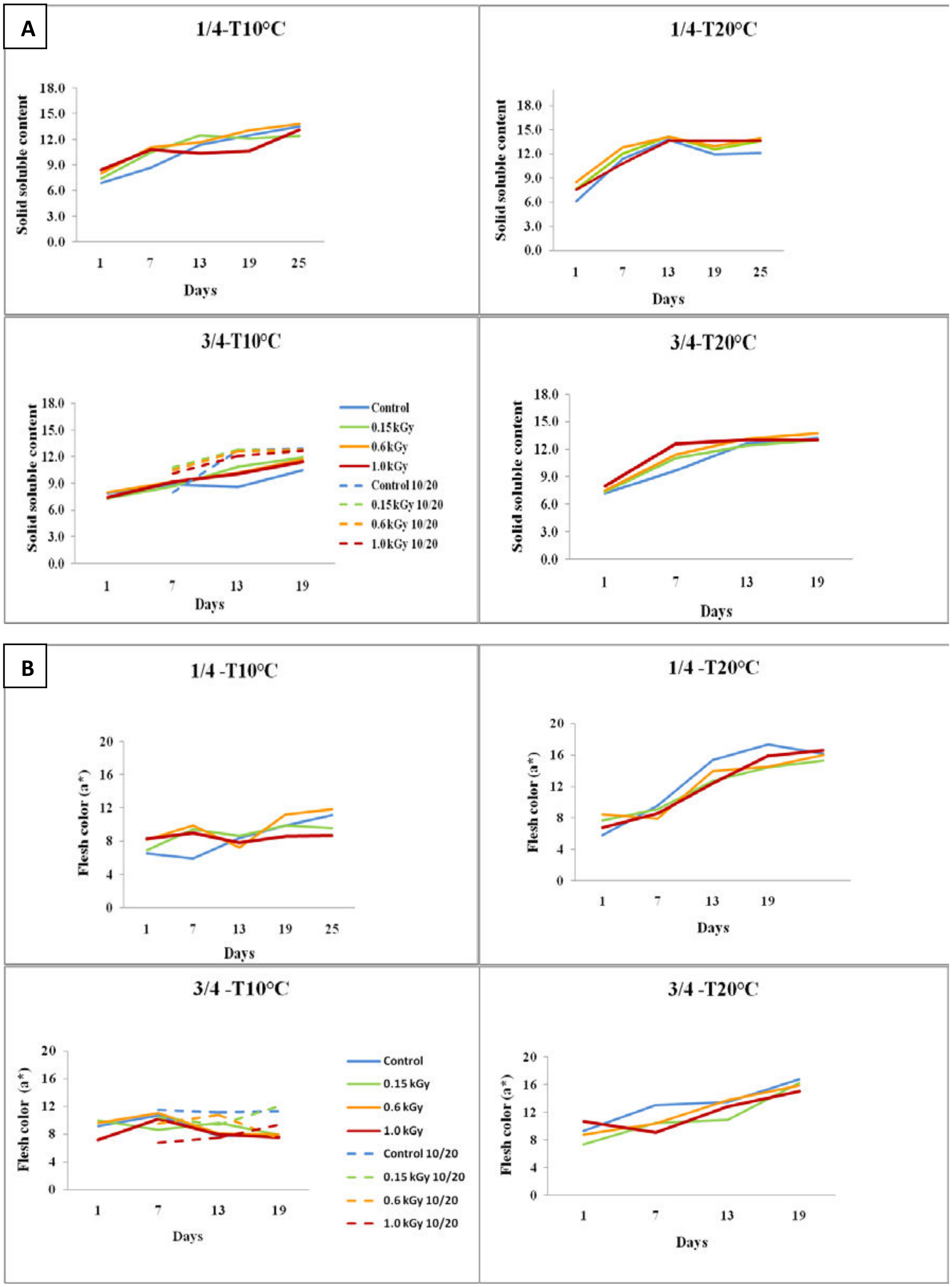



Figure 30 Changes of solid soluble content (A) and flesh color (B) in mango fruits cv 'Tommy Atkins' in different maturity stages (¼ and ¾), irradiated at different doses with gamma rays and stored at 10 and 20°C. Dotted lines indicate the fruits transferred from 10 to 20°C.

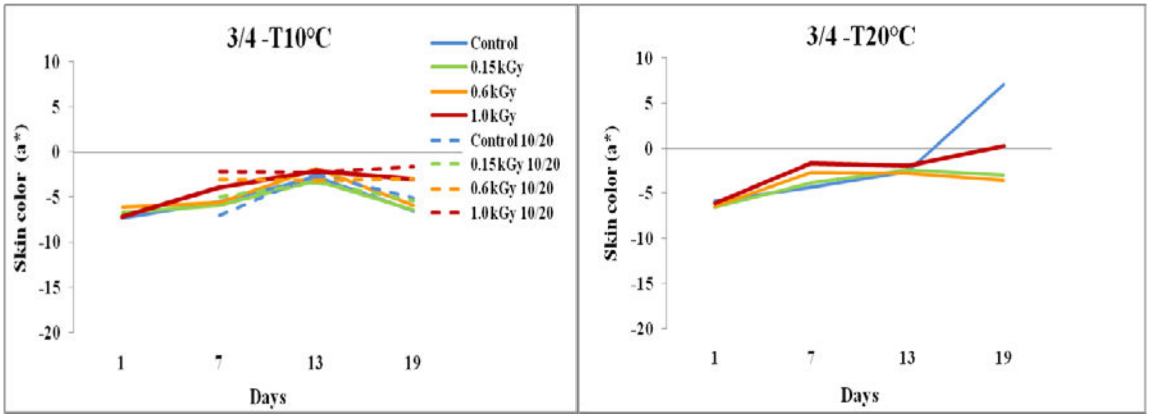



Figure 31 Changes in skin color of mango fruits cv 'Tommy Atkins' in different maturity stages (¼ and ¾), irradiated at different doses with gamma rays and stored at 10 and 20°C. Dotted lines indicate the fruits transferred from 10 to 20°C.

#### 4.1.3.2 Physicochemical quality changes in mango 'Haden'.

Firmness. This variety belongs to fruit with high firmness values. Fruit of both maturity stages and stored at 10 and 20°C continuously did not show significant differences between the different doses applied neither in the different sampling date (figure 32A, Annex 5); fruit in maturity stage ¼ and stored 19 days at 10°C and treated with 1.00 kGy showed higher firmness than the others treatments; although this difference disappeared after 25 days of storage. As in fruits of 'Tommy Atkins' variety, the differences in this response variable was only detected between the different date sampling, on seven day the fruit was more firm than the fruit stored for 13 or 19 days. As well as the statistical comparison of fruit stored continuously at 10°C and transferred to 20°C did not show significant differences respect of the doses applied.

The above data show that the doses applied did not affect the fruit softening process and that the storage at 10°C did not alter the following softening process when the fruit were transferred at 20°C.

Ascorbic acid. Figure 32B shows the changes of this component in fruit of this variety. Unlike of 'Tommy Atkins' variety; this variety did not show significant increases of this vitamin during storage, although the figure 32B there seems to be a lower content of ascorbic acid in fruit irradiated at 1.00 kGy, the statistical analysis did not show statistical differences between the treatments applied in both maturity stages and storage temperatures (Annex 5). In a similar way the fruit transferred from 10 to 20°C did not show differences between the treatments neither with the fruit stored at 20°C. In according with these findings, the ascorbic acid content of this variety did not appear to be affected by the irradiation doses applied.

Acidity. Fruit of ¼ and ¾ stored at 10°C during 19 days did not show changes related to irradiation doses and date analysis (figure 33A and Annex 5), observing that this temperature delayed the acidity changes during the storage. At 20°C in both maturity stages there were changes related with the date analysis; the lowest values were registered on day 19 (0.07 to 0.1%), but there were no effects attributable to irradiation doses applied. The transfer fruit from 10 to 20°C did not show differences between the irradiation doses or with the fruit stored at 20°C.

Weight loss. Fruit stored at 10°C lost less weight (5 to 6%) than those stored at 20°C which lost between 6 to 8.5% (figure 33B and Annex 5). In both maturity stages and temperature condition did not find significant differences related to irradiation doses applied, and as expected, statistically significant differences were also associated with the storage date. The fruit transferred from 10 to 20°C did not show statistically significant differences between irradiation doses and these were also similar to control fruit stored at 20°C.

According with the data of this variable, the weight loss did not be a good indicator to evaluating the irradiation dose effect.

Solid soluble content. In similar way that the titratable acidity the most important changes of this factor was due to storage temperature. All fruit stored at 20°C increased their solid soluble content during storage while the fruit stored at 10°C showed slight changes. The initial low values of solid soluble content seem indicate that the fruit was harvested in early maturity stages; however the changes of this variable during the storage at 20°C indicated maturity stages able to continue its ripening process (figure 34A).

All fruit in both maturity stages and stored at 10 and 20°C did not show significant differences between irradiation doses (figure 34A and Annex 5); however there were differences related to analysis date, fruit analyzed on 19 day had higher solid soluble contents than those analyzed on 1 or 13 days. Similarly the fruit stored at 10°C and transferred to 20°C did not show significant differences between different irradiation treatments and showed a similar pattern change to that followed by the fruit stored at 20°C continuously.

Flesh color. The major color changes of the flesh occurred in fruits stored at 20°C, whereas at 10°C the color evolution was light without to observe significant differences associated to irradiation doses or analysis dates confirming that the temperature of 10°C delayed the color change (figure34B and Annex 5).

Fruit of maturity ¼ stored at 20°C did not show significant color changes associated to doses applied; however, there were changes respect of analysis date; on 1 and 7 days of storage the lowest values were registered respect of the maximum values registered on 13 and 19 days. At each analysis date the effect irradiation doses did not observe in this variable. The fruit in maturity ¾ and stored at 20°C began their most noticeable color change from 7 day without to observe irradiation dose effect at each analysis date.

For all varieties in both maturity stages, the fruit transfer from 10 to 20°C favored slightly their color change without finding effects of irradiation doses; however, the values reached were no similar to values registered by the fruit stored at 20°C. These data indicated an important effect of temperature of 10°C on the color development and therefore would be advisable to store the fruit at 13°C instead of 10°C

Skin color. The skin color change (a* value) was delayed at 10°C; whereas at 20°C these changes were more noticeable (figure 35 and Annex 5). Fruit stored at 10°C maintained their color during the storage without some effect of irradiation doses as well as the storage time (Annex 5).

The fruit transfer from 10 to 20°C did not promote the color development and the values were very similar to those recorded for fruit stored at 10°C (figure 35). Again it is noteworthy that the skin color objective measurement did not show significant effects of irradiation doses unlike what happened with the external visual assessment; therefore the same hypothesis was made respect that the measurement area was not enough large to estimate the color changes with greater precision

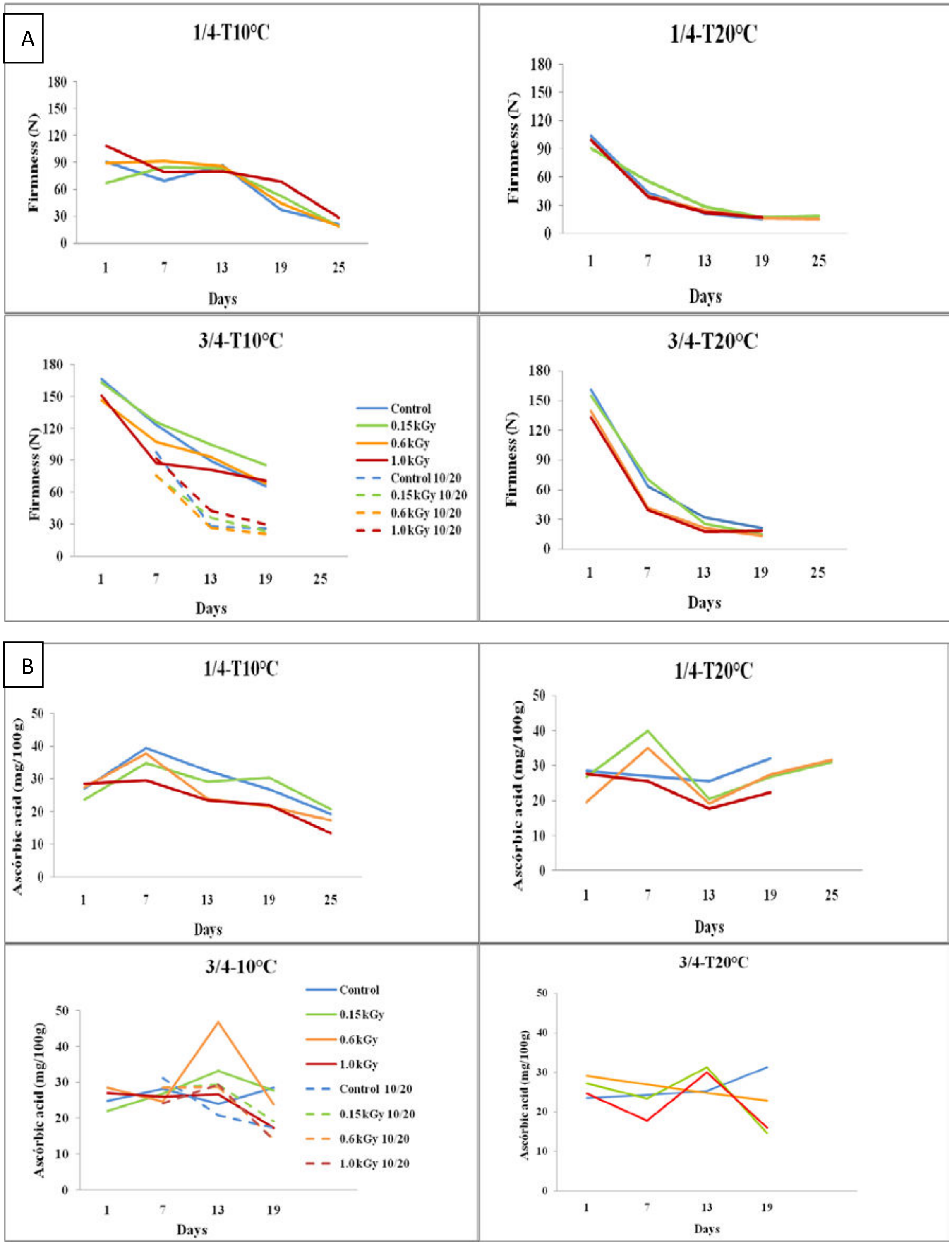



Figure 32 Changes in firmness (A) and ascorbic acid (B) in mango fruits cv 'Haden' at different maturity stages (¼ and ¾), irradiated at different doses and stored at 10 and 20 ° C. Dotted lines indicate the transfer of fruits from 10 to 20

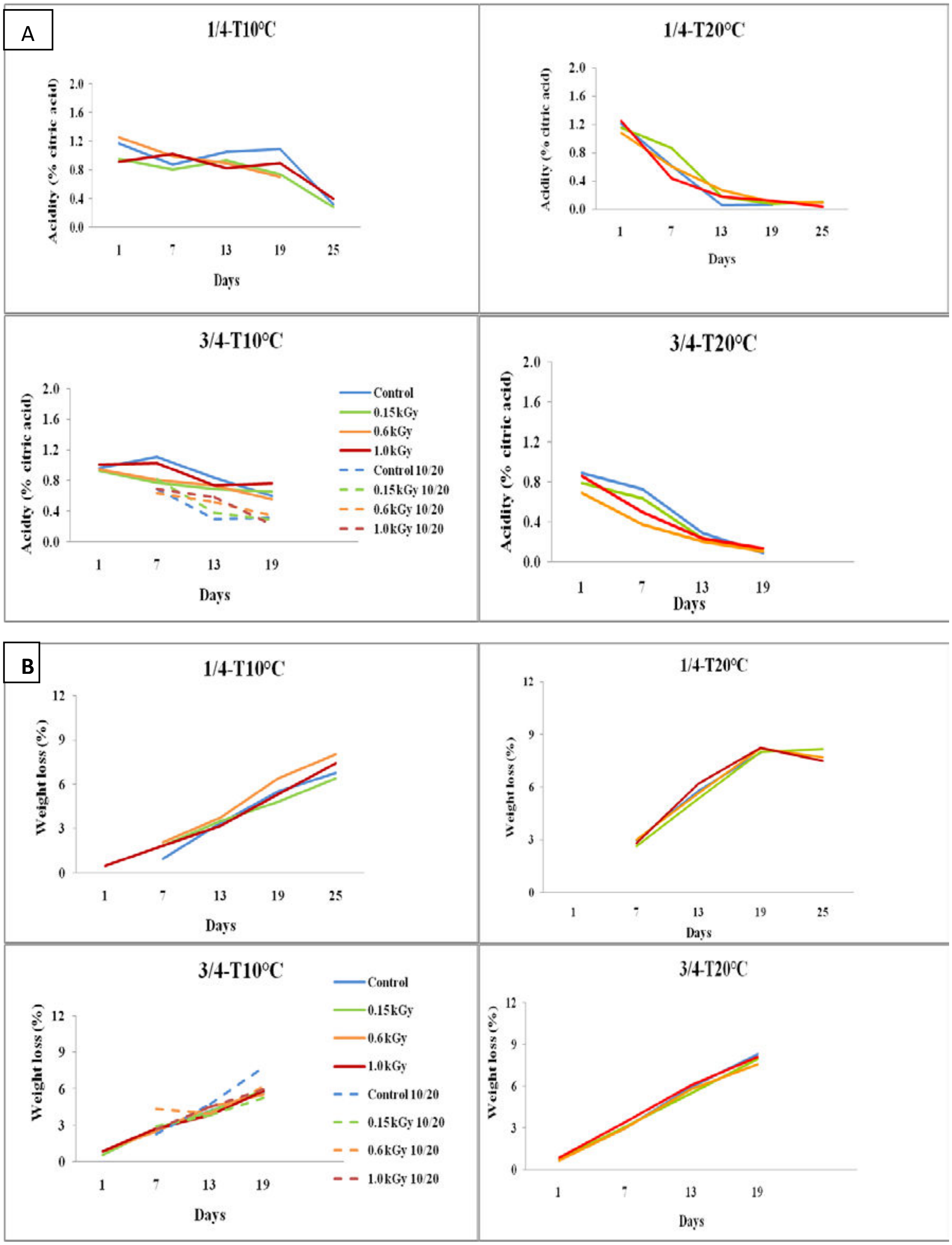



Figure 33 Changes in acidity (A) and weight loss (B) of mango fruits cv 'Haden' at different maturity stages (¼ and ¾), irradiated at different doses with gamma rays and stored at 10 and 20°C. Dotted lines indicate the fruit transferred from 10 to 20°C.

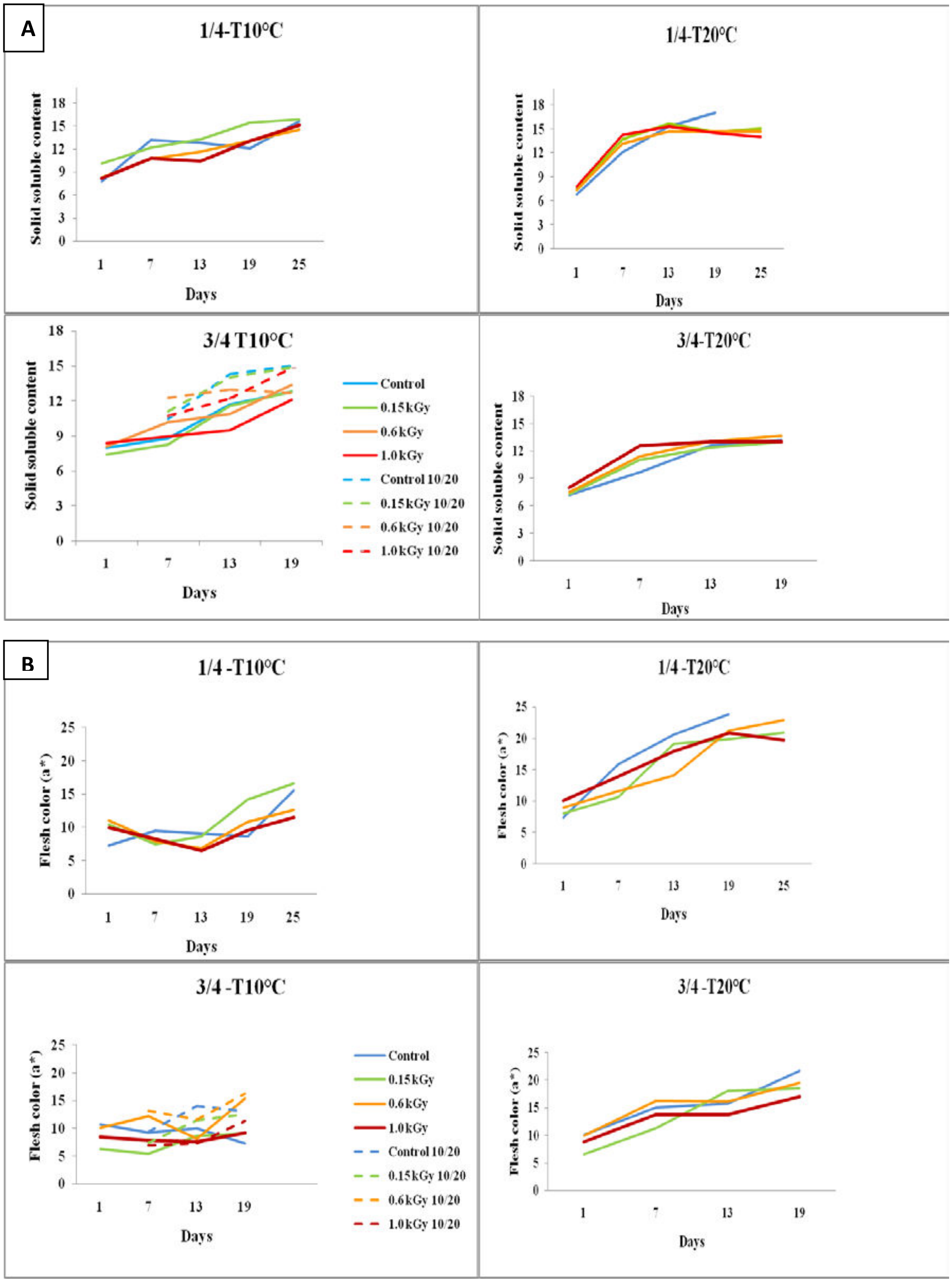



Figure 34 Changes of solid soluble content (A) and flesh color (B) in mango fruits cv 'Haden' in different maturity stages (¼ and ¾), irradiated at different doses with gamma rays and stored at 10 and 20°C. Dotted lines indicate the fruits transferred from 10 to 20°C.

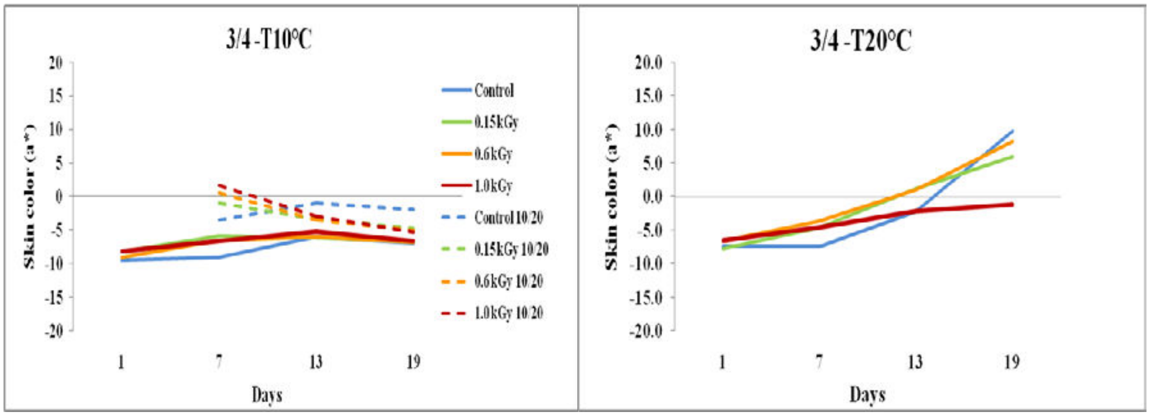



Figure 35 Changes in skin color of mango fruits cv 'Haden' in different maturity stages (¼ and ¾), irradiated at different doses with gamma rays and stored at 10 and 20°C. Dotted lines indicate the fruits transferred from 10 to 20°C.

#### 4.1.3.3 Physicochemical quality changes in mango 'Kent'.

Firmness. The firmness values registered one day after the irradiation treatments (Annex 6) classified this variety as high firmness fruit (78 to 164 N).

As expected for both maturity stages and irradiation doses applied, the storage at 20°C showed a more rapid loss of firmness respect of fruit stored at 10°C which keeps high their firmness values during the storage (figure 36A).

The statistical analysis showed significant differences related to maturity stage, storage temperature and dose applied (figure 36A and Annex 6). After 1 and 7 days of storage, the fruit in maturity ¼ treated at 1.00 kGy showed lower firmness values in both temperatures of storage. However, this difference did not be registered on 13 and 19 days of storage. The comparison between fruit stored at 10 and 20 °C indicated that the firmness was less in fruit stored at 20°C respect of the fruit stored at 10°C. For fruit in maturity ¾ the firmness measured one day after the treatments indicated that the control fruit had higher firmness than the irradiated fruits in both temperatures of storage; on the day 7 this difference was only observed in fruits stored at 10°C. After 13 and 19 days there are no differences between treatments. The fruits of both maturity stages and transferred from 10 to 20°C did not show statistical differences between treatments or with the fruit stored at 20°C.

The previous data indicated that the application of 1.00 kGy induced lower firmness values the first days after the treatment but this effect disappeared as the storage progressed. In addition, the firmness did not be altered by the fruit transfer from 10 to 20°C.

Ascorbic acid content. Although figure 36B suggest that the first 7 days of storage there were differences in the ascorbic acid content between the different irradiation doses applied; the statistical analysis (Annex 6) found specific differences on certain days and certain dose, storage temperature and maturity stage which disappeared as the storage progressed (days 13 and 19) and thus this response variable lost their significance as indicator of the fruit quality changes. After seven days of storage, the control fruit of both maturity stages and stored at 20°C showed a higher ascorbic acid content (42 to 45 mg $100g^{-1}$) than the fruit submitted at different irradiation doses (29 to 34 mg $100g^{-1}$) which were equal statistically to each other (figure 36B and Annex 6).

In all sampling dates, the fruit of both maturity stages stored at 10°C and transferred to 20°C did not show significant effect of the irradiation doses on their ascorbic acid content, although the fruit treated at 1.00 kGy had tendency to show lower values than the others treatments (figure 36B). The comparison on day 7 of the fruit transferred from 10 to 20°C in both maturity stages with those stored continuously at 20°C indicated that all fruit transferred had lower ascorbic acid content (29 to 32 mg $100g^{-1}$) than the control fruit stored at 20°C (42 mg 100g-1) indicating a negative effect of the storage at 10°C in addition to high irradiation dose (figure 36B). However, this difference did not be observed in subsequent sampling dates.

According with these data we can assume that in both temperatures studied the irradiation dose applied only had effects on the ascorbic acid content in the short- time storage but these effects disappeared after 13 or 19 days of storage. However, the fruit transferred from 10 to 20°C and irradiated at 1.00 kGy had lower ascorbic acid content than the control fruit stored at 20°C suggesting an additive effect of irradiation stress and chilling stress causes a greater loss of ascorbic acid. Therefore it is advisable to avoid the application of high irradiation doses (0.93 to 1.41 kGy).

Titratable acidity. Both maturity stages stored at 10°C did not show changes associated to irradiation dose applied or between time analysis (figure 37A and Annex 6). At 20°C there were no changes associated to irradiation dose in both maturity stages but there was a decrease of acidity contents during the storage. After 13 or 19 days the values were lower (0.2 to 0.3%) but statistically equal. In fruit of ¼ maturity submitted at 1.00 kGy and transferred from 10 to 20°C showed the highest values on day 19 (1.6%), while all other treatments had lower values and equal to each other. In fruit of maturity ¾ treated at 0.6 and 1.00 kGy and transferred from 10 to 20°C showed higher values than control fruits and irradiated at 0.15 kGy, this behavior is difficult to explain but may be an associated effect of irradiation doses or variability into the samples analyzed.

