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Quality Changes of Muscat of Alexandria Table Grapes as Influenced by Postharvest Cluster Stem Excision

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In 2003 and 2004, the potential of using table grapes, cv. Muscat of Alexandria, as fresh-cut products was evaluated by investigating the effects of postharvest cluster stem excision on several quality attributes. Clusters were harvested either at 17 or 19°Brix from mature grapevines grown in Okayama, Japan. The treatments included: (1) No excision (C): Intact clusters; (2) Excision at laterals (L): Branches carrying 2–7 berries; and (3) Excision at pedicels (P): Single berries without pedicels. Fruit was placed in commercial packages and stored for 6 days at 25°C. As regards aroma, linalool production by P increased markedly without major changes in the other monoterpenes. In addition, high geraniol production was observed in C, while minor aroma changes were observed in L. Total amino acid concentrations increased in P and C in comparison to L. Interestingly, at the end of the experiment, berries of treatment P had the highest firmness and visual quality, followed by C, while L was the lowest. It is concluded that grapes of Muscat of Alexandria are suitable for stemless marketing.

Key words : grape, postharvest, quality, cluster stem, fresh-cut.

Introduction

Nowadays the demand for high quality and attractive fresh-cut fruit and vegetables is increasing rapidly. The commercial preparation of fresh-cut produce may include de-stemming, trimming, cleaning, washing, sorting, peeling, slicing, coring, shredding, or chopping. Several terms are used to refer to the fresh-cut produce, e.g. lightly, minimally, partially and freshly processed or pre-prepared[12]. Considerable literature focuses on the postharvest behavior of fresh-cut fruit and vegetables[2]. However, little is known about the physiological responses of table grapes to fresh-cut preparation procedures. Preparations of fresh-cut table grapes primarily involve a partial or even complete cluster stem excision. In other cases, marketing of table grapes is done on the basis of package size, weight, or dimensions, which may require cluster trimming or partitioning. Previous work on table grapes revealed that different cluster components have different metabolic activities[6]. These differences may have implications on quality and shelf life. Consumers judge quality of fresh fruit on the basis of visual quality at the time of initial purchase and subsequent purchases are dependent on edible quality[7]. In this study we examined the effect of postharvest cluster stem excision on visual and edible quality of table grapes, cv. Muscat of Alexandria.

Materials and Methods

Plant material and growth conditions

The experiment was conducted over two seasons (2003 and 2004) at the Faculty of Agriculture of Okayama University in Okayama City (long. 133.92° E, lat. 34.66° N), Japan. Fifty clusters of *Vitis vinifera* L., cv. Muscat of Alexandria, were used. Soluble solids (°Brix) were measured at harvest in the field by means of a hand-held refractometer (Atago ATC-1E). In 2003, all clusters were harvested at 19°Brix from grapevines grown in the Okayama University Experimental Vineyard; the average cluster weight was 498.52 g (± 26.92). In 2004, clusters were harvested at 17°Brix from vines grown in a commercial vineyard near Okayama City, with an average cluster weight of 535.88 g (± 57.45). Samples were immediately transported to the laboratory. The treatments included: (1) No excision (C): Intact clusters; (2) Excision at lat-

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erals (L): Branches carrying 2–7 berries; and (3) Excision at pedicels (P): Single berries without pedicels. Fruit was placed in commercial packages and treatments were continued for 6 days in an incubator at 25 °C.

Sampling and analyses in 2003

Headspace volatile collection and GC analysis: Aroma collection was assessed on day 0, 3, and 6 of the experiment. Intact clusters, laterals, and berries were enclosed in 2.5 l glass jars (= one replicate); 6 replicates were used per treatment. A stream of air (600 ml·min^{-1}) passed through a Molecular Sieve 5A column (a water trap) and a liquid oxygen bath (a volatile cold trap) and then through the jars. The outlet air passed through a Tenax–TA column and the headspace volatiles were trapped for 2 h at 25 °C. Headspace volatiles were analyzed by connecting the Tenax–TA column using a flash sampler (Shimadzu FLS–1) to a GC (Shimadzu GC–14A) equipped with a FID detector. Analytical conditions: column, 3 mm × 2 m packed with PEG–20 M 10 %, Uniport–HP 80/100 mesh; carrier gas, N_2, 40 ml·min^{-1}; column temperature, from 70 °C to 220 °C (5 °C·min^{-1}); injection temperature, 170 °C; detector temperature, 230 °C. At the end of the storage, firmness of 10 berries per treatment was determined as the force inducing 10 % deformation of fruit diameter (30 mm · min^{-1}), using a deformation tester (flat steel plate UL–5LK, CAP.: 50 N, diameter: 30 mm, Orientec Corp.) mounted on a Tensilon machine (STM–T–50, Toyo Baldwin).

