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Effects of Temperature and Humidity on the Quality and Textural Properties of Melon Fruits During Development and Ripening

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Abstract The quality of melon fruit depends on the environmental growth conditions. We evaluated the effects of temperature and humidity in the greenhouse on the quality and textural properties of melon fruit during development and ripening. The greenhouse humidity and air and soil temperatures were monitored over two growth seasons of three melon varieties. The average air and soil temperatures were higher in spring than in autumn, whereas average air humidity was lower in spring. The contents of free amino acid, soluble protein, and soluble sugar in melon fruit were significantly higher in spring than in autumn. The activities of sucrose phosphate synthase and sucrose synthase were also significantly higher in spring than in autumn. In both seasons, the contents of water-soluble pectin and ionic soluble pectin increased during fruit maturation, whereas the content of covalent soluble pectin decreased. The cellulose and hemicellulose contents of the three melon cultivars decreased to different degrees during ripening. The activities of ploygalacturonase, pectinesterase, and β-galactosidase first increased and then decreased over time. The cellulase activity in the three cultivars increased steadily and peaked at maturity, suggesting that cell wall-modifying enzymes play important roles in the transformation of fruit texture.

Keywords Melon; Fruit quality; Textural Properties

Melon (*Cucumis melo* L.) is an economically important fruit crop that is primarily cultivated in temperate regions worldwide. Over 27 million tons of melon were produced in 2018, with nine million tons produced in China (FAO, 2018). Melon fruit is rich in vitamins, carbohydrates, carotenoids, and folic acid, which are beneficial nutrients in terms of human wellness (Lester and Hodges, 2008). The market value of melon is influenced by the fruit quality, including the color, texture, flavor and aroma, along with the exterior appearance (size, color, and shape) (Li et al., 2006). However, the yield and quality of horticultural crops are affected by genotypic variation along with the environmental conditions of growth, including temperature, humidity, and light (Olle and Viršile, 2013; Steindal et al., 2015; Sakamoto and Suzuki, 2015; Shi et al., 2021). In a study on Chinese broccoli (*Brassica oleracea*var. *Alboglabra* Bailey), He et al. (2020) found that the concentrations of soluble sugars and glucosinolates in the shoot were strongly enhanced at 10°C comparison to 20°C. Fu et al. (2017) reported that high light levels and low nitrogen contents were beneficial for the accumulation of vitamin C and depletion of nitrate in lettuce leaves.

During the ripening of melon fruit, a series of biochemical and physiological changes lead to modifications in fruit quality (Gur et al., 2016). The accumulation of sugars is important in the development of fruit quality. Sucrose (Suc), glucose (Glu), and fructose (Fru) are the major soluble sugars in melon fruit, with sucrose being the predominant sugar. The content of Suc at maturity is influenced by sucrose-metabolizing enzymes, and in the sweet melon cultivars, Suc rapidly accumulates as the fruit reaches full size (Dai et al., 2011; Saladié et al., 2015; Shin et al., 2017). The fruit ripening process is characterized by a softening of the texture, which is associated with the degradation of the cell wall components. Cellulose (CL), hemicellulose (HC), and pectin are the main components of the cell wall (Brummell, 2006; Bashline et al., 2014). These changes during fruit ripening are driven in part by degradation by enzymes including polygalacturase (PG), pectin methylesterase (PME),

β-galactosidase (β-Gal), and cellulase (Cx) (Wang et al., 2019). In the current study, we analyzed the effects of different environmental growth conditions on the quality and textural properties of melon fruit. We examined the contents of soluble protein, vitamin C, total free amino acids, carbohydrates, and cell wall components along with the activities of related enzymes in three melon cultivars from pollination to the mature fruit stage. The results provide a theoretical basis for the precise management of melons in solar greenhouses in East China and are expected to enhance the economic benefits of melons grown in greenhouses.

1 Results and Analysis

1.1 Greenhouse climate condition

We recorded the daily average air temperature, soil temperature, and soil humidity from pollination to the mature (M) stage. The results showed that except for the high soil temperature in early autumn, the air and soil temperatures in spring were generally higher than those in autumn throughout the monitoring period (Figure 1A; Figure 1B). Soil humidity was higher in autumn than in spring (Figure 1C).

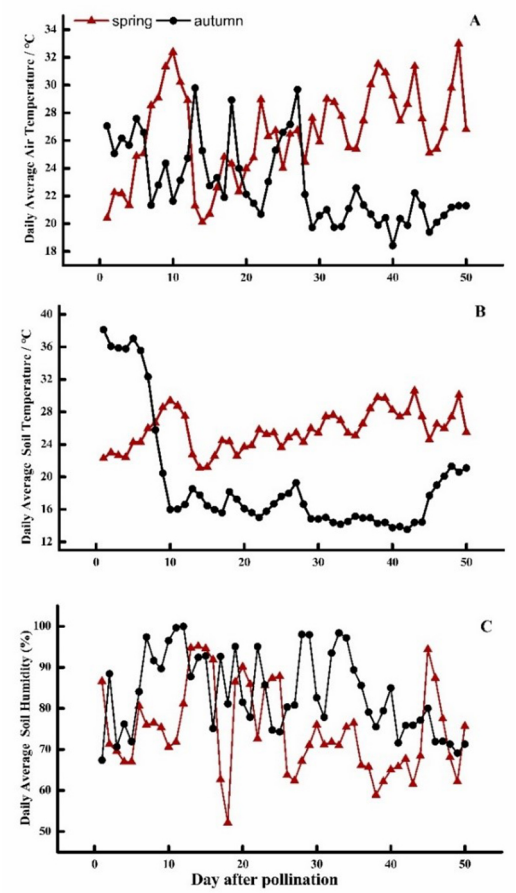

Figure 1 Changes in the average air temperature (A), soil temperature (B), and soil humidity (C), and in the greenhouse during melon development