These data suggest that the temperature was the most important factor which regulated the acidity changes. But the storage time at 10°C and the transfer to 20°C associated to high irradiation dose seem to alter the ripening process. This suggest the convenience to applying irradiation dose under 0.93 kGy

Weight loss. Fruit stored at 10°C lost less weight tan the fruit stored at 20°C (figure 37B and Annex 6). At 10°C it was detected significant differences due to irradiation doses applied and sampling time also. Fruit in maturity ¼ irradiated at 1.00 kGy and stored during 13 or 19 days at 20°C showed higher weight loss. The fruit transferred from 10 to 20 °C did not show significant differences due to irradiation dose and the weight loss was lower than the fruit stored at 20°C (figure 37B).

According with these data, the weight loss was not a good indicator to evaluate the irradiation dose effects. Although the fruit of maturity ¼, treated at 1.00 kGy and stored at 20°C lost more weight. Therefore it should be avoided the irradiation dose application into 0.93 to 1.41 kGy range.

Solid soluble content. As the titratable acidity, the most important changes observed during the storage were due to the storage temperature. All fruit stored at 20°C increased their solid soluble content more quickly as the storage progressed, while the fruit stored at 10°C showed slight changes (figure 38A and Annex 6).

During the first seven days the fruit in both maturities stages and stored at 10 and 20°C did not show differences between different irradiation doses applied (Annex 6). However, on 13 and 19 days the solid soluble contents were statistically higher but the fruit irradiated at 1.00 kGy had solid soluble contents statistically lower than the control fruit and treated at lower doses but equal to each other (figure 38A and Annex 6). These data indicate that the dose range into 0.93 to 1.41 kGy altered the ripening process of this variety preventing that the fruit reached higher solid soluble contents. This effect was more noticeable on fruit of maturity ¼. The fruit stored at 10°C and transferred to 20°C did not indicate significant differences between irradiation treatments and they were similar to changes followed by the fruit stored at 20°C continuously.

According with the data showed, this variable could be an indicator of the alterations of ripening process due to irradiation process at 0.93 to 1.41 kGy range. The effect of these doses increased when the maturity fruit was ¼. It is therefore recommended do not harvest fruit in maturity stage ¼ and to avoid the irradiation into the mentioned range.

Flesh color. The storage of fruit in maturity stage ¼ at 10°C delayed the flesh color changes without observing effects of time sampling or irradiation dose (figure 38B and Annex6). For ¾ maturity and during the first 13 days of storage at 10°C the control fruit showed higher color development than irradiated fruit at different doses, although on the day 19 all treatment did not show differences. At 20°C, there was a further flesh color development observing significant differences associated to irradiation treatments, the control fruit in maturity ¼ and irradiated at 0.15kGy showed greater color changes in the flesh than the fruit irradiated at 0.6 and 1.00 kGy (figure 38B) while in maturity ¾ there were no statistical differences between different treatments.

In both maturity stages the fruit transfer from 10 to 20°C favored slightly the color changes of the fruit without finding effects of irradiation dose. However, the values reached were different from those reached by the fruit stored at 20°C continuously (figure 38B).

These data indicate a significant effect of the temperature of 10°C in the color development and therefore would be advisable to store the fruit at 13°C instead of 10°C.

In general form, the objective measurement of flesh color indicated that the maturity stage of ¼ showed more alterations in the flesh color development when it was submitted at 0.6 to 1.41 kGy doses and it is advisable to avoid processing fruit in this maturity stage and preferably avoid high irradiation doses.

Skin color. The skin color change (a* value) in fruit of both maturity stages was delayed by the temperature of 10°C without statistical differences between irradiation doses and sampling times (figure 39 and Annex 6). At 20°C these changes were more noticeable, although there was no differences respect of dose applied.

Fruit transfer from 10 to 20°C showed discrete skin color changes similar to fruit stored at 20°C (figure 39). The skin color changes in this variety confirmed the observations of the external visual quality of these fruits.

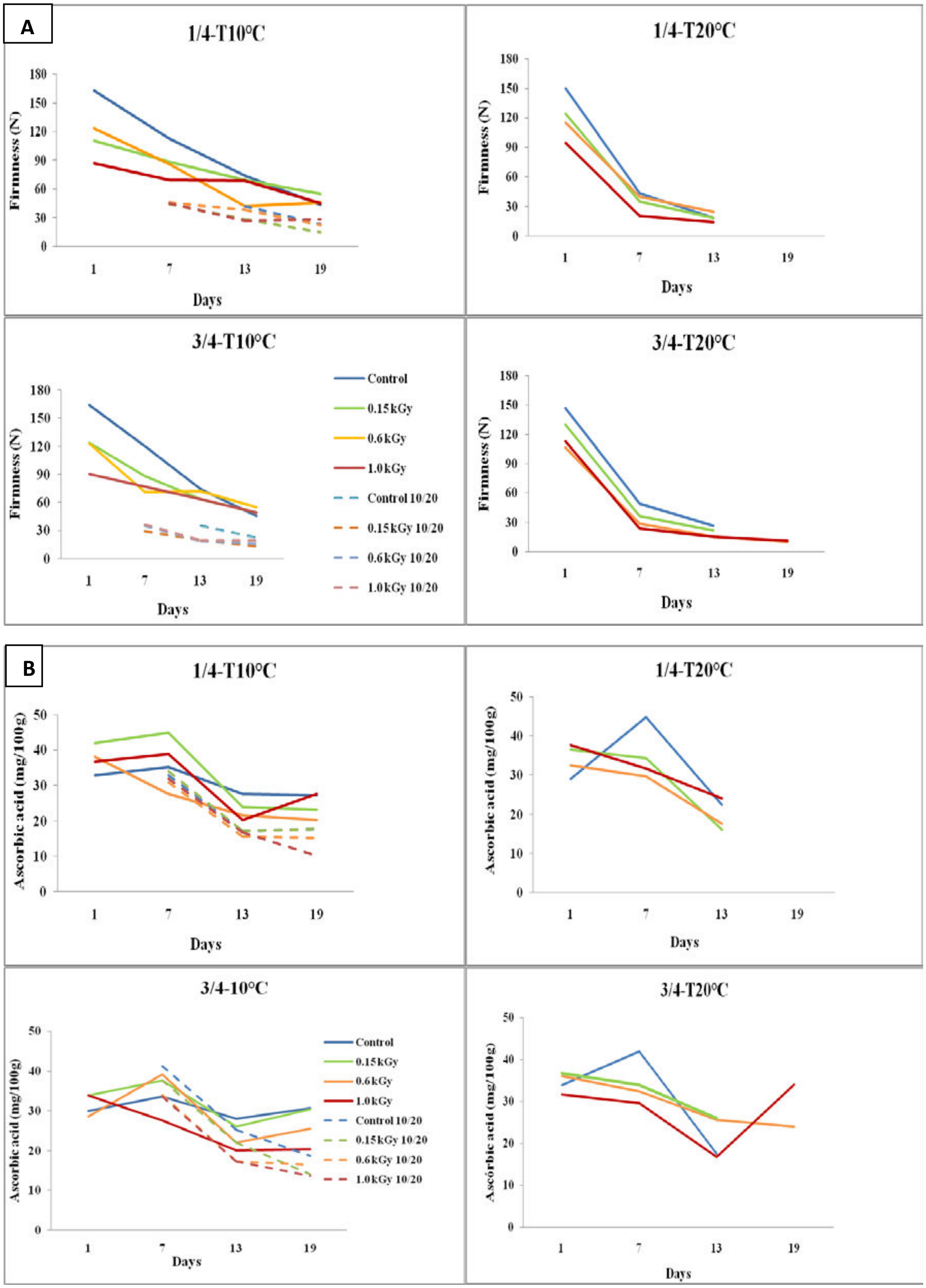



Figure 36 Changes in firmness (A) and ascorbic acid (B) in mango fruits cv 'Kent' at different maturity stages (¼ and ¾), irradiated at different doses and stored at 10 and 20 ° C. Dotted lines indicate the transfer of fruits from 10 to 20

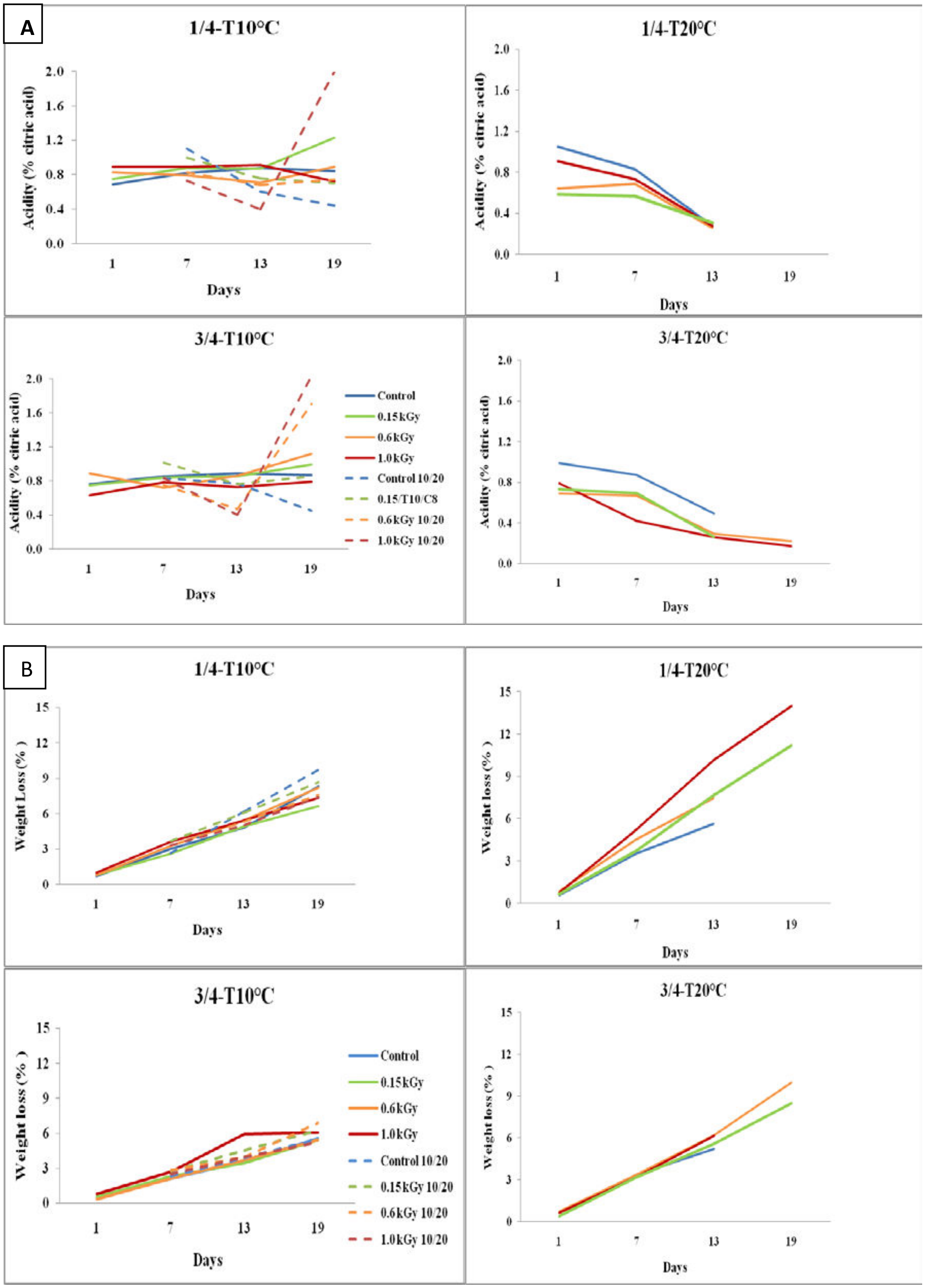



Figure 37 Changes in acidity (A) and weight loss (B) of mango fruits cv 'Kent' at different maturity stages (¼ and ¾), irradiated at different doses with gamma rays and stored at 10 and 20°C. Dotted lines indicate the fruit transferred from 10 to 20°C.

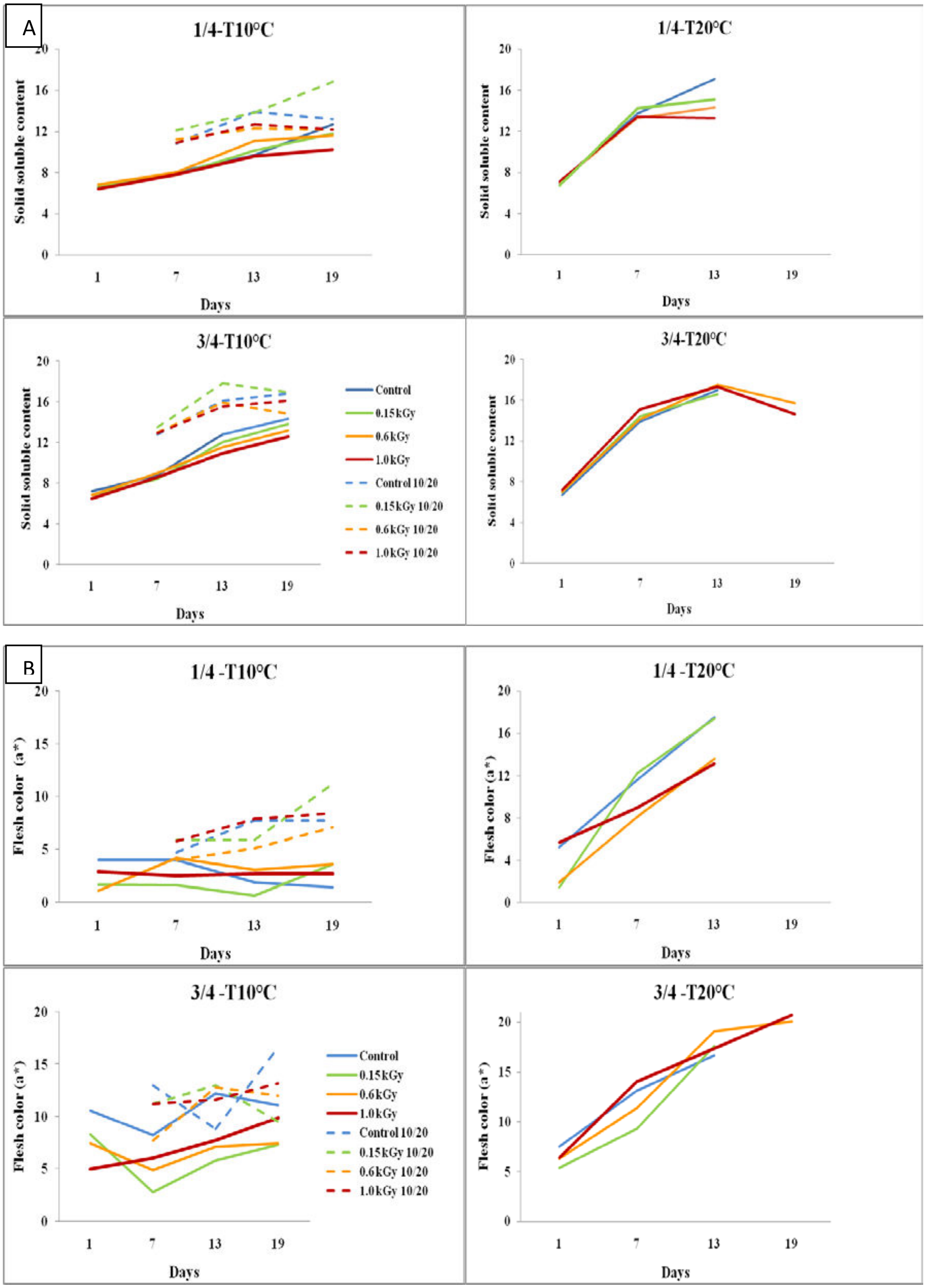



Figure Changes of solid soluble content (A) and flesh color (B) in mango fruits cv 'Kent' in different maturity stages (¼ and ¾), irradiated at different doses with gamma rays and stored at 10 and 20°C. Dotted lines indicate the fruits transferred from 10 to 20°C.

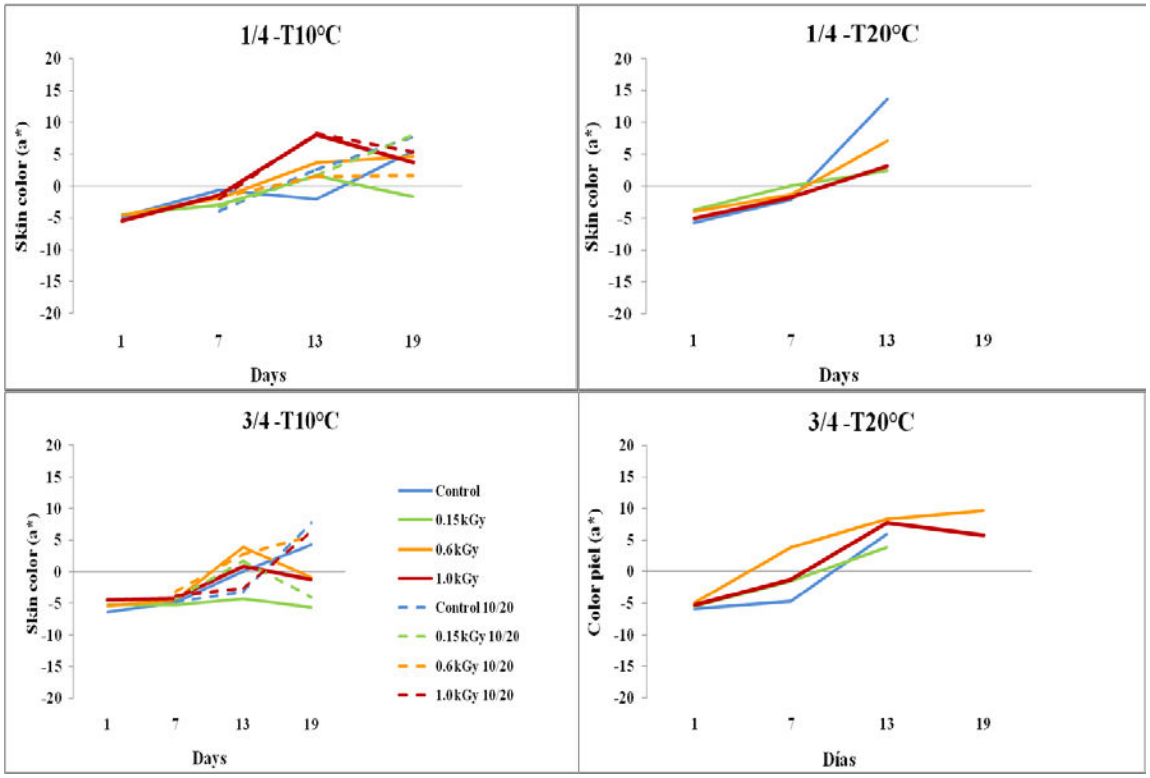



Figure 39 Changes in skin color of mango fruits cv 'Kent' in different maturity stages (¼ and ¾), irradiated at different doses with gamma rays and stored at 10 and 20°C. Dotted lines indicate the fruits transferred from 10 to 20°C.

#### 4.1.3.4 Physicochemical quality changes in mango 'Keitt'.

Firmness. According with the firmness values registered in the first day of the storage, this variety belongs also to fruit of high firmness. The most important changes of this factor during the storage were registered in fruit stored at 20°C while at 10°C the changes were minor. Fruit in maturity ¼ stored at 10°C did not show significant differences between irradiation dose at each time sampling observing similar values during the storage (figure 40A and Annex 7); control fruit and irradiated at 0.15 kGy in maturity ¾ and stored at 10°C for 13 and 19 days showed lower firmness values than fruit treated at 0.6 and 1.00 kGy indicating that these doses delayed the softening process of the fruits. At 20°C in both maturity stages it was observed that the fruit irradiated at 1.00 kGy showed the lowest firmness values. These data indicate that even at 10°C the irradiation process seems to delay the softening process, this effect was not observed during the storage at 20°C.

With regard to the fruit transferred from 10 to 20°C; in both maturity stages there was a decrease in firmness that reached similar values to those measured by the fruit stored at 20°C continuously without to observe significant differences between the irradiation dose applied (figure 40A)

These data indicate that the high irradiation dose accelerate the fruit softening process when they are stored at 20°C therefore seem reasonable do not recommend the application of high irradiation doses of these fruits.

Ascorbic acid. Fruit of maturity ¼ stored at 10° did not show effects of irradiation dose, although there were differences associated to sampling time, while in maturity ¾ the fruit irradiated at 0.6 and 1.00 kGy for 13 and 19 days showed low values (figure 40B and Annex 7). At 20°C, fruit in both maturity stages and irradiated at 0.6 and 1.00 kGy showed statistically lower values than control fruits and treated at 0.15 kGy. At the end of storage period the fruit in maturity ¼ irradiated at 1.00 kGy and transferred from 10 to 20°C showed the lowest values (20.6 mg $100g^{-1}$)respect other treatments (30 a 35 mg $100g^{-1}$) (figure 40B). In fruit of maturity ¾ there were only differences on the seven day of storage where again the fruit treated at 0.6 and 1.00 kGy showed lower ascorbic acid contents although in the posterior sampling times there were not differences between the groups.

The above data indicate that the ¼ maturity stage and high irradiation dose promote greater ascorbic acid lost suggesting that it is necessary to avoid the irradiation of mangos in maturity ¼ as well as the 0.54 to 1.51 kGy doses range.

Acidity. Fruit of maturity ¼ stored at 10°C did not show changes significant statistically during all period of storage, while the fruit in ¾ maturity stage showed changes during the storage but such changes did not be related to irradiation dose applied (figure 41A and Annex 7). Fruit in maturity ¼ stored at 20°C showed statistically significant differences related with the sampling period but not to irradiation dose, although the control fruit tended to register higher values (figure 41A and Annex 7). Fruit in maturity ¾ showed differences associated to sampling time and irradiation dose applied (Annex 7); after 13 and 19 days of storage the control fruit showed a smaller decrease in acidity compared to irradiated fruit which were equal to each other (figure 41A). The variability of data acidity in fruit transferred from 10 to 20°C did not allow observing differences between different treatments or with those that were stored at 20°C continuously. However, the figure 41A indicate that fruit in both maturity stages and irradiated at 1.00 kGy decreased their acidity more quickly.

The above data indicated that acidity did not allow observing clearly the effects of irradiation dose but these showed that the temperature of 10°C delayed the acidity changes becoming more evident in ¼ maturity fruits, while in fruit transferred at 20°C there was higher decrease of acidity in fruit irradiated at 1.00 kGy.

Weight loss. Fruit in both maturity stages and stored at 10°C lost less weight than those fruit stored at 20°C (figure 41B and Annex 7); but there were no significant differences between the different irradiation dose for each sampling date. However, there were differences between the different sampling dates; fruit stored for more time lost more weight (Annex 7). At 20°C and during the first 13 days of storage it was only observed significant differences associated to sampling dates but not to irradiation dose applied. On day 19, all irradiated fruits lost more weight respect to non-irradiated fruit (Annex 7). The fruit that were transferred from 10 to 20°C did not show statistically significant differences due to irradiation doses and they were similar to control fruit stored at 20°C.

According to data of this variable, the weight loss was not a good indicator to evaluating the irradiation dose effect.

Solids soluble content. As the acidity, the most important changes observed during storage were due to storage temperature. All fruits stored at 20°C increased their solid soluble content during the storage while those that were stored at 10°C showed slight changes (figure 42A). During the first seven days of storage at this temperature, the fruits irradiated at different doses did not show significant differences. However, after 13 or 19 days of storage the fruits irradiated at 1.00 kGy increased in lesser grade their content of soluble solid which indicated a delay in the ripening process. For the fruit in maturity ¾ and during the first 13 days of storage there were not significant differences between the different doses but on day 19, the fruit irradiated at 1.00 kGy showed a less solid soluble development (figure 42A) indicating a delay in the ripening process due to dose applied.

At 20°C the changes of solid soluble contents were the most noticeable respect of those observed at 10°C, however, no significant differences were observed between the different irradiation doses applied (Annex 7) and only there were significant differences between the different sampling times. The fruits of maturity ¼ transferred from 10 to 20°C did not show differences between the different doses applied or with the fruits stored at 20°C. The fruit in maturity ¾ irradiated at 1.00 kGy and transferred from 10 to 20°C only showed a smaller soluble solids development (Figure 42A) which indicated that this dose delayed the ripening process.

These data indicate that doses range of 0.87 to 1.51 kGy altered the ripening process in this variety avoiding that the fruit reached high solid soluble contents.

According to these data this variable response could be and indicator of alterations in the ripening process generated by the irradiation treatment into 0.87 to 1.51 kGy range. The effects of these doses were enhanced when the maturity stage was ¼. Therefore it is not advisable to harvest fruit in maturity ¼ and avoid the irradiation in the mentioned range.

Color flesh. The figure 42B shows the internal color changes (a* value) measured during the storage in fruit submitted to different irradiation doses, the Annex 7 resume the means comparison of statistical analysis.

As expected, the largest color changes occurred in fruits stored at 20°C, whereas at 10°C there was little color evolution. Fruit in maturity ¾ stage stored at 10°C during 13 days did not show color evolution in the flesh in all treatments. However, on day 19 it was observed that fruit irradiated at all doses showed color values statistically equal to each other but lower than the non irradiated fruit indicating that the irradiation altered the color changes of the fruit. The fruit in maturity stage ¾ did not show effect of the doses or sampling time (Annex 7) indicating that at 10°C the color changes were delayed. At 20°C the fruit of maturity stage ¼ did not show differences between the different irradiation doses and only there were differences between the different sampling times, fruit stored for 13 and 19 days showed higher color development respect the fruit stored for 1 or 7 days. Fruit transferred from 10 to 20°C showed less color development in all treatments and these fruit could not to achieve the color developed by the fruit fruits stored at 20°C continuously which indicated a significant effect of storage at 10°C. However, the fruits in maturity stage ¼ and irradiated at 1.00 kGy showed a further delay in the flesh color evolution indicating that this dose altered further the ripening process (figure 42B) which was associated with the spongy tissue development described in the internal visual appearance section.

In this variety the color change in the flesh of fruits of maturity stage ¾ was more pronounced than the color reached by the fruit of maturity ¼ which calling attention about the importance of harvest fruit in maturity stage ¾ instead ¼ .

In general, the objective color measurement of the flesh was only useful to detect deep color changes associated with dose of 1.00 kGy (0.87 to 1.51 kGy), although this measure did not exceeded the internal visual quality because the measurement was done in a circle of one centimeter in diameter.

Skin color. The statistical analysis of color data of the skin from fruit in both maturity stages stored at 10°C, only found differences associated to sampling time but not to irradiation doses (figure 43 and Annex 7). Also the fruit stored at 20°C in both maturity stages did not show differences associated to irradiation dose but there were significant differences because of the sampling time.

The fruits transferred from 10 to 20°C showed color changes smaller. The color value measured during the transfer was similar to the registered by the fruit stored at 20°C (figure 43).

In this variety the objective measurement of skin color did not allow to observe the same characteristics described in the external visual quality section. It is possible that the small orifice of the spectrophotometer where this variable was measured could not to register all changes indicated in that section.

