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INFLUENCE OF TEMPERATURE ON THE STORAGE QUALITY OF SOME LOCAL AVOCADO (*Persea americana* Mill) VARIETIES IN TAIWAN

S.Jeng-Jung
Professor of Department of Horticulture, National I-Lan University, Taiwan, R.O.C.

Avocado originated in Central America and southern Mexico. The United States, Chile, Mexico, South Africa, New Zealand, and Israel are major avocado-producing countries. Researches on avocado are very limited in Taiwan. The purpose of this research is to determine the effect of storage temperatures on the quality of the local produced avocados. Three varieties of avocado in Taiwan area were stored at 1℃, 3℃, 10℃, 17℃ and 20℃. Characteristics such as skin colour, flesh colour, firmness, chilling injuries, and rot during storage were studied. Changes in quality were also analyzed at ambient temperature after low temperature storage. Regarding 'Chanan' and 'Ching-Jin 2' avocados, they were fully ripened 3 days after harvest, and decay of the fruits started as of day 6 at ambient temperature storage. No chilling injury symptoms were observed during storage at 1℃ after 30 days; however, 3 days after fruits were moved to ambient temperature, serious chilling injuries occurred and ripening could not be completed. The optimum storage period for 'Chanan' avocado at 1℃ is 21 days and 14 days for 'Ching-Jin 2' avocado. 'CAES 3' showed poor storage ability at low temperature compared to the other varieties.

Key Words: avocado, variety, storage temperature, quality

INFLUENCIA DE LA TEMPERATURA EN LA CALIDAD DEL ALMACENAJE DE ALGUNAS VARIEDADES LOCALES DE AGUACATE (*Persea americana* Mill) EN TAIWÁN

S. Jeng-Jung
Professor of Department of Horticulture, National I-Lan University, Taiwan, R.O.C.

La palta tiene como origen América Central y el sur de México. Los Estados Unidos, Chile, México, Sudáfrica, Nueva Zelanda, e Israel son importantes países productores de palta a nivel mundial. Las investigaciones sobre la palta son muy limitadas en Taiwán. El propósito de esta investigación es determinar el efecto de las temperaturas de almacenamiento en la calidad de las paltas que se producen en Taiwán. Tres variedades de palta fueron almacenadas a 1° C, 3° C, 10° C, 17° C, y 20° C. Se estudiaron aspectos como el color de cáscara, color de pulpa, firmeza, daños por frío, y pudrición durante el almacenamiento. Los cambios en la calidad de las paltas también fueron analizados a temperatura ambiente después del almacenamiento a baja temperatura. En cuanto a la palta 'Chanan' y 'Ching-Jin 2', los frutos maduraron completamente 3 días después de la cosecha. La descomposición de los frutos comenzó a partir del día 6 de almacenamiento a temperatura ambiente. No se detecto ningún síntoma de daño por frío durante el almacenamiento a 1° C después de 30 días. Sin embargo, 3 días después que los frutos se llevaron a temperatura ambiente, se detectaron serios daños causados por el frío y la maduración no pudo completarse. El período óptimo de almacenamiento para

palta ‘Chanan’ a 1° C es de 21 días y 14 días para la palta ‘Ching-Jin 2’. La palta ‘CAES 3’ demostró una mala capacidad del almacenamiento a bajas temperaturas en comparación con otras variedades.

1. Introduction

Avocado is cultivated nearly 900 hectares in Taiwan, and annual production is about 9,000 tons. The main producing area is distributed in southern Taiwan, from Chayi county to Tainan county. In recent years, the
places, such as Kaohsjung county and Pingdong county also begin to cultivate sporadically. Based on the harvest season, avocadoes are divided into three groups, early-maturing, mid-maturing, and late-maturing, from June to February of next year in Taiwan. The early-maturing avocadoes are harvested from June to August, mid-maturing fruits are from August to October, and from December to early February is the season for late-maturing avocados. Avocado fruit is not able to be preserved long after harvest at room temperature. Fruits are naturally ripened at 25 usually in 5-10 days depended on variety. Hence, there is often a significant delay between harvesting and arrival of the fruit at the point of consumption, during which time fruit may ripen for overseas market. Fruits may also be stored during times of over production for domestic market. Generally speaking, the storage period of produce can be extended by the use of low temperature to reduce the rate of respiration (Wills, et al., 1989; Florissen, et al., 1996). However, chilling injury is induced during low temperature storage and resulted in a tremendous quality loss of stored avocados (Eaks, 1976; Zauberman et al., 1977). The symptoms of chilling injury in avocado are typically manifested as mesocarp discoloration, hardening of vascular strands and off flavors (Woolf and Laing, 1996; Woolf, 1997, Zauberman et al., 1997).

