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RESEARCH ARTICLE

ANALYSIS OF MAIN QUALITY CHARACTERISTICS OF PERSIMMON (*DIOSPYROS KAKI* L.) FRUITS.

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Abstract

Persimmon (*Diospyros kaki* L.) is an important commercial and deciduous fruit tree with lots of cultivars. It is grown in various countries and is increasingly appreciated for its nutritional value, health benefits and rich flavor. In this research, persimmon fruits were used as plant materials to evaluate the main fruit quality characteristics of 34 different cultivars and to study the effect of ethylene and salicylic acid (SA) in main quality characteristic of two persimmon cultivars, namely 'Xiaofangshi' and 'Naiyoushi', during different ripening stages. The average weight of fruit of non-astringent persimmon cultivars was heavier compared to astringent persimmon, while the differences in fruit shapes index among all the astringent persimmon cultivars was larger than that of non-astringent persimmon cultivars. Moreover, the average total soluble solids of the astringent persimmon cultivars was higher than that of the non-astringent persimmons, while titratable acidity was basically consistent in both non-astringent and astringent persimmon cultivars. On the other hand, results showed that there were no significant differences in main fruit quality including fruit weight, diameter and fruit shape index in two different cultivars during different ripening stages. While, both fruit firmness and total soluble solids showed significant differences in both two cultivars, results revealed that fruit treated with ethylene had the lowest firmness and the highest total soluble solids followed by control fruits, while fruit treated with SA had the highest firmness and the lowest total soluble solids. A comparison of fruit color between different persimmon cultivars showed that both the pulp and the peel of astringent persimmon had deeper orange red color compared to non-astringent cultivar. Moreover, hue angle (H°) of both 'Xiaofangshi' and 'Naiyoushi' was higher at harvest then decreased in different treatment during different ripening stages reflected the development in the color of fruit to deep orange.

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Introduction:-

Persimmon (*Diospyros kaki* L.) is a deciduous tree of the Ebenaceae family, it has been widely cultivated in East Asia. The fruits of *Diospyros kaki* are classified into astringent and non-astringent persimmon cultivars according to the presence of astringency in the fruits at harvest [1]. China, with its vast cultivable land and suitable climatic conditions is best suited for persimmon culture. Quality of persimmon is vital for consumer's acceptance and their increased consumption. The quality is determined by parameters like flavor, color, total soluble solids, titratable acidity, sugar/acid ratio, storability and nutritional value as reflected by minerals, vitamin C and sugar content. Fruit quality is the ultimate result of fruit setting, growth, development and maturation [2-5]. Therefore, this research was carried out to evaluate the main quality characteristic in different persimmon cultivars and to study the effect of ethylene and salicylic acid in main quality characteristic of two persimmon cultivars namely; 'Xiaofangshi' and 'Naiyoushi' during different ripening stage.

Materials and methods:-

Experiments were conducted in College of Horticulture and Plant Protection, Yangzhou University, Yangzhou, China during 2014-2016.

1. Plant materials and sampling

Persimmon fruit of 34 different cultivars were used in this research, including 8 non-astringent cultivars (namely *Diospyros kaki* cv. 'Chansiwanshi', 'Fuyoutianshi', 'Meiguohaikumanshi', 'Ribencilangshi', 'Ribenhuijinshenbuzhishi', 'Ribenruoshanxicilangshi', 'Ribenyangfengshi' and 'Shangxizaoshengshi') (Fig. 1) and 26 astringent cultivars (namely *Diospyros kaki* cv. 'Cangshantuoshi', 'Baoshandashuishi', 'Cexiangshuishi', 'Changanfojiandingshi', 'Changanquzhengshi', 'Gongchengyueshi', 'Gutianyadanshi', 'Haijiaxiaofangshi', 'Haiyangdabianshi', 'Hezebayuehuangshi', 'Jishanmimiguanshi', 'Jingchuanbiantatashi', 'Longhuiruanzaoshi', 'Mopanshi', 'Nanzhangchutoushi', 'Qidongshutouhongshi', 'Qiubeishuishi', 'Qujingniunaishi', 'Shengxianhuangtanshi', 'Xiangyangniuxinshi', 'Xingyangdayeshuishi', 'Xiuningbianshi', 'Yangshuoniuxinshi', 'Yongjibaishi', 'Yunyangdahuoguanshi' and 'Zhouqumomoshi') (Fig. 2). The fruits samples were harvested during ripening stage, in October 23, 2015 from National Germplasm Nursery of Persimmon (Yangling, Shaanxi, China).



Fig. 1:- Photo of fruits of different non-astringent persimmon cultivars

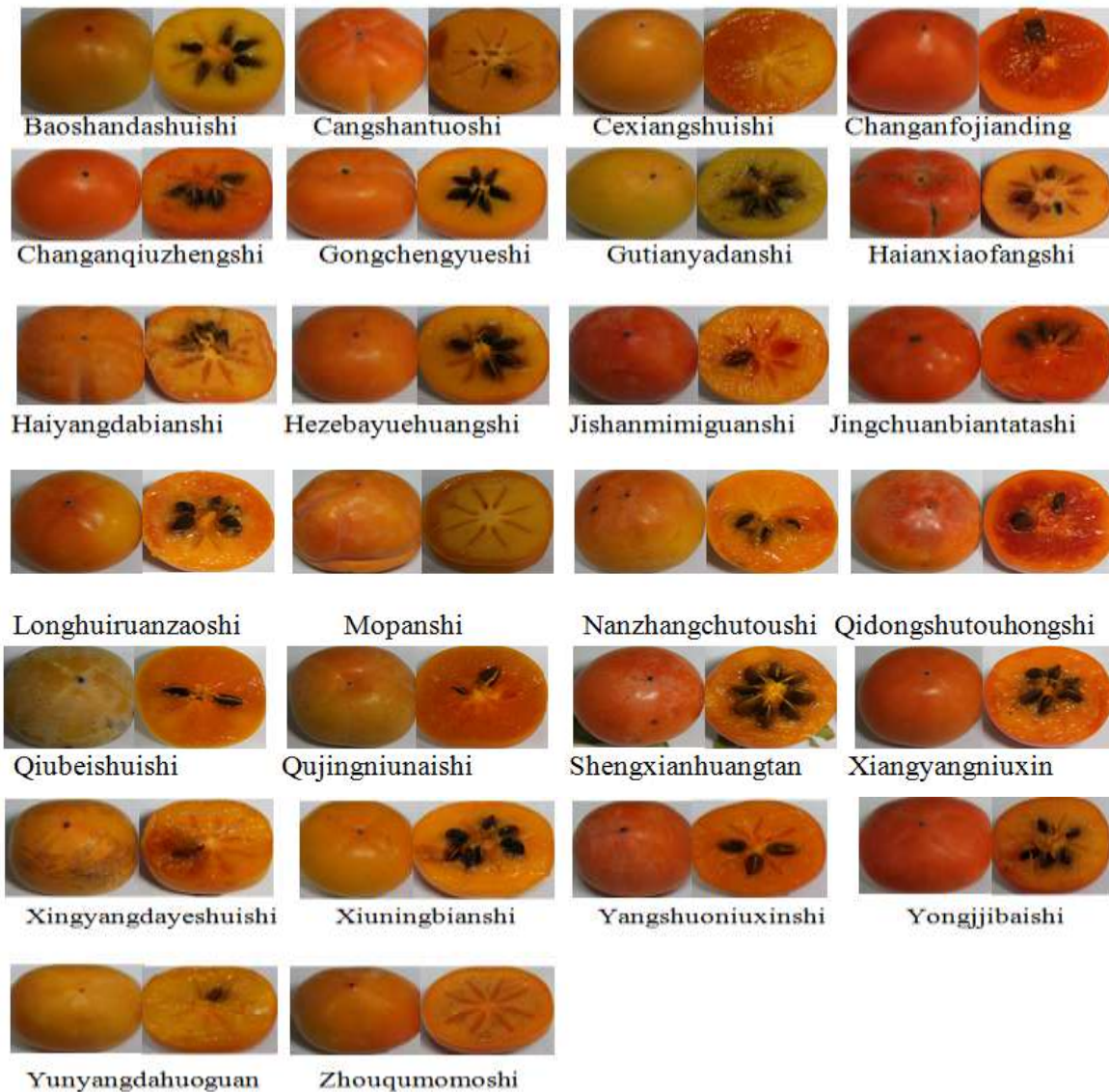


Fig. 2:- Photo of fruits of different astringent persimmon cultivars.