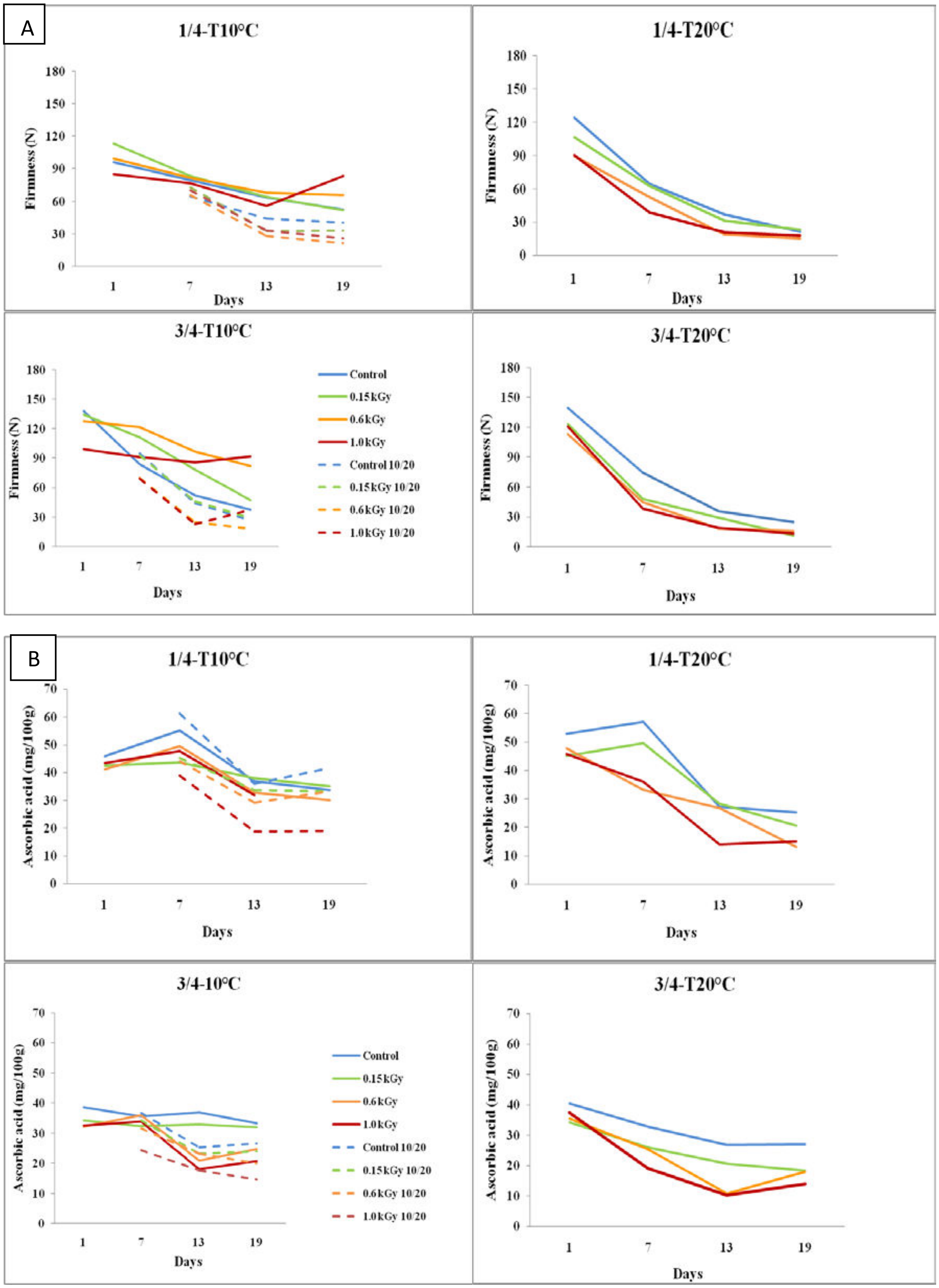



Figure 40 Changes in firmness (A) and ascorbic acid (B) in mango fruits cv 'Keitt' at different maturity stages (¼ and ¾), irradiated at different doses and stored at 10 and 20°C. Dotted lines indicate the transfer of fruits from 10 to 20

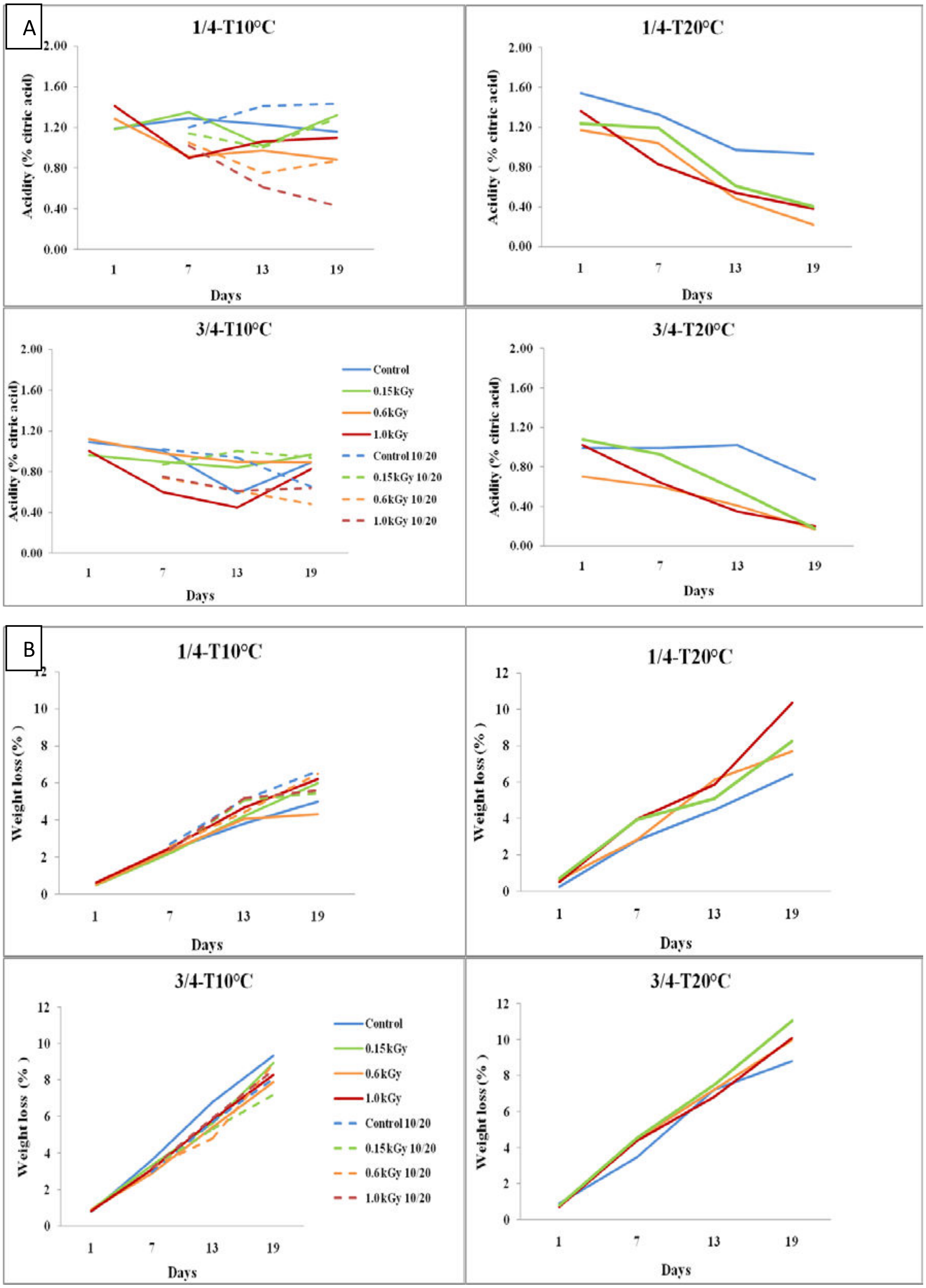



Figure 41 Changes in acidity (A) and weight loss (B) of mango fruits cv 'Keitt' at different maturity stages (¼ and ¾), irradiated at different doses with gamma rays and stored at 10 and 20°C. Dotted lines indicate the fruit transferred from 10 to 20°C.

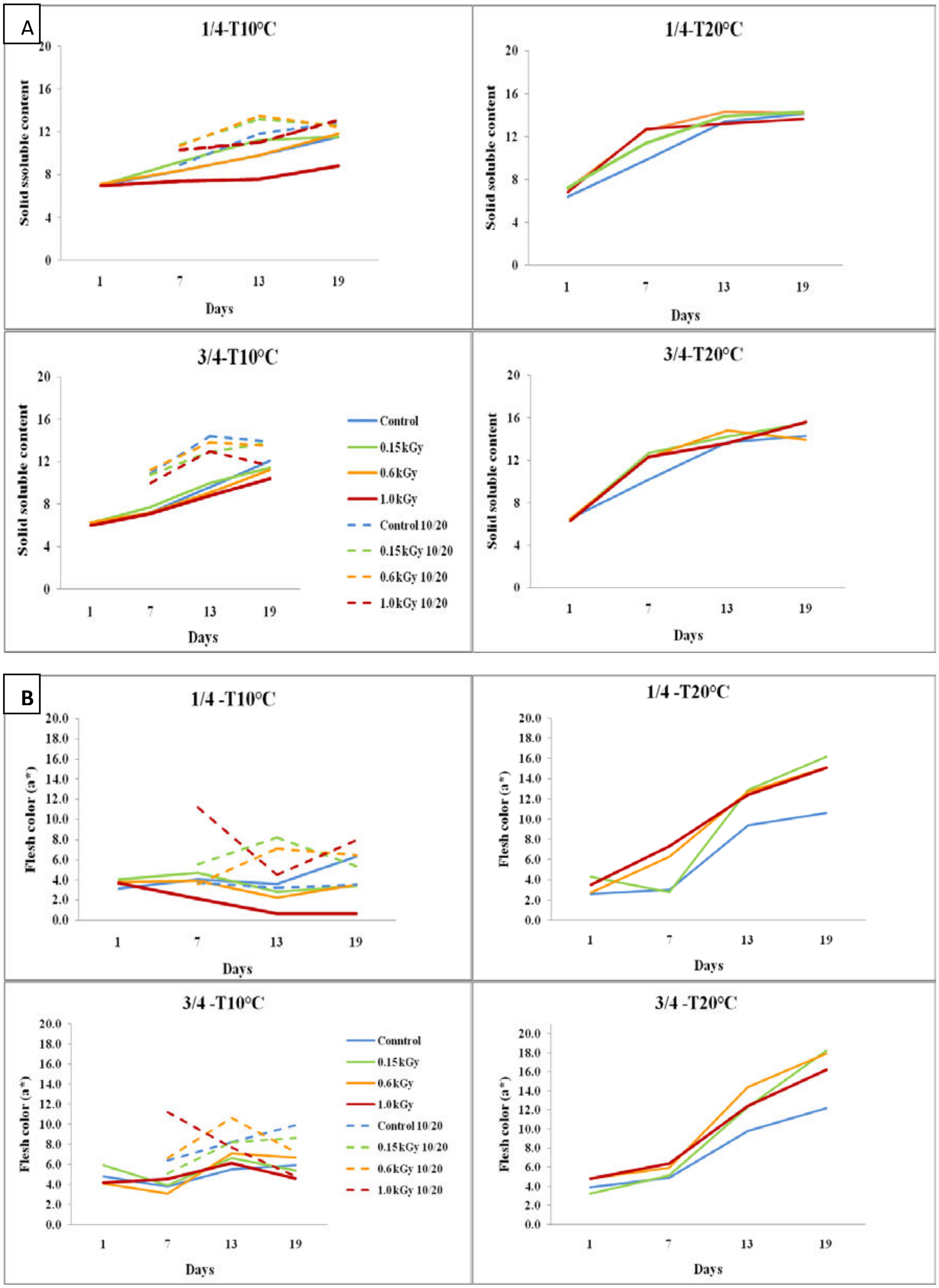



Figure 42 Changes of solid soluble content (A) and flesh color (B) in mango fruits cv 'Keitt' in different maturity stages (¼ and ¾), irradiated at different doses with gamma rays and stored at 10 and 20°C. Dotted lines indicate the fruits transferred from 10 to 20°C.

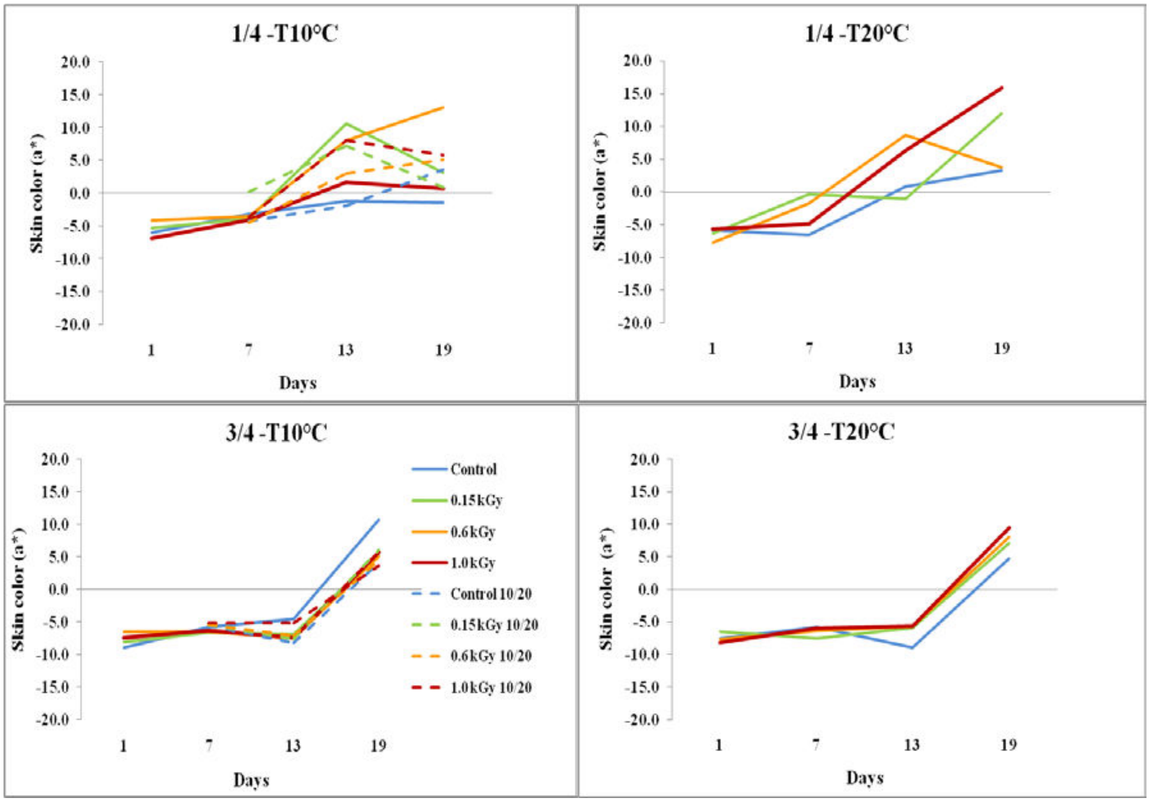



Figure 43 Changes in skin color of mango fruits cv 'Keitt' in different maturity stages (¼ and ¾), irradiated at different doses with gamma rays and stored at 10 and 20°C. Dotted lines indicate the fruits transferred from 10 to 20°C.

#### 4.1.3.5 Physicochemical quality changes in mango 'Ataulfo'.

Firmness. The firmness values measured one day after of irradiation treatments indicated that this variety had lower values firmness (38 to 74 N) and then this variety was defined as low mechanical resistance.

As expected the storage at 20°C caused a rapid loss of firmness in comparison of the fruits stored at 10°C which had high firmness values during the storage (figure 44A).

While the first day of storage at 10°C the fruit of ¼ maturity and treated at 1.00 kGy showed significant lower firmness values than the others fruit treated at other doses, the following days of storage there were no statistical differences between different doses applied (figure 44A). Fruit at this maturity stage stored at 20°C did not show significant differences between the different doses during all storage period (Annex 8). The fruit of ¾ maturity stored at 10°C did not show differences between the doses applied. However, the control group stored one day at 20°C showed lower firmness values than the values showed by other fruits treated by irradiation which were statistically similar itself but in the posterior days there were no significant differences between treatments. From commercial point of view the firmness changes that occurred during the storage are not significant in the practice and can say that the firmness was not affected by the irradiation dose applied.

Fruits transferred from 10 to 20°C in both maturity stage and irradiation doses did not show significant differences between the irradiation treatments or with control group stored at 20°C (figure 44A).

One aspect of commercial interest for this variety was that the firmness of fruit stored at 20°C or transferred from 10 to 20°C reached the minimum value after seven days of continuous storage at 20°C or after the first transfer and later these values were kept during the next two transfers (days 13 and 19 of storage). This behavior show an important difference with the other four varieties described before in which the softening process occurred more slowly.

Ascorbic Acid. This variety showed the highest contents of ascorbic acid respect of all varieties studied showing values into 61 – 151 mg per 100g-1 range in the different conditions of storage (figure 44B and Annex 8). Both maturity stages stored at 10°C during 19 days did not show significant differences of ascorbic acid content between the control groups and treated at 0.15 or 0.60 kGy. However, the fruit treated at 1.00 kGy showed significant lower values of this vitamin in comparison with other treatments (Annex 8).

Fruit in maturity ¼ irradiated at 1.00 kGy and stored one day at 20°C showed the highest values of this vitamin (151 mg $100g^{-1}$). However, after 19 days of storage this same group showed the lowest values (68 mg 100 $g^{-1}$) in comparison with other treatments (Annex 8). In the case of fruit in maturity ¾ stored at 20°C, the control fruit and treated at 0.15 and 0.60 kGy showed high values of this vitamin although this difference was not observed in the following sampling dates. These data indicated that this variety should not be irradiated in the range of 0.95 to 1.43 kGy.

During all storage period the fruit in maturity stage ¼ and transferred from 10 to 20°C did not show differences between the different irradiation treatments or with the control fruit. While the fruit in maturity ¾ and irradiated at 1.00 kGy showed lower values in comparison with other treatments (figure 44B).

The previous data suggest that this variety should be not subjected to doses in the range of 0.95 to 1.43 kGy.

Acidity titratable. The fruit in ¼ maturity stored at 10°C did not show differences associated to irradiation treatments (figure 45A and Annex 8), although there were differences associated to storage time. In fruit of maturity ¾ there were no differences associated to doses applied or with the storage time indicating that the temperature of 10°C delayed the ripening process. At 20°C in both maturity stages only it was detecting differences associated to irradiation doses but not to irradiation doses. Also in the fruit transferred from 10 to 20°C the behavior of this variable did not show statistical differences between treatments and all fruits had similarities with the fruit stored at 20°C.

In according with the data described in this section, the acidity titratable did not evaluate the effect associated to irradiation applied. Therefore the acidity was not a good indicator to evaluate the irradiation dose.

Weight loss. Fruit stored at 10°C lost less weight than the fruit stored at 20°C (figure 45B and Annex 8). In both maturity stage and temperature condition there were no significant differences associated to irradiation dose and as expected there were significant differences between storage days or sampling time. The fruit transferred from 10 to 20°C did not show significant differences associated to irradiation dose and they had similarity with the control fruit stored at 20°C.

In according with these data, the weight lost was not a good indicator to evaluate the effects of irradiation dose applied. However, the fruit in maturity ¾ stored at 10°C suggest that this variety should be not irradiated in the range of 0.95 to 1.43 kGy.

Solid soluble content. As the acidity titratable in this response variable the most important changes were due to storage temperature. All fruit stored at 20°C increased their solid soluble content during the storage while those stored at 10°C showed slight changes. The low content of solid soluble at the start of the experiment seems indicate harvest fruit in early stages. However, the changes of this variable during the storage at 20°C indicated that these maturity stages were able to continue with the ripening process.

Fruit in maturity ¼ stored at 10°C during 1 to 7 days did not show significant differences between the irradiation dose (figure 46A and Annex 8). However, fruit stored 13 and 19 days showed high solid soluble content but the fruit irradiated at 1.00 kGy had lower contents in comparison with the other fruit treated at different doses which showed high values but similar itself. For fruit in maturity ¾ show the same behavior but the effect of 1.00 kGy was observed until day 19. These data showed that the range doses of 0.95 to 1.43 altered the ripening process preventing the fruit would reach higher solid soluble content. Fruit of both maturity stages stored at 20°C showed significant increases from day 1 and 7 and continued until 13 and 19 days where the statistical analysis did not find differences between the different irradiation treatments applied. In a similar way, the fruit stored at 10°C and transferred at 20°C did not indicate significant differences between irradiation treatments and they were similar to the fruit stored at 20°C continuously.

In according with these data, this variable could be an indicator of the ripening process changes induced by the irradiation treatment at high doses or in the range of 0.93 to 1.43 kGy. The effect of these doses was increased when the maturity stage was ¼. Therefore it is suggest harvest fruit in maturity ¾ and avoid the irradiation in the range mentioned.

Flesh color. The fruit transfer of both maturity stages from 10 to 20°C slightly favored the flesh color changes. However, the fruits irradiated at 1.00 kGy notably delayed their flesh color change (figure 46B) and this values were not compared with those values reached by the fruit stored at 20°C continuously. This data indicated a significant effect of the temperature of 10°C in the color development which was related with the spongy tissue development that showed these fruit when were subjected to this radiation dose.

In fruit of maturity ¾ the flesh color changes were more pronounced respect of the color reached by the fruit in maturity ¼ which indicated the importance to harvest fruit in maturity ¾ instead ¼.

In general the objective color measurement only was useful to detect deep color changes associated to 1.00 kGy doses (range of 0.95 until 1.43 kGy) although these measurements did not exceed the visual fruit observation because this parameter was measured in a circular area of only one centimeter in diameter.

Skin color. The skin color changes (a* value) of fruits in both maturity stages was delayed at 10°C, whereas at 20°C these changes were more noticeable (figure 47).

Fruit of both maturity stages stored at 10°C remained delayed their color changes during its storage and they did not show effects of irradiation doses as well as of the storage time (figure 47 and Annex 8). At 20°C the fruit of both maturity stages did not show significant differences respect of irradiation doses applied but they showed significant differences associated to sampling time.

Fruit transferred from 10 to 20°C showed color changes in the skin associated to irradiation doses applied, fruit irradiated at 1.00 kGy developed less color respect the other irradiation doses indicating that this dose altered the color change of the fruit (figure 47). These data had relationship with the visual appearance of the fruit described in the external visual quality section where it was observed the browning areas development on the fruits.

In according with this variable it possible to indicate that high irradiation doses tended to alter the skin color and for this reason is advisable does not reach doses located above the range of 0.95 to 1.43 kGy.

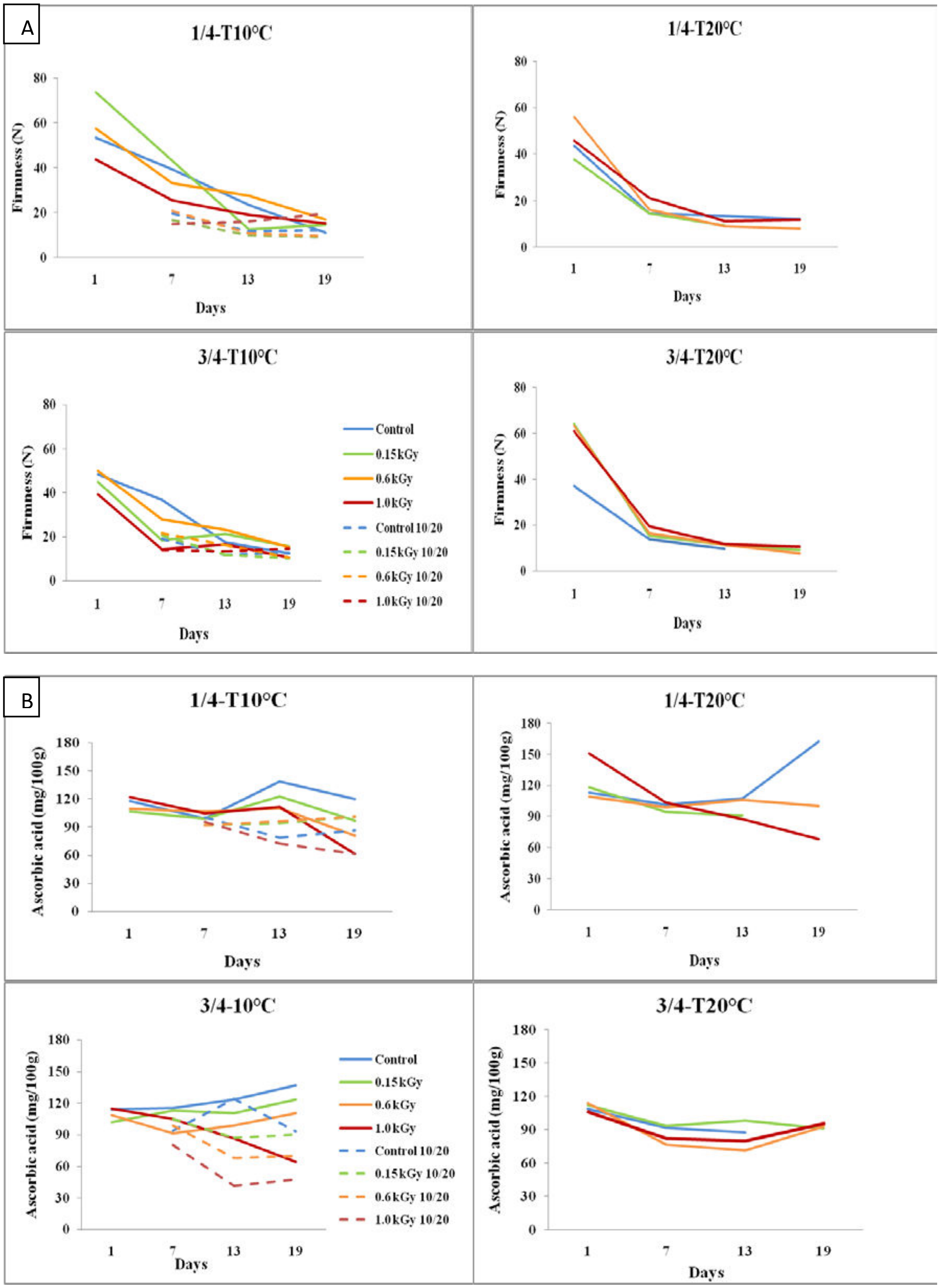



Figure 44 Changes in firmness (A) and ascorbic acid (B) in mango fruits cv 'Ataulfo' at different maturity stages (¼ and ¾), irradiated at different doses and stored at 10 and 20°C. Dotted lines indicate the transfer of fruits from 10 to 20

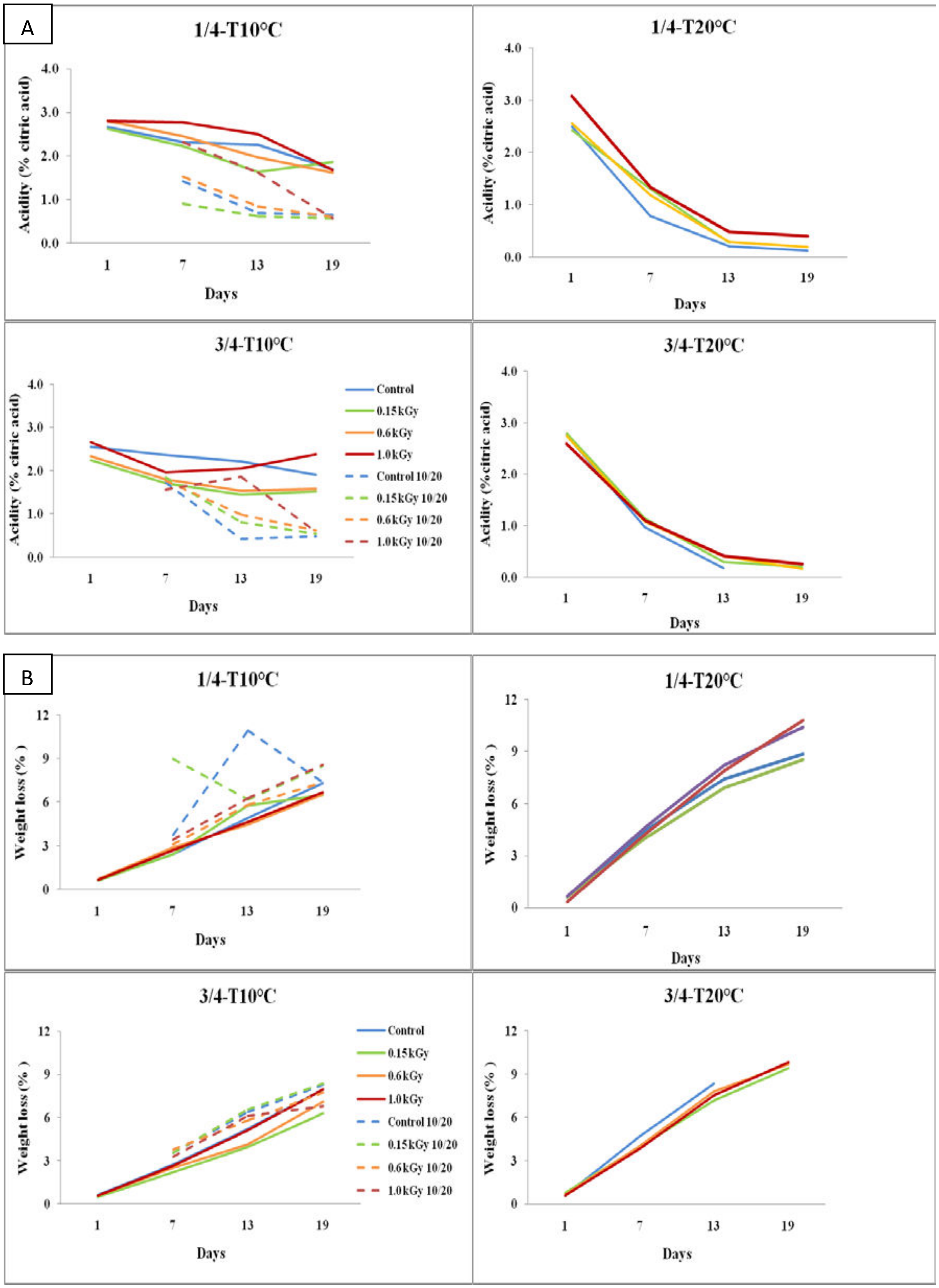



Figure 45 Changes in acidity (A) and weight loss (B) of mango fruits cv 'Ataulfo' at different maturity stages (¼ and ¾), irradiated at different doses with gamma rays and stored at 10 and 20°C. Dotted lines indicate the fruit transferred from 10 to 20°C.