The daily average air temperatures in the greenhouse in spring and autumn were 26.5℃ and 22.9℃, respectively. The average soil temperatures in spring and autumn were 25.7℃ and 19.4℃, respectively, while the average soil humidity was 74.7% and 83.5%, respectively. The daily minimum air temperatures in the spring and autumn were 22.3℃ and 18.4℃, respectively, and the daily maximum temperatures were 33.0℃ and 29.6℃, respectively. The daily lowest soil temperatures in the spring and autumn were 21.1℃ and 14.8℃, respectively, while the daily highest soil temperatures were 29.4℃ and 38.1℃, respectively. The daily lowest soil humidity values in the spring and autumn were 52.2% and 67.4%, respectively, and the daily highest soil humidity values were 95.1% and 99.9%, respectively.

1.2 Changes in sugar, soluble protein, vitamin C, and total free amino acid contents in different melon cultivars during fruit maturation

Melon fruit contains soluble sugars, soluble proteins, amino acids, vitamin C, and other nutrients, and their contents change during fruit development. The contents of soluble sugar and soluble protein gradually increased during fruit development in both seasons. The contents of free amino acid, soluble sugar, soluble protein, and vitamin C were highest at the M stage. In spring and autumn, the contents of amino acid, soluble sugar, and vitamin C in the 04-38F-1 cultivar at the M stage were 150.97 μmol/g FW and 121.78 μmol/g FW, 34.53 mg/g FW and 19.14 mg/g FW, 4.51 nmol/g FW and 1.90 nmol/g FW, respectively (Figure 2). The contents of free amino acid, free sugar, free protein, and vitamin C were higher in the spring than in the autumn.

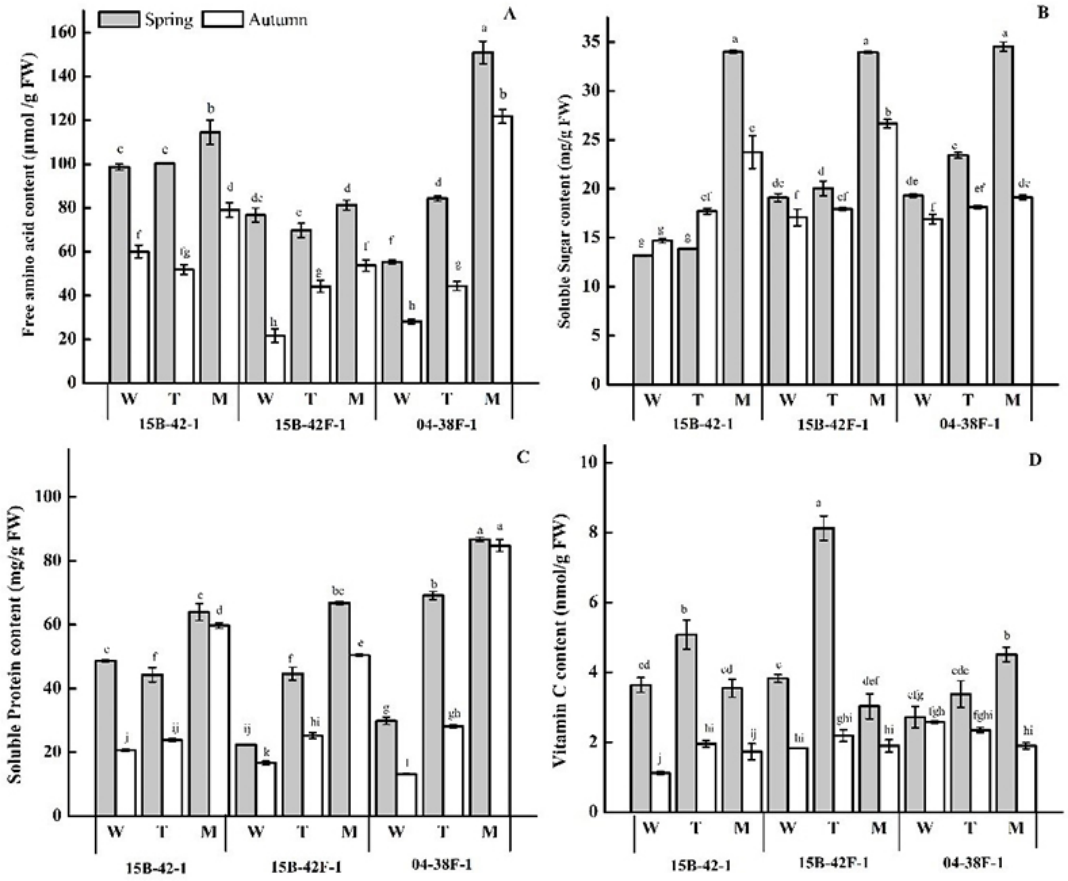

Figure 2 Contents of total free amino acid (A), soluble sugar (B), soluble protein (C), and vitamin C (D) in the three melon cultivars at different stages