Moreover, the fruits of two cultivars namely ‘Xiaofangshi’ and ‘Naiyoushi’ was obtained from the orchard of Xinjie, Dongtai, Yancheng City, Jiangsu Province, China, the fruits were harvested after the first signs of chlorophyll breakdown at September 26 and October 13, 2014, respectively. After transportation to the laboratory, unblemished fruits were selected for some main fruit quality indices measurement including size, shape and color. The fruits of ‘Xiaofangshi’ and ‘Naiyoushi’ were randomly divided into three lots: one lot was treated with ultra pure water (control fruit), the second lot was treated with ethylene, the fruits were dipped in 25L of an aqueous solution of 2 g L⁻¹ Ethrel 48 SL (Bayer Crop Science S.A.; ethephon, 2-chloroethyl phosphonic acid) and the last one was treated with 0.3 µl L⁻¹ salicylic acid both on the same day of harvest for 30 minutes. After each treatment, the fruits processed for ventilation till dry then each fruit was packed in 0.02 mm thick polyethylene bags and allowed to ripen at 20 °C. Fruits were collected at different ripening stage with an interval of about 3 days.

Ten intact fruits were selected to determine the main quality indices of different cultivars of persimmon fruits and during different ripening stages.

2. Assessment of physical and chemical characteristics

Determination of fruit weight: Fruit weight was determined using a top loading balance (Gandg Testing Instrument Factory, China).

Determination of fruit diameters: The vertical (length) and horizontal (width) diameters were measured by micrometer scale (Taizhou Xinshangliang Measuring Tools Co., Ltd., China).

Determination of fruit shape index: The fruit shape index is the ratio of the vertical and horizontal diameters.

Determination of seed number: Number of seeds was counted in each fruit of different cultivars.

Determination of fruit firmness: Firmness was measured using the Firm Tech II (BioWorks Inc., USA) provided with a flat tip of 2 cm. Two measurements on each equatorial side were performed on each fruit. The mean of each replicate was recorded and expressed as newtons (N) \pm standard error (SE).

Determination of total soluble solid (TSS): TSS was determined by a portable refractometer (Chengdu Optical Instrument Factory, China) and the measurements were performed on the opposite sides of the equatorial plane on each fruit.

Determination of titratable acidity (TA): TA was determined according to the titration method [6] as follows: 5 g of the pulp was grinded to homogenate with 5 ml distilled water. Subsequently, after filtration and centrifugation for 10 min at 10,000 rpm/m, 3 ml of the supernatant was titrated against fresh 0.02M NaOH to phenolphthaleine end point (pale permanent pink colour, pH 8.2). Each sample was repeated three times and calculated as follow: TA content % = $C \times V_2 \times M \times 10 / m \times V_1$, Where: C means concentration of NaOH, V_2 means ml of NaOH used, M means Molecular weight of NaOH, m means sample weight and V_1 means ml of juice.

3. Assessment of fruit color

The color of the opposite sides of the equatorial plane on each fruit were evaluated using a TC-P2A chroma meter (Beijing Optical Instrument Factory, China) using three color parameters including L^* (lightness or darkness), a^* (green or red) and b^* (blue or yellow) values. These values were converted to hue angle degree ($H^\circ = \arctangent(b^*/a^*)$) and chroma values ($C^* = (a^{*2} + b^{*2})^{1/2}$) according to the methods reported previously [7, 8].

4. Statistical Analysis

Fruit weight, diameter, shape index, TSS, TA and fruit color were the mean value of ten fruits. All the other data were means of three replicates with standard error. Microsoft Excel (Microcal Software Inc., Northampton, MA, USA) was used to calculate standard error. Figures were drawn by Graphpadprism (SanDiego, CA, USA, version 7).

Results:-

1. Physical and chemical characteristics of persimmon fruits

1.1 Physical and chemical characteristics of different persimmon cultivars

The fruit weight, size, shape, TSS and titratable acidity varied due to different persimmon cultivars, no matter whether astringent or non-astringent (Table S1). Results showed that, ‘Mopianshi’ had the largest fruit weight of 271.08 g and ‘Gutianyadanshi’ had the smallest fruit weight of 39.94 g. While fruit shape index varied between 1.16 to 0.63 in ‘Cexiangshuishi’ and ‘Jingchuanbiantatashi’, respectively. Firmness varied between 15.28N to 2.34N in ‘Ribencilangshi’ and ‘Cangshantuoshi’, respectively. ‘Shengxianhuangtanshi’ contain the highest number of seed, while, ‘mopianshi’, ‘Yunyangdahuoguanshi’ and ‘Zhouqumomoshi’ contain only one seed. On the other hand, TSS reached the highest value of 21.17 in ‘Xingyangdayeshuishi’ and the lowest value of 11.32 in ‘Shangxizaoshengshi’. Moreover, results of titratable acidity showed that the values varied from 0.72 in ‘Gongchengyueshi’ to 0.11 in ‘Haiyangdabianshi’ and ‘Longhuiruanzaoshi’. Generally, the average weight of fruit of non-astringent persimmon cultivars was heavier compared to astringent persimmon, while the differences in fruit shapes index among all the astringent persimmon cultivars was larger than that of non-astringent persimmon cultivars. Moreover, the average TSS of the astringent persimmon cultivars was higher than that of the non-astringent persimmons, while, TA was basically consistent in both non-astringent and astringent persimmon cultivars (Fig. 3).

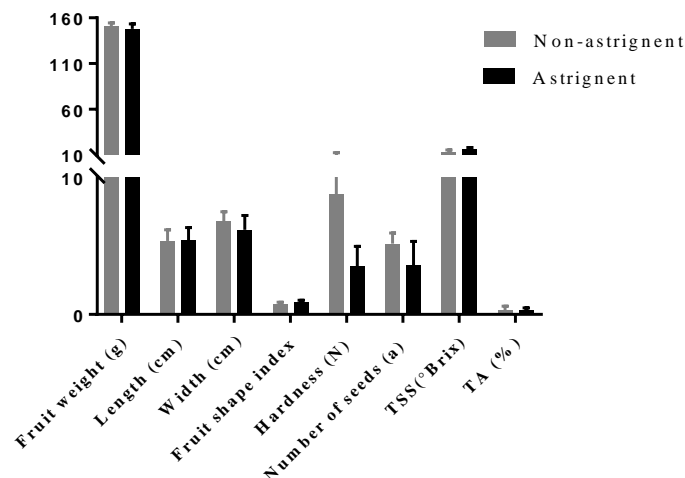


Fig. 3:- Basic fruit quality indices of non- astringent and astringent persimmon (*Diospyros kaki* L.).

1.2 Effect of Ethylene and Salicylic Acid in Physical and Chemical Characteristics of Two Persimmon Cultivars during Different Ripening Stages

There were no significant differences in fruit weight, length width and fruit shape index in different treatment in both two cultivars. However, in ‘Xiaofangshi’ the mean value varied between 148.75-140.00, 48.61-41.06, 70.03-64.7 and 0.73-0.68, respectively. While, in ‘Naiyoushi’ the value varied between 191.86-180.03, 58.1-51.59, 70.98-73.69, 0.79-0.73, respectively (Fig. 4 to Fig. 7). Generally, ‘Naiyoushi’ had higher value compared to ‘Xiaofangshi’. On the other hand results showed significant differences in fruit firmness and total soluble solids in different treatment in both two cultivars (Fig. 8 & Fig. 9). Fruit firmness decreased during different ripening stages of

persimmon fruits, however, fruit treated with ethylene had the lowest firmness followed by control fruits, while, fruit treated with salicylic acid had the highest firmness. Total soluble solids progressively increased during different ripening stages of persimmon fruits, however, fruit treated with ethylene had the highest TSS followed by control fruits, while, fruit treated with salicylic acid had the lowest value. In ‘Xiaofangshi’ the highest TSS value were 13.36, 12.46, and 11.67, while, in ‘Naiyoushi’ the highest TSS value were 17.55, 16.13 and 15.48, respectively. Generally, ‘Naiyoushi’ had higher firmness and TSS compared to ‘Xiaofangshi’.