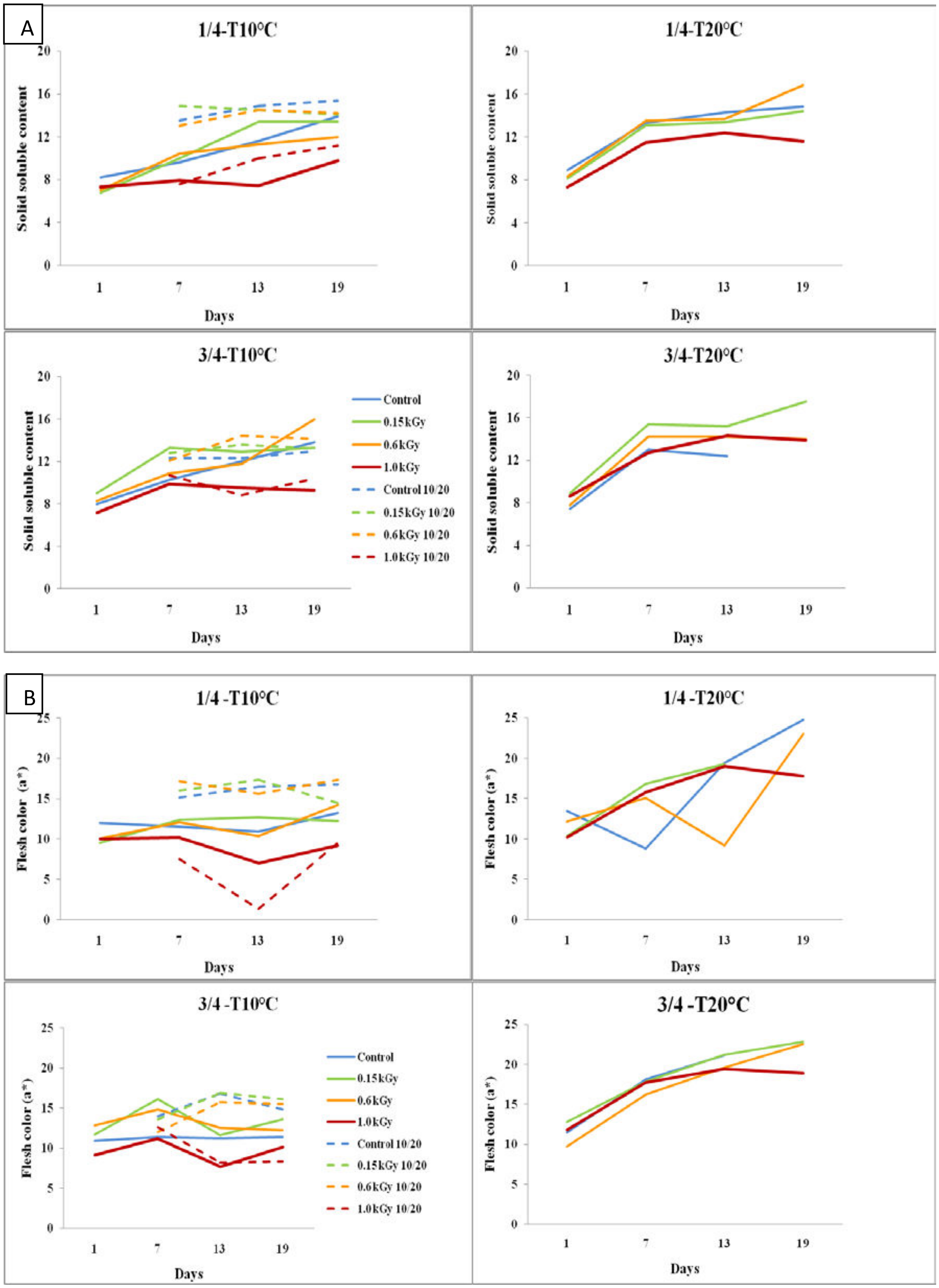



Figure 46 Changes of solid soluble content (A) and flesh color (B) in mango fruits cv 'Ataulfo' in different maturity stages (¼ and ¾), irradiated at different doses with gamma rays and stored at 10 and 20°C. Dotted lines indicate the fruits transferred from 10 to 20°C.

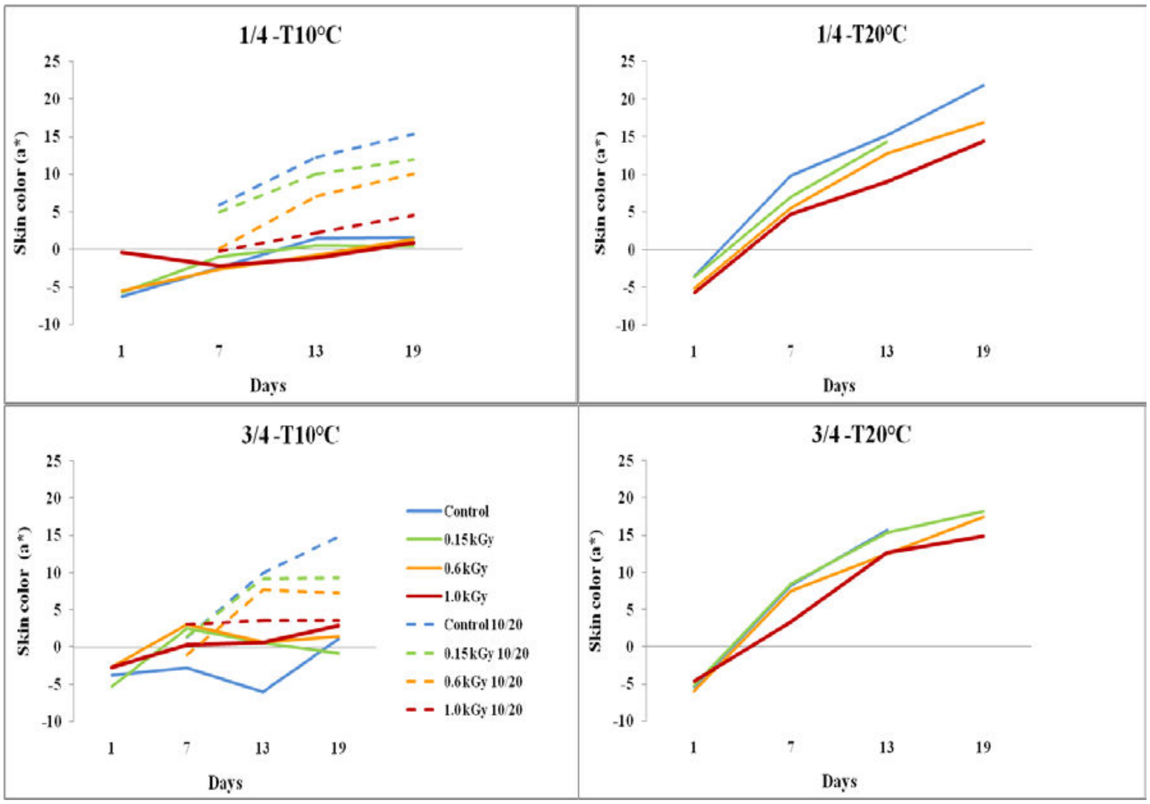



Figure 47 Changes in skin color of mango fruits cv 'Ataulfo' in different maturity stages (¼ and ¾), irradiated at different doses with gamma rays and stored at 10 and 20°C. Dotted lines indicate the fruits transferred from 10 to 20°C.

#### 4.1.3.6 Physicochemical quality changes in mango 'Manila'.

Firmness. Firmness values measured one day after the irradiation treatments classified this variety as the lowest firmness variety with values oscillating between 14 to 45 N.

Like all varieties, the storage at 20°C caused a rapid firmness lost respect of the fruit stored at 10°C which maintained higher their firmness during the storage.

Although the figure 48A appears to show differences in the firmness values for both maturity stages and different irradiation treatments, the statistical analysis (Annex 9) of the fruit stored 10°C did not show significant differences between doses applied (Annex 9) in spite of the treatment at 1.00 kGy appeared to show higher firmness values whereas the control group appeared to show the lowest values.

Only the first day of storage the fruit in both maturity stages and treated with different irradiation doses and stored at 20°C showed high values of firmness (19 – 31 N) respect of the control group that showed the lowest values (13 – 18.5 N). This condition was not maintained in the following days of storage where there were no differences between the treatments.

Fruit in both maturities stages and transferred from 10 to 20°C showed the lowest values of firmness after seven days of storage and there were no statistical differences associated to irradiation doses applied or with the fruit group stored at 20°C continuously.

In according to data of this variable it can say that this variable was not a good indicator to observe the irradiation doses effects

The previous data suggest that mangos with high firmness, the dose of 1.00 kGy (range of 0.96 to 1.33 kGy) appear to induce lower values in firmness during the first days of storage while in mango fruits whose firmness was lower, the same dose appeared to maintain higher firmness but this condition was not retained during the storage.

Ascorbic acid. After the 'Ataulfo' variety the 'manila variety showed also high contents of ascorbic acid respect the other varieties with contents between the range of 42.8 a 91.2 mg $100g^{-1}$ (Annex 9). As special feature of this variety, the fruit in both maturity stages showed a trend to increase the ascorbic acid content during the storage (figure 48B) observing the highest values on day 19.

This behavior was not altered by the irradiation dose applied (Annex 9). At 20°C there was a similar pattern, although given the perishable of these fruits the analysis was carried out only until the day 13. Fruit transferred from 10 to 20°C in maturity stage of ¼ did not show significant differences during all transfers, although there was a trend to measure high values on day 19. In fruit of maturity ¾ the control treatment and irradiated at 0.15 kGy showed the highest values (78 a 83 mg 100 $g^{-1}$) in comparison with the fruits treated at 0.60 and 1.00 kGy (47 to 54 mg 100 $g^{-1}$) without to observe differences between the fruit stored at 20°C continuously.

Acidity titratable. The most important changes in acidity during the storage were due to storage temperature. The fruit stored at 20°C decreased their acidity content during the storage while the fruit stored at 10°C showed slight changes (figure 49A) due to delay in the ripening observing at this temperature (Annex 9). The acidity contents measured in this variety were lower than 'Ataulfo' variety but higher (1.4 to 2%) respect of other varieties.

At 10°C there were no differences associated to irradiation treatments or between the sampling time in both maturity stages (figure 49A and Annex 9) indicating again that this temperature delayed the ripening process. At 20°C both maturity stages showed significant differences associated to sampling times but not to irradiation dose. Also the fruit transferred from 10 to 20°C did not show statistical differences between doses applied or with the fruit stored at 20°C.

In according with these data, the acidity did not estimate the effects associated with irradiation doses and their changes observed depending of the storage temperature; at 10°C the ripening process was delayed while this did not occur at 20°C, Therefore the acidity was not an appropriate indicator to assess the irradiation doses effects.

Weight loss. This variety showed visible signs of wilting as the fruit lost weight and these were visible when the weight loss was higher than 8%, in this condition it was considered the end of their useful life. Fruit stored at 10°C lost less weight than those stored at 20°C (figure 49B and Annex 9). However, the fruit in maturity ¾, irradiated at 1.00 kGy and stored at 10°C lost more weight on day 19 but excluding this exception, there were no significant differences associated to irradiation doses in both maturity stages and storage temperature. However and as expected, there were significant differences associated to sampling times, Fruits transferred from 10 to 20°C did not show significant differences due to irradiation dose and they were similar to control fruit set stored at 20°C.

According to data of this variable, the weight loss was not a good indicator to evaluate the effects of irradiation dose. Although the changes only were detected in the maturity stage ¾, it seems reasonable indicate that the dose range of 0.96 to 1.33 kGy should be avoided.

Solid soluble content. As the acidity titratatble in this response variable the most important changes observed during the storage were due to storage temperature (figure 50A and Annex 9). All fruit stored at 20°C increased their solid soluble content during the storage while those fruit stored at 10°C showed slight changes.

Although the variability of data did not allow observing significant effects of the irradiation dose, fruit of both maturity stages, irradiated at 1.00 kGy and stored at 10°C tended to show lower changes than the other treatments. These data indicated that the range doses of 0.96 to 1.33 kGy altered the ripening process by preventing that the fruit reached higher solids soluble contents. At 20°C both maturity stages showed significant increases from the days 1 and 7 and continued until days 13 and 19 where the statistical analysis did not find differences between the irradiation doses. The fruit of both maturity stages irradiated at 1.00 kGy and stored at 10°C showed lower values of solid soluble respect of the other treatments that were similar to each other, and likewise there was no difference with the fruit stored at 20°C continuously (Annex 9).

According to the previous data this variable could be an indicator of the changes of the ripening process as a result of irradiation treatment at high doses or in the range of 0.96 to 1.33 kGy. The effects of these doses were increased when the maturity stage was of ¼. It is suggested does not harvest fruit in maturity ¼ and avoid the irradiation in the range mentioned.

Flesh color. As expected the largest color changes occurred in fruits stored at 20°C while at 10°C there was little color evolution (figure 50B and Annex 9). The flesh color in fruit of both maturity stages irradiated at 1.00 kGy and stored at 10°C showed little color change in comparison with other treatments (figure 50B).

The most noticeable color changes were observed from day 7 at 20°C with no observed effects of irradiation dose in each sampling period. It is possible that the color differences observed at 1.00 and 0.60 kGy could be associated to spongy tissue development which was observed in these doses.

In general the objective color measurement of the flesh only was useful to detect drastic color changes associated to 1.00 kGy dose (range of 0.96 to 1.33 kGy) although this measure did not exceed the visual observation of the fruit because this parameter was measured only in a circle of one centimeter in diameter.

Skin color. The skin color changes (a* value) of the fruit in both maturity stages was delayed in temperature of 10°C, whereas at 20°C these changes were more noticeable (figure 51 and Annex 9).

Fruit in maturity ¼ and stored at 10°C did not show color changes during the storage and there were no significant effects of irradiation dose as well as the storage time (Annex 9). However, those fruits irradiated at 1.00 kGy tended show less color changes in comparison with other treatments (figure 51). In a similar way, the fruit in maturity ¾ that were irradiated and stored for 7 and 13 days showed less color changes respect the control fruit (figure 51).

Fruit of both maturities stages irradiated at 0.60 and 1.00 kGy and stored at 20°C showed minor changes respect to control fruit and irradiated at 0.15 kGy (figure 51) indicating that these doses delayed the color change. These data corresponded with the external visual appearance that these fruit showed (figure 24).

The transfer of the fruit from 10 to 20°C showed noticeable changes in skin color, for the maturity stage ¼ the control fruits and irradiated at 0.15 kGy developed more color than the fruit treated at 0.6 and 1.00 kGy (figure 51) whereas the control fruit in maturity stage ¾ developed more color that the fruit irradiated to different doses. These data corresponded with visual appearance of the fruit described in the external visual quality section in which was described the presence of dark discolorations on the fruits.

According with these data the high irradiation doses altered the external color of the fruit. Therefore it is advisable not to apply doses that are located above the range of 0.6 kGy.

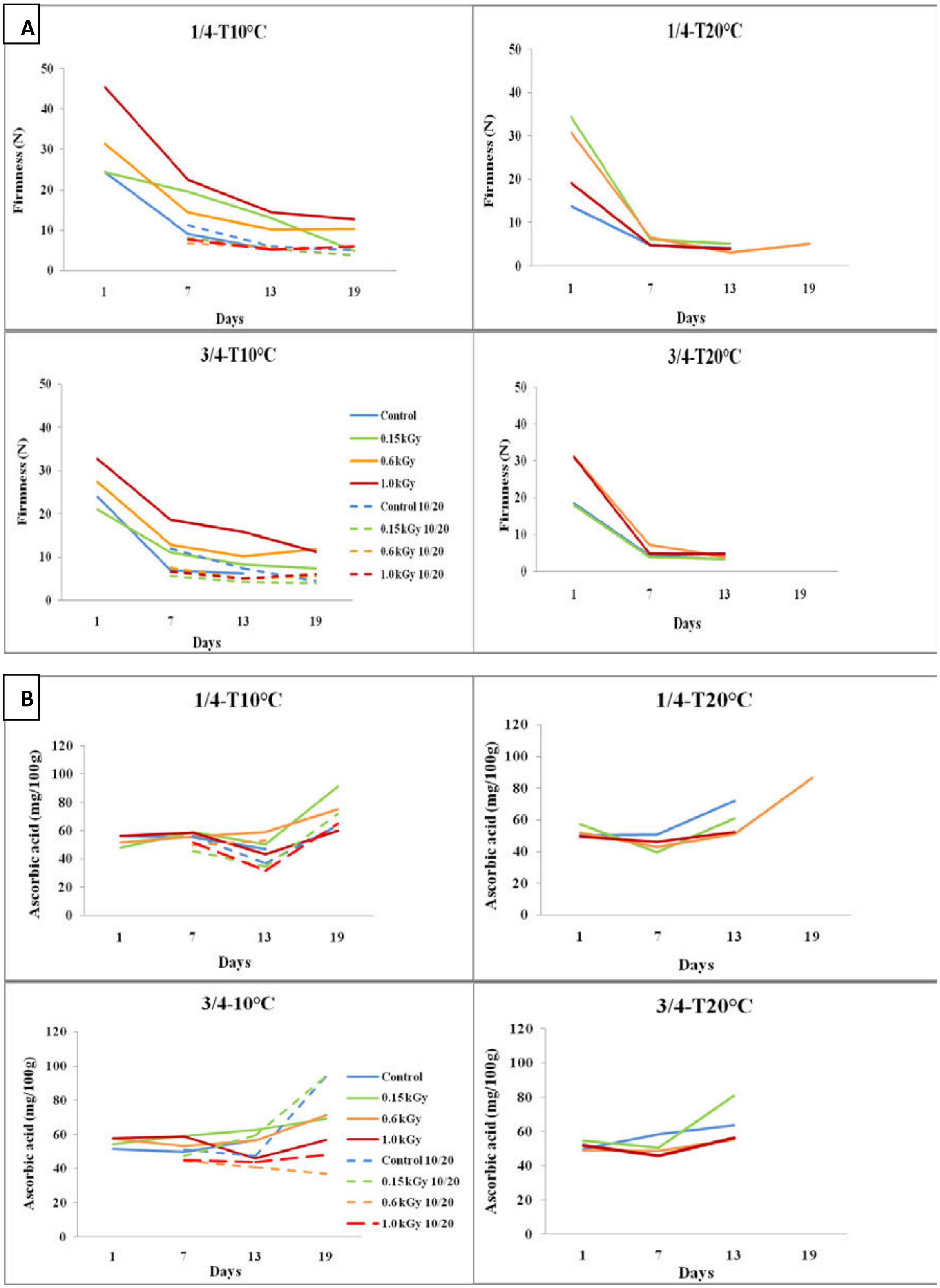



Figure 48 Changes in firmness (A) and ascorbic acid (B) in mango fruits cv 'Manila' at different maturity stages (¼ and ¾), irradiated at different doses and stored at 10 and 20°C. Dotted lines indicate the transfer of fruits from 10 to 20

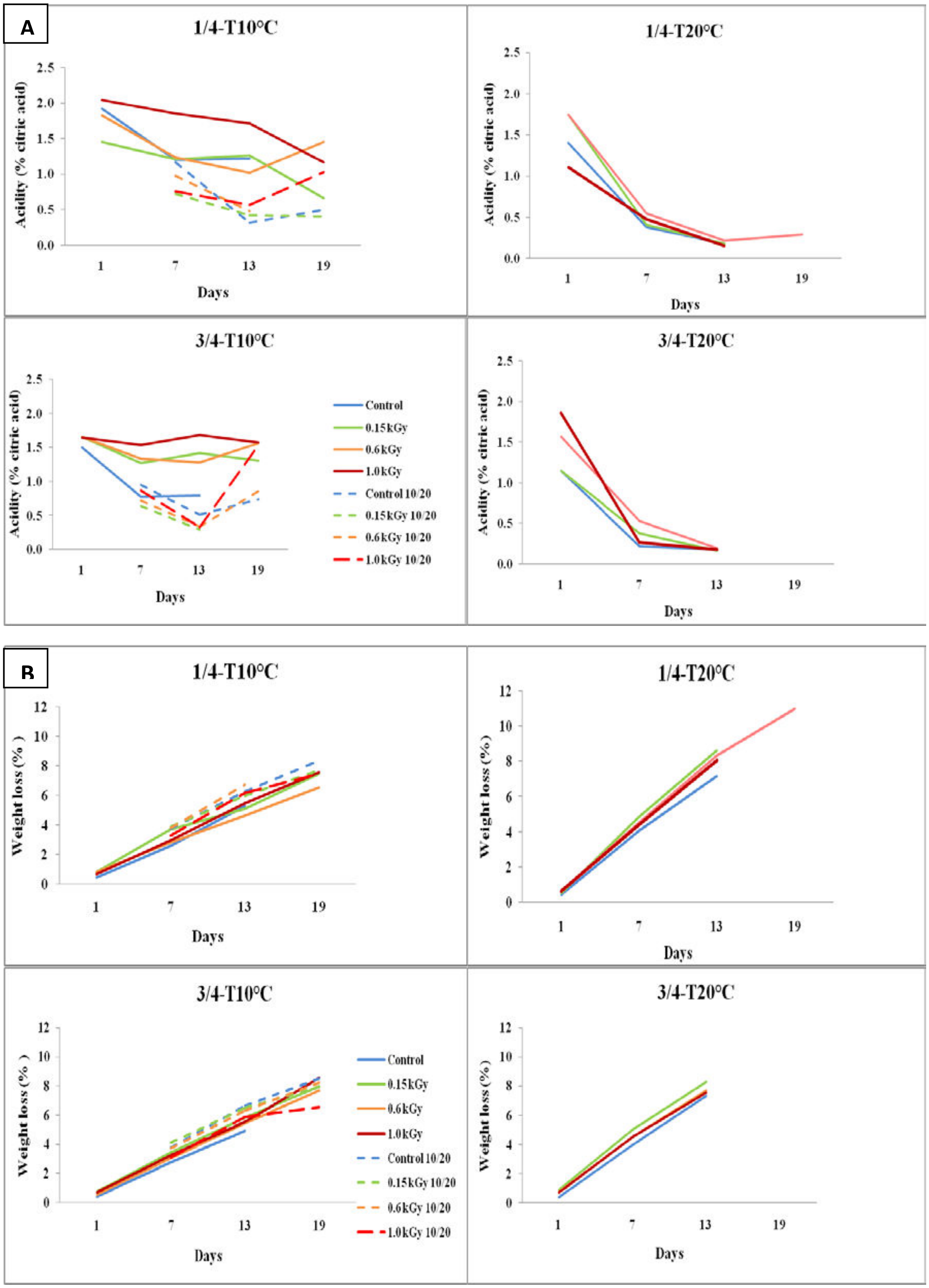



Figure 49 Changes in acidity (A) and weight loss (B) of mango fruits cv 'Manila' at different maturity stages (¼ and ¾), irradiated at different doses with gamma rays and stored at 10 and 20°C. Dotted lines indicate the fruit transferred from 10 to 20°C.

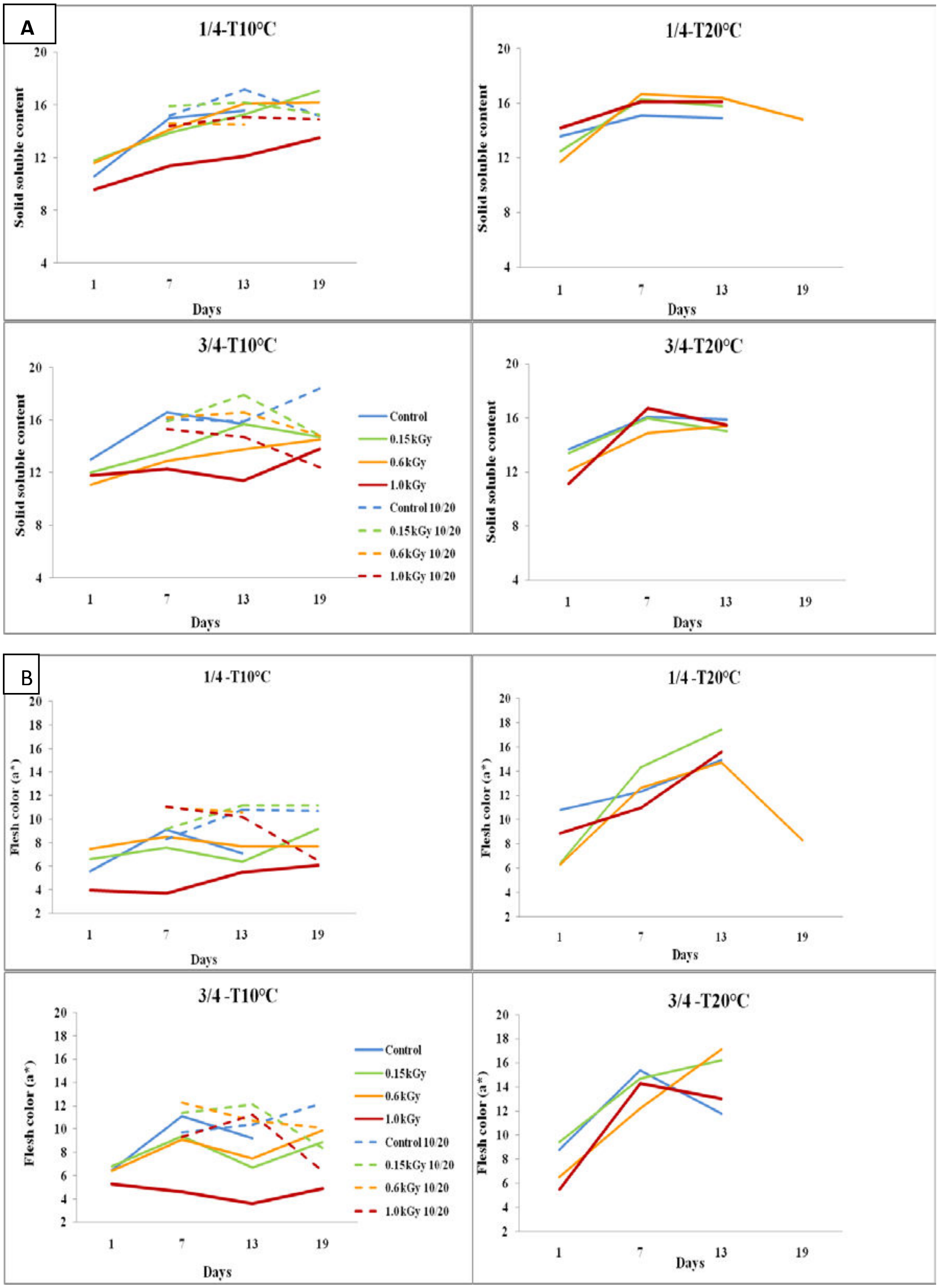



Figure 50 Changes in the solids soluble content (A) and flesh color (B) in Mango fruit cv 'Manila' in two maturity stages (¼ and ¾), stored at 10 and 20°C. Dotted lines indicate the fruit transferred from 10 to 20°C.