Note: Different letters denote significant differences at $p \leq 0.05$ according to Duncan's multiple range tests. The fruits were classified into three different developmental stages according to the color of the receptacle: the white fruit stage (W); turn color fruit stage (T); and mature stage fruit (M)

1.3 Changes in carbohydrate content in different melon cultivars during fruit maturation

Melon fruits contain three types of sugar: Fru, Glu, and Suc. In both seasons, the Suc contents in the three melon cultivars remained low before the turn color (T) stage and then increased significantly at the M stage. In the M stage, the contents of Suc in the 15B-42-1, 15B-42F-1, and 04-38F-1 cultivars were 17.15%, 55.64%, and 15.03% higher in the spring than in the autumn. In the spring, the Fru contents in the three cultivars gradually increased throughout fruit maturation. In autumn, the Fru contents first increased and then decreased during maturation, reached the maximum values at the T stage. In the M stage, the Fru contents in the 15B-42-1, 15B-42F-1, and 04-38F-1 cultivars were 16.28%, 16.38%, and 84.71% higher in the spring than in autumn. The Glu contents in the melon fruits increased significantly from the T stage, reaching the highest values in the M stage. The carbohydrate contents in the different melon cultivars were higher in the spring than in autumn (Figure 3).

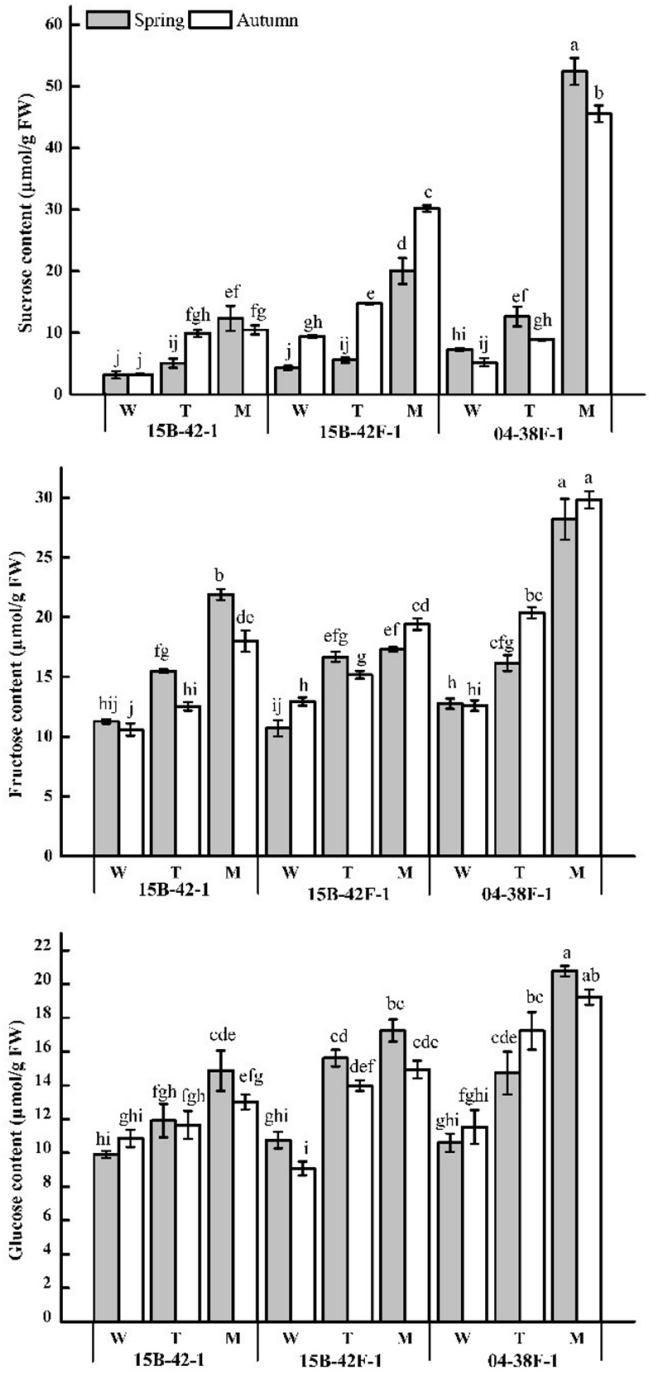

Figure 3 Contents of fructose, glucose, and sucrose in the three melon cultivars at different stages

Note: Different letters denote significant differences at $p \leq 0.05$ according to Duncan's multiple range tests. The fruits were classified into three different developmental stages according to the color of the receptacle: the white fruit stage (W); turn color fruit stage (T); and mature stage fruit (M)

1.4 Changes in carbohydrate-metabolizing enzyme activities in different melon cultivars during fruit maturation

It can be seen the changes in the activities of enzymes related to Suc metabolism during fruit development in spring and autumn (Figure 4). In the two seasons, the sucrose phosphate synthase (SPS) and sucrose synthase (SS) activities in the three melon cultivars increased during maturation, reaching the maximum values in the M stage. With exception of SPS activity in the 15B-42-1 cultivar in the M stage, the SPS and SS activities were higher in spring than in autumn.