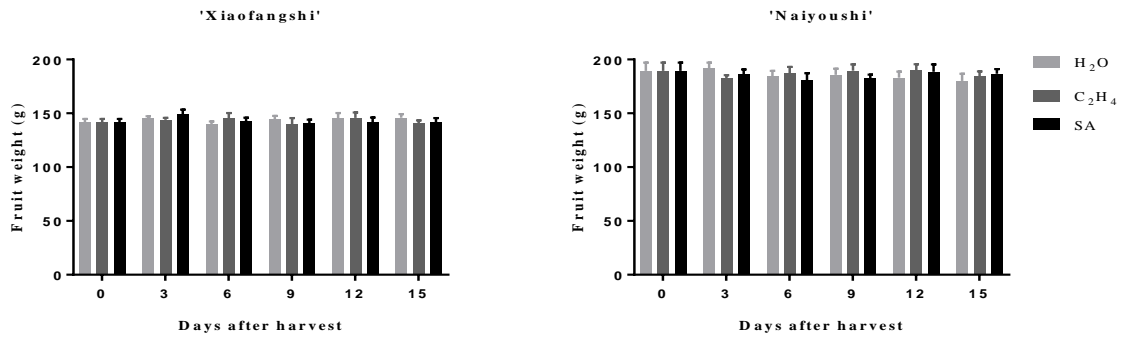


Fig. 4:- Effect of ethylene and salicylic acid on weight of persimmon (*Diospyros kaki* cv. ‘Xiaofangshi’ and ‘Naiyoushi’) fruits during different ripening stages.

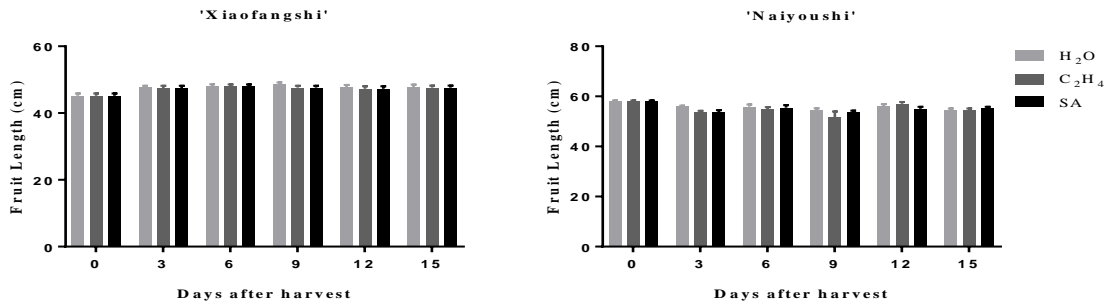


Fig. 5:- Effect of ethylene and salicylic acid on length of persimmon (*Diospyros kaki* cv. ‘Xiaofangshi’ and ‘Naiyoushi’) fruits during different ripening stages.

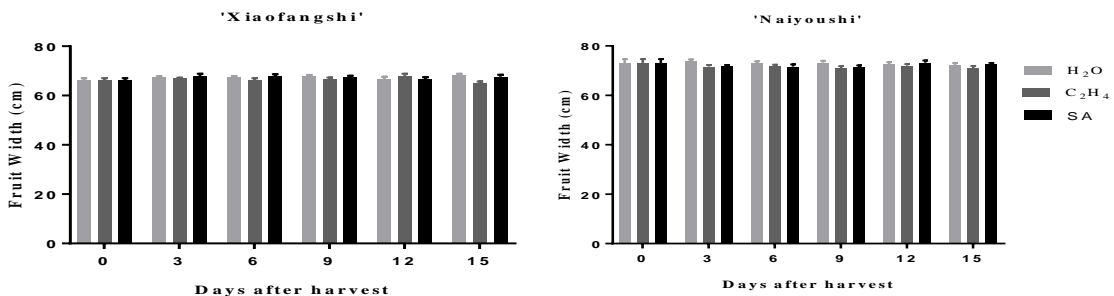


Fig. 6:- Effect of ethylene and salicylic acid on width of persimmon (*Diospyros kaki* cv. ‘Xiaofangshi’ and ‘Naiyoushi’) fruits during different ripening stages.

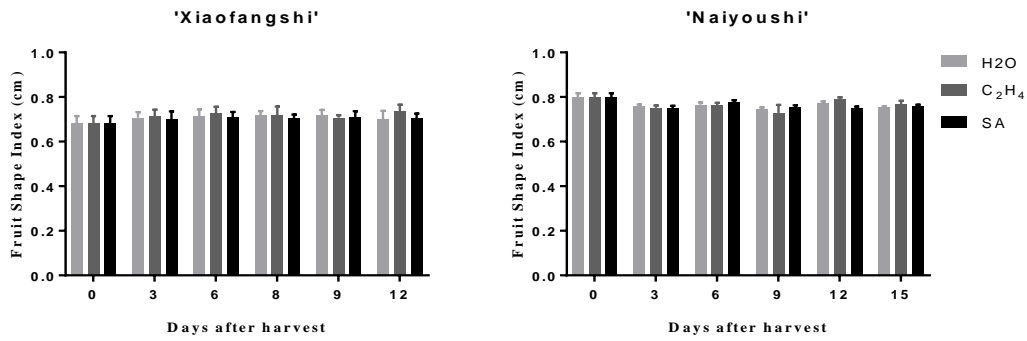


Fig. 7:- Effect of ethylene and salicylic acid on shape index of persimmon (*Diospyros kaki* cv. ‘Xiaofangshi’ and ‘Naiyoushi’) fruits during different ripening stages.

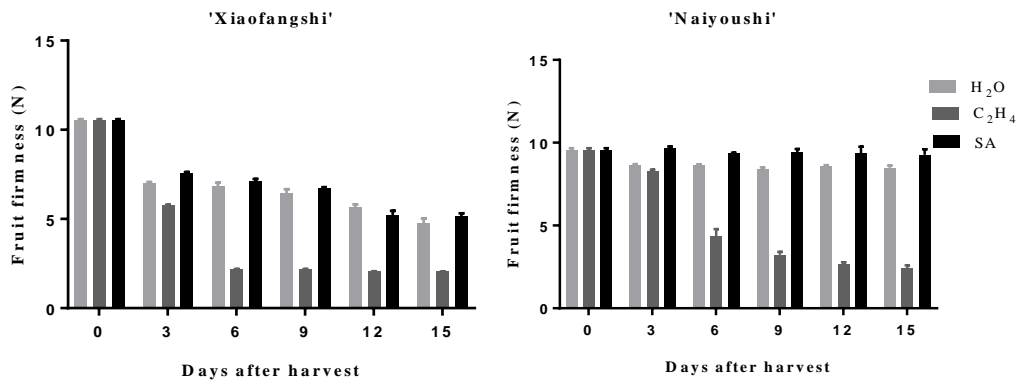


Fig. 8:- Effect of ethylene and salicylic acid on firmness of persimmon (*Diospyros kaki* cv. ‘Xiaofangshi’ and ‘Naiyoushi’) fruits during different ripening stages.