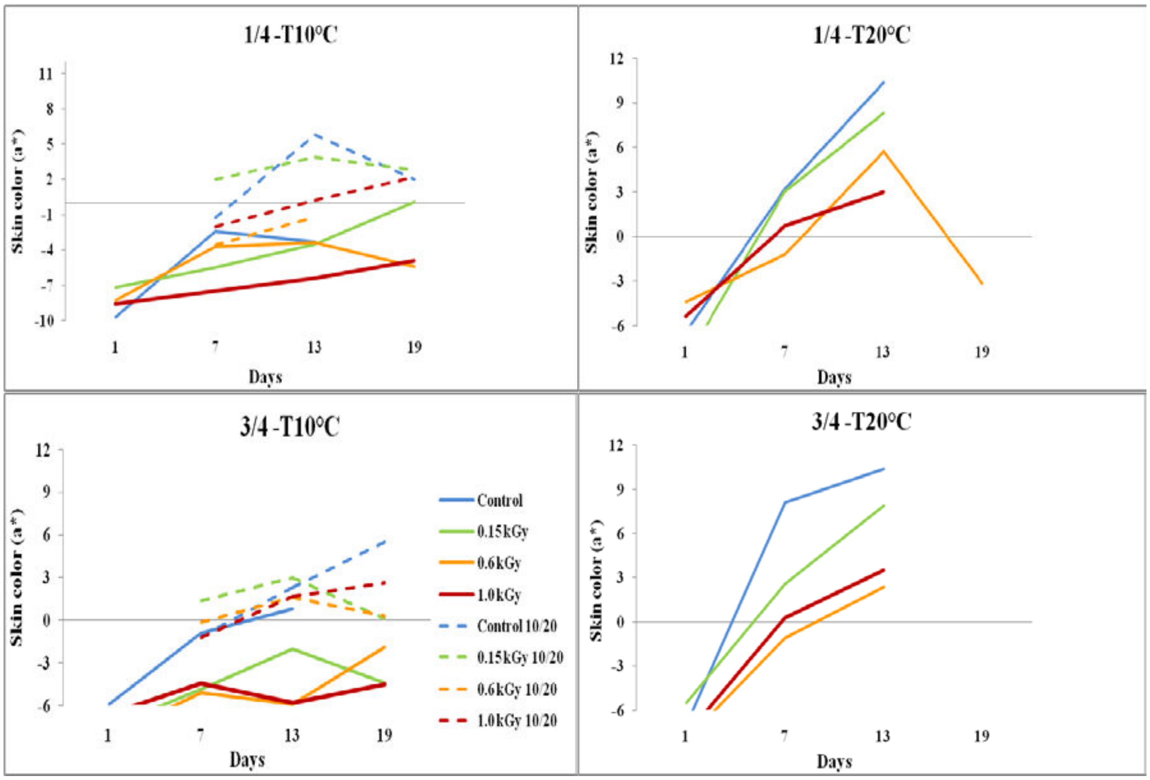



Figure 51 Changes in skin color of mango fruits cv 'Manila' in different maturity stages (¼ and ¾), irradiated at different doses with gamma rays and stored at 10 and 20°C. Dotted lines indicate the fruits transferred from 10 to 20°C.

### 4.1.3.8 General considerations of physicochemical factors

In general the physicochemical data analysis applied to six varieties of mango showed that none of the variable analyzed proved to be an adequate estimator for evaluating the irradiation effects because the responses of these variables depended on the variety, their maturity stage and storage conditions. However, when negative effects of the irradiation doses were observed in any of the response variable those generally were associated to high irradiation doses in addition to the maturity stage of ¼. Therefore and based on physicochemical data is advisable to process fruit in maturity ¾ but not irradiate them above 0.93 kGy.

## 4.2 General resume of results

Data generated in this project indicated that all varieties studied were not affected in their general quality by the application of doses of 0.15 kGy that the FDA office requires as minimum quarantine treatment to control the Mexican fruit fly (*Anasthrepha ludens*). The protocol of irradiation quarantine treatment also indicate a maximum dose of 1.00 kGy, this dose was not supported by any of the varieties studied so the commercial application of this technology must take in account the different sensitivity of each variety. According to these studies the varieties 'Tommy Atkins', 'Haden', 'Keitt' and 'Manila' showed high sensitivity to high irradiation doses and these cannot be irradiated at doses exceeding the 0.6 kGy while the varieties 'Kent' and 'Ataulfo' can be irradiated until 0.86 kGy.

The most obvious damages of the application of high irradiation doses were observed in the external and internal visual quality of the fruit which included the skin and flesh browning and spongy tissue development. Annex 10 summarizes the changes in the visual quality of different varieties, these damages are important because it would affect the purchase intent by the consumer.

Regarding the physicochemical factors tested, the Annex 11 summarizes the effects of different irradiation doses in each variety and maturity stage assessed. The 'Haden' variety did not show negative effects of the applications of different irradiation doses in the physicochemical variables considered. For the other five varieties, the response was different in each variable analyzed, although it was possible to indicate that there were a greater number of negative events in the high doses in addition to maturity stage of ¼, therefore and for practical or industrial proposes is not recommended to irradiate mango fruits with high doses and avoid to irradiate fruits in maturity ¼.

Although this study did not included to evaluate the shelf life of the fruits; the observations made in each variety during the storage allowed to point out that the most important factor that increased the shelf life of the fruit was to store them at 10°C while the irradiation doses applied did not show significant effects to increase the storage period.

According with the data obtained in this study, the application of irradiation treatment under the conditions indicated for each variety, the irradiation treatment would have the advantage to process fruit in maturity stage ¾ at room temperature, this would eliminate the hydro thermal stress to which currently are submitted the mango fruit and therefore would improve the sensory quality perceived by the consumer.

## 5.0 CONCLUSIONS

The fruit size was not an important factor in the responses to irradiation doses applied.

The maturity stage was an important factor in the response of the fruit to irradiation doses. Fruit in maturity stage ¼ showed high susceptibility to high irradiation doses.

The skin and flesh browning as well as the spongy tissue development were the factors that determined the irradiation doses effects and changed the visual quality of the fruit.

All varieties in both maturity stages did not show external and internal damages when they were subjected to irradiation ranges of 0.15 to 0.44 kGy.

Also all varieties showed external and internal damages when they were exposed to dose range of 0.92 to 1.53 kGy.

Under the above restrictions the maximum dose tolerated depended of the variety. The varieties 'Kent' and 'Ataulfo' were the most tolerant and can withstand up to 0.86 kGy, while the varieties 'Tommy Atkins', 'Haden', 'Manila' and 'Keitt' were the most sensitive suggesting not radiate them above 0.60 kGy.

The storage of fruits at 10°C increased the damages caused by the irradiation which were visually evident when the fruit were transferred at 20°C, which indicated that there was an additive effect of radiation stress and low temperature stress.

The dose applied in the study did not improve the fruit shelf life of the fruit above the storage life at low temperatures.

The physicochemical analysis data obtained from the six varieties showed that none of the variable analyzed was an indicator appropriate to measure the irradiation doses effect in all varieties because the responses of these variables depended of the variety, maturity stage and storage conditions.

However, when there were negative effects of irradiation dose in any of these variables, these responses were usually associated with the maturity stage of ¼ and high irradiation doses. It is therefore recommended to process fruits in maturity ¾ and not irradiate above 0.93 kGy.

**ANNEX 1: Harvesting operations, packaging and mango irradiation**

Mango harvest, shoulders filling (to identify maturity stage) and packaging of fruit selected in commercial boxes to exportation market.

Facilities of Sterigenics irradiation plant in Tepeji del Rio Hidalgo Mexico with irradiation chamber of 60Co.


Fruits in pallets and placement dosimeters on the fruits into the boxes


Placing boxes in front of the $_{60}$Co irradiation source


Alanine dosimeters and Electron Spin Resonance equipment used to measure the absorbed dose

**ANNEX 2. Nominal dose and Minimum, Maximum, Median and Mean doses registered with Alanine dosimeters placed on mango fruit located at center and corners of the boxes (values indicated in kGy).**

| Variety | Nominal Dose | Minimum dose | Maximum dose | Median | Mean |
|---|---|---|---|---|---|
| Haden | 0.15 | 0.16 | 0.38 | 0.19 | 0.23±0.074 |
| | 0.60 | 0.56 | 0.87 | 0.64 | 0.67±0.079 |
| | 1.00 | 0.92 | 1.39 | 1.07 | 1.07±0.092 |
| Tommy Atkins | 0.15 | 0.16 | 0.40 | 0.30 | 0.27±0.098 |
| | 0.60 | 0.50 | 0.67 | 0.60 | 0.59±0.052 |
| | 1.00 | 0.97 | 1.30 | 1.12 | 1.13±0.090 |
| Kent | 0.15 | 0.16 | 0.19 | 0.17 | 0.18±0.010 |
| | 0.60 | 0.52 | 0.66 | 0.62 | 0.61±0.037 |
| | 1.00 | 0.93 | 1.26 | 1.06 | 1.07±0.103 |
| Keitt | 0.15 | 0.15 | 0.21 | 0.17 | 0.18±0.023 |
| | 0.60 | 0.54 | 0.82 | 0.65 | 0.65±0.077 |
| | 1.00 | 0.87 | 1.34 | 1.12 | 1.10±0.140 |
| Manila | 0.15 | 0.17 | 0.22 | 0.19 | 0.19±0.014 |
| | 0.60 | 0.57 | 0.76 | 0.65 | 0.67±0.057 |
| | 1.00 | 0.96 | 1.25 | 1.05 | 1.09±0.093 |
| Ataulfo | 0.15 | 0.18 | 0.24 | 0.20 | 0.20±0.017 |
| | 0.60 | 0.58 | 0.72 | 0.63 | 0.63±0.037 |
| | 1.00 | 0.95 | 1.15 | 1.08 | 1.06±0.057 |

Data of dose registered in mango fruits placed on box center.

| Variety | Nominal Dose | Minimum dose | Maximum dose | Median | Mean |
|---|---|---|---|---|---|
| Haden | 0.15 | 0.190 | 0.440 | 0.220 | 0.274±0.091 |
| | 0.60 | 0.659 | 0.880 | 0.778 | 0.783±0.052 |
| | 1.00 | 1.040 | 1.420 | 1.270 | 1.259±0.098 |
| Tommy Atkins | 0.15 | 0.190 | 0.410 | 0.230 | 0.273±0.082 |
| | 0.60 | 0.640 | 0.830 | 0.740 | 0.745±0.056 |
| | 1.00 | 1.220 | 1.520 | 1.335 | 1.346±0.083 |
| Kent | 0.15 | 0.210 | 0.230 | 0.220 | 0.216±0.006 |
| | 0.60 | 0.580 | 0.830 | 0.780 | 0.765±0.063 |
| | 1.00 | 1.170 | 1.410 | 1.280 | 1.273±0.072 |
| Keitt | 0.15 | 0.190 | 0.230 | 0.215 | 0.213±0.013 |
| | 0.60 | 0.680 | 0.840 | 0.800 | 0.790±0.046 |
| | 1.00 | 1.140 | 1.510 | 1.300 | 1.303±0.103 |
| Manila | 0.15 | 0.210 | 0.240 | 0.225 | 0.222±0.011 |
| | 0.60 | 0.610 | 0.870 | 0.760 | 0.758±0.066 |
| | 1.00 | 1.060 | 1.330 | 1.210 | 1.204±0.085 |
| Ataulfo | 0.15 | 0.220 | 0.260 | 0.230 | 0.232±0.015 |
| | 0.60 | 0.540 | 0.820 | 0.730 | 0.715±0.090 |
| | 1.00 | 1.060 | 1.430 | 1.300 | 1.286±0.108 |

Data of dose registered in mango fruit of different varieties placed on the boxes corner.

| Variety | Nominal Dose | Minimum dose | Maximum dose | Median | Mean |
|---|---|---|---|---|---|
| Haden | 0.15 | 0.160 | 0.440 | 0.220 | 0.253±0.085 |
| | 0.60 | 0.560 | 0.880 | 0.742 | 0.726±0.088 |
| | 1.00 | 0.920 | 1.420 | 1.160 | 1.163±0.135 |
| Tommy Atkins | 0.15 | 0.160 | 0.410 | 0.235 | 0.270±0.089 |
| | 0.60 | 0.520 | 0.830 | 0.655 | 0.667±0.095 |
| | 1.00 | 0.970 | 1.520 | 1.235 | 1.235±0.141 |
| Kent | 0.15 | 0.160 | 0.230 | 0.210 | 0.197±0.022 |
| | 0.60 | 0.520 | 0.830 | 0.660 | 0.691±0.094 |
| | 1.00 | 0.930 | 1.410 | 1.170 | 1.159±0.136 |
| Keitt | 0.15 | 0.150 | 0.230 | 0.210 | 0.196±0.025 |
| | 0.60 | 0.540 | 0.840 | 0.740 | 0.721±0.094 |
| | 1.00 | 0.870 | 1.510 | 1.190 | 1.200±0.159 |
| Manila | 0.15 | 0.170 | 0.240 | 0.210 | 0.208±0.019 |
| | 0.60 | 0.570 | 0.870 | 0.710 | 0.709±0.076 |
| | 1.00 | 0.960 | 1.330 | 1.140 | 1.145±0.106 |
| Ataulfo | 0.15 | 0.180 | 0.260 | 0.220 | 0.219±0.020 |
| | 0.60 | 0.540 | 0.820 | 0.645 | 0.672±0.081 |
| | 1.00 | 0.950 | 1.430 | 1.125 | 1.172±0.144 |

Data of doses average in mango fruit packaging on cardboard boxes.

**ANNEX 3. Probability values of dose, storage temperature and maturity stage effects and their interactions on the fruit quality. WL weight loss; SSC solid soluble content; a*int internal a*value; a* ext external a* value**

'Tommy Atkins' variety

| Factor/Variable | Firmness | Ascorbic | Acidity | % WL | SSC | a* int |
|---|---|---|---|---|---|---|
| Dose (D) | 0.0001 | 0.0001 | 0.0001 | 0.0128 | 0.0002 | 0.1235 |
| Temp. (T) | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| Maturity (M) | 0.0001 | 0.0001 | 0.0179 | 0.0001 | 0.0036 | 0.0013 |
| Day (d) | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| D*T | 0.0001 | 0.0002 | 0.2115 | 0.0739 | 0.0972 | 0.1313 |
| D*M | 0.1152 | 0.2826 | 0.0808 | 0.3525 | 0.0077 | 0.9563 |
| D*d | 0.0001 | 0.0001 | 0.0001 | 0.9790 | 0.0304 | 0.4759 |
| T*M | 0.2019 | 0.0146 | 0.4110 | 0.3354 | 0.0544 | 0.7671 |
| T*d | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| M*d | 0.0001 | 0.0021 | 0.0105 | 0.1392 | 0.0200 | 0.0002 |

'Haden' variety

| Factor/Variable | Firmness | Ascorbic | Acidity | % WL | SSC | a* int |
|---|---|---|---|---|---|---|
| Dose (D) | 0.7818 | 0.0314 | 0.5993 | 0.2658 | 0.4658 | 0.0169 |
| Temp. (T) | 0.0001 | 0.0004 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| Maturity (M) | 0.0001 | 0.6921 | 0.9859 | 0.0107 | 0.0514 | 0.2114 |
| Day (d) | 0.0001 | 0.1540 | 0.0001 | 0.0001 | 0.0001 | 0.0027 |
| D*T | 0.3543 | 0.7360 | 0.0261 | 0.0543 | 0.0006 | 0.6465 |
| D*M | 0.6269 | 0.0571 | 0.0012 | 0.8835 | 0.0011 | 0.0115 |
| D*d | 0.5209 | 0.6504 | 0.6188 | 0.9508 | 0.1917 | 0.0171 |
| T*M | 0.0328 | 0.2980 | 0.1751 | 0.0007 | 0.0001 | 0.3323 |
| T*d | 0.0001 | 0.2231 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| M*d | 0.1177 | 0.0001 | 0.3608 | 0.1301 | 0.3924 | 0.2251 |

'Kent' variety

| Factor/Variable | Firmness | Ascorbic | Acidity | % WL | SSC | a*int | a* ext |
|---|---|---|---|---|---|---|---|
| Dose (D) | 0.0001 | 0.0001 | 0.0015 | 0.0001 | 0.0198 | 0.0087 | 0.1595 |
| Temp. (T) | 0.0001 | 0.9311 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0017 |
| Maturity (M) | 0.4154 | 0.7174 | 0.7734 | 0.0001 | 0.0001 | 0.0001 | 0.0102 |
| Day (d) | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| D*T | 0.0009 | 0.0331 | 0.0024 | 0.4906 | 0.5413 | 0.3916 | 0.5609 |
| D*M | 0.8361 | 0.0002 | 0.0017 | 0.5312 | 0.5983 | 0.2761 | 0.2434 |
| D*d | 0.0001 | 0.0001 | 0.0107 | 0.0055 | 0.1477 | 0.9021 | 0.1224 |
| T*M | 0.7736 | 0.0850 | 0.1714 | 0.2163 | 0.3693 | 0.0037 | 0.3938 |
| T*d | 0.0001 | 0.1160 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0735 |
| M*d | 0.4962 | 0.0827 | 0.4647 | 0.0001 | 0.0001 | 0.1008 | 0.5526 |

'Keitt' variety

| Factor/Variable | Firmness | Ascorbic | Acidity | % WL | SSC | a*int | a* ext |
|---|---|---|---|---|---|---|---|
| Dose (D) | 0.0935 | <.0001 | <.0001 | 0.0035 | <.0001 | 0.0067 | 0.0443 |
| Temp. (T) | <.0001 | <.0001 | <.0001 | <.0001 | <.0001 | <.0001 | 0.4671 |
| Maturity (M) | <.0001 | <.0001 | <.0001 | <.0001 | 0.3260 | <.0001 | <.0001 |
| Day (d) | <.0001 | <.0001 | <.0001 | <.0001 | <.0001 | <.0001 | <.0001 |
| D*T | <.0001 | 0.0002 | 0.0018 | 0.0837 | <.0001 | 0.4484 | 0.8162 |
| D*M | <.0001 | <.0001 | <.0001 | <.0001 | <.0001 | <.0001 | 0.4218 |
| D*d | <.0001 | <.0001 | 0.5166 | <.0001 | 0.0004 | 0.0799 | <.0001 |
| T*M | 0.0003 | 0.8715 | 0.7623 | 0.3112 | 0.0004 | 0.1737 | 0.7418 |
| T*d | <.0001 | 0.0151 | <.0001 | 0.0012 | <.0001 | <.0001 | 0.1945 |
| M*d | 0.0900 | 0.5646 | 0.1424 | 0.0164 | 0.0357 | 0.7180 | 0.0228 |

'Ataulfo' variety

| Factor/Variable | Firmness | Ascorbic | Acidity | % WL | SSC | a*int | a* ext |
|---|---|---|---|---|---|---|---|
| Dosis (D) | 0.2190 | 0.0001 | 0.0026 | 0.0014 | 0.0001 | 0.0001 | 0.0439 |
| Temp. (T) | 0.0001 | 0.0152 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| Maturity (M) | 0.3722 | 0.0175 | 0.2102 | 0.9853 | 0.0022 | 0.1284 | 0.1105 |
| Day (d) | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| D*T | 0.0007 | 0.7690 | 0.0212 | 0.4103 | 0.0683 | 0.0355 | 0.0001 |
| D*M | 0.9578 | 0.1095 | 0.2275 | 0.0495 | 0.0176 | 0.1014 | 0.1820 |
| D*d | 0.0944 | 0.0001 | 0.9655 | 0.1012 | 0.0025 | 0.5641 | 0.0256 |
| T*M | 0.0004 | 0.0378 | 0.0200 | 0.7997 | 0.3267 | 0.7038 | 0.1435 |
| T*d | 0.0013 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| M*d | 0.2989 | 0.0729 | 0.1089 | 0.2936 | 0.5413 | 0.7048 | 0.5106 |

'Manila' variety

| Factor/Variable | Firmness | Ascorbic | Acidity | % WL | SSC | a* int | a* ext |
|---|---|---|---|---|---|---|---|
| Dose (D) | 0.1651 | 0.0018 | 0.5716 | 0.0030 | 0.4541 | 0.0630 | 0.0003 |
| Temp. (T) | 0.0991 | 0.0478 | 0.0001 | 0.0001 | 0.4007 | 0.0006 | 0.0001 |
| Maturity (M) | 0.8689 | 0.9540 | 0.8089 | 0.9175 | 0.5402 | 0.9670 | 0.8677 |
| Day (d) | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| D*T | 0.0594 | 0.0528 | 0.2209 | 0.3612 | 0.0166 | 0.3036 | 0.7613 |
| D*M | 0.2705 | 0.5615 | 0.1909 | 0.7611 | 0.1330 | 0.3227 | 0.0043 |
| D*d | 0.3468 | 0.0262 | 0.5040 | 0.1309 | 0.4819 | 0.5444 | 0.0001 |
| T*M | 0.3725 | 0.6547 | 0.7905 | 0.1538 | 0.3362 | 0.2976 | 0.0110 |
| T*d | 0.8180 | 0.0038 | 0.0001 | 0.0001 | 0.5624 | 0.0001 | 0.0001 |
| M*d | 0.6276 | 0.2187 | 0.4817 | 0.9699 | 0.4193 | 0.7883 | 0.9701 |

**ANNEX 4. Comparison between means of different response variables in mango fruit cv 'Tommy Atkins' from different maturity stage (¼ and ¾), irradiated at different dose and stored at 10 (T10) and 20°C (T20) during 19 days. Different letters in the same column means statistical differences (Tuckey 0.05)**

Firmness: Values in Newtons.

| Day | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | 129.3ab | 157.4a | 135.2a | 185.4a |
| | 0.15 | 119.2bcd | 155.3ab | 122.8ab | 150.9ab |
| | 0.6 | 104.5cde | 139.2abcd | 97.2c | 134.8bc |
| | 1.0 | 99.5cdef | 137.4abcd | 98.2c | 110.1bc |
| 7 | Control | 144.1a | 141.8abc | 97.7c | 103.3cd |
| | 0.15 | 120.4bc | 120abcde | 100.7bc | 96.3cde |
| | 0.6 | 108.7bcde | 117.8bcde | 78.4cd | 96.4cde |
| | 1.0 | 97.3defg | 112.6cdef | 62.6def | 55.7efg |
| 13 | Control | 91.2efg | 102.2defg | 46.7efgh | 54.0efg |
| | 0.15 | 76.1gh | 85.1efgh | 66.6de | 64.3def |
| | 0.6 | 77.9fgh | 91.9efgh | 39.3ghij | 43.4fg |
| | 1.0 | 92.2efg | 104.3cdefg | 32.3hij | 31.2fg |
| 19 | Control | 67.0hi | 63.7h | 58.6defg | 31.4fg |
| | 0.15 | 47.4i | 66.6gh | 43.4fghi | 38.7fg |
| | 0.6 | 52.7i | 73.4gh | 23.3ij | 31.4fg |
| | 1.0 | 65.0hi | 75.5fgh | 19.7j | 20.9g |

Ascorbic acid: mg of ascorbic acid in 100g of flesh.

| Day | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | 19.6efgh | 16.5cdef | 20.2ab | 15.4abc |
| | 0.15 | 19.4fgh | 16.5cdef | 20.4ab | 18.7ab |
| | 0.6 | 17.5fgh | 15.4cdef | 18.1abc | 16.1ab |
| | 1.0 | 16.4gh | 22.4abc | 17.0bc | 18.7ab |
| 7 | Control | 29.0abc | 26.0a | 22.3a | 19.1ab |
| | 0.15 | 32.9a | 27.3a | 22.3a | 20.8a |
| | 0.6 | 30.3ab | 21.7abc | 20.4ab | 15.6abc |
| | 1.0 | 22.1cdefh | 13.9def | 16.3bcd | 13.4abcd |
| 13 | Control | 27.1abcde | 20.9abcd | 11.7defg | 8cde |
| | 0.15 | 24.7bcdef | 20.4abcd | 13.2cdef | 6.8de |
| | 0.6 | 23.0bcdefg | 12.4ef | 9.3fg | 12.5abcde |
| | 1.0 | 14.7h | 10.4f | 9.8efg | 6.8de |
| 19 | Control | 27.5abcd | 24.3ab | 14.7cde | 7.8bcde |
| | 0.15 | 22.8cdefg | 18.6bcde | 10.9efg | 6.1de |
| | 0.6 | 21.2defgh | 18.6bcde | 11.7defg | 4.9e |
| | 1.0 | 18.0fgh | 17.6bcdef | 7.8g | 6.9de |

Acidity titratable. Grams of citric acid in 100 g of fresh tissue.

| Day | Dose kGy | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | 1.1a | 1.0abcd | 1.2a | 1.2a |
| | 0.15 | 1.1abc | 1.1abcd | 1.2a | 1.0ab |
| | 0.6 | 1.12ab | 1.1abcd | 1.3a | 0.9ab |
| | 1.0 | 1.0abc | 1.1abc | 1.1ab | 1.15a |
| 7 | Control | 1.0abc | 1.1abcd | 0.9bc | 1.0a |
| | 0.15 | 1.1a | 1.3a | 1.0abc | 1.15a |
| | 0.6 | 1.0abc | 1.0abcd | 0.8cd | 1.1a |
| | 1.0 | 0.9abcd | 1.1abcd | 0.6de | 0.7abc |
| 13 | Control | 1,0abc | 0.9abcd | 0.3ef | 0.6bcde |
| | 0.15 | 1.1a | 0.9abcd | 0.9bcd | 0.7bcd |
| | 0.6 | 0.9abc | 0.8bcd | 0.4ef | 0.6cde |
| | 1.0 | 0.8bcd | 0.7cd | 0.2f | 0.3cde |
| 19 | Control | 1.1abc | 1.2a | 0.1f | 0.2e |
| | 0.15 | 1.1abc | 1.2ab | 0.3ef | 0.2de |
| | 0.6 | 0.8cd | 0.9abcd | 0.1f | 0.2e |
| | 1.0 | 0.6d | 1.0abcd | 0.1f | 0.2e |

Weight loss. Percentage of weight loss respect of original weight.

| Day | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | 0.4d | 0.6e | | 0.6d |
| | 0.15 | 0.4d | 0.6e | | 0.7d |
| | 0.6 | 0.4d | 0.7e | | 0.8d |
| | 1.0 | 0.4d | 0.6e | | 0.7d |
| 7 | Control | 1.7c | 1.9d | 2.2c | 2.5c |
| | 0.15 | 1.8c | 2.0cd | 2.2c | 2.9c |
| | 0.6 | 1.8c | 1.9d | 2.3c | 2.8c |
| | 1.0 | 1.6c | 2.1cd | 2.7c | 3.2c |
| 13 | Control | 3.1b | 3.3b | 4.6b | 4.8b |
| | 0.15 | 3.4b | 3.1bc | 4.4b | 4.9b |
| | 0.6 | 3.1b | 3.5b | 4.7b | 5.1b |
| | 1.0 | 3.2b | 3.4b | 5.0b | 5.0b |
| 19 | Control | 4.4a | 5.0a | 6.8a | 6.7a |
| | 0.15 | 4.9a | 4.8a | 6.6a | 6.8a |
| | 0.6 | 4.5a | 5.2a | 6.4a | 6.8a |
| | 1.0 | 4.6a | 5.1a | 6.6a | 7.7a |