2. Material and methods

2.1. Materials

Three avocado varieties, ‘Chanan’, ’CAES 3’ and ‘Ching-Jin 2’, were selected for this experiment. Avocado fruits were harvested from the orchard of local farmer in Cha-I county, Taiwan. Sufficient fruits were hand-picked from the trees treated by the same agricultural practices. Fruits were packed in carton boxes and transferred to laboratory within 24 hours. Fruits were graded for size by weight. Free from damage and sunburn avocados were randomized for further analysis.

2.2. Methods

2.2.1. Low temperature storage

Avocado fruits were harvested on the mid of August in 2005 and 2006. Fruits were packed in carton boxes and promptly cooled and air stored at
1℃ 3 °C 10 °C 17 °C and 20℃ without ethylene and monitored every 3 days in a period of 30 days. Observation was stopped if the serious decay was found during storage. After treatment the fruits were allowed to ripen at 21℃.

2.2.2. Quality analysis

For all experiments, quality analysis was based on 3 replicates of 3 fruits. Quality parameters including color of skin, color of flesh, and hardness of flesh, symptoms of chilling injury and decay of the fruits were assessed objectively.

2.2.2.1. Measurement of Color

Skin color of the fruits were measured using a color differential meter (ZE-2000 Nippon Denshoku Japan) to determined Hunter Lab's L value (lightness or brightness), a value (redness or greenness), and b value (yellowness or blueness) by averaging four measurements taken around the fruit equator. Color of flesh was determined on the surface of flesh, 0.5 cm beneath the skin. Measurements were taken for three samples and the average of L, a, and b values were obtained. The colorimeter was warmed up for 30 min and calibrated with a white standard tile: L=95.87, a=-0.86 and b=2.47.

2.2.2.2. Measurement of Hardness

Texture measurements were made using a texture analyzer (TA-XT2 Texture analyzer Stable Micro Systems(SMS) England). Samples were subjected to a puncture test at a constant speed of 2mm/sec, using a 5mm diameter round tipped puncture probe. Four measurements were taken on each fruit at different location, 0.5 cm beneath the skin, around the fruit equator. Measurements were taken for three samples and the average values were obtained.

2.2.2.3. Assessment of chilling injury

The degree of ripening of each fruit was determined using a subjective assessment of softness determined by hand (Florissen et al., 1996). Once ripe, the fruit was checked the appearance first, then cut in half longitudinally and examined for symptoms of chilling injury. Chilling injury was rated on a relative scale of 4 stages, where stage0 is for no occurrence; stage1, <25%; stage2, 25-50%; stage3, >50% of the fruit surface.

2.2.5. Statistical analysis

One way analysis of variance (ANOVA) was used in order to detect significant differences among avocado samples with different treatments. The significant level used was p~0.05. Duncan's multiple range tests were conducted to compare the mean values in different storage days. Statistical analysis was carried out using SAS software (SAS Institute, Cary, NC, USA).

3. Results and discussion

3.1. Low temperature storage

3.1.1. 'Chanan'

Fruits were fully softened only 3 days at 20
similar hardness was obtained from the samples stored at 17 for 6 days. Under 10condition, fruits spent 9 days to reach fully ripening. Eighteen days was required for fruits to become fully ripening when storage temperature was
3stage1 After 30 days
the same as of fruits before storage (Fig.1). From Fig.2, it can be found that
that 1 u r e s for and keeping 3 are color better of skin tha
during low temperature storage. Similar Hunter labs L, a, and b value were obtained from fruits stored at 1
fruits before storage. The changes of flesh color were much complicated. L value decreased at the beginning of storage, then back to almost the same as it before storage, and kept the value until the end of storage at 3
decay of fruits was found 3 days after storage at 20
days at 1 0 . pom were found No decay for the and fruits h
stored at 3 and 1 i o d of storage. during the w

3.1.2. Ching-Jin 2

The change of hardness for Ching-Jin 2variety was very similar to that of Chananvariety. Fruits were fully softened only 3 days at 20 storage temperature. A similar hardness was obtained from the samples stored at 1 7 for 6 days. Under 10 ripening. Eighteen days was required for fruits to become fully ripening when storage temperature was 3 . A avocado fruits was almost the same as of fruits before storage (Fig.4). The color of skin was no different from fruits storage day 0 and day 30 at 3 by comparison of L, a, and b value. Fruits stored at 1 the color of flesh during the whole storage. Stage 1 chilling injury was found in the internal of fruits stored at 3 symptom were found for the fruits stored at 1 storage.