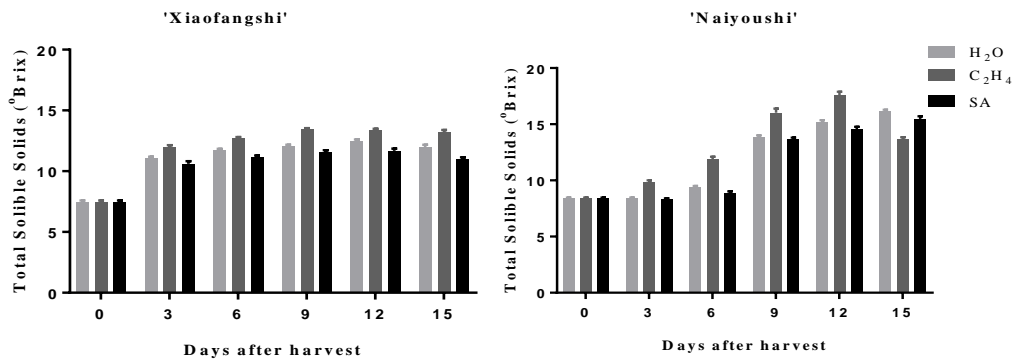


Fig. 9:- Effect of ethylene and salicylic acid on total soluble solids of persimmon (*Diospyros kaki* cv. ‘Xiaofangshi’ and ‘Naiyoushi’) fruits during different ripening stages.

2. Fruit color indices of persimmon fruits

2.1 Fruit color indices of different persimmon cultivars

The main color indices L^* , a^* and b^* had a positive value in both fruits pulp and peel of different persimmon cultivars (Table S2 & S3). However, in the pulp the highest value of L^* , a^* and b^* were 66.09, 12.19 and 29.52 in ‘Ribenuoshanxicilangshi’, ‘Yongjibaishi’ and ‘Ribenuoshanxicilangshi’, respectively, and the lowest value were 32.61, 1.76 and 14.68 in ‘Qujingniunaishi’, ‘Ribenyangfengshi’ and ‘Qiubeishuishi’, respectively. While in the peel the highest value of L^* , a^* and b^* were 64.00, 20.65 and 31.89 in ‘Ribenkuijinshenbuzhishi’, ‘Jingchuanbiantatashi’ and ‘Ribenkuijinshenbuzhishi’ and the lowest value were 44.84, 2.36 and 19.24 in ‘Shengxianhuangtanshi’, ‘Shangxizaoshengshi’ and ‘Shengxianhuangtanshi’, respectively. The mean color a^*/b^* , H° and C^* values of fruits of different persimmon cultivars were also described. In the pulp the values of a^*/b^* varied from 0.76 to 0.07 in ‘Shengxianhuangtanshi’ and ‘Ribenyangfengshi’, respectively. While, the value of H° varied from 179.12 in ‘Ribenyangfengshi’ to 1.19 in ‘Qidongshutouhongshi’, indicating that ‘Ribenyangfengshi’ tend more to green color while ‘Qidongshutouhongshi’ tend more to orange-red color. While the value of C^* varied from 29.84 in ‘Ribenuoshanxicilangshi’ to 16.60 in ‘Gongchengyueshi’. Generally, the pulp of astringent persimmon had deeper orange red color compared to non-astringent. On the other hand, results of the peel color showed that the values of a^*/b^* varied from 0.96 in ‘Shengxianhuangtanshi’ to 0.08 in ‘Shangxizaoshengshi’ and H° varied from 174.82 in ‘Shangxizaoshengshi’ to 5.17 in ‘Changanfujiandingshi’, indicating that ‘Shangxizaoshengshi’ tend more to green color while ‘Changanfujiandingshi’ tend more to orange-red color. While, the value of C^* varied from 33.40 in ‘Yunyangdahuoguanshi’ to 25.29 in ‘Gongchengyueshi’. Generally, the peel of astringent persimmon had deeper orange red color compared to non-astringent (Fig. 10).

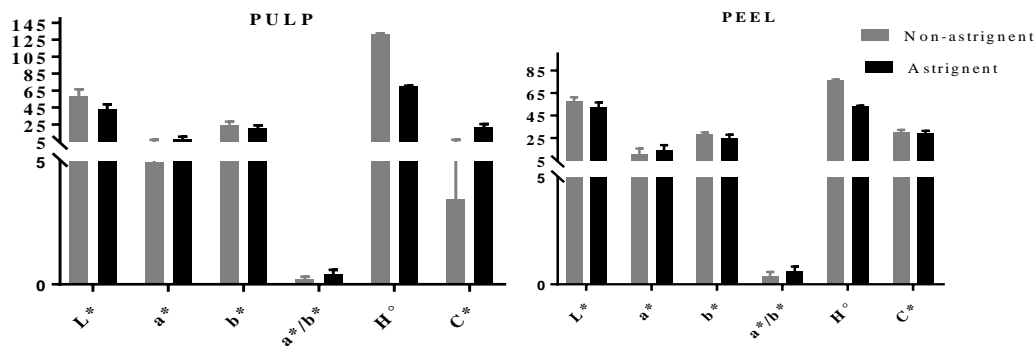


Fig. 10:- Basic color indices of non- astringent and astringent persimmon (*Diospyros kaki* L.) fruits.

2.2 Fruit colour indices of persimmon fruits during different ripening stages

In the pulp of ‘Xiaofangshi’ L^* value was directly decreased after harvest, however, fruits treated with ethylene had the lowest value followed by control fruits and fruits treated with salicylic acid. While L^* value was increased in the peel during different ripening stages. In both the pulp and the peel of the fruits a^* directly change to positive value after 3 days and b^* value trended similarly with L^* value. In addition, the color was well described by a^*/b^* ratio, results revealed that the ratio is negative at harvest and directly change to positive after 3 days in both the pulp and

the peel of the fruits. Alternatively, the color also could be depicted by H° which was higher at harvest then decreased in different treatment during different ripening stages. C^* also represented the lightness which trended similarly with L^* value. In 'Naiyoushi' L^* value was decreased in the pulp during different ripening stages, however, fruits treated with ethylene had the lowest value followed by control fruits, then fruits treated with salicylic acid. While in the peel L^* value was decreased in fruit treated with ethylene and slightly increased in control fruits and fruits treated with salicylic acids. In both the pulp and the peel of the fruits a^* had positive value and b^* value trended similarly with L^* value. a^*/b^* ratio was positive in both the pulp and the peel of the fruits. C^* was trended similarly with L^* value, and H° decreased in different treatment during different ripening stages with lowest value in fruit treated with ethylene (Table S4 & S5).

Discussion:-

Persimmon (*Diospyros kaki* L.) which could be divided into two types, namely, astringent persimmon and non-astringent persimmon, is widely cultivated in East Asia such as China, Korea and Japan [9, 10]. Persimmon is not only an important fruit, which is eaten as a fresh fruit, but also traditionally used for many medicinal purposes [11]. The physical and chemical characteristics of persimmon fruits are important in assessing fruit quality and identifying correlations between changes in these characteristics, making quality control easier. Various quality characteristics of persimmon cultivars including chemical composition, physical characteristics and volatile compounds have been previously studied [12-16].