Solid Soluble Content. °Brix

| Day | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | 6.9i | 7.9e | 6.1f | 7.2e |
| | 0.15 | 7.3i | 7.3e | 7.6f | 7.3e |
| | 0.6 | 8.4ghi | 8.0de | 8.1ef | 7.5e |
| | 1.0 | 8.0i | 7.4e | 7.3f | 8.0de |
| 7 | Control | 9.4fgh | 8.9bcde | 11.1cd | 9.7cd |
| | 0.15 | 10.2defg | 8.7cde | 11.4bcd | 11.0bc |
| | 0.6 | 11abcdef | 9.2bcde | 13.1ab | 11.4abc |
| | 1.0 | 9.9efg | 9.2bcde | 9.9de | 12.6ab |
| 13 | Control | 11.9abcd | 8.6cde | 13.9a | 12.6ab |
| | 0.15 | 12.4ab | 10.9ab | 13.2ab | 12.4ab |
| | 0.6 | 11.5abcde | 10.2abcd | 14.3a | 13.1ab |
| | 1.0 | 10.3cdef | 10.1abcd | 13.4ab | 13.0ab |
| 19 | Control | 12.2ab | 10.5abc | 12.5abc | 13.2ab |
| | 0.15 | 12.1abc | 11.9a | 12.7abc | 13.0ab |
| | 0.6 | 12.7a | 11.7a | 13.4ab | 13.7a |
| | 1.0 | 10.6bcdef | 11.4a | 13.3ab | 13.0ab |

Flesh color. a* values on CIE L*a*b* scale

| Day | Dose | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | 5.6b | 9.2a | 5.3g | 9.3de |
| | 0.15 | 6.3b | 10.0a | 6.2fg | 7.4e |
| | 0.6 | 7.8ab | 9.6a | 7.5efg | 8.8de |
| | 1.0 | 7.8ab | 7.2a | 5.4fg | 10.7cde |
| 7 | Control | 6.8b | 10.8a | 9.4def | 12.8abcd |
| | 0.15 | 8.6ab | 8.6a | 8.5defg | 10.5cde |
| | 0.6 | 8.5ab | 11.0a | 8.1efg | 10.4cde |
| | 1.0 | 7.9ab | 10.2a | 8.5defg | 9.3de |
| 13 | Control | 8.4ab | 7.8a | 14.7abc | 12.8abcd |
| | 0.15 | 7.2ab | 7.9a | 11.2cde | 10.9bcde |
| | 0.6 | 6.7b | 8.1a | 13.6abc | 13.8abcd |
| | 1.0 | 6.8ab | 8.1a | 12.3bcd | 12.8abcd |
| 19 | Control | 8.8ab | 7.6a | 16.7a | 16.8a |
| | 0.15 | 9.0ab | 7.9a | 15.2abc | 16.3a |
| | 0.6 | 11.2a | 7.9a | 15.7ab | 15.9ab |
| | 1.0 | 7.9ab | 7.6a | 15.0abc | 15.2abc |

Skin color: a* values on CIE L*a*b* scale

| Day | Dose | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | | -7.3d | | -5.9c |
| | 0.15 | | -6.8cd | | -6.5c |
| | 0.6 | | -6.1abcd | | -6.4c |
| | 1.0 | | -7.2d | | -6.1c |
| 7 | Control | | -5.5abcd | | -4.3bc |
| | 0.15 | | -5.9abcd | | -3.8bc |
| | 0.6 | | -5.6abcd | | -2.7bc |
| | 1.0 | | -4.0abcd | | -1.7bc |
| 13 | Control | | -2.7abc | | -3.1bc |
| | 0.15 | | -3.2abcd | | -2.4bc |
| | 0.6 | | -1.8a | | -2.8bc |
| | 1.0 | | -2.1ab | | -19bc |
| 19 | Control | | -6.5cd | | 7.1a |
| | 0.15 | | -6.4bcd | | -3.0bc |
| | 0.6 | | -5.9abcd | | -3.5bc |
| | 1.0 | | -3.0abcd | | 0.3b |

**ANNEX 5. Comparison between means of different response variables in mango fruit cv 'Haden' from different maturity stage (¼ and ¾), irradiated at different dose and stored at 10 (T10) and 20°C (T20) during 19 days. Different letters in the same column means statistical differences (Tuckey 0.05)**

Firmness: Values in Newtons.

| Day | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | 90.4ab | 166.4a | 104.0a | 161.1a |
| | 0.15 | 67.7abcde | 163.3a | 90.6a | 154.8a |
| | 0.6 | 89.1ab | 146.4ab | 99.6a | 134.1a |
| | 1.0 | 108.4a | 150.8ab | 99.6a | 132.7a |
| 7 | Control | 69.8abcde | 123.7abc | 43.2bc | 63.4bc |
| | 0.15 | 85.3ab | 126.0abc | 55.7b | 70.5b |
| | 0.6 | 91.3ab | 107.5bcd | 39.5bcd | 42.0bcd |
| | 1.0 | 80.7ab | 87.9cd | 39.2bcde | 39.7bcd |
| 13 | Control | 87.0ab | 89.7cd | 21.6cdef | 31.7cd |
| | 0.15 | 83.9ab | 104.7bcd | 28.6cdef | 25.8d |
| | 0.6 | 86.1ab | 93.2cd | 24.5cdef | 20.9d |
| | 1.0 | 79.9abc | 73.1d | 22.8cdef | 17.7d |
| 19 | Control | 34.4e | 66.0d | 16.0def | 21.5d |
| | 0.15 | 45.8cde | 85.8cd | 16.2f | 14.7d |
| | 0.6 | 42.7de | 68.5d | 15.7ef | 13.7d |
| | 1.0 | 65.2bcd | 71.0d | 15.1f | 13.3d |

Ascorbic acid: mg of ascorbic acid in 100g of flesh.

| Day | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | 26.9abc | 24.9b | 28.4abc | 23.5abcd |
| | 0.15 | 23.6bc | 22.0b | 26.8abc | 27.1abc |
| | 0.6 | 27.4abc | 28.6b | 19.7bc | 29.0ab |
| | 1.0 | 25.4abc | 27.1b | 27.6abc | 24.6abcd |
| 7 | Control | 39.4a | 28.2b | 26.9abc | 24.3abcd |
| | 0.15 | 34.7ab | 26.9b | 30.8ab | 23.4abcd |
| | 0.6 | 37.7a | 24.7b | 35.1a | 26.9abc |
| | 1.0 | 30.8abc | 26.0b | 25.6abc | 17.8bcd |
| 13 | Control | 32.5abc | 24.0b | 25.6abc | 25.3abcd |
| | 0.15 | 29.0abc | 33.3ab | 20.4bc | 31.2a |
| | 0.6 | 23.8bc | 46.7a | 19.1c | 24.7abcd |
| | 1.0 | 23.4bc | 26.7b | 17.8c | 30.0a |
| 19 | Control | 29.2abc | 28.6b | 32.1ab | 31.2a |
| | 0.15 | 27.7abc | 27.7b | 33.2a | 14.6d |
| | 0.6 | 24.6bc | 23.8b | 28.3abc | 22.8abcd |
| | 1.0 | 21.6c | 17.3b | 23.5bc | 16.0cd |

Acidity titratable. Grams of citric acid in 100 g of fresh tissue.

| Days | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | 1.17ab | 0.97abc | 1.21a | 0.89a |
| | 0.15 | 0.95abc | 0.93abc | 1.16ab | 0.79ab |
| | 0.6 | 1.25a | 0.95abc | 1.3a | 0.69abc |
| | 1.0 | 0.91abc | 1.01ab | 1.25a | 0.86a |
| 7 | Control | 0.87abc | 1.12a | 0.62cd | 0.73ab |
| | 0.15 | 0.80abc | 0.77bc | 0.87bc | 0.65abc |
| | 0.6 | 0.99abc | 0.81abc | 0.62cd | 0.38cd |
| | 1.0 | 0.98abc | 1.03ab | 0.44de | 0.50bcd |
| 13 | Control | 1.05abc | 0.84abc | 0.07f | 0.29d |
| | 0.15 | 0.94abc | 0.69c | 0.18ef | 0.23d |
| | 0.6 | 0.89abc | 0.74bc | 0.27ef | 0.21d |
| | 1.0 | 0.82abc | 0.74bc | 0.18ef | 0.24d |
| 19 | Control | 1.02abc | | 0.07f | |
| | 0.15 | 0.81bc | | 0.08f | |
| | 0.6 | 0.74c | | 0.10f | |
| | 1.0 | 0.80bc | | 0.11f | |

Weight loss. Percentage of weight lost respect of original weight.

| Days | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | | 0.8ef | 0.5d | 0.7e |
| | 0.15 | 0.5h | 0.7f | 0.4d | 0.8e |
| | 0.6 | | 0.8ef | 0.4d | 0.7e |
| | 1.0 | 0.5h | 0.8ef | 0.6d | 0.9e |
| 7 | Control | 2.0efgh | 2.6de | 3.0c | 3.0d |
| | 0.15 | 1.8fgh | 2.7cde | 2.6c | 3.1d |
| | 0.6 | 2.1efgh | 2.5def | 3.0c | 3.0d |
| | 1.0 | 1.8gh | 2.8cde | 2.8c | 3.4d |
| 13 | Control | 3.4def | 4.2abcd | 5.8b | 5.9c |
| | 0.15 | 3.5cde | 4.1abcd | 5.4b | 5.5c |
| | 0.6 | 3.7bcd | 4.5abc | 5.7b | 5.8c |
| | 1.0 | 3.2defg | 3.9bcd | 6.2b | 6.1bc |
| 19 | Control | 5.6a | 5.8ab | 8.0a | 8.3a |
| | 0.15 | 4.9abc | 5.9a | 8.2a | 8.0ab |
| | 0.6 | 5.6a | 5.6ab | 8.0a | 7.6abc |
| | 1.0 | 5.0ab | 5.9a | 8.5a | 8.1a |

Solid Soluble Content. °Brix

| Days | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | 7.8f | 8.0ef | 6.8d | 8.1c |
| | 0.15 | 10.1cdef | 7.4f | 7.5d | 7.7c |
| | 0.6 | 8.3def | 8.1ef | 7.3d | 9.7c |
| | 1.0 | 8.2ef | 8.4def | 7.8d | 8.7c |
| 7 | Control | 13.2abc | 8.8cdef | 12.1c | 13.2ab |
| | 0.15 | 12.2abc | 8.6cdef | 13.7abc | 12.8b |
| | 0.6 | 10.7cdef | 10.2abcdef | 13.2bc | 15.6ab |
| | 1.0 | 11.0bcdef | 9.0bcdef | 14.2abc | 14.0ab |
| 13 | Control | 12.8abc | 11.7abc | 15.3abc | 13.7ab |
| | 0.15 | 13.3abc | 11.6abcd | 15.7ab | 15.5ab |
| | 0.6 | 11.6abcd | 10.9abcde | 14.7abc | 15.9a |
| | 1.0 | 10.4cdef | 9.5bcdef | 15.3abc | 14.7ab |
| 19 | Control | 13.7ab | 12.8a | 17.0a | 14.3ab |
| | 0.15 | 14.3a | 12.8a | 14.6abc | 15.3ab |
| | 0.6 | 13.9a | 13.4a | 14.8abc | 15.6ab |
| | 1.0 | 12.5abc | 12.1ab | 15.0ab | 14.8ab |

Flesh color. a* values on CIE L*a*b* scale

| Days | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | 7.3b | 10.7ab | 7.4g | 10.1cde |
| | 0.15 | 10.4ab | 6.3b | 8.0fg | 6.6e |
| | 0.6 | 11.0ab | 10.2ab | 9.0fg | 9.9cde |
| | 1.0 | 9.9ab | 8.5ab | 10.2efg | 8.8de |
| 7 | Control | 9.5ab | 9.3ab | 15.9bcde | 15.0abcd |
| | 0.15 | 7.5b | 5.4b | 10.7efg | 11.4bcde |
| | 0.6 | 7.9ab | 12.2ab | 11.6defg | 16.2abc |
| | 1.0 | 8.6ab | 7.8b | 14.0cdefg | 13.7bcde |
| 13 | Control | 9.0ab | 10.0ab | 20.6abc | 15.8abcd |
| | 0.15 | 8.6ab | 8.7ab | 19.9abc | 18.1ab |
| | 0.6 | 6.9b | 8.1ab | 19.9abc | 16.1abcd |
| | 1.0 | 6.5b | 7.6b | 17.8abcd | 13.8bcde |
| 19 | Control | 9.2ab | 7.3b | 23.9a | 21.6a |
| | 0.15 | 14.1a | 9.1ab | 21.1ab | 18.5ab |
| | 0.6 | 10.6ab | 15.4a | 19.9abc | 19.6ab |
| | 1.0 | 10.2ab | 9.2ab | 21.2ab | 17.1abc |

Skin color: a* values on CIE L*a*b* scale

| Day | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | | -9.5a | | -7.4c |
| | 0.15 | | -8.3a | | -7.8c |
| | 0.6 | | -9.1a | | -6.6abc |
| | 1.0 | | -8.1a | | -6.6bc |
| 7 | Control | | -9.1a | | -7.4c |
| | 0.15 | | -5.9a | | -4.6abc |
| | 0.6 | | -6.6a | | -3.7abc |
| | 1.0 | | -6.7a | | -4.6abc |
| 13 | Control | | -6.0a | | -2.3abc |
| | 0.15 | | -6.2a | | 1.1ab |
| | 0.6 | | -6.0a | | 1.0a |
| | 1.0 | | -5.2a | | -2.1abc |
| 19 | Control | | | | |
| | 0.15 | | | | |
| | 0.6 | | | | |
| | 1.0 | | | | |

**ANNEX 6. Comparison between means of different response variables in mango fruit cv 'Kent' from different maturity stage (¼ and ¾), irradiated at different dose and stored at 10 (T10) and 20°C (T20) during 19 days. Different letters in the same column means statistical differences (Tuckey 0.05)**

Firmness: Values in Newtons.

| Day | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | 163.4a | 164.0a | 150.3b | 146.9b |
| | 0.15 | 110.3bc | 123.7b | 124.4f | 130.1bc |
| | 0.6 | 123.7b | 122.8b | 115.5fg | 107.0c |
| | 1.0 | 86.9cd | 90.7cd | 95.2g | 112.8c |
| 7 | Control | 113.1bc | 120.1bc | 43.7c | 49.5d |
| | 0.15 | 88.7cd | 88.5de | 35.0cdh | 36.7de |
| | 0.6 | 86.5cd | 71.6defg | 40.5cd | 28.5de |
| | 1.0 | 69.7def | 77.15def | 20.4dh | 24.1de |
| 13 | Control | 74.5de | 74.2defg | 18.2dh | 27.0de |
| | 0.15 | 69.6def | 63.7defg | 18.7dh | 21.7de |
| | 0.6 | 42.1f | 72.0defg | 24.4cdh | 15.7e |
| | 1.0 | 69.2def | 66.3defg | 14.0h | 15.2e |
| 19 | Control | 43.4ef | 45.5g | | |
| | 0.15 | 55.2ef | 49.1fg | 16.6cdh | |
| | 0.6 | 46.0ef | 55.2efg | 24.1cdh | 10.8de |
| | 1.0 | 46.5ef | 49.7fg | | 11.2de |

Ascorbic acid: mg of ascorbic acid in 100g of flesh.

| Day | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | 32.9bcde | 29.9bcd | 29.0cde | 33.8bcd |
| | 0.15 | 42.0ab | 33.8abc | 36.4bc | 36.8bc |
| | 0.6 | 38.1abcd | 28.6cde | 32.5cde | 36.0bcd |
| | 1.0 | 36.8abcd | 33.8abc | 37.7bc | 31.6bcd |
| 7 | Control | 35.2abcd | 33.6abc | 44.8b | 42b |
| | 0.15 | 44.8a | 37.6ab | 34.4bcd | 34bcd |
| | 0.6 | 27.6def | 39.2a | 29.6cde | 32.4bcd |
| | 1.0 | 38.8abc | 27.6cde | 31.6cde | 29.6cde |
| 13 | Control | 27.6def | 28cde | 22.4ef | 17.6f |
| | 0.15 | 24ef | 26cde | 16.12f | 20ef |
| | 0.6 | 21.6f | 22de | 17.6f | 25.6def |
| | 1.0 | 20.4f | 20e | 24.0def | 16.8f |
| 19 | Control | 27.2def | 31.0abcd | | |
| | 0.15 | 23.2ef | 30.3bcd | 30bcdef | |
| | 0.6 | 20.4f | 25.5cde | 8.0f | 24cdef |
| | 1.0 | 27.6cdef | 20.3e | | 34bcde |

Acidity titratable. Grams of citric acid in 100 g of fresh tissue.

| Day | Dose | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | 0.7b | 0.8ab | 1.0b | 1.0b |
| | 0.15 | 0.7b | 0.7ab | 0.6cdfg | 0.7bcde |
| | 0.6 | 0.9b | 0.9ab | 0.6cdf | 0.7bcdef |
| | 1.0 | 0.8ab | 0.6b | 0.9bc | 0.8bcd |
| 7 | Control | 0.8b | 0.9ab | 0.8bcf | 0.9bc |
| | 0.15 | 0.9ab | 0.8ab | 0.6cdfg | 0.7bcdef |
| | 0.6 | 0.8b | 0.72ab | 0.7bcf | 0.7bcdefg |
| | 1.0 | 0.9ab | 0.8ab | 0.7bcf | 0.4defgh |
| 13 | Control | 0.9ab | 0.9ab | 0.3dg | 0.5cdefgh |
| | 0.15 | 0.9ab | 0.8ab | 0.3dg | 0.3h |
| | 0.6 | 0.7b | 0.9ab | 0.3g | 0.3fgh |
| | 1.0 | 0.9ab | 0.7ab | 0.3dg | 0.3gh |
| 19 | Control | 0.8ab | 0.9ab | | |
| | 0.15 | 1.2a | 0.9a | 0.2cdfg | |
| | 0.6 | 0.9ab | 1.1a | 0.2dfg | 0.2defgh |
| | 1.0 | 0.7b | 0.8ab | | 0.2efgh |

Weight loss. Percentage of weight lost respect of original weight.

| Day | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | 0.7g | 0.5ef | 0.6g | 0.4e |
| | 0.15 | 0.8g | 0.5f | 0.6g | 0.4e |
| | 0.6 | 0.8g | 0.4f | 0.8g | 0.7e |
| | 1.0 | 1.0fg | 0.8def | 0.7g | 0.6e |
| 7 | Control | 3.0e | 2.1cdef | 3.5f | 3.2d |
| | 0.15 | 2.6ef | 2.3cdef | 3.7f | 3.2d |
| | 0.6 | 3.2de | 2.1cdef | 4.5f | 3.4d |
| | 1.0 | 3.6de | 2.7bcdef | 5.2ef | 3.2d |
| 13 | Control | 4.8cd | 3.6abcd | 5.6ef | 5.2c |
| | 0.15 | 4.9bcd | 3.4abcde | 7.7de | 5.6c |
| | 0.6 | 5.4bc | 3.7abc | 7.5e | 6.2c |
| | 1.0 | 5.4bc | 5.9ab | 10.1cd | 6.2c |
| 19 | Control | 8.3a | 5.5ab | | |
| | 0.15 | 6.6ab | 5.4ab | 11.2c | 8.5b |
| | 0.6 | 8.2a | 5.4abc | | 10.0b |
| | 1.0 | 7.3a | 6.0a | 14.0b | |

Solid Soluble Content. °Brix

| Day | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | 6.5e | 7.2ghi | 6.9d | 6.9d |
| | 0.15 | 6.6e | 6.8hi | 6.7d | 6.9f |
| | 0.6 | 6.8e | 6.8i | 7.0d | 7.0f |
| | 1.0 | 6.4e | 6.5i | 7.1d | 7.2f |
| 7 | Control | 8.0de | 8.8fg | 13.7bc | 14.0de |
| | 0.15 | 7.8de | 8.4fgh | 14.2bc | 14.4cde |
| | 0.6 | 8.0cde | 9.0f | 13.3c | 14.1e |
| | 1.0 | 7.8de | 8.6fg | 13.4c | 15.1bcde |
| 13 | Control | 9.7bcd | 12.8abcd | 17.1b | 17.0bcd |
| | 0.15 | 10.1bc | 12.0cde | 15.1bc | 16.6bcde |
| | 0.6 | 11.1ab | 11.5de | 14.3bc | 17.5b |
| | 1.0 | 9.6bcd | 10.9e | 13.3c | 17.3bc |
| 19 | Control | 12.7a | 14.3a | | |
| | 0.15 | 11.8ab | 13.8ab | 11.1bcd | |
| | 0.6 | 11.6ab | 13.2abc | 12.2bcd | 15.7bcde |
| | 1.0 | 10.2bc | 12.6bcd | | 14.6bcde |

Flesh color. a* values on CIE L*a*b* scale

| Day | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | 4.0a | 10.6ab | 5.2efg | 7.5def |
| | 0.15 | 1.7a | 8.3abc | 1.5g | 5.4f |
| | 0.6 | 1.1a | 7.4abc | 1.9fg | 6.3ef |
| | 1.0 | 2.9a | 5.0bc | 5.7defg | 6.4def |
| 7 | Control | 4.0a | 8.2abc | 11.6bcde | 13.2bcde |
| | 0.15 | 1.6a | 2.8c | 12.2bcde | 9.4cdef |
| | 0.6 | 4.2a | 4.9bc | 8.1cdefg | 11.4bcdef |
| | 1.0 | 2.5a | 6.0abc | 8.9cdefg | 14.1bcd |
| 13 | Control | 1.9a | 12.3a | 17.9b | 16.7bc |
| | 0.15 | 0.6a | 5.8abc | 17.4b | 17.6b |
| | 0.6 | 3.0a | 7.1abc | 13.6bc | 19.1b |
| | 1.0 | 2.7a | 7.7abc | 13.1bcd | 17.4b |
| 19 | Control | 1.4a | 11.1ab | | |
| | 0.15 | 3.6a | 7.3abc | 16.2bcdef | |
| | 0.6 | 3.6a | 7.4abc | | 20.2bc |
| | 1.0 | 2.7a | 9.8abc | | 20.7b |

Skin color: a* values on CIE L*a*b* scale

| Day | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | -4.8b | -6.4b | -5.7e | -6bc |
| | 0.15 | -4.4b | -5.2ab | -3.7e | -5.5bc |
| | 0.6 | -4.6b | -5.5ab | -4e | -5bc |
| | 1.0 | -5.5b | -4.5ab | -5e | -5.1bc |
| 7 | Control | -0.6ab | -4.9ab | -1.1d | -4.7bc |
| | 0.15 | -3.1ab | -5.3ab | 0.1bcd | -1.4bc |
| | 0.6 | -1.9ab | -4.5ab | -1.3d | 3.9bc |
| | 1.0 | -1.5ab | -4.2ab | -1.7d | -1.3bc |
| 13 | Control | -2.1ab | 0.1ab | 13.7a | 6.0 bc |
| | 0.15 | 1.5ab | -4.2ab | 2.5bcd | 3.9bc |
| | 0.6 | 3.6ab | 3.9ab | 7.1ab | 8.3b |
| | 1.0 | 8.1ª | 0.9ab | 3.1bc | 7.7bc |
| 19 | Control | 5.5ab | 4.2a | | |
| | 0.15 | -1.7ab | -5.6ab | 16.1a | |
| | 0.6 | 4.8ab | -0.9ab | 3.7bc | 9.7bc |
| | 1.0 | 3.7ab | -1.2ab | 3.1bc | 5.8bc |

**ANNEX 7. Comparison between means of different response variables in mango fruit cv 'Keitt' from different maturity stage (¼ and ¾), irradiated at different dose and stored at 10 (T10) and 20°C (T20) during 19 days. Different letters in the same column means statistical differences (Tuckey 0.05)**

Firmness: Values in Newtons.

| Day | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | 96.3abc | 138.4a | 124.2a | 139.9a |
| | 0.15 | 113.8a | 134.9a | 106.5ab | 123.2a |
| | 0.6 | 99.5ab | 128.2ab | 89.7b | 113.1a |
| | 1.0 | 85.3abcd | 99.4bcde | 90.5b | 120.7a |
| 7 | Control | 79.9abcd | 84.8def | 64.8c | 74.7b |
| | 0.15 | 83.8abcd | 111.6abcd | 62.6c | 47.8bc |
| | 0.6 | 82abcd | 122.1abc | 52.7cd | 45.0bcd |
| | 1.0 | 76.9bcd | 91.0cde | 39.1de | 38.7cde |
| 13 | Control | 63.6cd | 52.2fgh | 37.3de | 35.5cde |
| | 0.15 | 64.3cd | 78.2efg | 31.8de | 29.3cde |
| | 0.6 | 67.9bcd | 96.7bcde | 18.6e | 18.6cde |
| | 1.0 | 55.8d | 85.9de | 21e | 18.9cde |
| 19 | Control | 52.5d | 37.3h | 21.7e | 24.5cde |
| | 0.15 | 52.1d | 47.5gh | 23.2e | 11.1e |
| | 0.6 | 65.9bcd | 82.3def | 15.5e | 16.1de |
| | 1.0 | 83.7abcd | 91.8cde | 17.9e | 12.9de |

Ascorbic acid: mg of ascorbic acid in 100g of flesh.

| Day | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | 45.9abcd | 38.6a | 52.9ab | 40.3a |
| | 0.15 | 42.5abcdef | 34.2ab | 45.1bcd | 34.2ab |
| | 0.6 | 41.2bcdef | 32.1abc | 47.7abc | 35.5ab |
| | 1.0 | 43.3abcde | 32.5abc | 45.9abc | 37.3ab |
| 7 | Control | 55.2a | 35.7ab | 57.2a | 32.7abc |
| | 0.15 | 43.6abcde | 32.3abc | 49.6ab | 26bcd |
| | 0.6 | 49.6ab | 36ab | 33.2def | 25.3bcd |
| | 1.0 | 47.6abc | 34ab | 36cde | 19de |
| 13 | Control | 36.8bcdefg | 37a | 27.2efg | 26.7bcd |
| | 0.15 | 38bcdef | 33ab | 28.4efg | 20.7cde |
| | 0.6 | 32.8defg | 21cd | 26.8efg | 10.7e |
| | 1.0 | 32efg | 18d | 14h | 10.3e |
| 19 | Control | 33.7defg | 33.3ab | 25.2efgh | 27bcd |
| | 0.15 | 35cdefg | 32abc | 20.5fgh | 18.4de |
| | 0.6 | 30fg | 24.7bcd | 13gh | 18de |
| | 1.0 | 24.7g | 20.7cd | 15gh | 14de |

Acidity titratable. Grams of citric acid in 100 g of fresh tissue.

| Day | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | 1.2a | 1.1a | 1.5a | 1.0ab |
| | 0.15 | 1.2a | 1.0ab | 1.2ab | 1.1a |
| | 0.6 | 1.3a | 1.1a | 1.2abc | 0.7abc |
| | 1.0 | 1.4a | 1.0ab | 1.4ab | 1.0ab |
| 7 | Control | 1.3a | 1.0ab | 1.3ab | 1.0ab |
| | 0.15 | 1.4a | 0.9abc | 1.2abc | 0.9ab |
| | 0.6 | 0.9a | 1.0ab | 1.0abcd | 0.6abcde |
| | 1.0 | 0.9a | 0.6bc | 0.8bcde | 0.6abcde |
| 13 | Control | 1.2a | 0.6bc | 1.0abcde | 1.0ab |
| | 0.15 | 1.0a | 0.8abc | 0.6cde | 0.6bcde |
| | 0.6 | 1.0a | 0.9abc | 0.5de | 0.4cde |
| | 1.0 | 1.1a | 0.5c | 0.5de | 0.3cde |
| 19 | Control | 1.2a | 0.9abc | 0.9bcde | 0.7abcd |
| | 0.15 | 1.3a | 1.0ab | 0.4e | 0.2de |
| | 0.6 | 0.9a | 0.9abc | 0.2de | 0.2e |
| | 1.0 | 1.1a | 0.8abc | 0.4e | 0.2cde |

Weight loss. Percentage of weight lost respect of original weight.