3.1.3.CAES 3

Under 20, 17, and 1 0 units were not able to be co inhibited. Fruits were fully softened between 6 and 9 days. No texture change was found for fruits stored at 1 and 3 maintained as similar to the samples before storage at 3 of flesh was found a better maintaining effect at 1 browning was found in fruits at both storage temperatures on day 18th. Chilling injury became much serious as the increase of storage time. For the fruits stored at 1 , samples stored stage 2 for 18 ching days. inj

3.2. Quality changes of 1 st to 3.2.1. 'Chanan'

Fruits were stored at 1 for ripening characteristics of avocado fruits. Three fruits were moved out the 1 cold room every week and loaded at 21 changes including decay and skin color were observed. Color of flesh, hardness of flesh, and chilling injury symptoms were analyzed. Fully softening was found for samples stored for 7 and 14 days (Fig.10). No matter the appearance or the internal characteristics both reached the quality level as same as of fruits without storage (Fig. 11 and 12). Serious chilling injury symptom (stage2) was found in fruits stored 21 days during ripening even they were under good condition at the moment removed from 1 injury was found in fruits stored for 28 days during ripening. Fruits were not able to fully soften and small brown spots found on the skin.

3.2.2. 'Ching-Jin 2'

Fully softening was found for samples stored for 7 days (Fig.10). No matter the appearance or the internal characteristics both reached the quality level as same as of fruits without storage (Fig. 11 and 12). Stage1 chilling injury was found in some of the fruits stored 14 days. For those samples, fully ripening can be obtained also. Serious chilling injury symptom (stage2) was found in fruits stored 21 days during ripening even they were under good condition at the moment removed from 1 . Stage 3 chilling injury was found in fruits stored for 28 days during ripening. Fruits were not able to fully soften and

small brown spots found on the skin.

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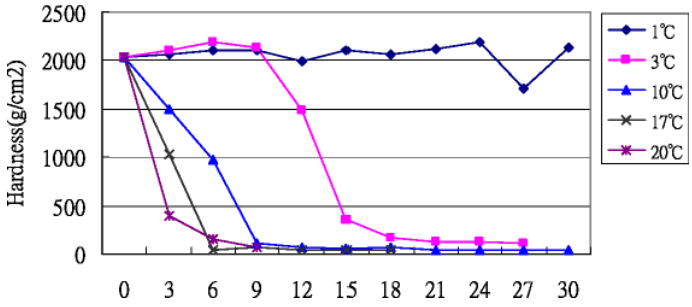
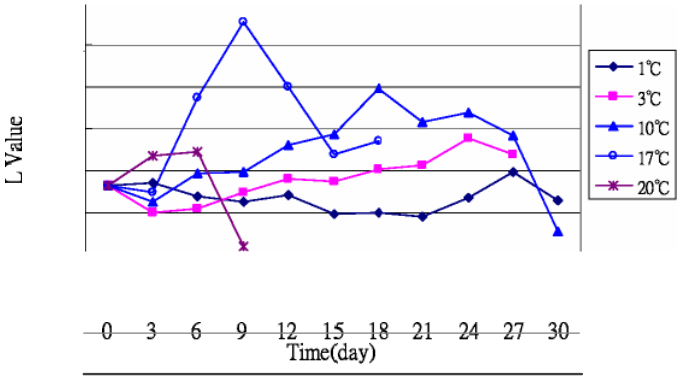


Fig.1. Changes of hardness of ‘Chanan’ avocado fruit under different storage temperatures
Fig.1. Cambios de la dureza del ‘Chanan’ aguacate del ` bajo diversas temperaturas del almacenaje



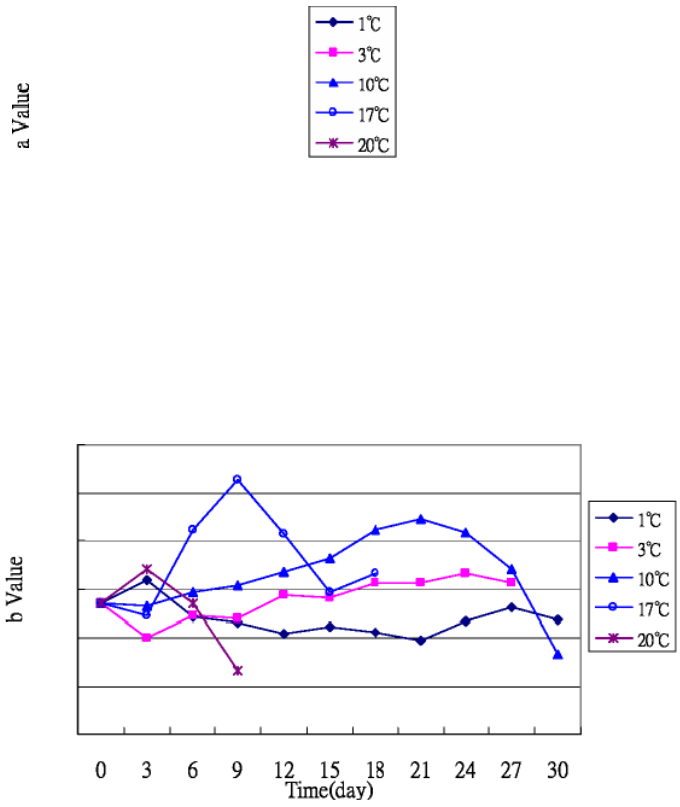
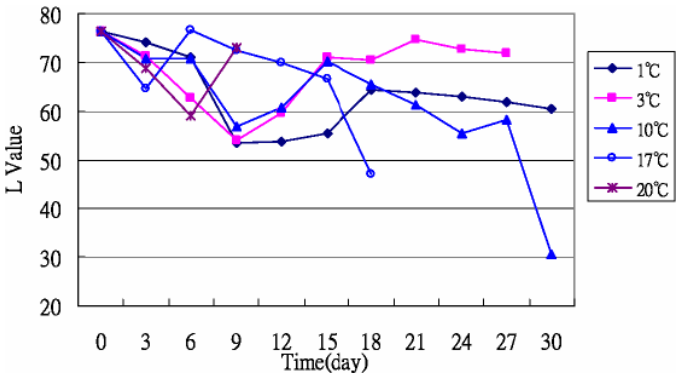