Sampling and analyses in 2004

All the quality parameters were assessed on day 0, 3, and 6, and each treatment was replicated 3 times. Volatile extraction and GC analysis: 5 berries per treatment were randomly sampled, deseeded, and homogenized (= one replicate). Ten grams of the homogenate were poured into a separation funnel with 10 μl of 2–octanol 0.1 % (as internal standard) and 50 ml of n-pentane. Monoterpenes were extracted by shaking for 6 min. The supernatant was dehydrated with Na_2SO_4 anhydride and concentrated to 0.3 ml *in vacuo*. A one μl aliquot was injected into the GC port (Shimadzu GC–14 A). Analytical conditions: CBJ – WAX capillary column, 0.5 mm × 30 m; N_2 as a carrier gas at 40 ml · min^{-1}; column temperature was held initially at 70 °C and increased at 5 °C · min^{-1} to 220 °C and held at the final temperature. Injection temperature was at 170 °C and detector temperature 230 °C. Another 20 berries were peeled off, deseeded, and the flesh was homogenized (= one replicate). The homogenate was centrifuged at 6,500 rpm for 10 min. The supernatant was used for the analysis of amino acids, sugars, and organic acids. As regards amino acids, a 0.5 ml aliquot of sample juice was mixed with 1 ml of water and 0.5 ml of 40 % TCA. After standing for an hour at 5 °C, the mixture was centrifuged at 5,000 rpm for 5 min at 4 °C. The supernatant was washed 3 times with 2 ml of diethyl ether to remove excess TCA. After removing the diethyl ether from the mixture *in vacuo*, the sample solution was filtered then analyzed by an automatic amino acid analyzer (JEOL JLC–300). For sugars and organic acids, two ml of juice aliquot was loaded to a column of Amberlite CG–120 (H^+) ion-exchange resin. The column was eluted with 48 ml of deionized water. The eluate was collected and was analyzed by HPLC (HITACHI L–7100). HPLC conditions for sugars: column, Shodex Asahipak NH2P–50 4E, 4.6 mm × 250mm; detector, RID–10A SHIMADZU; mobile phase, CH_3CN : H_2O = 75 : 25; flow rate, 1 ml · min^{-1}; column temp, 40 °C. HPLC conditions for organic acids: column ODS, 4.6 mm × 250 mm; detector, UV–VIS Detector (HITACHI L–7420); wave length, 210 nm; mobile phase, 0.1 M $NH_4H_2PO_4$ (pH 2.5 adjusted by H_3PO_4); flow rate, 0.6 ml · min^{-1}; column temp, 40 °C.

Data analysis was done by a one-factor ANOVA. Mean comparisons were performed using the Tukey-Kramer test to examine differences among treatments. Significance was determined at $P < 0.05$ or $P < 0.01$.

Results and Discussion

The volatile aroma production in Muscat of Alexandria grape berries responded to the postharvest treatments. Table 1 shows that, in 2003, linalool emission by P–berries increased significantly ($P < 0.05$) at day 6 of experiment compared to C–berries, whereas L–berries did not differ significantly from the other treatments. Compared with L– and P–treatments, the emission of geraniol was markedly higher in C–berries ($P < 0.01$). In 2004, the concentration of linalool in P–berries increased after 3 d of storage at 25 °C to approximately 46 μg·100 g^{-1} FW, *i.e.* it was significantly higher ($P < 0.05$) than that of C– and L–berries (Table 2). Concentrations of linalool did not continue to increase to the higher levels which were seen in the first season. The concentration of geraniol increased significantly ($P < 0.05$) in C–berries to approximately 212 μg·100 g^{-1} FW, and also fell again by the end of the experiment, while stem excision treatments resulted in low geraniol levels. After 6 d of storage, the nerol concentration increased significantly ($P < 0.05$) in P–berries in comparison to C– and L–berries. In our study, the postharvest aroma changes took place in

Table 1 Effect of postharvest cluster stem excision on aroma emission from Muscat of Alexandria grape berries