In this research, results showed that the main fruit quality was varied among different persimmon cultivars. Generally, non-astringent persimmon cultivars had the highest average weight, while, astringent persimmon cultivars had the largest fruit shapes index and TSS. Moreover, results showed that there were no significant differences in main fruit quality including fruit weight, diameter and fruit shape index in two different cultivars during different ripening stages. Generally, 'Naiyoushi' had higher value compared to 'Xiaofangshi'. On the other hand, both fruit firmness and TSS showed significant differences in both two cultivars, result revealed that fruit treated with ethylene had the lowest firmness and the highest TSS followed by control fruits, while fruit treated with salicylic acid had the highest firmness and the lowest TSS. Generally, 'Naiyoushi' had higher firmness and TSS compared to 'Xiaofangshi'. Zhou *et al.*, [17] showed that the fruit size, shape, TSS and TA content varied due to different persimmon cultivars, no matter whether astringent or non-astringent. The average weight of individual fruit of the astringent persimmon cultivars was heavier than that of the non-astringent persimmon and the differences in fruit shapes among all the astringent persimmon cultivars was larger than that among the non-astringent persimmon cultivars. The average TSS content of the astringent persimmon cultivars was lower than that of the non-astringent persimmon, while, TA was on the reverse trend. However, the great differences of quality indexes among different cultivars might result from genetic and geographical origins. Flesh firmness at harvest is an important criterion to maintain quality during the postharvest period. Celik and Ercisli found the skin and flesh firmness of cv. Hachiya as 59.4 and 36.3 N, respectively [14]. The flesh firmness of persimmon cv. Harbiye decreased during fruit growth and reached 51-54 N in the third week of October [13]. On the other hand, ethylene plays important roles in the regulation of plant development and senescence [18] and profoundly affects the quality of harvested products [19]. It

has been widely accepted that ethylene plays an important role during the ripening of climacteric fruit, initiating and coordinating diverse processes such as color development, softening and aroma formation. Persimmon is a climacteric fruit that has a short shelf-life due to accelerated fruit softening. Ethylene plays a critical role in fruit softening of persimmon [20]. This softening process is accelerated after the removal of astringency, and significantly influences the acceptability of the fruit. As expected in previous studies, ethylene production in 'Pingxiangli' pear reached a peak on day 6 of the 12-day ripening period and then decreased. The ethylene production rate decreased on day 12. Similarly, fruit firmness decreased dramatically from 19.58 N at harvest to 3.24 N on day 6 and then remained the same for the rest of the ripening period [21]. On the other hand, application of salicylic acid is useful in inhibiting tissue softening in fruits by reducing cell wall hydrolases activities and maintaining cell membrane consistency [22]. In tomato fruit ascorbic acid content, total soluble solid, titratable acidity, firmness and L^* (lightness) retained by salicylic acid treatments [23]. Babalar *et al.* [24] reported that the use of salicylic acid decrease TSS of strawberry fruits and consequently, effectively delays fruit senescence process. Treatment of kiwifruits maintained a lower TSS content than the control fruits at the end of cold storage [25].

To analyze the development of fruit color, the color of the pulp and surface of the peel of persimmon fruits was measured with a colorimeter, which provided L^* , a^* and b^* values. These values were converted to H° and C^* , which quantify the intensity or purity of the hue [7]. In the uniform color space, L^* represented the lightness, a^* represented ratio of red/magenta and green and b^* represented ratio of yellow and blue. A comparison of fruit color between different persimmon cultivars showed that both the pulp and the peel of astringent persimmon had deeper orange red color compared to non-astringent. Moreover, H° was higher at harvest then decreased in different treatment during different ripening stages reflected the development in the color of fruit to deep orange. The color of persimmon fruit ranges from yellow, orange to deep red [9], which, mainly results from carotenoids accumulation [26]. Therefore, high carotenoids content, not only play an important role in biological property, but also are favored from the marketing perspective [27, 28]. A comparison of fruit color between "Niuxinshi" and "Nishimurawase"; representatives of astringent and non-astringent varieties showed that they had similar tendency, but only had differences in quantity. With the development of fruit, L^* value was constantly increased, but declined when fruit color deepened. a^* was negative value and constantly growth which showed that the fruit color changed from green to red. b^* value trended similarly with L^* value, which revealed that the fruit color was yellow and gradually deepening, and C^* also represented the lightness which trended similarly with L^* value. [29]. In addition, the color was well described by a^*/b^* ratio which was negative for green fruits, zero for yellow fruits, and positive for orange fruits [30]. Alternatively, the color also could be depicted by H° as follows: 0° for reddish-purple, 90° for yellow, 180° for bluish-green and 270° for blue [31, 32]. These two values all showed that the fruit color of both "Niuxinshi" and "Nishimurawase" changed from green to yellow, and "Nishimurawase" was more evident [29]. In 'Pingxiangli' pear hue angle decreased during fruit ripening. The change in hue angle reflected the change in the skin color of 'Pingxiangli' fruit from green to yellow-green [21].

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Table S1:- Basic fruit quality indices of different cultivars of persimmon (*Diospyros kaki* L.)

Cultivars	Fruit weight (g)	Length (cm)	Width (cm)	Fruit shape index	Firmness (N)	Number of seeds	TSS (°Brix)	TA (%)
Non-astringent								
Chansiwan	144.69±18.13	5.58±3.58	6.56±2.78	0.85±0.05	6.42±0.36	6.50±1.08	11.62±0.38	0.24±0.01
Fuyoutianshi	121.56±19.02	4.64±2.22	6.66±3.72	0.70±0.03	4.70±0.32	5.70±1.41	15.36±0.32	0.14±0.02
Meiguohaikuman	218.93±20.66	7.15±4.16	7.19±2.04	0.99±0.04	11.32±0.10	4.83±2.04	16.60±0.73	0.16±0.04
Ribencilang	185.27±26.40	5.12±2.09	7.55±2.99	0.68±0.01	15.28±0.16	4.50±1.76	15.17±0.46	0.28±0.01
Ribenkuaijinshenbuzhi	78.25±6.66	4.69±1.35	5.45±1.84	0.86±0.04	5.56±0.33	4.20±1.23	12.28±0.29	1.17±0.01
Ribenruoshanxicilang	182.92±15.46	5.18±2.34	7.58±2.27	0.68±0.03	8.08±0.94	5.80±1.14	13.26±0.43	0.15±0.02
Ribenyanfeng	144.69±12.76	5.67±2.15	6.79±2.31	0.83±0.03	12.44±0.20	4.62±1.06	12.91±0.42	0.14±0.01
Shangxizaosheng	126.70±10.24	4.82±1.65	6.67±2.13	0.72±0.02	6.16±0.46	5.10±0.99	11.32±0.42	0.23±0.01
Average value	150.38±4.13	5.36±0.82	6.81±0.68	0.79±0.11	8.74±3.82	5.16±0.78	13.56±1.93	0.31±0.35
Astringent								
Baoshandashuishi	126.60±23.43	5.32±2.52	5.91±3.97	0.90±0.04	4.52±0.18	4.83±0.75	17.08±0.34	0.66±0.03
Cangshantuoshi	170.64±29.99	5.70±5.13	6.68±5.06	0.85±0.05	2.34±0.13	1.57±1.81	16.64±0.48	0.58±0.02
Cexiangshuishi	96.16±8.54	5.91±1.30	5.10±2.60	1.16±0.07	2.38±0.19	3.38±1.60	13.50±0.30	0.48±0.01
Changanfujianding	179.95±15.01	6.73±1.43	6.26±2.01	1.08±0.03	5.28±0.22	4.17±2.23	16.38±0.26	0.36±0.01
Changanqiuzhengbing	145.80±13.02	5.63±3.92	6.21±2.32	0.91±0.04	2.68±0.13	4.60±1.14	16.70±0.41	0.68±0.04
Gongchengyue shi	114.24±11.8	4.60±1.80	5.70±2.18	0.81±0.03	3.46±0.20	4.86±2.19	17.39±0.24	0.72±0.02
Gutianyadanshi	39.94±6.37	4.29±2.38	3.83±2.67	1.12±0.08	2.46±0.17	5.00±1.56	15.30±0.44	0.26±0.04
Haianxiaofangshi	187.64±24.07	5.21±2.76	6.95±3.90	0.75±0.06	2.66±0.17	4.00±1.58	17.20±0.48	0.18±0.02
Haiyangdabianshi	175.12±8.87	4.61±2.09	7.15±2.21	0.64±0.03	2.46±0.30	4.17±1.33	14.83±0.38	0.11±0.02
Hezebayuehuang	74.53±14.08	4.12±1.44	5.04±3.98	0.82±0.05	5.36±0.28	2.60±1.17	13.88±0.38	0.16±0.05
Jishānmimiguàn	68.09±9.78	5.11±2.14	4.60±2.80	1.11±0.05	2.60±0.23	2.70±1.77	16.50±0.29	0.19±0.03