Fig.2. Changes of skin color of ‘Chanan’ avocado fruit under different storage
Fig.2. Cambios del color de la piel del ‘Chanan’ aguacate bajo diverso almacenaje



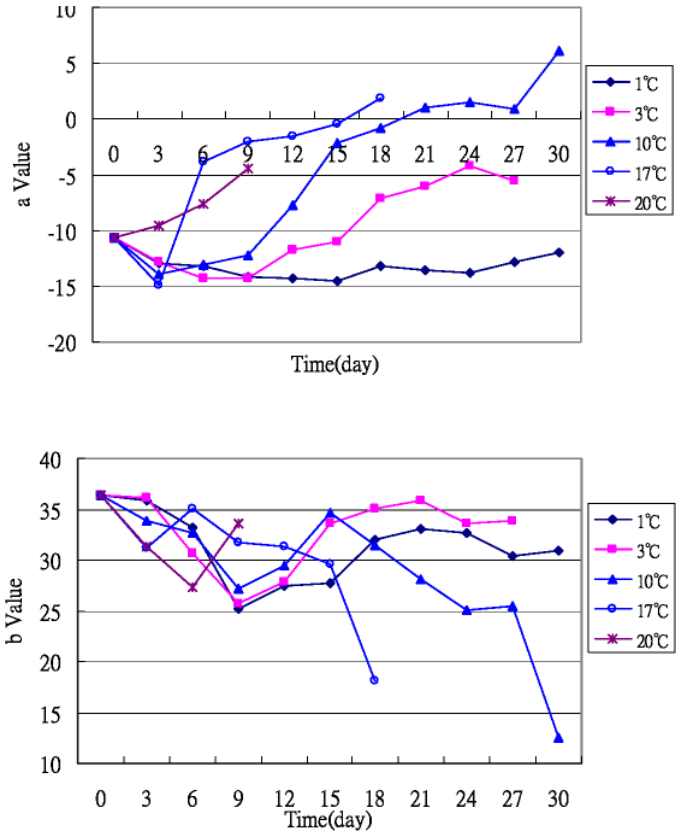


Fig.3. Changes of flesh color of ‘Chanan’ avocado fruit under different storage temperatures
Fig.3. Cambios del color de la carne del ‘Chanan’ aguacate bajo diversas temperaturas del almacenaje

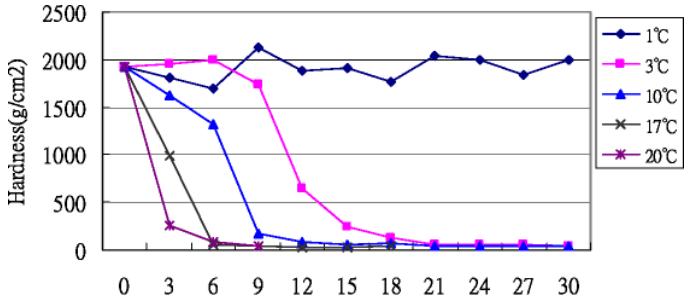


Fig.4. Changes of hardness of ‘Ching-Jin 2’ avocado fruit under different storage temperatures
Fig.4. Cambios de la dureza del ‘Ching-Jin 2’ aguacate bajo diversas temperaturas del almacenaje