| Day | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | 0.6fg | 0.8f | 0.2h | 0.9f |
| | 0.15 | 0.5g | 0.8f | 0.7fgh | 0.8f |
| | 0.6 | 0.5g | 0.9f | 0.6fgh | 0.8f |
| | 1.0 | 0.6fg | 0.8f | 0.5gh | 0.7f |
| 7 | Control | 2.4de | 3.6e | 2.8efgh | 3.6e |
| | 0.15 | 2.2ef | 3.3e | 3.9defg | 4.6e |
| | 0.6 | 2.3e | 2.9e | 2.8efgh | 4.5e |
| | 1.0 | 2.5cde | 3.1e | 4.0def | 4.4e |
| 13 | Control | 3.8bcde | 6.8cd | 4.5cde | 7.1cd |
| | 0.15 | 4.2bc | 5.6d | 5.1bcde | 7.5cd |
| | 0.6 | 4.0bcd | 5.4d | 6.1bcde | 7.2cd |
| | 1.0 | 4.7ab | 5.8d | 5.9bcde | 6.8d |
| 19 | Control | 5.0ab | 9.3a | 6.4bcd | 8.6bc |
| | 0.15 | 6.0a | 9.0ab | 8.2ab | 11.1a |
| | 0.6 | 4.3b | 7.9bc | 7.7abc | 10.0ab |
| | 1.0 | 6.2a | 8.3ab | 10.4a | 10.1ab |

Solid Soluble Content. °Brix

| Day | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | 7.0f | 6.0g | 6.4d | 6.5e |
| | 0.15 | 7.0f | 6.2g | 7.2d | 6.4e |
| | 0.6 | 7.1f | 6.3g | 7.1d | 6.5e |
| | 1.0 | 7.0f | 4.0g | 6.8d | 6.3e |
| 7 | Control | 8.4cdef | 7.2fg | 9.8c | 10.2d |
| | 0.15 | 9.2cd | 7.7ef | 11.4bc | 12.7bc |
| | 0.6 | 8.4cdef | 7.2fg | 12.6ab | 12.3c |
| | 1.0 | 7.4ef | 7.1fg | 12.7ab | 12.3c |
| 13 | Control | 10.0bc | 9.6cd | 13.4ab | 13.7abc |
| | 0.15 | 11.2ab | 10.0bcd | 13.9a | 14.2ab |
| | 0.6 | 9.8bc | 9.1cde | 14.3a | 14.8a |
| | 1.0 | 7.6def | 8.7de | 13.2ab | 13.6abc |
| 19 | Control | 11.5a | 12.1a | 14.1a | 14.3ab |
| | 0.15 | 11.5a | 11.4ab | | 15.5a |
| | 0.6 | 11.8a | 11.2ab | 14.2ab | 13.9abc |
| | 1.0 | 8.8cde | 10.4bc | 13.6ab | 15.6a |

Flesh color. a* values on CIE L*a*b* scale

| Day | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | 3.05ab | 4.8a | 2.6f | 3.9e |
| | 0.15 | 4.0ab | 6.0a | 4.3def | 3.2e |
| | 0.6 | 3.8ab | 4.1a | 2.7f | 4.8e |
| | 1.0 | 3.8ab | 4.2a | 3.5ef | 4.8e |
| 7 | Control | 4.0ab | 3.8a | 3.0ef | 4.8de |
| | 0.15 | 4.7ab | 4.0a | 2.8f | 5.1de |
| | 0.6 | 3.9ab | 3.2a | 6.4cdef | 5.9de |
| | 1.0 | 2.1ab | 4.5a | 7.3bcdef | 6.4de |
| 13 | Control | 3.6ab | 5.5a | 9.4abcde | 9.9cd |
| | 0.15 | 2.8ab | 6.6a | 12.9ab | 12.3bc |
| | 0.6 | 2.2ab | 7.1a | 12.7abc | 14.5abc |
| | 1.0 | 0.6b | 6.1a | 12.4abc | 12.4bc |
| 19 | Control | 6.3a | 5.9a | 10.6abcd | 12.2bc |
| | 0.15 | 3.4ab | 5.4a | 16.2a | 18.2a |
| | 0.6 | 3.5ab | 6.7a | 15.1abc | 18.0a |
| | 1.0 | 0.6b | 4.7a | 15.1a | 16.3ab |

Skin color: a* values on CIE L*a*b* scale

| Day | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | -6c | -9b | -5.8cd | -7.6b |
| | 0.15 | -5.3c | -8.1b | -6.3d | -6.5b |
| | 0.6 | -4bc | -6.5b | -7.8d | -7.7b |
| | 1.0 | -7c | -7.4b | -5.7cd | -8.2b |
| 7 | Control | -3.2bc | -5.8b | -6.7d | -5.8b |
| | 0.15 | -4bc | -6.6b | -0.4bcd | -7.5b |
| | 0.6 | -3.5bc | -6.5b | -1.8bcd | -6.4b |
| | 1.0 | -4.1bc | -6.3b | -4.8cd | -6.1b |
| 13 | Control | -1.3abc | -4.5b | 0.8abcd | -8.9b |
| | 0.15 | 10.6ab | -6.9b | -1.1bcd | -6b |
| | 0.6 | 8.1abc | -7.5b | 8.7abc | -5.7b |
| | 1.0 | 1.7abc | -7.4b | 6.3abcd | -5.6b |
| 19 | Control | -1.4abc | 10.7a | 3.3abcd | 4.7a |
| | 0.15 | 3.2abc | 5.3a | 11.9ab | 7.1a |
| | 0.6 | 13.2a | 5.1a | 3.7abcd | 8.0a |
| | 1.0 | 0.7abc | 5.8a | 16.0a | 9.5a |

**ANNEX 8**. **Comparison between means of different response variables in mango fruit cv 'Ataulfo' from different maturity stage (¼ and ¾), irradiated at different dose and stored at 10 (T10) and 20°C (T20) during 19 days. Different letters in the same column means statistical differences (Tuckey 0.05)**

Firmness: Values in Newtons.

| Day | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | control | 53.5 ab | 48.5 a | 43.6 ab | 37.3 c |
| | 0.15 | 73.7 a | 45.2 ab | 38 abc | 64.4 b |
| | 0.6 | 57.7 ab | 49.9 a | 56.1 a | 63.5 b |
| | 1.0 | 43.7 bc | 39.4 abc | 46.0 ab | 61.2 b |
| 7 | control | 39.5 bcde | 36.8 abcd | 14.6 d | 13.8 d |
| | 0.15 | 42.9 bcd | 18.3 cde | 14.7 d | 15.5 d |
| | 0.6 | 33.1 bcdef | 28 abcde | 16.2 d | 16.4 d |
| | 1.0 | 25.57 cdef | 14.3 de | 21.2 cd | 19.4 cd |
| 13 | control | 23.6 cdef | 17.5 cde | 13.6 d | 9.9 d |
| | 0.15 | 12.53 f | 21.2 cde | 9.5 d | 11.7 d |
| | 0.6 | 27.7 cdef | 23.1 bcde | 9.1 d | 11.5 d |
| | 1.0 | 19.06 cdef | 16.4 cde | 11.3 d | 11.9 d |
| 19 | control | 11.1 f | 12.3 de | 12 d | |
| | 0.15 | 14.7 ef | 15.6 cde | 7.9 bcd | 9.1 d |
| | 0.6 | 17 def | 15.2 cde | 7.9 d | 7.9 d |
| | 1.0 | 15.31 ef | 10.48 e | 11.9 d | 10.7 d |

Ascorbic acid: mg of ascorbic acid in 100g of flesh.

| Day | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | 118 ab | 114 a | 112.8 c | 108.8 bc |
| | 0.15 | 107 abc | 102 ab | 118.4 bc | 112.4 bc |
| | 0.6 | 109.3 abc | 108.7 ab | 109 c | 114 b |
| | 1.0 | 121.9 ab | 115 a | 150.8 ab | 106 bcd |
| 7 | Control | 99.2 abc | 115.6 a | 101.6 cd | 91.6 bcd |
| | 0.15 | 98.87 abc | 112.8 a | 94.4 cd | 93.6 bcd |
| | 0.6 | 106.4 abc | 91.2 ab | 99.2 cd | 76.8 cd |
| | 1.0 | 104.4 abc | 105.2 ab | 103.2 c | 82 bcd |
| 13 | Control | 138.8 a | 123.6 a | 107.6 c | 88 bcd |
| | 0.15 | 122.8 ab | 110.4 ab | 90.4 cd | 98.4 bcd |
| | 0.6 | 110 abc | 98.8 ab | 106.05 c | 71.6 d |
| | 1.0 | 111.6 abc | 86.4 ab | 87.6 cd | 80 bcd |
| 19 | Control | 120 ab | 136.8 a | 162.4 a | |
| | 0.15 | 97.2 abc | 123.2 a | 134.4 abc | 91.2 bcd |
| | 0.6 | 81.12 bc | 110.4 ab | 100 cd | 92.8 bcd |
| | 1.0 | 61.6 c | 64 b | 68.0 d | 95.52 bcd |

Acidity titratable. Grams of citric acid in 100 g of fresh tissue.

| Day | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | 2.7 abc | 2.6 a | 2.5 a | 2.8 b |
| | 0.15 | 2.6 abc | 2.3 a | 2.4 a | 2.8 b |
| | 0.6 | 2.8 a | 2.3 a | 2.6 a | 2.7 b |
| | 1.0 | 2.8 a | 2.7 a | 3.0 a | 2.6 b |
| 7 | Control | 2.3 abc | 2.4 a | 0.8 bcd | 0.9 cde |
| | 0.15 | 2.2 abc | 1.7 a | 1.3 b | 1.1 c |
| | 0.6 | 2.4 abc | 1.8 a | 1.2 bc | 1.08 cd |
| | 1.0 | 2.8 ab | 1.9 a | 1.3 b | 1.1 cd |
| 13 | Control | 2.3 abc | 2.2 a | 0.2 d | 0.1 f |
| | 0.15 | 1.6 c | 1.4 a | 0.3 d | 0.3 ef |
| | 0.6 | 2 abc | 1.5 a | 0.3 d | 0.4 def |
| | 1.0 | 2.5 abc | 2.1 a | 0.4 bcd | 0.4 def |
| 19 | Control | 1.7 bc | 1.9 a | 0.1 cd | |
| | 0.15 | 1.9 abc | 1.5 a | 0.3 bcd | 0.2 f |
| | 0.6 | 1.6 c | 1.6 a | 0.2 cd | 0.17 ef |
| | 1.0 | 1.7 c | 2.4 a | 0.4 cd | 0.3 ef |

Weight loss. Percentage of weight lost respect of original weight.

| Day | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | 0.7 f | 0.6 gh | 0.6 d | 0.6 f |
| | 0.15 | 0.6 f | 0.5 h | 0.6 d | 0.8 f |
| | 0.6 | 0.7 f | 0.6 gh | 0.6 d | 0.6 f |
| | 1.0 | 0.7 f | 0.6 gh | 0.4 d | 0.6 f |
| 7 | Control | 2.4 e | 2.7 ef | 4.5 c | 4.7 e |
| | 0.15 | 2.4 e | 2.2 fg | 4.0 c | 4.0 e |
| | 0.6 | 2.9 de | 2.5 ef | 4.7 c | 4.0 e |
| | 1.0 | 2.7 e | 2.6 ef | 4.2 c | 3.8 e |
| 13 | Control | 4.9 bc | 5.2 cd | 7.4 b | 8.1 bcd |
| | 0.15 | 5.8 abc | 3.9 de | 7.0 b | 7.2 d |
| | 0.6 | 4.5 cd | 4.1 de | 8.2 b | 7.8 cd |
| | 1.0 | 4.6 c | 5.1 cd | 7.9 b | 7.5 cd |
| 19 | Control | 7.3 a | 8 ab | 8.9 ab | |
| | 0.15 | 6.5 ab | 6.3 bc | 8.5 ab | 9.4 bc |
| | 0.6 | 6.5 ab | 7.1 ab | 10.4 a | 9.7 b |
| | 1.0 | 6.7 a | 7.96 a | 10.8 a | 9.8 b |

Solid Soluble Content. °Brix

| Day | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | 8.2 efg | 8.0 ef | 8.9 cde | 7.4 f |
| | 0.15 | 6.8 g | 9.0 def | 8.0 de | 8.9 def |
| | 0.6 | 7.0 fg | 8.3 ef | 8.3 de | 7.8 f |
| | 1.0 | 7.3 fg | 7.1 f | 7.3 e | 8.6 ef |
| 7 | Control | 9.6 defg | 10.3 bcdef | 13.3 ab | 13.0 c |
| | 0.15 | 10.0 cdefg | 13.3 abc | 13.1 ab | 15.4 bc |
| | 0.6 | 10.4 bcdef | 10.9 bcdef | 13.5 ab | 14.2 bc |
| | 1.0 | 7.9 efg | 9.9 bcdef | 11.5 bcd | 12.7 cd |
| 13 | Control | 11.6 abcd | 11.9 abcde | 14.3 ab | 12.4 cde |
| | 0.15 | 13.4 abc | 12.9 abcd | 13.4 ab | 15.2 bc |
| | 0.6 | 11.3 abcde | 11.8 abcde | 13.7 ab | 14.1 bc |
| | 1.0 | 7.4 fg | 9.5 bcdef | 12.4 abc | 14.3 bc |
| 19 | Control | 13.9 a | 13.8 ab | 14.8 ab | |
| | 0.15 | 13.4 ab | 13.3 abc | 14.4 abcd | 17.5 b |
| | 0.6 | 12.0 abcd | 15.9 a | 16.8 a | 14 bc |
| | 1.0 | 9.8 defg | 9.3 cdef | 11.6 bcd | 13.9 bc |

Flesh color. a* values on CIE L*a*b* scale

| Day | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | 4.0a | 10.6ab | 5.2efg | 7.5def |
| | 0.15 | 1.7a | 8.3abc | 1.5g | 5.4f |
| | 0.6 | 1.1a | 7.4abc | 1.9fg | 6.3ef |
| | 1.0 | 2.9a | 5.0bc | 5.7defg | 6.4def |
| 7 | Control | 4.0a | 8.2abc | 11.6bcde | 13.2bcde |
| | 0.15 | 1.6a | 2.8c | 12.2bcde | 9.4cdef |
| | 0.6 | 4.2a | 4.9bc | 8.1cdefg | 11.4bcdef |
| | 1.0 | 2.5a | 6.0abc | 8.9cdefg | 14.1bcd |
| 13 | Control | 1.9a | 12.3a | 17.9b | 16.7bc |
| | 0.15 | 0.6a | 5.8abc | 17.4b | 17.6b |
| | 0.6 | 3.1a | 7.1abc | 13.6bc | 19.1b |
| | 1.0 | 2.7a | 7.7abc | 13.1bcd | 17.4bc |
| 19 | Control | 1.4a | 11.1ab | | |
| | 0.15 | 3.6a | 7.3abc | 16.2bcdef | |
| | 0.6 | 3.6a | 7.4abc | | 20.2bc |
| | 1.0 | 2.7a | 9.9abc | | 20.7b |

Skin color: a* values on CIE L*a*b* scale

| Day | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | -6.3 c | -3.8ab | -3.5ef | -5.4e |
| | 0.15 | -5.7bc | -5.3ab | -3.6ef | -5.3e |
| | 0.6 | -5.5bc | -2.7ab | -5.1f | -6.0e |
| | 1.0 | -0.4ab | -2.7ab | -5.7f | -4.6e |
| 7 | Control | -2.5abc | -2.8ab | 9.8bd | 8.2cd |
| | 0.15 | -1.0 abc | 2.5a | 7.0bd | 8.4cd |
| | 0.6 | -2.7abc | 3.0a | 5.5bd | 7.5cd |
| | 1.0 | 2.2abc | 0.3ab | 4.7de | 3.3d |
| 13 | Control | 1.1a | -0.7ab | 15.2ab | 15.7b |
| | 0.15 | 0.5a | 0.6ab | 14.3ab | 15.3b |
| | 0.6 | -0.8abc | 0.6ab | 12.8abd | 12.5bc |
| | 1.0 | -1.1abc | 0.6ab | 8.9bd | 12.7bc |
| 19 | Control | 1.6a | 1.1ab | 21.8a | |
| | 0.15 | 0.4a | -0.9ab | | 18.3b |
| | 0.6 | 1.3a | 1.4ab | 16.9ab | 15.5b |
| | 1.0 | 0.9a | 2.9a | 14.4ab | 14.9bc |

**ANNEX 9. Comparison between means of different response variables in mango fruit cv 'Manila' from different maturity stage (¼ and ¾), irradiated at different dose and stored at 10 (T10) and 20°C (T20) during 19 days. Different letters in the same column means statistical differences (Tuckey 0.05)**

Firmness: Values in Newtons.

| Day | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | 24.4abc | 24.1ab | 13.7c | 18.5b |
| | 0.15 | 24.5abc | 21.0ab | 34.4b | 18.1b |
| | 0.6 | 31.4ab | 27.5ab | 30.8b | 31.3a |
| | 1.0 | 45.5a | 32.7a | 19.1bc | 31.2a |
| 7 | Control | 9.1c | 6.9b | 4.9c | 4.2c |
| | 0.15 | 19.6bc | 11.1ab | 6.0c | 4.0c |
| | 0.6 | 14.4bc | 12.8ab | 6.5c | 7.2bc |
| | 1.0 | 22.5bc | 18.6ab | 4.8c | 4.8c |
| 13 | Control | 5.2c | 6.3b | 4.1c | 4.8c |
| | 0.15 | 13.0bc | 8.3b | 5.1c | 3.5c |
| | 0.6 | 10.3bc | 10.2ab | 3.0c | 4.0c |
| | 1.0 | 14.3bc | 15.8ab | 3.8c | 4.7c |
| 19 | Control | 4.5c | 4.8ab | | |
| | 0.15 | 5.0c | 7.4ab | | |
| | 0.6 | 10.3bc | 11.8ab | 5.2c | |
| | 1.0 | 12.7bc | 11.2ab | | |

Ascorbic acid: mg of ascorbic acid in 100g of flesh.

| Day | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | 56.4bc | 51.6bcd | 50.0bce | 49.6b |
| | 0.15 | 48.0c | 54.4bcd | 57.2bce | 54.8ab |
| | 0.6 | 51.5c | 57.2bcd | 52.0bce | 49.2b |
| | 1.0 | 56.4bc | 57.6bcd | 49.2ce | 52.0b |
| 7 | Control | 55.2bc | 49.6d | 50.4bce | 58.4ab |
| | 0.15 | 59.2bc | 59.2bcd | 39.4e | 50.4b |
| | 0.6 | 56bc | 53.2bcd | 42.8e | 48.8b |
| | 1.0 | 58.4bc | 58.8bcd | 46.0e | 46.0b |
| 13 | Control | 46.8c | 56.8bcd | 72.0bc | 63.8ab |
| | 0.15 | 50.4c | 62.4bcd | 60.8bce | 80.8a |
| | 0.6 | 59.2bc | 56.4bcd | 50.9bce | 55.2ab |
| | 1.0 | 43.2c | 46.0d | 52.2bce | 56.4ab |
| 19 | Control | 72.0abc | 100.8a | | |
| | 0.15 | 91.2a | 69.0abc | | |
| | 0.6 | 75.2ab | 71.2ab | 86.4b | |
| | 1.0 | 60.0bc | 56.6bcd | | |

Acidity titratable. Grams of citric acid in 100 g of fresh tissue.

| Day | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | 1.92ab | 1.50a | 1.40bc | 1.15ab |
| | 0.15 | 1.45ab | 1.66b | 1.75b | 1.16ab |
| | 0.6 | 1.84ab | 1.67a | 1.76b | 1.56a |
| | 1.0 | 2.04a | 1.66a | 1.10bcd | 1.86a |
| 7 | Control | 1.20ab | 0.78a | 0.38de | 0.22c |
| | 0.15 | 1.21ab | 1.27a | 0.41de | 0.39c |
| | 0.6 | 1.24ab | 1.34a | 0.55de | 0.53bc |
| | 1.0 | 1.85ab | 1.55a | 0.48de | 0.27c |
| 13 | Control | 1.23ab | 0.80a | 0.18e | 0.18c |
| | 0.15 | 1.26ab | 1.42a | 0.18e | 0.17c |
| | 0.6 | 1.02ab | 1.29a | 0.22e | 0.20c |
| | 1.0 | 1.71ab | 1.68a | 0.16e | 0.18c |
| 19 | Control | 1.66ab | 1.15a | | |
| | 0.15 | 0.66b | 1.37a | | |
| | 0.6 | 1.45ab | 1.56a | 0.30cde | |
| | 1.0 | 1.17ab | 1.57a | | |

Weight loss. Percentage of weight lost respect of original weight.

| Day | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | 0.4g | 0.4f | 0.5e | 0.4c |
| | 0.15 | 0.8g | 0.9f | 0.6e | 0.9c |
| | 0.6 | 0.8g | 0.6f | 0.6e | 0.7c |
| | 1.0 | 0.7g | 0.7f | 0.6e | 0.7c |
| 7 | Control | 2.6f | 2.8e | 4.1d | 4.0b |
| | 0.15 | 3.7de | 3.4de | 4.8d | 5.0b |
| | 0.6 | 2.8ef | 3.1e | 4.5d | 4.5b |
| | 1.0 | 2.9ef | 3.3e | 4.4d | 4.5b |
| 13 | Control | 5.3bc | 4.9c | 7.2c | 7.5a |
| | 0.15 | 5.1bc | 5.8c | 8.6c | 8.3a |
| | 0.6 | 4.6cd | 5.5c | 8.3c | 7.7a |
| | 1.0 | 5.5bc | 5.6c | 8.1c | 7.6a |
| 19 | Control | 7.5a | 5.7bcd | | |
| | 0.15 | 7.5a | 8.0ab | | |
| | 0.6 | 6.5ab | 7.7ab | 11.0b | |
| | 1.0 | 7.6a | 8.6a | | |

Solid Soluble Content. °Brix

| Day | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | 10.6cd | 13.0ab | 13.6bcd | 13.7abcd |
| | 0.15 | 11.8abcd | 12.0ab | 12.5cd | 13.4bcd |
| | 0.6 | 11.6bcd | 11.1b | 11.7d | 12.1cd |
| | 1.0 | 9.6d | 11.8ab | 14.2bcd | 11.1d |
| 7 | Control | 15.0ab | 16.6a | 15.1bcd | 16.1ab |
| | 0.15 | 13.9abcd | 13.6ab | 16.3bc | 16.0ab |
| | 0.6 | 14.1abc | 12.9ab | 16.7b | 14.9abc |
| | 1.0 | 11.4bcd | 12.3ab | 16.1bc | 16.7a |
| 13 | Control | 15.6ab | 15.7ab | 14.9bcd | 15.9ab |
| | 0.15 | 15.3ab | 15.7ab | 15.8bc | 15.0abc |
| | 0.6 | 16.1a | 13.8ab | 16.4bc | 15.4ab |
| | 1.0 | 12.1abcd | 11.4b | 16.1bc | 15.5ab |
| 19 | Control | 15.1abcd | 15.8ab | | |
| | 0.15 | 17.1ab | 14.7ab | | |
| | 0.6 | 16.2ab | 14.5ab | 14.8bcd | |
| | 1.0 | 13.5abcd | 13.8ab | | |

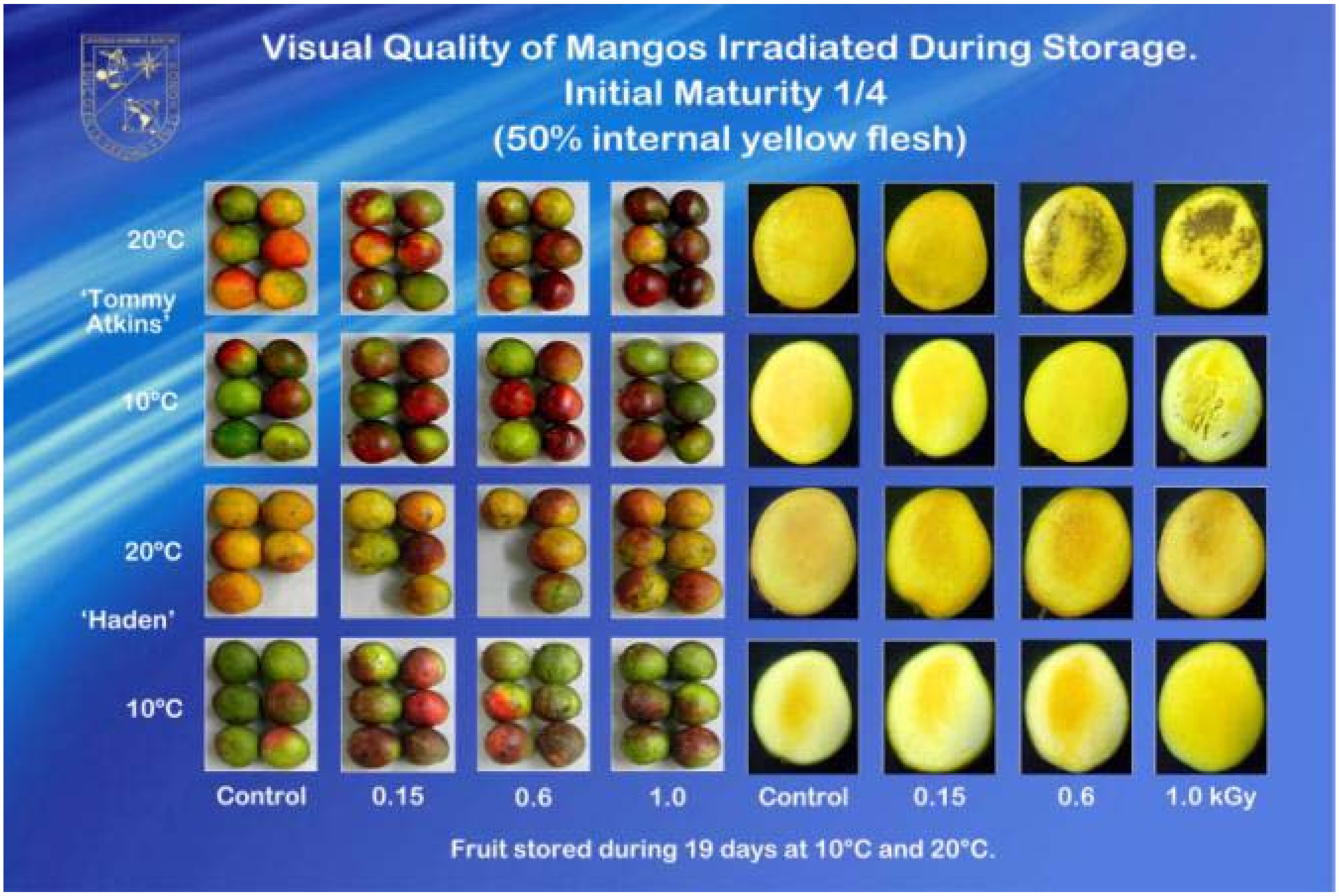
Flesh color. a* values on CIE L*a*b* scale