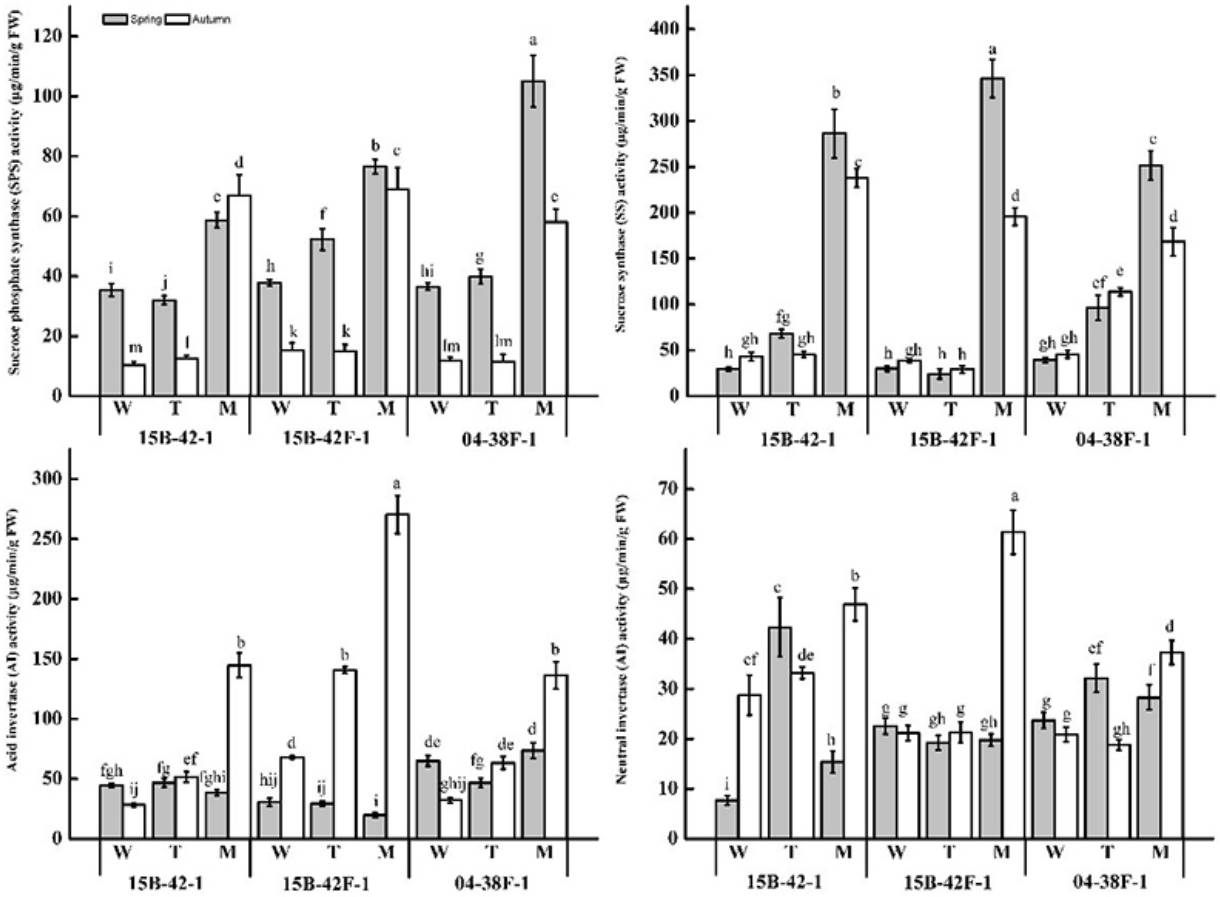

Figure 4 Activities of sugar-metabolizing enzymes in the three melon cultivars at different stages

Note: Different letters denote significant differences at $p \leq 0.05$ according to Duncan's multiple range tests. The fruits were classified into three different developmental stages according to the color of the receptacle: the white fruit stage (W); turn color fruit stage (T); and mature stage fruit (M)

In autumn, the soluble acid invertase (AI) activities in the three melon fruits gradually increased during maturation, and the maximum values were observed in the M stage. In spring, the AI activities in the 15B-42-1 and 15B-42F-1 cultivars did not change significantly during maturation, while the AI activity in the 04-38F-1 cultivar first decreased and then increased during fruit maturation. In autumn, the neutral invertase (NI) activities of the three melon cultivars increased significantly in the M stage. In spring, the NI activities of the 15B-42-1 and 04-38F-1 cultivars increased significantly in the T stage. The accumulation of Suc in melon fruit in the late developmental stage is mainly due to the increase in SPS and SS activities.

1.5 Changes in the contents of cell wall materials in different melon cultivars during fruit maturation

In both spring and autumn, the water-soluble pectin (WSP) contents in melon fruit increased constantly during fruit maturation. However, the WSP contents showed differences between the melon cultivars with different tastes. Among the cultivars, the WSP content was highest in 15B-42F-1, followed by 15B-42-1 and 04-38F-1 (Figure 5).

The ionic soluble pectin (ISP) contents of the different cultivars during fruit development showed different degrees of increase (Figure 5). Among the cultivars, 15B-42-1 had the highest ISP content in the M stage in both seasons. For all three cultivars, the ISP contents were significantly higher in the spring than in autumn, and the peak ISP contents occurred in the M stage. In contrast, the covalent soluble pectin (CSP) contents gradually decreased during fruit ripening. Among the cultivars, the decrease in CSP content was most obvious in 15B-42-1, particularly during the M stage, when the pulp softens rapidly. The CSP content in the 15B-42-1 cultivar was significantly higher in spring than in autumn (Figure 5).