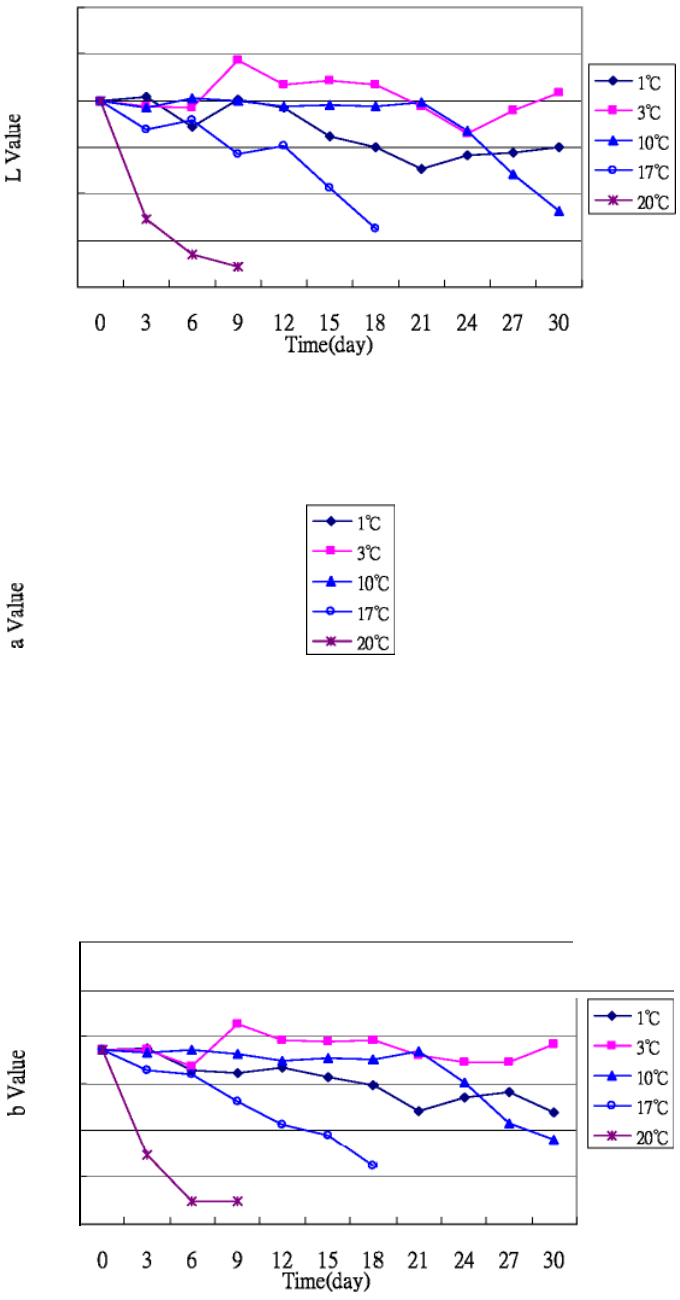


Fig.5. Changes of skin color of ‘Ching-Jin 2’ avocado fruit under different storage temperatures

Fig.5. Cambios del color de la piel del ‘Ching-Jin 2’ aguacate bajo diverso almacenaje

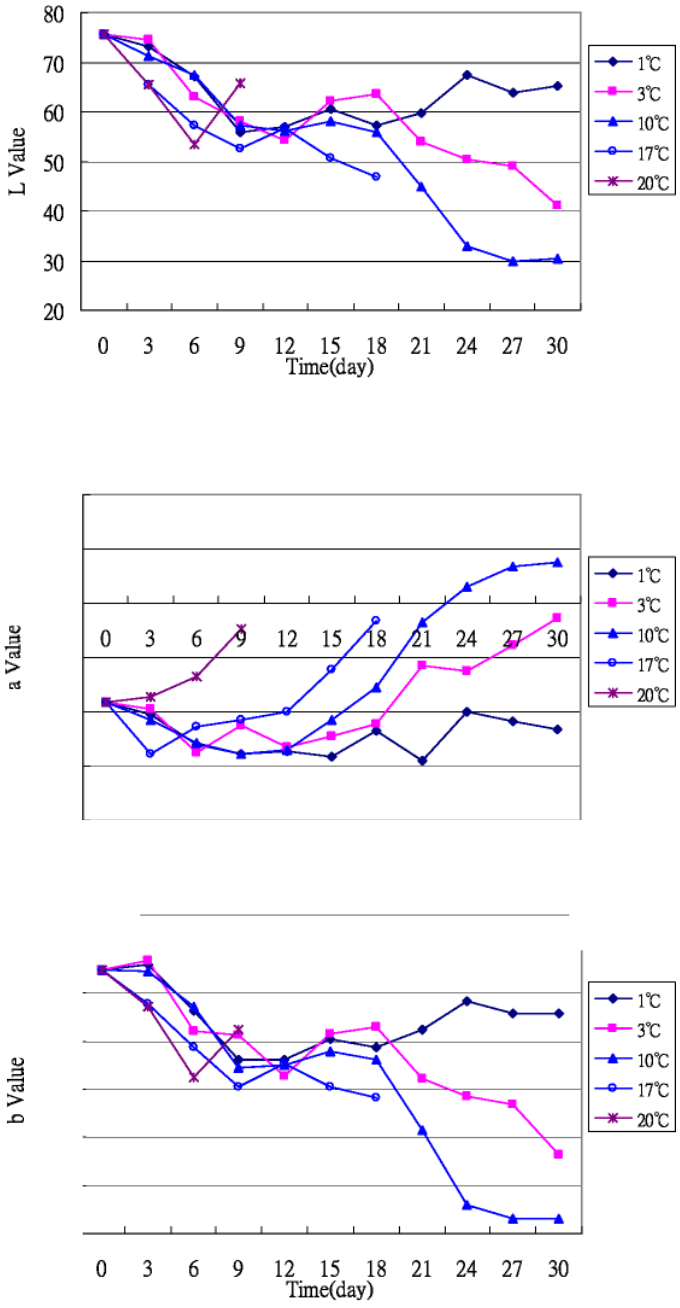


Fig.6 Changes of flesh color of ‘Ching-Jin 2’ avocado fruit under different storage temperatures