Jingchuanbiantata	118.49±15.08	4.01±2.80	6.34±3.30	0.63±0.03	3.65±0.21	4.75±2.12	15.78±0.39	0.21±0.05
Longhuiruanzaao	152.61±14.74	5.68±2.97	6.46±2.59	0.88±0.04	2.54±0.28	6.00±0.82	13.46±0.33	0.11±0.02
Mopanshi	271.08±19.57	6.26±5.889	8.11±3.62	0.77±0.10	4.47±0.15	1.00±0.08	13.50±0.40	0.27±0.01
Nanzhangchutoushi	237.96±23.65	6.83±4.69	7.66±3.34	0.89±0.07	2.58±0.22	1.40±0.05	14.75±0.47	0.36±0.02
Qidongshutouhongshi	206.00±13.02	6.14±7.65	6.87±1.91	0.89±0.10	2.58±0.19	2.00±1.63	17.00±0.20	0.15±0.01
Qiubeishuishi	141.51±14.39	4.82±2.56	6.53±2.60	0.74±0.04	2.41±0.26	1.86±1.21	14.75±0.35	0.19±0.02
Qujingniunaishi	129.03±25.07	4.51±2.82	6.17±5.45	0.73±0.04	2.54±0.24	3.71±1.38	15.71±0.30	0.36±0.01
Shengxianhuangtanshi	46.38±2.36	4.11±1.80	4.14±0.68	0.99±0.03	2.61±0.26	6.80±0.92	17.08±0.39	0.22±0.05
Xiangyagniuxinshi	207.64±28.45	6.50±4.52	6.83±3.22	0.95±0.04	2.60±0.20	4.40±2.20	16.55±2.21	0.15±0.02
Xingyangdayeshuishi	144.25±24.17	5.45±3.24	5.98±4.88	0.92±0.08	3.58±0.19	2.00±0.26	21.17±0.64	0.17±0.01
Xiuningbianshi	157.68±9.21	4.81±1.40	6.75±2.23	0.71±0.04	2.57±0.17	6.33±0.52	18.62±0.47	0.21±0.01
Yangshuoniuxinshi	118.86±8.03	6.02±1.33	5.55±1.65	1.08±0.04	8.36±0.12	3.71±0.70	20.11±0.43	0.15±0.04
Yongjibaishi	162.46±16.15	5.19±1.62	6.87±3.43	0.76±0.03	3.44±0.21	5.40±0.55	15.35±0.28	0.19±0.01
Yunyangdahuoguanishi	248.30±12.67	7.38±3.58	7.22±0.87	1.02±0.06	5.48±0.26	1.00±0.12	15.00±0.35	0.37±0.02
Zhouqumomoshi	127.84±11.61	6.12±3.27	5.64±2.05	1.08±0.03	5.40±0.25	1.00±0.02	17.85±0.28	0.22±0.03
Average value	148.03±5.32	5.42±0.92	6.18±1.03	0.89±0.15	3.50±1.47	3.59±1.73	16.23±1.90	0.30±0.18

Table S2:- Fruit pulp color indices of different persimmon (*Diospyros kaki* L.) cultivars.

Cultivars	L*	a*	b*	a*/b*	H°	C*
Non-astringent						
Chansiwanshi	46.62±3.31	7.34±1.15	18.87±1.77	0.39±0.08	70.97±0.07	20.29±1.62
Fuyoutianshi	59.37±3.40	4.75±2.96	25.29±0.80	0.19±0.12	139.33±0.11	25.88±1.01
Meiguohaikumanshi	46.21±2.46	4.28±1.12	20.03±1.04	0.21±0.06	129.61±0.06	20.51±1.00
Ribencilangshi	63.02±4.36	3.48±1.74	27.47±1.37	0.13±0.06	160.28±0.06	27.73±1.37
Ribenkuaijinshenbuzhishi	64.81±6.18	7.09±2.50	26.99±2.77	0.27±0.12	111.00±0.11	28.05±2.25
Ribenruoshanxicilangshi	66.09±3.78	3.67±2.28	29.52±1.24	0.13±0.08	160.46±0.08	29.84±1.00
Ribenyanfengshi	65.78±2.32	1.76±0.72	24.05±1.64	0.07±0.03	179.12±0.03	24.12±1.63
Shangxizaoshengshi	55.03±2.69	7.22±2.09	24.92±1.76	0.29±0.08	104.78±0.08	26.01±1.95
Average value	58.37±8.24	4.95±2.07	24.64±3.64	0.21±0.10	131.94±0.35	25.30±3.47
Astringent						
Baoshandashuishi	46.77±2.30	3.76±2.17	21.60±2.17	0.17±0.09	144.42±0.09	22.00±2.36
Cangshantuoshi	48.99±4.86	10.88±4.08	24.91±2.37	0.45±0.21	57.55±0.16	27.48±1.70
Cexiangshuishi	39.74±3.10	6.10±2.72	17.02±2.37	0.37±0.16	80.90±0.14	18.25±2.44
Changanfujiandingshi	36.88±1.74	8.91±3.77	16.08±1.55	0.57±0.29	26.04±0.20	18.70±1.45
Changanqiuzhengbingshi	43.11±1.50	8.85±3.75	20.11±2.30	0.45±0.22	57.68±0.18	22.24±2.12
Gongchengyueshi	36.91±2.73	4.72±3.61	15.50±2.66	0.33±0.28	97.54±0.24	16.60±2.21
Gutianyadanshi	46.65±2.25	3.55±1.44	22.06±1.69	0.16±0.07	147.62±0.07	22.39±1.64

Haianxiaofangshi	37.62±3.72	11.81±5.91	16.89±3.07	0.70±1.93	14.26±0.48	20.61±6.66
Haiyangdabianshi	54.60±4.14	8.33±4.52	26.56±2.28	0.31±0.16	98.91±0.14	28.07±3.10
Hezebayuehuangshi	46.16±2.65	8.76±4.39	23.08±1.98	0.38±0.18	77.87±0.16	24.99±2.61
Jishanmimiguangshi	38.63±2.79	8.21±3.25	17.62±2.16	0.47±0.19	50.14±0.16	19.66±2.40
Jingchuanbiantatashi	39.37±4.17	9.17±5.51	18.16±3.31	0.49±0.22	46.88±0.17	20.63±5.24
Longhuiruanzaoshi	39.05±1.71	6.23±2.80	17.18±2.06	0.37±0.18	79.64±0.16	18.47±1.84
Mopanshi	48.01±1.61	3.90±2.83	24.27±1.34	0.16±0.12	148.41±0.11	24.71±1.38
Nanzhangchutoushi	51.17±0.54	6.86±3.10	24.88±1.13	0.28±0.13	109.61±0.12	25.95±1.32
Qidongshutouhongshi	38.52±4.76	10.79±3.66	17.09±3.36	0.67±0.31	1.19±0.21	20.55±2.50
Qiubeishuishi	36.09±3.04	8.47±3.21	14.68±3.20	0.63±0.37	14.52±0.23	17.30±2.52
Qujingniunaishi	32.61±8.57	7.16±3.70	17.14±1.86	0.43±0.24	64.40±0.20	18.90±1.71
Shengxianhuangtanshi	34.41±2.59	11.60±4.81	15.25±2.42	0.76±0.28	21.77±0.20	19.49±3.88
Xiangyagniuxinshi	36.30±5.99	10.34±5.42	16.32±4.24	0.62±0.20	8.19±0.15	19.52±6.14
Xingyangdayeshuishi	38.88±4.85	5.75±2.50	17.54±3.41	0.35±0.18	87.77±0.16	18.64±3.07
Xiuningbianshi	48.80±0.75	5.37±2.67	22.87±1.67	0.24±0.13	122.14±0.12	23.63±1.39
Yangshuoniuxinshi	49.96±2.90	11.25±2.23	25.72±2.03	0.44±0.10	56.83±0.08	28.16±1.86
Yongjibaishi	40.11±2.93	12.19±3.82	20.21±0.73	0.60±0.18	13.92±0.14	23.77±2.26
Yunyangdahuoguan	54.50±0.73	4.08±1.87	27.95±0.82	0.15±0.07	153.38±0.07	28.29±0.78
Zhouqumomoshi	41.55±2.12	9.22±1.92	19.01±1.92	0.49±0.10	43.30±0.08	21.18±2.12
Average value	42.52±6.30	7.93±2.71	19.99±3.94	0.42±0.17	70.19±0.47	21.93±3.56

Table S3:- Fruit peel color indices of different persimmon (*Diospyros kaki* L.) cultivars.