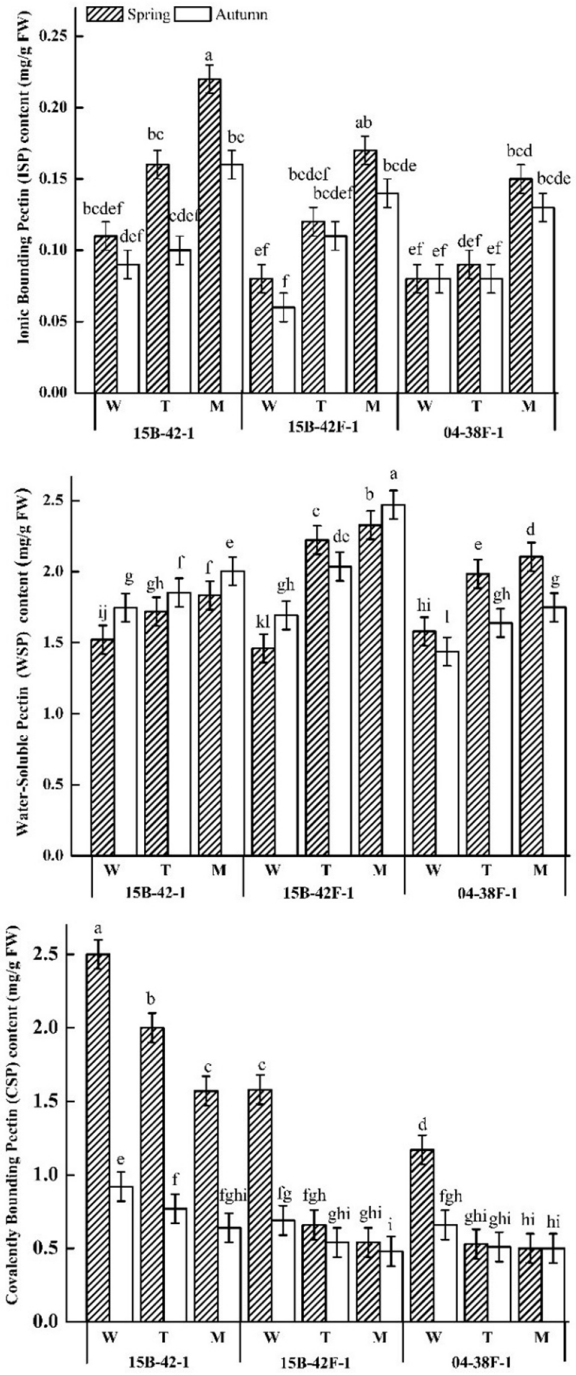

Figure 5 Pectin contents in the three melon cultivars at different stages

Note: Different letters denote significant differences at $p \leq 0.05$ according to Duncan's multiple range tests. The fruits were classified into three different developmental stages according to the color of the receptacle: the white fruit stage (W); turn color fruit stage (T); and mature stage fruit (M)

1.6 Changes in the CL and HC contents in different melon cultivars during fruit maturation

During the ripening process, the CL and HC contents of three different melon cultivars showed different degrees of decline (Figure 6). Among the cultivars, the CL content in 04-38F-1 showed the smallest decline. In the M stage, the CL content was highest in the 04-38F-1 cultivar and lowest in the 15B-42-1 cultivar. With exception of the 15B-42F-1 cultivar in the white fruit (W) stage, there was little difference in the CL contents of melon fruits between spring and autumn. The HC content in 04-38F-1 was greater than those in the other cultivars in all stages and seasons. The content of HC in 15B-42F-1 was significantly higher in autumn than in spring (Figure 6).

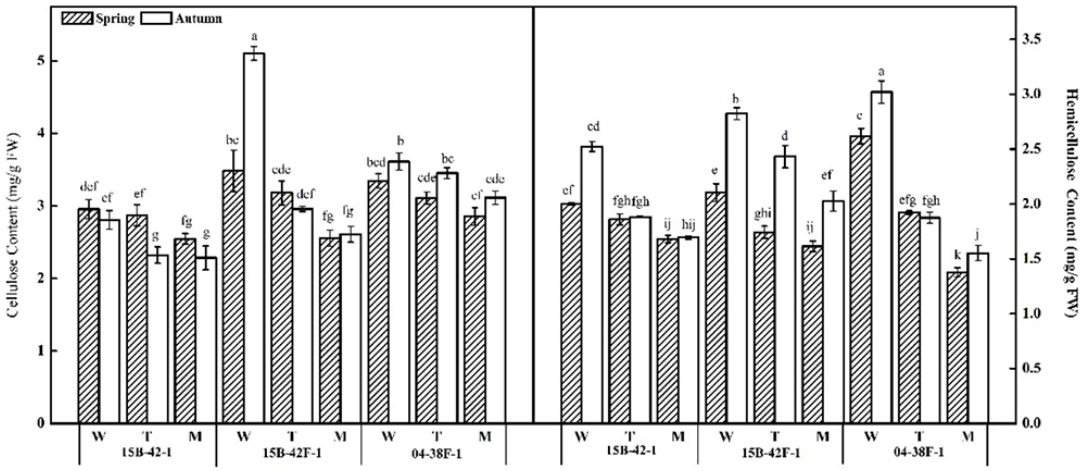

Figure 6 Cellulose (CL) and hemicellulose (HC) contents in the three melon cultivars at different stages

Note: Different letters denote significant differences at $p \leq 0.05$ according to Duncan's multiple range tests. The fruits were classified into three different developmental stages according to the color of the receptacle: the white fruit stage (W); turn color fruit stage (T); and mature stage fruit (M).