Fig.6. Cambios del color de la carne del ‘Ching-Jin 2’ aguacate bajo diversas temperaturas del almacenaje

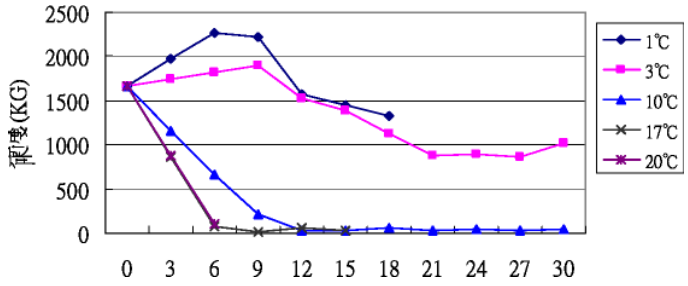
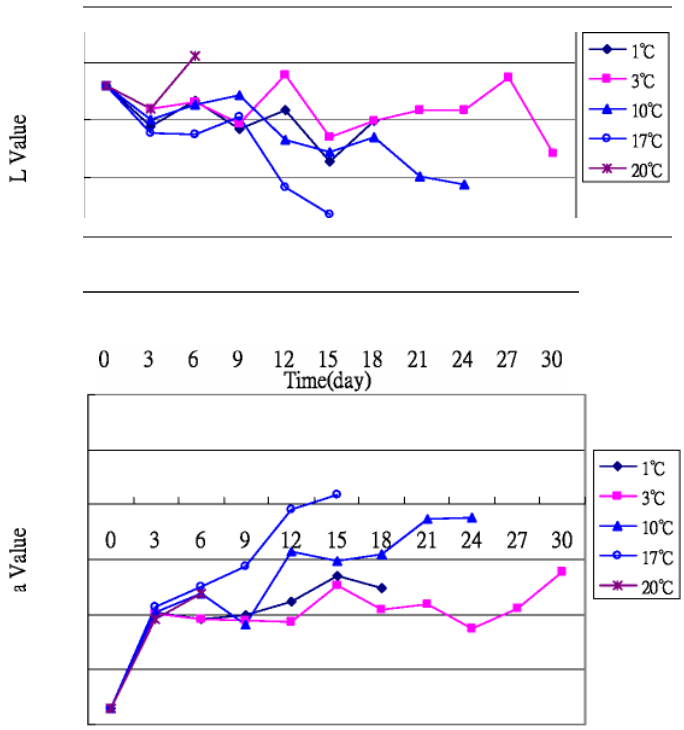


Fig.7 Changes of hardness of 'CAES 3'avocado fruit under different storage temperatures
Fig.7. Cambios de la dureza del 'CAES3' aguacate bajo diversas temperaturas del almacenaje