Treatment[a)]	Linalool	α-Terpineol	Citronellol (ng·100 g^{-1} FW)	Nerol	Geraniol
Day 0					
C	11.04 ± 3.98[b)c)]	5.63 ± 1.68	1.41 ± 0.87	2.17 ± 0.69	1.91 ± 0.45
Day 3					
C	13.22 ± 3.87 a	3.88 ± 1.95 a	Trace	2.51 ± 0.62 b	21.31 ± 1.01 A
L	11.50 ± 4.03 a	4.09 ± 1.77 a	1.39 ± 0.39	3.87 ± 0.75 a	5.79 ± 1.69 B
P	19.53 ± 4.76 a	2.74 ± 0.75 a	Trace	3.01 ± 0.65 ab	2.55 ± 1.48 B
Day 6					
C	8.54 ± 3.40 b	3.17 ± 1.71 a	Trace	3.39 ± 0.44 a	9.40 ± 1.46 A
L	13.67 ± 5.89 ab	3.56 ± 0.60 a	Trace	4.00 ± 0.53 a	1.96 ± 0.86 B
P	20.36 ± 3.70 a	2.57 ± 1.18 a	Trace	4.12 ± 0.89 a	2.71 ± 1.24 B

[a)]C = No excision; L = Excision at laterals; P = Excision at pedicels.
[b)]Values in columns followed by the same letter are not significantly different. Uppercase letters indicate significant difference at $P < 0.01$; lowercase letters indicate significant difference at $P < 0.05$.
[c)]Values are means ± standard deviation, n = 6.

Table 2 Effect of postharvest cluster stem excision on aroma concentration in Muscat of Alexandria grape berries

Treatment[a)]	Linalool	α-Terpineol	Citronellol (μg·100 g^{-1} FW)	Nerol	Geraniol
Day 0					
C	32.75 ± 11.75	18.21 ± 1.05	16.80 ± 1.46	59.71 ± 11.98	151.18 ± 8.07
Day 3					
C	31.57 ± 2.50 b	19.35 ± 2.77 a	19.67 ± 4.64 a	66.10 ± 15.43 a	212.09 ± 21.85 a
L	32.35 ± 4.22 b	18.21 ± 0.24 a	17.29 ± 1.41 a	60.45 ± 15.79 a	154.43 ± 28.89 ab
P	46.47 ± 8.40 a	18.00 ± 0.39 a	16.92 ± 0.31 a	61.24 ± 14.69 a	138.21 ± 30.93 b
Day 6					
C	19.78 ± 3.17 a	19.98 ± 2.84 a	19.08 ± 3.53 a	51.45 ± 5.79 b	168.68 ± 28.98 a
L	27.34 ± 2.35 a	17.83 ± 0.79 a	17.00 ± 0.75 a	56.82 ± 6.12 ab	138.52 ± 3.59 a
P	32.70 ± 11.28 a	19.15 ± 0.56 a	18.52 ± 2.09 a	71.24 ± 9.10 a	168.27 ± 33.72 a

[a)]For details, see Table 1, n = 3.

the major contributors to the aroma of Muscat of Alexandria grapes, in particular linalool, geraniol and nerol, while slight changes were observed in α-terpineol and citronellol. This is in agreement with previous observations indicating that clusters of Muscat of Alexandria, stored under room temperature, emitted high levels of volatile monoterpenes 2 d after harvest[11)]. Investigations for the postharvest aroma production in Muscat grapes are few. In non-climacteric grapes, cv. Agiorgitiko[4)], and strawberries, cv. Kent[9)], and climacteric apples, cv. Fuji[1)], a significant release of aroma volatiles was recorded during storage. However, little is known about the increased release of free aroma volatiles after harvest; the rate of release depends on the volatility of the monoterpene and the properties of cellular and intracellular membranes through which the compound has to diffuse[5)]. At harvest, the concentration of total amino acids in the control sample juice was 17.82 mmol·l^{-1} (Table 3). After 3 d of storage at 25 °C, the concentration in C increased to 22.95 mmol·l^{-1}, *i.e.* it was greater than that for L and P, but the differences were only significant ($P < 0.05$) between C and L. However, at day 6 of the experiment, juice of treatment P had the highest amino acid concentration of approximately 25 mmol·l^{-1} which was only significantly different ($P < 0.05$) from L. Arginine was the predominant amino acid in Muscat of Alexandria berry juice, followed by alanine, proline, γ-aminobutyric acid, and glutamic acid. In our study, most amino acids differed significantly among treatments. Similarly, a significant increase in the concentration of most amino acids of grapes under carbon dioxide atmosphere storage was previously shown[4)]; especially for γ-aminobutyric acid and glycine, but not for glutamic acid. Additional investigation is