1.7 Changes in activities of cell wall-degrading enzymes in different melon cultivars during fruit maturation

The PG, PME, and β-GAL contents first increased and then decreased during fruit development in both spring and autumn. In the 15B-42F-1 cultivar, the PG, PME, and β-GAL activities were notably higher in the T stage compared to the other stages. Meanwhile, the Cx activities in the three cultivars increased steadily and peaked at the M stage (Table 1). The rate of increase in Cx activity was higher in 15B-42F-1 compared to the other cultivars. The Cx activity increased from nearly 110.86 μg/min/g FW at the W stage to its peak value of 334.61 μg/min/g FW at the M stage; in contrast, in 04-38F-1, the Cx activity increased to a peak value of 135.25 μg/min/g FW at the M stage. The PG, β-GAL, and PME activities were significantly higher in spring than in autumn. However, the Cx activities of the different melon varieties were generally lower in spring than in autumn (Table 1).

Table 1 Activities of enzymes related to cell wall metabolism in three melon varieties during fruit development

Cultivar	Time	Growth stages	Polygalacturonase (PG; mg/h/g FW)	β-galactosidase (β-GAL; nmol/min/g FW)	Pectin methylesterase (PME; Ug/g FW)	Catalase (Cx; μg/min/g FW)
15B-42-1	Autumn	W	15.86±1.15cd	771.08±4.07e	1.27±0.01e	91.73±2.64g
		T	18.33±0.73cd	1100.66±35.04bc	2.59±0.02b	112.83±2.34f
		M	17.14±0.75cd	993.32±13.63cd	1.77±0.02d	191.29±7.81c
	Spring	W	35.16±0.67c	1289.72±73.59de	2.08±0.02h	106.82±4.47c
		T	48.64±6.34b	1438.53±66.41cd	2.86±0.05f	170.13±1.57a
		M	46.61±2.00b	1393.91±22.08cd	2.53±0.05g	183.46±9.22a
15B-42F-1	Autumn	W	37.93±4.22b	901.99±15.19de	2.57±0.05b	110.86±7.25f
		T	60.52±1.48a	1364.90±64.58a	3.01±0.02a	285.88±3.73b
		M	55.58±4.14a	1066.02±59.98c	2.70±0.02b	334.61±3.94a
	Spring	W	31.96±2.89d	1596.34±140.77c	3.08±0.07ef	108.15±1.57c
		T	69.82±2.22a	2222.74±102.81a	4.42±0.07a	131.02±8.31b
		M	64.87±1.28a	1937.55±43.60b	4.12±0.04b	166.58±8.38a
04-38F-1	Autumn	W	12.28±0.45e	914.05±36.33de	2.09±0.08c	130.66±3.13e
		T	37.87±0.70b	1236.06±41.19ab	2.97±0.13a	162.53±6.72d
		M	22.48±0.65c	783.28±88.35e	2.66±0.06b	301.22±9.75b
	Spring	W	32.29±2.84c	927.36±14.72f	3.13±0.10de	107.07±3.81c
		T	47.83±0.60b	1092.95±130.53ef	3.76±0.02c	121.68±2.26bc
		M	44.76±0.30b	1033.66±50.29ef	3.37±0.18d	135.25±10.93b

Note: Different letters denote significant differences at $p \leq 0.05$ according to Duncan's multiple range tests. The fruits were classified into three different developmental stages according to the color of the receptacle: the white fruit stage (W); turn color fruit stage (T); and mature stage fruit (M)

2 Discussion

Melon is one of the main vegetable crops cultivated in greenhouse facilities in China. Temperature and light are important factors affecting the yield and commercial value of vegetable products. Turner et al. (2016) reported that plantain cultivars grown at different altitudes show genetic responses to the temperature and photoperiod. Other studies on grapes have determined the effects of temperature on the metabolism of sugars, acids, and anthocyanins (Cohen et al., 2012; Rienth et al., 2016; Movahed et al., 2016). In the current study, we recorded air temperature, soil humidity, and temperature data to evaluate the effects of different climatic factors on melon fruit quality and texture. During the early stage of fruit development, the air and soil temperature gradually increased in spring but showed downward trends in autumn. In most cases, the air and soil temperature in spring are significantly higher than those in autumn during the same period of fruit development. In this study, the average air temperature and average soil temperature were higher in spring than in autumn (Figure 1). Previous studies have shown that the contents of nutrients in fruits and vegetables are affected by various environmental factors, particularly temperature and irradiance (Poiroux-Gonord et al., 2010). In the present study, we found that the contents of free amino acid, soluble protein, and soluble sugar in the M stage were higher in melon fruit grown in spring than in melon grown in autumn (Figure 2). Ren et al. (2019) reported that higher average daily temperature and larger difference between daytime and nighttime temperatures may induce compact shoots, promote root growth, and improve the quality of *Astragalus membranaceus* seedlings. These results indicate that higher temperatures are more favorable for the growth of melon fruits.