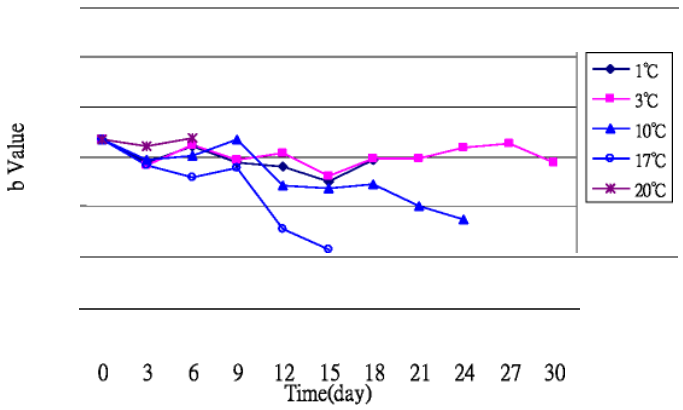
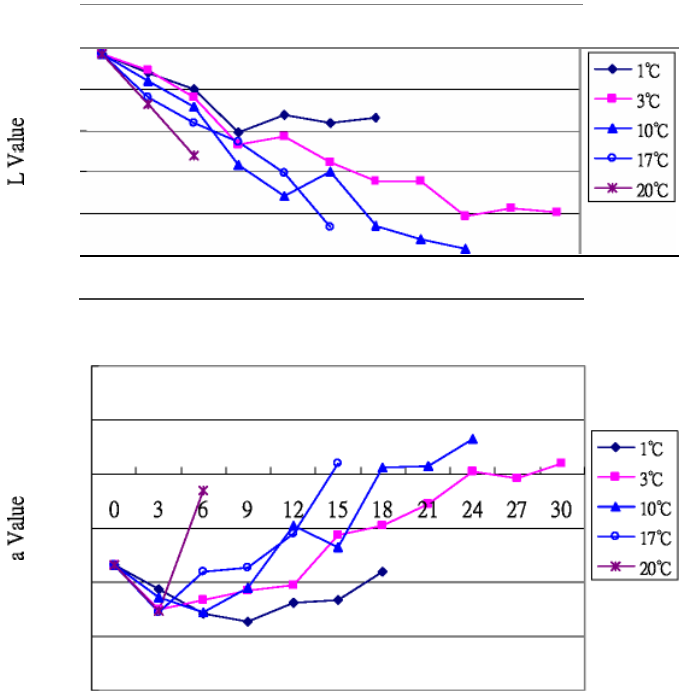
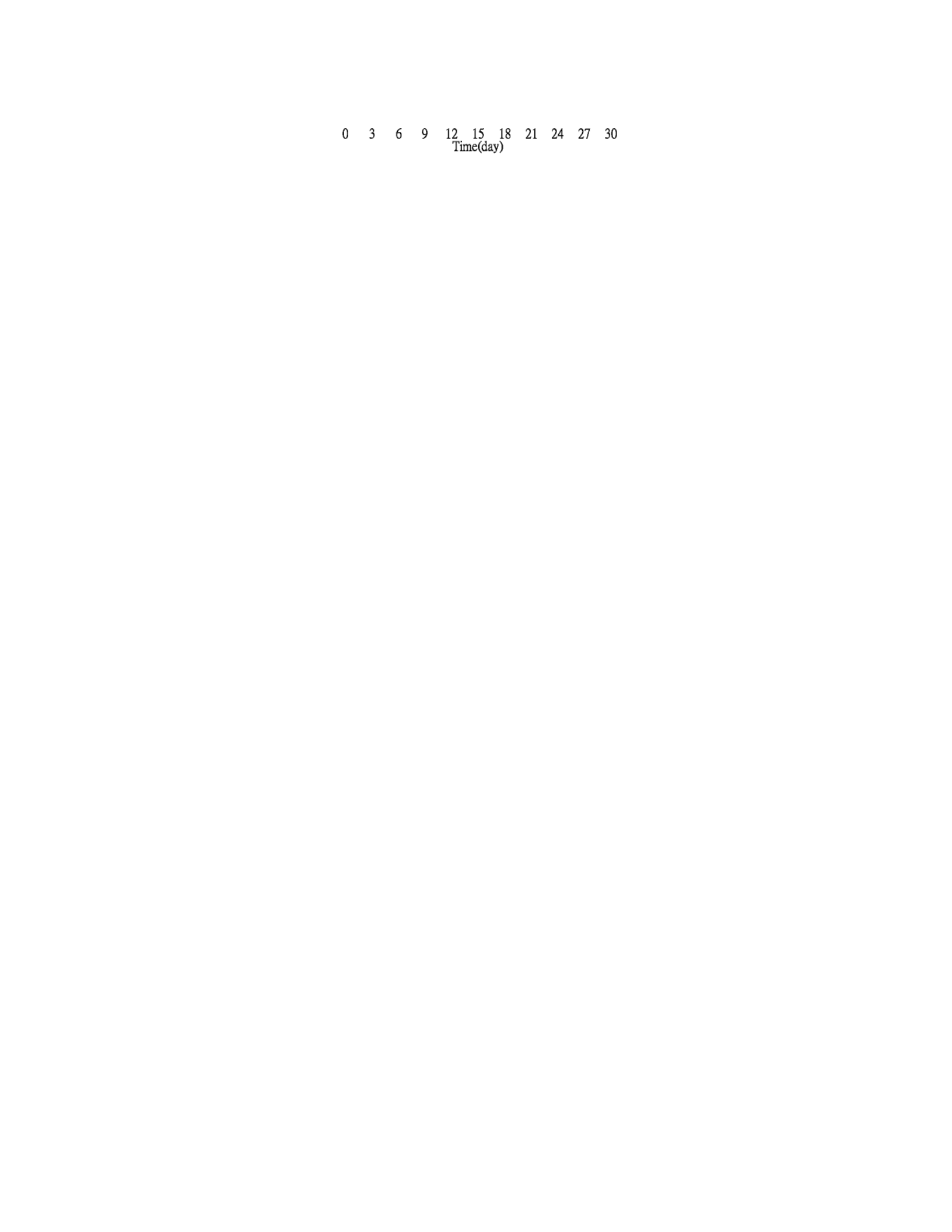


Fig.8 Changes of skin color of 'CAES 3' avocado fruit under different storage temperatures
Fig.8. Cambios del color de la piel del 'CAES 3' aguacate bajo diverso almacenaje