Table 3 Amino acids concentration in Muscat of Alexandria berry juice as affected by postharvest cluster stem excision

Treatment[a)]	ARG	ALA	GABA	PRO	GLU	SER	THR	ASP	GLN	HIS	Others	Total
	(mmol · l^{-1} juice)											
Day 0												
C	8.91	2.30	1.26	1.42	0.93	0.45	0.40	0.38	0.31	0.27	1.19	17.82 ± 0.36
Day 3												
C	11.71 A	2.37 a	1.50 ab	2.42 A	1.22 a	0.57 a	0.50 A	0.51 a	0.28 a	0.37 A	1.50 a	22.95 ± 0.88 A
L	8.25 B	1.92 a	1.29 b	1.40 B	1.02 a	0.45 b	0.37 B	0.45 a	0.24 a	0.27 B	1.17 b	16.85 ± 0.41 B
P	9.69 AB	2.13 a	1.61 a	2.18 A	1.14 a	0.51 ab	0.43 AB	0.48 a	0.25 a	0.28 B	1.25 b	19.97 ± 2.56 AB
Day 6												
C	11.71 A	2.11 b	1.54 a	1.65 b	0.90 c	0.47 B	0.43 b	0.41 B	0.40 a	0.39 a	1.72 a	21.74 ± 2.19 A
L	8.02 B	1.43 c	1.13 b	1.42 b	1.08 b	0.42 B	0.35 b	0.46 B	0.22 b	0.26 b	1.19 b	15.98 ± 0.62 B
P	13.09 A	2.69 a	1.69 a	2.06 a	1.21 a	0.61 A	0.53 a	0.55 A	0.34 ab	0.42 a	1.74 a	24.92 ± 1.12 A

[a)]For details, see Table 1, n = 3.

Table 4 Sugars and organic acid contents in Muscat of Alexandria berry juice as influenced by postharvest cluster stem excision

Treatment[a)]	Glucose	Fructose	Glucose/ Fructose ratio	Tartaric acid	Malic acid	Tartaric/ malic acid ratio
	(g·100 ml^{-1})			(g·100 ml^{-1})		
Day 0						
C	8.66 ± 0.60	8.18 ± 0.15	1.06	0.28 ± 0.01	0.20 ± 0.02	1.40
Day 3						
C	8.33 ± 0.29 a	8.08 ± 0.10 a	1.03	0.29 ± 0.00 A	0.26 ± 0.00 a	1.12
L	7.74 ± 0.09 a	7.72 ± 0.13 b	1.00	0.27 ± 0.01 B	0.21 ± 0.02 b	1.29
P	8.01 ± 0.40 a	7.67 ± 0.18 b	1.04	0.27 ± 0.01 B	0.25 ± 0.01 a	1.08
Day 6						
C	7.96 ± 0.62 a	7.71 ± 0.24 b	1.03	0.27 ± 0.01 B	0.23 ± 0.01 a	1.17
L	8.04 ± 0.16 a	8.08 ± 0.10 ab	1.00	0.28 ± 0.00 B	0.23 ± 0.01 a	1.22
P	8.57 ± 0.87 a	8.23 ± 0.32 a	1.04	0.34 ± 0.01 A	0.24 ± 0.03 a	1.42

[a)]For details, see Table 1, n = 3.