Fruit sweetness is the major determinant of melon quality and consumption. Suc, Glu, and Fru are the major soluble sugars in melon, with Suc being the predominant sugar at maturity (Dai et al., 2011). Suc accumulation is influenced by environmental factors along with the activities of major enzymes involved in synthesis, hydrolysis, and hormonal signaling (SPS, SS, NI, and AI) (Stein and Granot, 2019). In this study, the 04-38F-1 cultivar showed a higher Suc content than the other cultivars in the spring. In addition, in the 04-38F-1 cultivar, the SPS and SS activities were higher in spring than in autumn, resulted in a greater Suc content (Figure 3; Figure 4). Several studies have been conducted on the effects of high temperatures on chicory root. Sharma and Sharma (2018) reported a significant increase in Suc content, a reduction in SS activity, and an increase in AI activity during early transplanting when rice encountered heat stress. Takashi and Hisashi (2007) reported that the sugar composition in the flesh of apples was highly correlated with heat summation. Kano (2006) and Fukuoka et al. (2009) found that heat treatment during the early stage of fruit enlargement was effective in promoting the accumulation of Suc in melon and watermelon fruits.

The fruit texture is largely dependent on the cell wall composition. During the ripening of melon fruit, the gradual decrease in firmness is associated with depolymerization of the cell wall components (Brummell, 2006). Enzymes such as β-GAL, PG, PME, and PL play important roles in fruit ripening, although the findings regarding specific enzymes and their encoding genes vary greatly among studies (Payasi et al., 2009). In the present study, we found that the WSP and ISP contents in melon fruit increased constantly during fruit ripening, whereas the CSP content gradually decreased. Vicente et al. (2007) reported that pectin became more soluble, and HC was depolymerized during the ripening and softening of blueberry fruit. In this study, during fruit development, the activities of PG, PME, and β-GAL first increased and then decreased. Meanwhile, the Cx activity in the three cultivars increased steadily and peaked at maturity (Table 1), which was similar to the results reported by Sanudo-Barajas et al. (2009) in papaya, Figueroa et al. (2010) in strawberry, Sun et al. (2013) in Chinese bayberry, and Raffo et al. (2011) in pear.

Fruit HC is composed of crosslinked cellulose microfibrils, which are responsible for the integrity of the cell wall (Bennett and Labavitch, 2008). The decrease in HC content during ripening varies among species and cultivars and is closely related to softening (Brummell, 2006; Vicente et al., 2007; Figueroa et al., 2010; Sun et al., 2013). In the present study, the HC contents of the three melon cultivars decreased to different degrees during ripening (Figure 6). However, no significant changes were observed in CL content during ripening (Table 1), in agreement with previous studies (Bennett and Labavitch, 2008; Figueroa et al., 2010). These results suggest that the changes

in HC content are more important than changes in CL content in the softening of fruits. Altogether, the results suggest that melon softening may be related to polysaccharide degradation during ripening. The detailed mechanism is an interesting topic for further study.

3 Materials and Methods

3.1 Plant materials

Three melon cultivars (15B-42-1, 15B-42F-1, and 04-38F-1) were grown in a greenhouse at the Shanghai Academy of Agricultural Science, Shanghai, China under natural light. Irrigation was carried out according to standard practices. The fruits were classified into three different developmental stages according to the color of the receptacle: the white fruit stage (W); turn color fruit stage (T); and mature stage fruit (M). The mesocarp tissues were sampled from the center-equatorial portion of each fruit. All samples were frozen in liquid nitrogen and stored at -80°C for further analysis. Five individual fruits were chosen at each time point and used for later analysis. Each point therefore represents the average of five samples. Error bars represent standard deviations (±SD).

3.2 Experimental site

The field experiment was conducted at the Shanghai Academy of Agricultural Science in Shanghai, China in autumn 2020 and spring 2021. Shanghai is located at 121°10"N longitude, 31°15"E latitude within the subtropical monsoon climate zone with the average temperature of 16°C. Rainfall is mainly concentrated from May to September. The average annual rainfall is 1 200 mm, the average evaporation is 1 400 mm, and the frost-free period is approximately 230 days. The air temperature, soil temperature, and humidity were recorded using probe-type temperature and humidity recorders (DL-WS211 and DL-W111). Data were recorded every 30 min, and the daily average temperature and humidity were calculated based on the recorded data.

3.3 Fruit quality traits

The soluble sugar content was determined by anthrone colorimetry. The soluble protein content was determined by coomassie blue staining. The content of vitamin C (ascorbic acid) was measured using the 2,6-dichlorophenol-indophenol dye method (Law et al., 1983). Total free amino acids were determined using 2,4-dinitrofluorobenzene according to the method of Chen et al. (2009).

3.4 Carbohydrate content

Glucose (Glc), sucrose (Suc), and fructose (Fru) were extracted from 0.1 g samples using the methods of Zommick et al., (2014) with some modifications. The supernatant was collected used for the determination of Glc, Suc, and Fru contents based on the microplate methods of Bergmeyer et al. (1974), Bernt and Bergmeyer (1974).

3.5 Cell wall materials

Cell wall materials were assayed as described in Melton and Smith (2005) with some modifications. Melon fruit (10 g) was homogenized in 80% ethanol (v:v) followed by the addition of 30 mL of 80% ethanol kept in a water bath at 90°C for 1h, cooling, and filtering through glass filter paper. Next, 30 mL of 90% dimethyl sulfoxide was added at 25°C, 200 r/min shaking extraction for 6 h followed by re-filtering. The residue was extracted for 4 h with 30 mL of chloroform: methanol (1:1, v:v), filtered, and washed with 30 mL of acetone. The resulting cell wall materials were then dried for 12 h at 45°C and weighed.