Cultivars	L*	a*	b*	a*/b*	H°	C*
Non-astringent						
Chansiwanshi	58.92±1.80	5.22±1.75	26.86±1.60	0.19±0.06	136.78±0.06	27.41±1.70
Fuyoutianshi	55.55±0.88	14.96±2.13	26.48±0.93	0.56±0.08	20.97±0.06	30.47±1.36
Meiguohaikumanshi	57.57±2.07	10.58±2.24	27.98±1.50	0.38±0.10	74.82±0.09	30.00±0.72
Ribencilangshi	51.36±7.57	15.66±3.86	25.03±1.53	0.63±0.17	6.00±0.12	29.70±2.10
Ribenkuaijinshenbuzhishi	64.00±1.36	7.84±3.42	31.89±1.19	0.24±0.10	119.85±0.09	32.97±1.80
Ribenruoshanxicilangshi	58.17±2.56	12.51±2.50	26.99±1.38	0.47±0.11	49.47±0.09	29.85±1.12
Ribenyanfengshi	57.91±0.84	15.39±3.22	29.02±0.72	0.53±0.12	30.79±0.09	32.98±1.07
Shangxizaoshengshi	58.53±0.92	2.36±1.90	28.00±1.12	0.08±0.07	174.82±0.07	28.16±1.04
Average value	57.75±3.52	10.56±5.01	27.78±2.04	0.38±0.20	76.69±0.24	30.19±1.99
Astringent						
Baoshandashuishi	59.15±1.08	5.74±2.20	29.99±0.51	0.19±0.08	137.45±0.07	30.60±0.35
Cangshantuoshi	45.74±2.83	18.26±5.16	20.05±3.01	0.90±0.16	55.46±0.09	27.21±5.50
Cexiangshuishi	53.37±2.28	11.66±6.39	25.92±1.66	0.45±0.24	59.23±0.20	28.93±3.23
Changanfujiandingshi	48.49±1.67	14.64±3.08	21.97±1.64	0.67±0.16	5.17±0.11	26.54±1.89
Changanqizhengbingshi	50.77±1.77	16.95±2.27	23.73±1.54	0.72±0.12	17.44±0.08	29.24±1.51
Gongchengyueshi	47.03±1.21	12.93±1.59	21.70±0.50	0.60±0.07	12.50±0.05	25.29±0.98
Gutianyadanshi	58.08±1.04	7.27±2.76	29.95±0.81	0.24±0.10	119.91±0.09	30.93±0.70
Haianxiaofangshi	48.38±3.16	20.46±5.99	22.29±2.09	0.92±2.86	61.89±0.34	30.26±6.35
Haiyangdabianshi	51.05±3.51	20.58±4.04	24.10±2.71	0.86±0.14	47.60±0.08	31.79±4.01
Hezebayuehuangshi	53.44±1.77	15.82±3.20	26.16±1.33	0.61±0.16	10.51±0.10	30.73±1.12
Jishanmimiguangshi	47.22±1.39	15.33±4.20	20.93±1.41	0.74±0.23	19.01±0.16	26.22±1.94
Jingchuanbiantatashi	47.73±1.28	20.65±4.81	22.21±1.22	0.92±0.18	60.51±0.10	30.45±3.95
Longhuiruanzaoshi	53.59±1.79	15.31±6.23	25.69±1.07	0.60±0.25	16.98±0.19	30.37±2.65
Mopanshi	56.59±3.01	6.92±3.03	27.43±1.99	0.25±0.10	117.84±0.10	28.39±2.37
Nanzhangchutoushi	61.45±2.10	10.42±3.05	30.86±1.21	0.34±0.11	88.35±0.10	32.69±0.90
Qidongshutouhongshi	51.34±0.45	13.38±3.44	24.19±1.39	0.55±0.13	25.77±0.10	27.74±2.57
Qiubeishuishi	50.34±2.07	8.61±3.75	21.87±2.13	0.40±0.18	71.42±0.16	23.75±2.19
Qujingniunaishi	52.91±1.51	10.32±4.39	25.03±1.16	0.42±0.18	66.39±0.16	27.37±1.32
Shengxianhuangtanshi	44.84±1.26	18.49±3.23	19.24±1.22	0.96±0.18	68.13±0.09	26.78±2.50

Xiangyagniuixinshi	49.42±1.64	18.30±1.47	22.79±1.24	0.80±0.09	37.98±0.05	29.26±1.12
Xingyangdayeshuishi	51.18±4.55	11.86±4.06	24.62±3.83	0.47±0.12	49.00±0.10	27.42±4.98
Xiuningbianshi	57.06±1.63	10.27±3.43	28.32±1.00	0.36±0.13	80.94±0.11	30.28±0.96
Yangshuoniuxinshi	53.97±1.96	15.75±2.19	23.21±1.94	0.68±0.14	9.19±0.09	28.15±1.44
Yongjibaishi	49.10±0.52	20.20±2.62	22.82±0.68	0.89±0.14	54.36±0.08	30.54±1.42
Yunyangdahuoguanshi	59.12±2.62	13.37±3.63	30.46±0.52	0.44±0.13	57.56±0.10	33.40±1.27
Zhouqumomoshi	53.21±3.39	14.19±5.33	25.40±2.20	0.58±0.28	24.07±0.19	29.53±1.28
Average value	52.10±4.43	14.14±4.42	24.65±3.26	0.60±0.23	52.87±0.78	28.99±2.29

Table S4:- Pulp and peel color indices of persimmon (*Diospyros kaki* cv. 'Xiaofangshi') fruits during different ripening stages.