needed to interpret this point. Glucose, fructose, and glucose to fructose ratios are given in Table 4. At harvest, the glucose to fructose ratio was 1.06. Thereafter, the ratios decreased in all treatments and the average ratios for C, L and P fruits were respectively 1.03, 1.00 and 1.04 after 3 and 6 d of storage, a result which may indicate a slight change in sweetness (greater proportion of fructose than glucose). Concentration of fructose differed significantly among treatments ($P < 0.05$), while no significant changes were observed for glucose. During grape berry maturation, the enzymatic conversion of glucose to fructose, with sorbitol as an intermediate, might be responsible for the changes in the glucose to fructose ratios[8)]. Simultaneous decreases in the tartaric to malic acid ratios were also observed in all treatments with some fluctuations in treatment P (Table 4). Concentration of tartaric acid tended to change remarkably among treatments ($P < 0.01$). Postharvest cluster stem excision affected the physical quality of the fruit (Fig. 1). At the end of the experiment, and contrary to what was expected, P-berries had the highest firmness value of 5.65 N, followed by C- and L-berries. The differences were only significant ($P < 0.05$) between P and L. Table grapes are subject to cumulative water losses between harvest and consumption, which may lead to stem drying and browning, berry shatter, and wilting and shriveling of berries[10)]. Previous study on grapes, cv. Flame seedless[6)], showed that stems are more prone to dehydration than berries, and that the average respiration rates of complete clusters, berries, and stems were 8.7, 7.5, and 211.1 mL $CO_2 \cdot kg^{-1} \cdot h^{-1}$, respectively. Textural differences in our study may be attributed to the degree of water loss and the rate of respiration, although this would require further testing. From Fig. 2 it can be seen that C- and L-treatments exhibited an increase in stem browning symptoms after 3 and 6 d of storage; Moreover, by the end

Fig. 2 Postharvest visual quality of Muscat of Alexandria grapes as influenced by cluster stem excision. Fruit was kept at 25 °C for six days. For treatments, see Table 1.

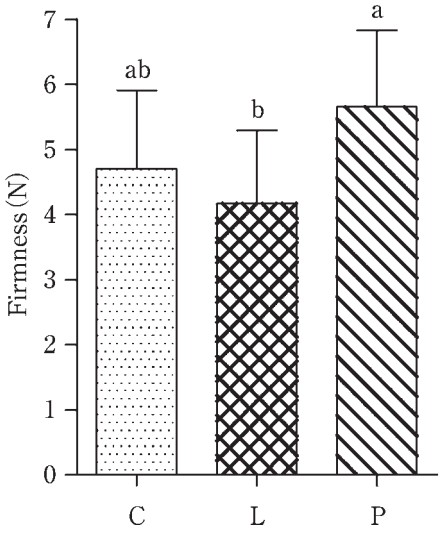

Fig. 1 Effect of postharvest cluster stem excision on firmness of Muscat of Alexandria grape berries kept at 25 °C for six days (measured as the force that induced 10% deformation of berry diameter). T bars = SD, n = 10. Lowercase letters above SD bars indicate significant difference at $P < 0.05$. For treatments, see Table 1.

of the experiment, they resulted in pronounced shrinking at the junctions of the laterals with the rachis and the pedicels with the laterals, as well as the incipient of visible symptoms of berry shriveling and berry abscission. In terms of appearance quality, these symptoms may render the table grapes commercially unacceptable. In contrast, berries of treatment P were still turgid with more fresh appearance and consistent visual quality. Water loss and the high rate of respiration of stems are the main contributors to stem browning which is the major limitation to the cluster's postharvest life[3,6].

Conclusion

In this study we evaluated the potential of using Muscat of Alexandria table grapes as fresh-cut products for the local market. We found that excision of laterals and pedicels significantly affect several quality aspects of fruit. Stemless grapes maintained the best edible and visual quality, followed by intact clusters, while laterals were the lowest. We believe that the potential for using table grapes as fresh-cut products will be of great importance in the near future. Thus, further investigations for keeping quality and safety, especially under low temperature conditions, as well as studies to elucidate the physiological mechanisms involved in quality changes, are warranted.

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マスカット・オブ・アレキサンドリア収穫果房の切り分けが果実品質に及ぼす影響

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マスカット・オブ・アレキサンドリアの果房がカットフルーツとして適するかどうかを，2003年と2004年に検討した．岡山で生産された完熟した果房を，房全体のまま（果房），穂軸を切り離して２―７果粒の小房に切り分け（切り房），小果梗で切り離して個々の果粒に切り分け（果粒），の３区とした．これらを箱詰めし，25℃で６日間，保蔵した．保蔵中の果実の品質変化を分析した結果，主要な香気成分であるリナロールは果粒ごとの区で最も大きく増加し，ゲラニオールの増加は果房のままの区で大きかった．全アミノ酸含量の増加は，切り房区に比べて果粒区と果房区で大きかった．しかし，果粒区では保蔵後の果粒硬度が最も高く，外観も優れ，次いで果房区，切り房区の順であった．以上の結果から，マスカット果房を小果梗で切除し，果粒単位の状態で出荷することによって品質を最も高く保つことが可能である．

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