Next, a series of extractions was carried out to create different soluble cell wall fractions. After each extraction, the slurry was centrifuged, the supernatant was retained, and the pellet was resuspended in the next solvent. The extraction series and corresponding fractions were as follows: 10 mL ultrapure water for 4 h at 25°C (water-soluble pectin, WSP); 10 mL 50 mmol/L cyclohexane-diamine-tetraacetic acid (CDTA) solution for 4 h at 25°C (ionic soluble pectin, ISP); 10 mL 50 mmol/L Na_2CO_3 solution for 4 h at 25°C (covalent soluble pectin, CSP); and 200 mL 4 mol/L KOH solution for 5 h at 25°C (HC); and 30 mL 60% H_2SO_4 solution at 25°C and 200 r/min shaking extraction for 0.5 h, centrifugation at 12,000×g for 15 min, pipette of 5 mL of supernatant and to 50 mL (CL). The carbazole colorimetric method was used to determine the contents of different soluble pectin

substances following Wang et al. (2019) with slight modification. The HC and CL contents were determined using the anthrone-sulfuric acid colorimetric method according to Cao et al. (2007) with slight modification.

3.6 Carbohydrate metabolizing enzyme activities

Sucrose phosphate synthase (SPS; EC 2.4.1.14) and sucrose synthase (SS; EC 2.4.1.13) were extracted according to the method of Doehlert and Felker (1988), and the SPS and SS activities were assayed using the method of Rufty and Huber (1983). Fruits (0.5 g) were homogenized with 5 mL Hepes-NaOH buffer (pH 7.5) and then centrifuged at 12,000×g for 10 min at 4°C. The supernatant was collected for the measurement of enzyme activity. The reaction mixtures contained 50 μL Hepes-NaOH (pH 7.5), 20 μL 50 mM $MgCl_2$, 20 μL 100 mM uridie diphosphate glucose (UDPG), 20 μL 100 mM fructose-6-phosphate, and 50 μL crude enzyme. After incubation at 30°C for 30 min, 200 μL of 40% NaOH was added to stop the reaction. Next, the reaction mixture was kept in boiling water for 10 min followed by the addition of 2.8 mL of 30% HCl and 0.8 mL of 0.1% resorcinol. After incubation at 80°C for 10 min, the absorbance was measured at 485 nm. The SS activity was determined similarly except that fructose was substituted with fructose 6-phosphate.

The activities of soluble acid invertase (AI; EC 3.2.1.26) and neutral invertase (NI; EC 3.2.1.26) were determined following the method of Schaffer et al. (1987) with some modifications. Samples were homogenized with liquid nitrogen and mixed with 4 mL of buffer solution (200 mM potassium phosphate, pH 7.5) containing 0.1% β-mercaptoethanol, 5 mM $MgCl_2$, 0.05% bovine serum albumin (BSA), 0.05% Triton-X100, and 2% polyvinylpolypyrrolidone (PVPP). After incubation at 4°C for 20 min and centrifugation at 12,000×g for 30 min at 4°C, the supernatant fraction was collected and made 80% saturated with $(NH_4)_2SO_4$. The supernatant solution was allowed to stand for 30 min and centrifuged at 12,000×g for 20 min at 4°C. After discarding the supernatant, desalted buffer solution (200 mM potassium phosphate, pH 7.5) was added. The enzyme extract was used to determine the enzyme activity. The AI and NI activities were measured according to Ranwala et al. (1991) with some modifications. The enzyme extract (0.1 mL) was mixed with 0.7 mL of 80 mM acetic acid-sodium acetate buffer (pH 4.5) and 0.2 mL of 100 mM sucrose followed by incubation for 30 min at 37°C. The reaction was terminated by the addition of 1.5 mL of 3,5-dinitrosalicylic acid (DNS) reagent followed by incubation in boiling water for 5 min. The absorbance was then measured at 540 nm. The NI activity was determined in a similar way except that the sodium acetate buffer was substituted with potassium phosphate buffer.

3.7 Cell wall degrading enzyme

The PG, β-Gal, and Cx activities were measured using specific enzyme assay kits (PG-1-G, GALB-1-Y, and CL-1-Y, respectively; Suzhou Comin Biotechnology Co., Ltd, China) according to the manufacturer's instructions with separate 0.1g samples.

3.8 Statistical analysis

Two independent experiments were performed with three replicates in each treatment. Data were statistically analyzed using Duncan's multiple range test at the 0.05 level of significance. Charts were made using Origin 8.0 software.

4 Conclusions

We have explored the changes in fruit quality and textural properties of three melon cultivars grown under different environmental conditions. The air and soil temperature were generally higher in spring than in autumn. The seasonal variations in the air and soil temperatures affected the quality of melon fruit by influencing the contents of soluble protein, vitamin C, and total free amino acid along with the activities of SPS and SS, which are related to the Suc content. However, the difference in temperature between spring and autumn had little effect on the texture of melon fruit. In both spring and autumn, the WSP and ISP contents constantly increased during melon fruit ripening, whereas the CSP content decreased. The CL and HC contents of the three melon cultivars decreased to different degrees during ripening. The results also suggest that the activities of PG, PME, and β-GAL play important roles in the transformation of melon fruit texture.

Authors' Contributions

DQN was the executor of the experimental design and research in this study. CYY, YDW and ZWX completed the data analysis, and the first draft of the paper. XYP participated in the experimental design and the analysis of experimental results. DQN, ZYP and FHW were the project designer and director, guiding experimental design, data analysis, manuscript writing and revision. All authors read and approved the final manuscript.

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