Treatment	Ripening stages	L*	a*	b*	a*/b*	H ^o	C*
Pulp							
H ₂ O	0	74.18±0.52	-6.63±0.53	27.72±0.42	-0.24±0.02	103.47±1.09	28.54±0.4
	3	58.45±5.5	6.86±1.09	25.82±2.58	0.35±0.09	72.22±4.32	27.21±2.21
	6	67.77±1.31	6.46±0.66	30.16±0.28	0.21±0.02	77.99±1.16	30.9±0.34
	9	65.29±2.11	6.95±1.07	30.42±0.96	0.24±0.04	76.89±2.29	31.41±0.8
	12	50.37±5.3	6.8±0.59	23.44±2.89	0.56±0.07	61.55±2.88	26.38±2.74
	15	65.47±1.4	10.33±1.11	30.88±0.24	0.34±0.04	71.63±1.94	32.72±0.3
C ₂ H ₄	0	74.18±0.52	-6.63±0.53	27.72±0.42	-0.24±0.02	103.47±1.09	28.54±0.4
	3	59.02±5.17	5.95±0.69	26.38±2.29	0.27±0.06	75.5±2.87	27.29±2.07
	6	30.56±0.41	11.04±1.1	11.53±0.45	0.99±0.14	47.35±3.55	16.24±0.64
	9	32.85±0.53	6.8±0.59	12.71±0.55	0.56±0.07	61.55±2.97	14.59±0.28
	12	31.57±0.89	8.94±0.74	12.43±0.8	0.77±0.09	53.85±3.55	15.58±0.49
	15	30.03±0.63	10.56±0.28	11.39±0.62	0.94±0.05	46.89±1.26	15.57±0.59
SA	0	74.18±0.52	-6.63±0.53	27.72±0.42	-0.24±0.02	103.47±1.09	28.54±0.4
	3	58.62±4.76	6.73±1.2	26.59±2.16	0.31±0.08	55.78±16.46	27.93±1.75
	6	67.63±1.24	6.39±0.68	30.47±0.26	0.21±0.02	78.2±1.24	31.2±0.27
	9	67.07±0.99	4.92±0.7	31.58±0.3	0.16±0.02	81.14±1.3	32.03±0.26
	12	52.61±5.39	10.47±0.89	23.94±2.93	0.52±0.08	63.56±3.55	26.49±2.69
	15	64.78±1.19	11.88±0.83	31.23±0.32	0.38±0.03	69.19±1.5	33.51±0.17
Peel							
H ₂ O	0	50.69±0.52	-9.81±0.22	22.8±0.37	-0.43±0.01	113.29±0.55	24.82±0.36
	3	51.90±1.90	1.40±2.32	24.46±1.43	0.09±0.11	85.77±5.83	25.57±1.21
	6	57.23±0.46	4.39±0.77	27.12±0.35	0.09±0.03	112.84±17.5	27.32±0.31
	9	60.33±0.60	4.39±1.42	30.17±0.44	0.14±0.05	82.07±2.55	30.76±0.58
	12	55.85±2.85	11.27±1.52	27.92±1.97	0.44±0.07	67.13±3.57	30.58±1.72
	15	61.65±0.54	8.2925±1.25	31.26±0.34	0.26±0.04	75.45±2.05	32.52±0.59
C ₂ H ₄	0	50.69±0.52	-9.81±0.22	22.8±0.37	-0.43±0.01	113.29±0.55	24.82±0.36
	3	52.69±2.01	0.708±1.97	25.07±1.33	0.06±0.09	86.97±4.83	25.84±1.16
	6	36.69±0.34	11.934±0.4	13.78±0.35	0.87±0.04	49.13±1.36	18.28±0.31
	9	37.49±0.54	10.21±0.88	14.87±0.42	0.7±0.07	55.76±2.92	18.26±0.31
	12	36.74±0.4	12.37±0.56	14.2±0.33	0.88±0.05	49.07±1.73	18.91±0.32
	15	38.06±0.8	12.62±0.69	14.46±0.69	0.89±0.06	48.94±1.95	19.29±0.74
SA	0	50.69±0.52	-9.81±0.22	22.8±0.37	-0.43±0.01	113.29±0.55	24.82±0.36
	3	54.63±1.73	0.37±1.71	26.23±1.27	0.04±0.08	88.28±4.27	26.8±1.09
	6	56.97±0.54	1.07±0.96	27.06±0.41	0.04±0.04	93.77±1.28	27.24±0.38
	9	61.16±0.55	4.17±1.06	30.88±0.39	0.13±0.03	82.54±1.86	31.31±0.49
	12	56.14±3.16	11.91±1.56	28.05±2.26	0.49±0.1	65.5±4.32	31.12±1.76
	15	60.85±0.5	11.24±1.53	31.36±0.34	0.36±0.05	70.64±2.5	33.58±0.6

Table S5:- Pulp and peel color indices of persimmon (*Diospyros kaki* cv. 'Naiyoushi') fruits during different ripening stages.

Treatment	Ripening stages	L^*	a^*	b^*	a^*/b^*	H°	C^*
Pulp							
H ₂ O	0	66.82±0.67	5.34±0.34	31.24±0.29	0.17±0.01	80.31±0.61	31.71±0.29
	3	66.24±0.72	7.1±0.54	32.28±0.22	0.22±0.02	77.65±0.91	33.09±0.27
	6	67.2±0.52	4.52±0.34	32.44±0.16	0.14±0.01	82.1±0.58	32.77±0.18
	9	66.82±0.77	7.6±0.48	32.52±0.21	0.23±0.01	76.9±0.76	33.43±0.28
	12	66.26±0.75	8.99±0.44	32.81±0.2	0.27±0.01	74.69±0.73	34.05±0.22
	15	65.08±0.72	6.45±0.35	32.5±0.34	0.2±0.01	78.77±0.62	33.15±0.34
C ₂ H ₄	0	66.82±0.67	5.34±0.34	31.24±0.29	0.17±0.01	80.31±0.61	31.71±0.29
	3	64.58±0.92	8.87±0.34	31.92±0.3	0.28±0.01	74.46±0.68	33.15±0.22
	6	59.25±2.4	6.59±0.34	29.08±1.16	0.23±0.02	77.03±0.89	29.85±1.12
	9	46.47±2.12	10.99±0.52	22.641±1.21	0.49±0.02	63.89±1.06	25.2±1.24
	12	47.04±2.87	10.46±0.3	23.62±1.55	0.46±0.02	65.6±1.07	25.87±1.51
	15	49.45±1.49	11.88±0.95	20.68±1.13	0.57±0.03	60.47±1.34	23.9±1.38
SA	0	66.82±0.67	5.34±0.34	31.24±0.29	0.17±0.01	80.31±0.61	31.71±0.29
	3	66.47±0.82	6.61±0.54	32.03±0.18	0.21±0.02	78.39±0.9	32.74±0.24
	6	66.79±0.67	4.17±0.43	31.78±0.26	0.13±0.01	82.55±0.74	32.08±0.28
	9	65.47±0.95	8.45±0.55	32.34±0.3	0.26±0.02	75.36±1	33.47±0.23
	12	66.78±0.56	8.12±0.37	32.8±0.18	0.25±0.01	76.12±0.61	33.81±0.19
	15	57.55±0.4	9.53±1.12	27.39±0.4	0.35±0.04	71.15±1.84	29.14±0.7
Peel							
H ₂ O	0	54.26±0.47	0.08±0.59	24.56±0.31	0.003±0.02	89.84±1.34	24.63±0.32
	3	53.97±0.31	5.28±0.57	25.23±0.23	0.21±0.02	78.29±1.24	25.83±0.29
	6	54.38±0.35	7.78±0.81	25.26±0.27	0.31±0.03	73.07±1.65	26.53±0.4
	9	54.11±0.57	8.32±0.73	25.12±0.41	0.33±0.03	71.73±1.58	26.55±0.4
	12	55.71±0.37	11.85±0.7	25.89±0.32	0.48±0.03	65.54±1.25	28.54±0.46
	15	58.21±0.55	13.08±0.7	27.53±0.4	0.47±0.02	64.7±1.08	30.53±0.57
C ₂ H ₄	0	54.26±0.47	0.08±0.59	24.56±0.31	0.003±0.02	89.84±1.34	24.63±0.32
	3	54.82±0.3	11.51±0.86	26.14±0.29	0.44±0.03	66.49±1.31	28.63±0.61
	6	54.53±0.72	9.89±1.05	25.26±0.7	0.39±0.04	68.78±2.05	27.29±0.79
	9	51.83±0.95	16.97±0.53	22.92±0.84	0.75±0.04	53.37±1.27	28.58±0.77
	12	51.39±1.58	16.39±0.68	22.24±0.91	0.75±0.06	53.52±1.4	27.7±0.9
	15	49.45±1.49	11.88±0.95	20.68±1.13	0.57±0.03	60.47±1.34	23.9±1.38
SA	0	54.26±0.47	0.08±0.59	24.56±0.31	0.003±0.02	89.84±1.34	24.63±0.32
	3	54.02±0.41	5.16±1.09	25.12±0.48	0.2±0.04	78.84±2.08	25.8±0.69
	6	54.44±0.3	3.49±0.8	24.61±0.41	0.19±0.03	82.16±1.71	24.96±0.5
	9	55.46±0.51	10.94±1.05	25.88±0.47	0.42±0.04	67.41±1.76	28.22±0.75
	12	56.53±0.52	11.31±0.87	26.35±0.39	0.43±0.03	67.01±1.37	28.74±0.66
	15	57.55±0.4	9.53±1.12	27.39±0.4	0.35±0.04	71.15±1.84	29.14±0.7

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