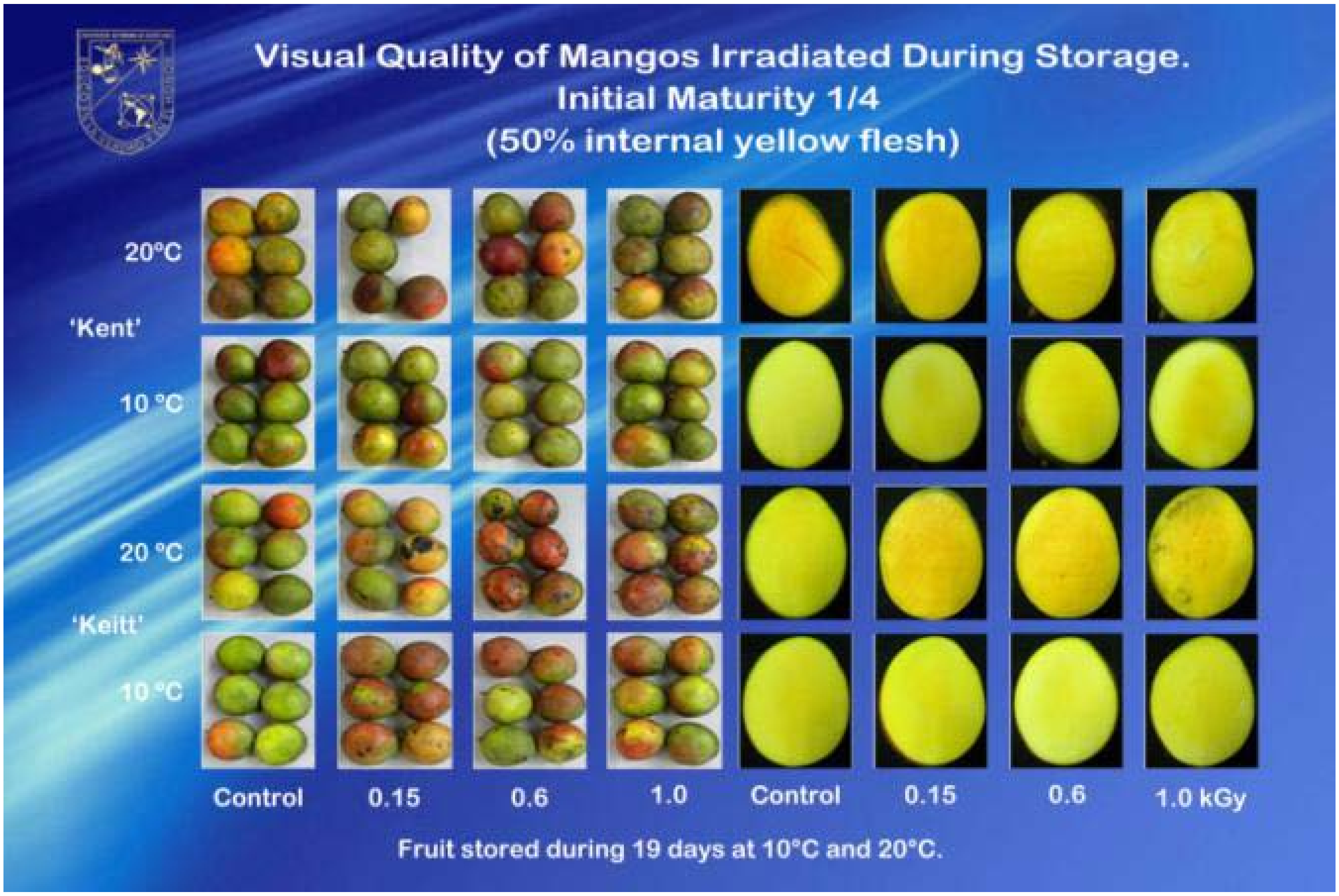
| Day | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | 5.7a | 6.5ab | 10.8bce | 8.8cde |
| | 0.15 | 6.6a | 6.8ab | 6.4e | 9.4bcde |
| | 0.6 | 7.5a | 6.4ab | 6.3e | 6.5de |
| | 1.0 | 4.0b | 5.3ab | 8.9ce | 5.5e |
| 7 | Control | 9.2a | 11.1a | 12.4bcde | 15.4ab |
| | 0.15 | 7.6a | 9.4ab | 14.3bcd | 14.7abc |
| | 0.6 | 8.6a | 9.1ab | 12.6bcde | 12.2abcd |
| | 1.0 | 3.7b | 4.6ab | 11.0bcde | 14.3abc |
| 13 | Control | 7.1a | 9.2ab | 15.0bcd | 11.7abcde |
| | 0.15 | 6.4a | 6.7ab | 17.5d | 16.2a |
| | 0.6 | 7.7a | 7.5ab | 14.7bcd | 17.1a |
| | 1.0 | 5.5b | 3.6b | 15.6bd | 13.1abc |
| 19 | Control | 5.4a | 7.3ab | | |
| | 0.15 | 9.2a | 8.9ab | | |
| | 0.6 | 7.7a | 9.9ab | 8.3bcde | |
| | 1.0 | 6.1a | 4.9ab | | |

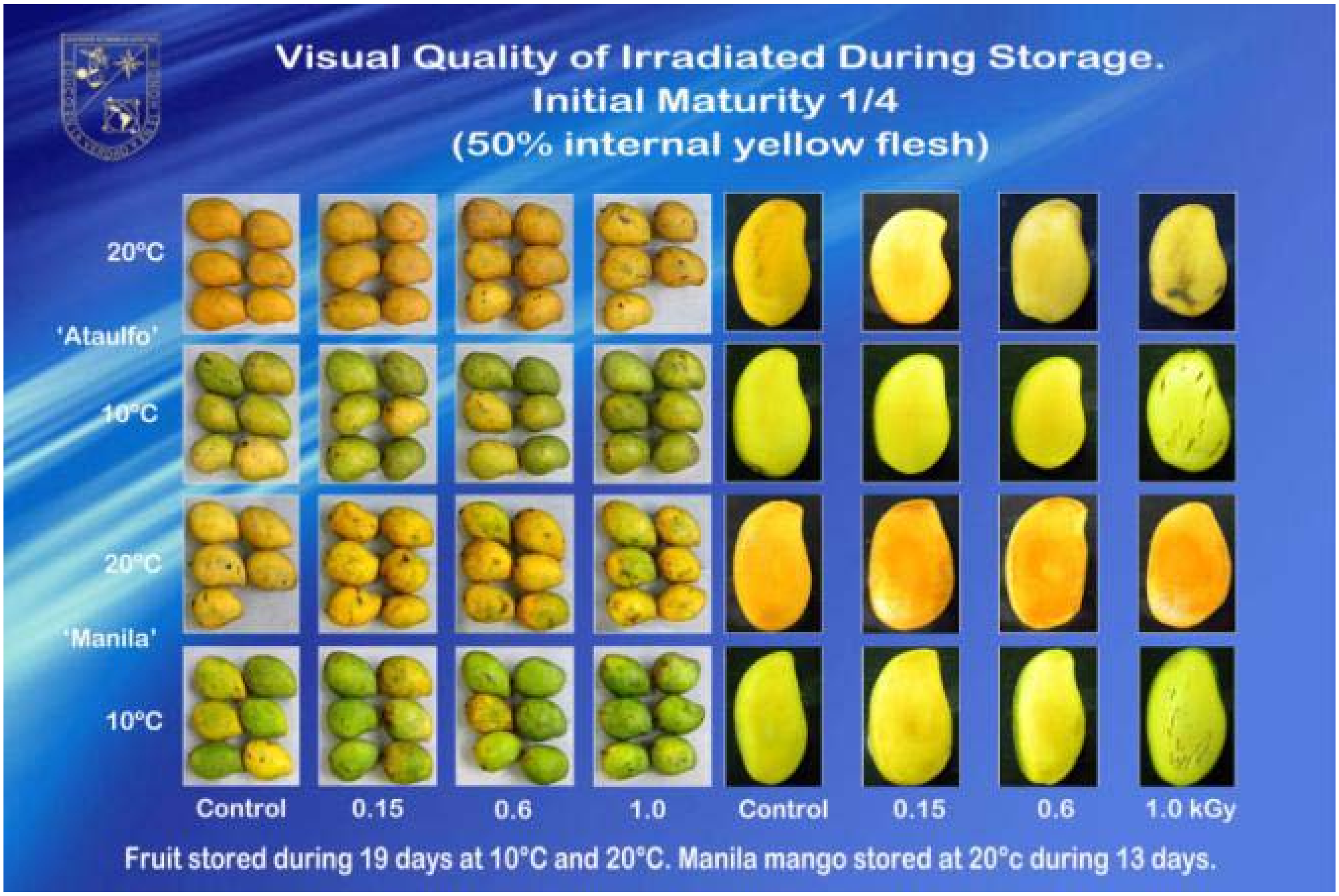
Skin color: a* values on CIE L*a*b* scale

| Day | Dose (kGy) | T10, 1/4 | T10, 3/4 | T20 1/4 | T20, 3/4 |
|---|---|---|---|---|---|
| 1 | Control | -9.7e | -5.9bcde | -6.4gh | -7.0de |
| | 0.15 | -7.2bcde | -7.5de | -8.3h | -5.5cde |
| | 0.6 | -8.3cde | -8.2e | -4.4fgh | -8.0e |
| | 1.0 | -8.7de | -6.6cde | -5.5fgh | -7.7e |
| 7 | Control | -2.5ab | -0.9ab | 3.3cde | 8.1a |
| | 0.15 | -5.5abcde | -4.9bcde | 2.95cde | 2.6ab |
| | 0.6 | -3.8abcd | -5.1bcde | -1.2dfg | -1.1bcd |
| | 1.0 | -7.5bcde | -4.4abcde | 0.7cdf | 0.3bc |
| 13 | Control | -3.3ab | 0.8a | 10.b | 10.4a |
| | 0.15 | -3.5abc | -2.0abc | 8.3be | 7.9a |
| | 0.6 | -3.4abc | -5.95bcde | 5.7bce | 2.4ab |
| | 1.0 | -6.4abcde | -5.8bcde | 3.0cde | 3.6ab |
| 19 | Control | -4.3abcde | 2.2abcd | | |
| | 0.15 | 0.2a | -4.4abcde | | |
| | 0.6 | -5.4abcde | -6.3bcde | -3.2dfgh | |
| | 1.0 | -5.0abcde | -4.6abcde | | |

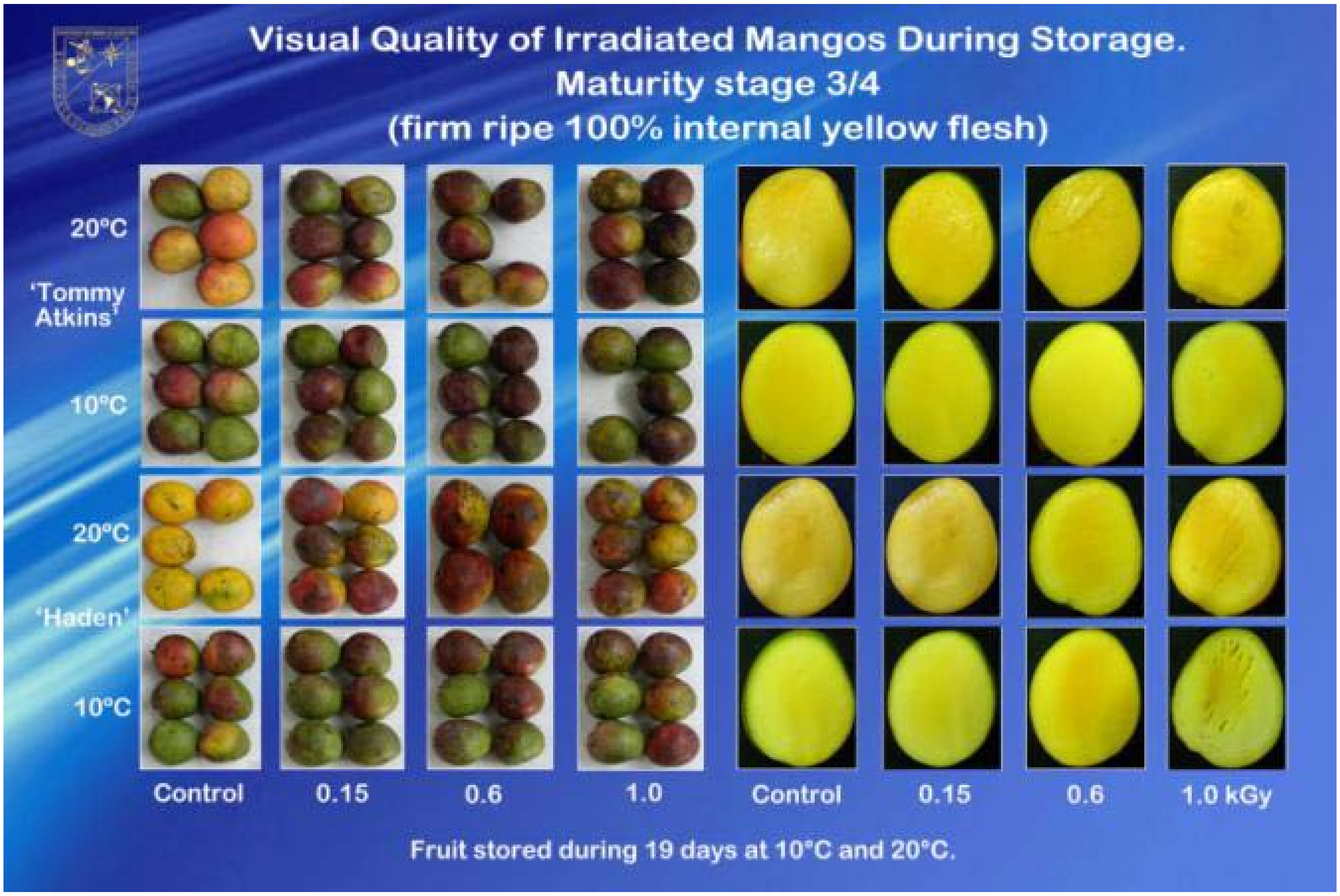
ANNEX 10. Internal and external visual quality changes of different mango varieties from two maturity stages subjected to different irradiation doses and stored at 10 and 20°C. (Data on CD)

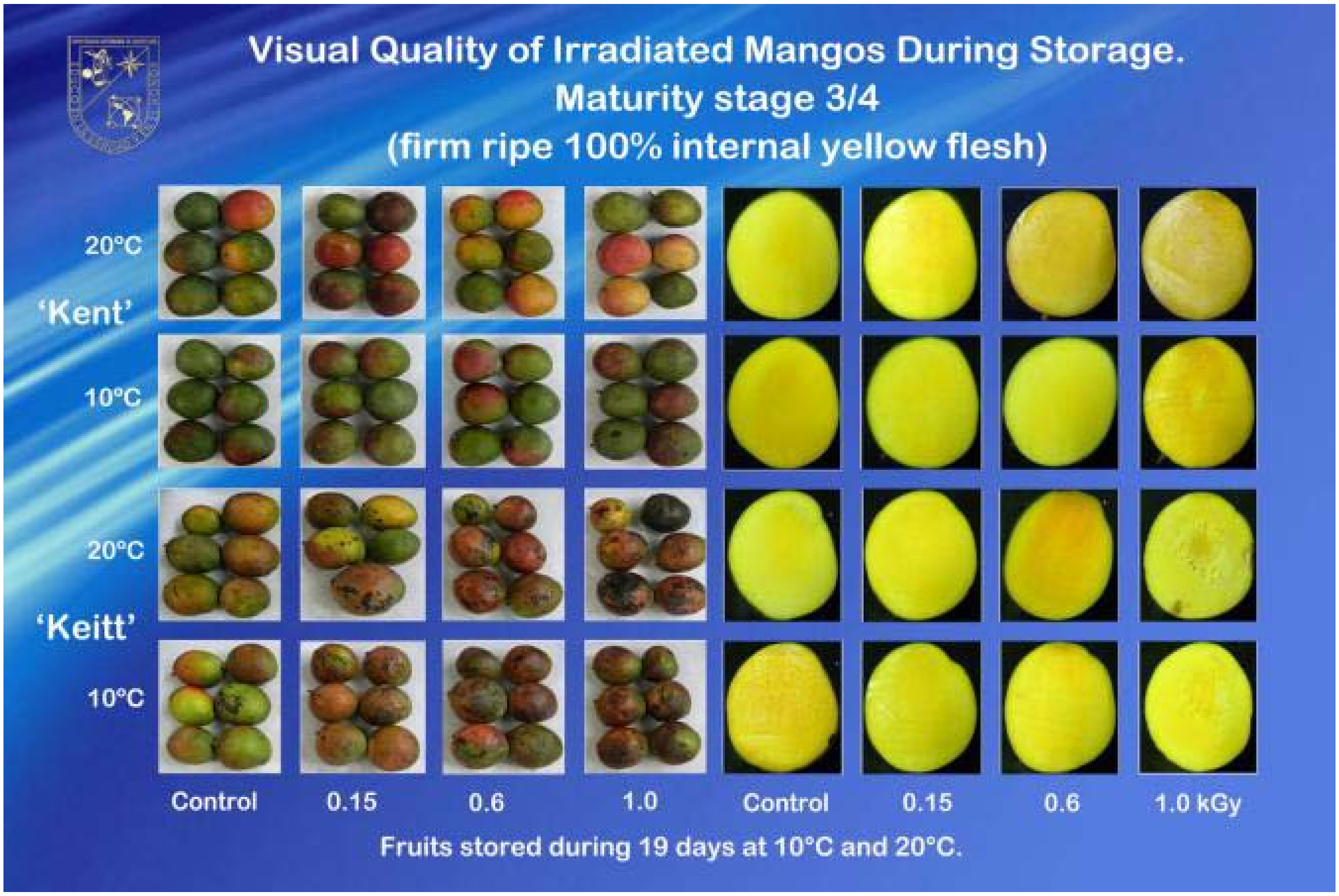


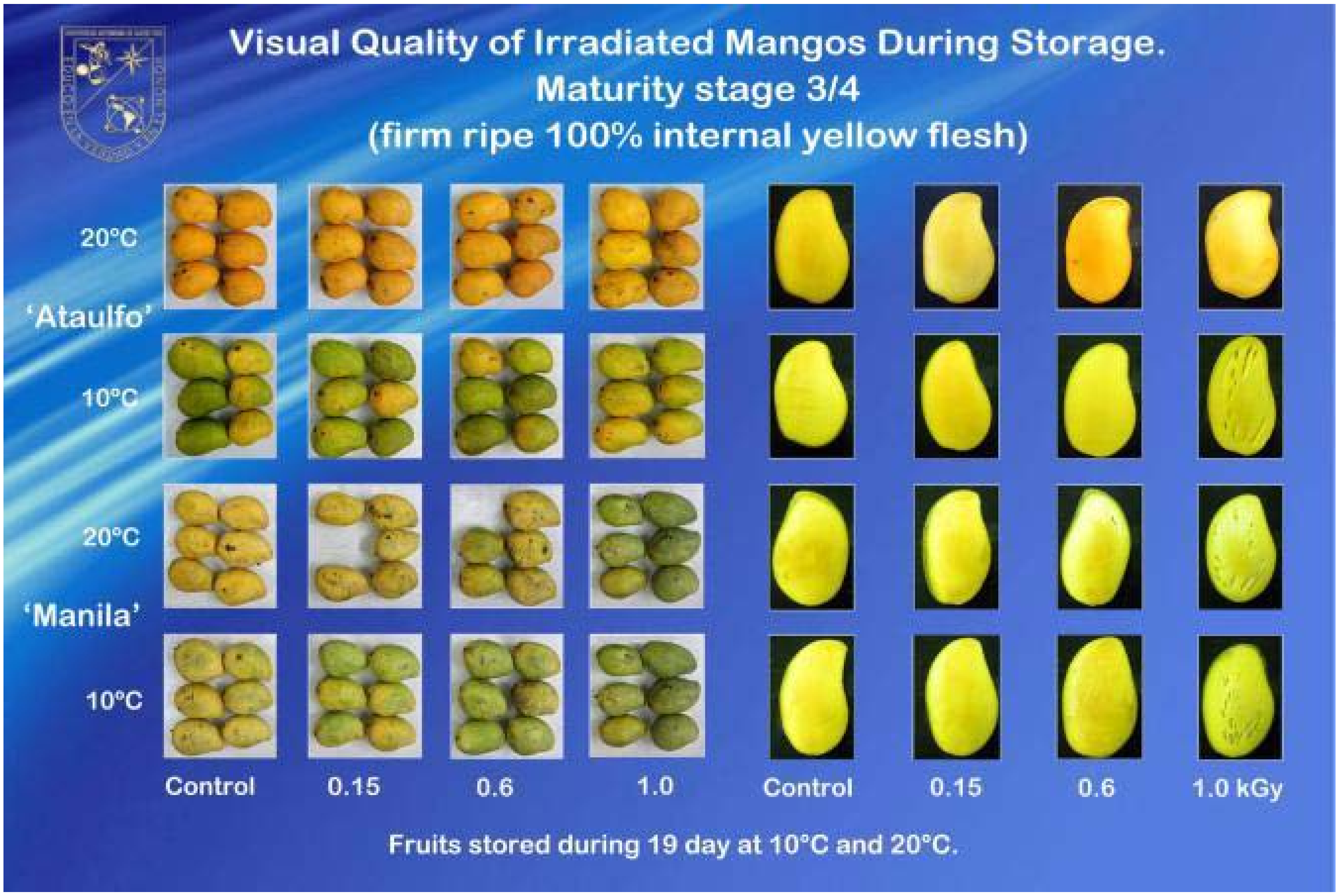

Visual Quality of Mangos Irradiated During Storage.
Initial Maturity 1/4
(50% internal yellow flesh)
20°C
'Kent'
10 °C
20 °C
'Keitt'
10 °C
Control
0.15
0.6
1.0
Control
0.15
0.6
1.0 kGy
Fruit stored during 19 days at 10°C and 20°C.



Visual Quality of Irradiated During Storage.
Initial Maturity 1/4
(50% internal yellow flesh)
20°C
'Ataulfo'
10°C
20°C
'Manila'
10°C
Control
0.15
0.6
1.0
Control
0.15
0.6
1.0 kGy
Fruit stored during 19 days at 10°C and 20°C. Manila mango stored at 20°c during 13 days.


Visual Quality of Irradiated Mangos During Storage.
Maturity stage 3/4
(firm ripe 100% internal yellow flesh)
20°C
'Tommy Atkins'
10°C
20°C
'Haden'
10°C
Control
0.15
0.6
1.0
Control
0.15
0.6
1.0 kGy
Fruit stored during 19 days at 10°C and 20°C.


Visual Quality of Irradiated Mangos During Storage.
Maturity stage 3/4
(firm ripe 100% internal yellow flesh)
20°C
'Kent'
10°C
20°C
'Keitt'
10°C
Control
0.15
0.6
1.0
Control
0.15
0.6
1.0 kGy
Fruits stored during 19 days at 10°C and 20°C.


Visual Quality of Irradiated Mangos During Storage.
Maturity stage 3/4
(firm ripe 100% internal yellow flesh)
20°C
'Ataulfo'
10°C
20°C
'Manila'
10°C
Control
0.15
0.6
1.0
Control
0.15
0.6
1.0 kGy
Fruits stored during 19 day at 10°C and 20°C.

**ANNEX 11. Square resume of gamma irradiation effects on physicochemical and visual quality of six varieties of mangoes produced in different regions of Mexico, harvested in two maturity stages, irradiated at different doses and stored at 10 and 20°C.**

| Variety | Mat/Temp. | External Visual quality | | | | Firmness | | | | Ascorbic acid | | | | Acidity | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Dose --- | 0.0 | 0.15 | 0.60 | 1.00 | 0.0 | 0.15 | 0.60 | 1.00 | 0.0 | 0.15 | 0.60 | 1.00 | 0.0 | 0.15 | 0.60 | 1.00 |
| Tommy Atkins | ¼ (10) | WE | WE | NE | NE | WE | WE | NE | NE | WE | WE | NE | NE | WE | WE | NE | NE |
| | ¼ (20) | WE | WE | NE | NE | WE | WE | NE | NE | WE | WE | WE | WE | WE | WE | WE | WE |
| | ¾ (10) | WE | WE | NE | NE | WE | WE | NE | NE | WE | WE | NE | NE | WE | WE | NE | NE |
| | ¾ (20) | WE | WE | NE | NE | WE | WE | NE | NE | WE | WE | WE | WE | WE | WE | WE | WE |
| Haden | ¼ (10) | WE | WE | NE | NE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE |
| | ¼ (20) | WE | WE | NE | NE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE |
| | ¾ (10) | WE | WE | NE | NE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE |
| | ¾ (20) | WE | WE | NE | NE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE |
| Kent | ¼ (10) | WE | WE | WE | NE | WE | WE | WE | NE | WE | WE | WE | NE | WE | WE | WE | WE |
| | ¼ (20) | WE | WE | WE | NE | WE | WE | WE | WE | WE | WE | WE | NE | WE | WE | WE | WE |
| | ¾ (10) | WE | WE | WE | NE | WE | WE | WE | WE | WE | WE | WE | NE | WE | WE | WE | WE |
| | ¾ (20) | WE | WE | WE | NE | WE | WE | WE | WE | WE | WE | WE | NE | WE | WE | WE | WE |
| Keitt | ¼ (10) | WE | WE | NE | NE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE |
| | ¼ (20) | WE | WE | NE | NE | WE | WE | WE | NE | WE | WE | NE | NE | WE | WE | WE | WE |
| | ¾ (10) | WE | WE | NE | NE | WE | PE | PE | PE | WE | WE | NE | NE | WE | WE | WE | NE |
| | ¾ (20) | WE | WE | NE | NE | WE | WE | WE | NE | WE | WE | NE | NE | WE | NE | NE | NE |
| Ataulfo | ¼ (10) | WE | WE | WE | NE | WE | WE | WE | WE | WE | WE | WE | NE | WE | WE | WE | WE |
| | ¼ (20) | WE | WE | WE | NE | WE | WE | WE | WE | WE | WE | WE | NE | WE | WE | WE | WE |
| | ¾ (10) | WE | WE | WE | NE | WE | WE | WE | WE | WE | WE | WE | NE | WE | WE | WE | WE |
| | ¾ (20) | WE | WE | WE | NE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE |
| Manila | ¼ (10) | WE | WE | NE | NE | WE | WE | WE | WE | WE | WE | NE | NE | WE | WE | WE | WE |
| | ¼ (20) | WE | WE | NE | NE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE |
| | ¾ (10) | WE | WE | NE | NE | WE | WE | WE | WE | WE | WE | NE | NE | WE | WE | WE | WE |
| | ¾ (20) | WE | WE | NE | NE | WE | WE | WE | WE | WE | WE | WE | SE | WE | WE | WE | WE |

| Variety | Mat/Temp | Weight loss | | | | Solid soluble content | | | | Flesh Color | | | | Skin Color | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Dose --- | 0.0 | 0.15 | 0.60 | 1.00 | 0.0 | 0.15 | 0.60 | 1.00 | 0.0 | 0.15 | 0.60 | 1.00 | 0.0 | 0.15 | 0.60 | 1.00 |
| Tommy Atkins | ¼ (10) | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE |
| | ¼ (20) | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE |
| | ¾ (10) | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE |
| | ¾ (20) | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE |
| Haden | ¼ (10) | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE |
| | ¼ (20) | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE |
| | ¾ (10) | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE |
| | ¾ (20) | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE |
| Kent | ¼ (10) | WE | WE | WE | WE | WE | WE | WE | NE | WE | WE | NE | NE | WE | WE | WE | WE |
| | ¼ (20) | WE | WE | WE | NE | WE | WE | WE | NE | WE | WE | NE | NE | WE | WE | WE | WE |
| | ¾ (10) | WE | WE | WE | WE | WE | WE | WE | NE | WE | WE | WE | WE | WE | WE | WE | WE |
| | ¾ (20) | WE | WE | WE | WE | WE | WE | WE | NE | WE | WE | WE | WE | WE | WE | WE | WE |
| Keitt | ¼ (10) | WE | WE | WE | WE | WE | WE | WE | NE | WE | NE | NE | NE | WE | WE | WE | WE |
| | ¼ (20) | WE | NE | NE | NE | WE | WE | WE | WE | WE | WE | NE | NE | WE | WE | WE | WE |
| | ¾ (10) | WE | WE | WE | WE | WE | WE | WE | NE | WE | WE | WE | WE | WE | WE | WE | WE |
| | ¾ (20) | WE | NE | NE | NE | WE | WE | WE | NE | WE | WE | NE | NE | WE | WE | WE | WE |
| Ataulfo | ¼ (10) | WE | WE | WE | WE | WE | WE | WE | NE | WE | WE | WE | NE | WE | WE | WE | NE |
| | ¼ (20) | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE |
| | ¾ (10) | WE | WE | WE | NE | WE | WE | WE | NE | WE | WE | WE | NE | WE | WE | WE | NE |
| | ¾ (20) | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE |
| Manila | ¼ (10) | WE | WE | WE | WE | WE | WE | WE | NE | WE | WE | WE | NE | WE | WE | WE | NE |
| | ¼ (20) | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | EN | NE |
| | ¾ (10) | WE | WE | WE | NE | WE | WE | WE | NE | WE | WE | WE | NE | WE | WE | WE | NE |
| | ¾ (20) | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | WE | NE | NE |

WE, without effect; NE, Negative effect; PE, Positive effect