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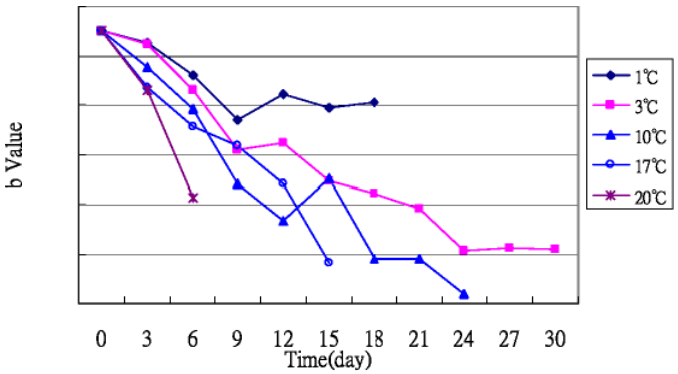
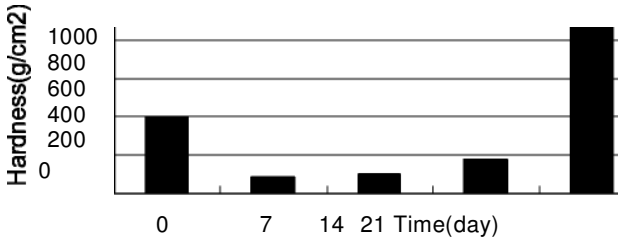


Fig.9 Changes of flesh color of ‘CAES 3’ avocado fruit under different storage temperatures

Fig.9. Cambios del color de la carne del ‘CAES 3’ aguacate bajo diversas temperaturas del almacenaje 'Chanan'



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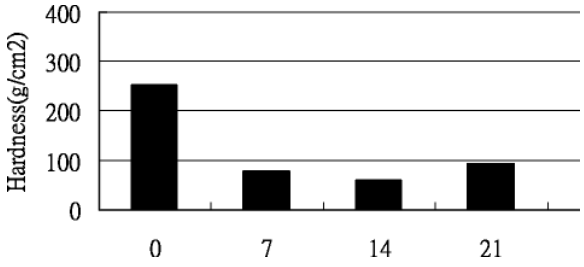
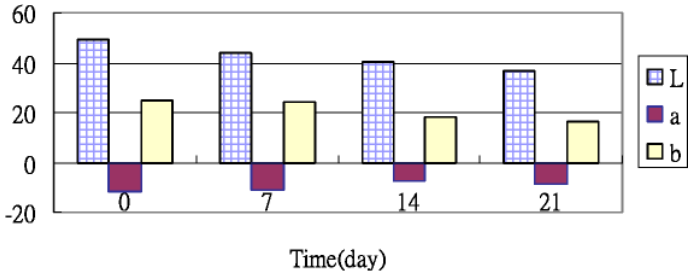


Fig.10. Influence of storage time at 1 ripening

Fig.10. Influencia del tiempo de almacenaje en 1
durante la maduración



'Ching-Jin 2'

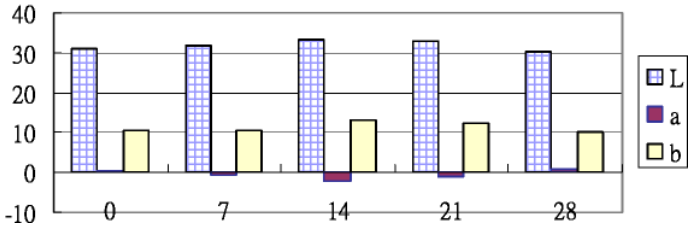


Fig.11. Influence of storage time at 1
ripening

Fig.11. Influencia del tiempo de almacenaje en 1
aguacate durante la maduración

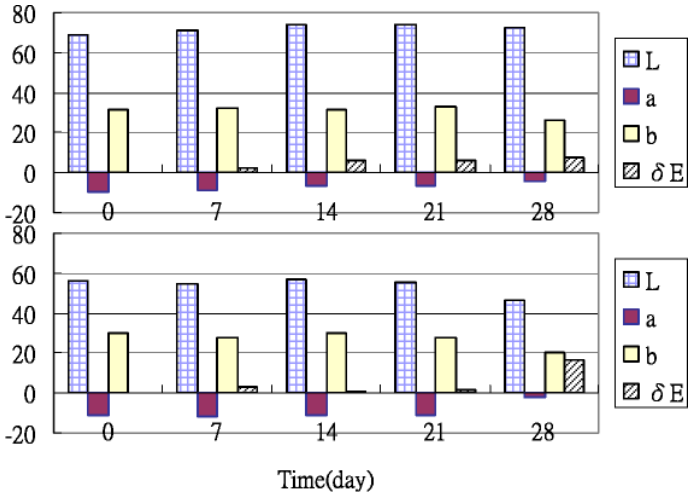


Fig.12. Influence of storage time at 1
ripening
Fig.12. Influencia del tiempo de almacenaje en 1
aguacate durante la maduración