Effects of different fruit-preserving and puffing-fruit formulations on the formation of berry russet and fruit quality of ‘Shine Muscat’ Grape

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Abstract. In this study, 5 years-old ‘Shine Muscat’ grapes were used as experimental materials to study the effects of different fruit-preserving and puffing-fruit formulations on the formation of fruit russet and fruit quality of ‘Shine Muscat’ grapes by using random block experiment and spraying water as control. The results showed that J3 treatment significantly decreased the fruit russet index, but significantly increased the fruit weight, brightness value, yellow saturation and soluble sugar content of ‘Shine Muscat’ grapes. The content of phenolic compounds in pericarp was decreased by different formulas, which indicated that the formation of fruit russet was closely related to the accumulation of phenolic compounds. The content of lignin in the pericarp was decreased by different treatments at fruit ripening stage, and the content of lignin in J3 treatment was the lowest, which indicated that it inhibited lignin production. The results of this experiment can provide guidance for the high-quality production of ‘Shine Muscat’ grape.

1. Introduction
Under the natural fruit-setting conditions of ‘Shine Muscat’ grapes, when the ear is sparse, the fruit setting is unstable, the size of the fruit is large and the fruit is fully mature, the fruit surface will have different degrees of fruit rust [1-3], which seriously affects the yield, quality and commercial property of the grapes and reduces the benefit. In the actual production, a variety of fruit preserving and swelling products are widely used, which play a regulatory role in the growth and development of ‘Shine Muscat’ grapes, so as to achieve the effect of increasing and stabilizing yield. Due to the improper use of time, type and concentration of the fruit-preserving and bulky formula, the hollow percentage and hardness of the ‘Shine Muscat’ fruits would increase, the coarseness of the fruit stem would be increased, and the postharvest grains would fall easily, and the content of soluble solids would be reduced [4]. At present, the commonly used formulas of ‘Shine Muscat’ to keep fruit and bulge fruit include plant growth regulator combination formula and compound formula containing trace elements or other special ingredients. In actual production, the formula used by the growers is different, the results were mixed, in order to improve the commercial of ‘Shine Muscat’ grapes, enhance market competitiveness, this study aimed at ‘Shine Muscat’ grapes fruit swelling formula comparison and selection, and explore different insurance fruit swelling formula for ‘Shine Muscat’ grapes fruit rust formation and the influence of important fruit quality, for ‘Shine Muscat’ grapes quality and production to provide important theoretical basis.
2. Materials and methods

2.1. Materials

Plant materials: the 5 years-old ‘Shine Muscat’ grape with the same tree potential, consistent soil, fertilizer and water management in the field in the modern agricultural research and development base of Sichuan Agricultural University, free of diseases and pests, and robust growth. Plant spacing was 1.5m×3.0m, and 150 plants were planted 667m².

Experimental drugs: gibberellin (GA₃), forchlorfenuron (CPPU) and thiabenolon (TDZ), all produced by Sichuan Lanyue Science and Technology, the net content of GA₃ crystal powder was 1g/package, and the active ingredient content was 75%;The net content of chlorfenuron was 20ml/ vial, and the active ingredient was 0.1%. The net content of thiabenolon was 5.5g/package, and the active ingredient content was 0.8%.DBY powder (mainly composed of zinc, boron, molybdenum and Marine biological extracts) and gibberellic acid for ‘Shine Muscat’ grape produced by Zhengzhou Fruit Research Institute, Sichuan run er, science and technology co., LTD production of guoguang protect fruit formula No.1 (30mL 0.1% S - inductin, 30mL 0.1% forchlorfenuron, 10mL humic acid,30mL 4% gibberellie , the 10 kg of water clusters) and swelling formula No.2 (50mL 0.1% S-inductin, 50mL 0.1% forchlorfenuron ,10mL humic acid,10mL 4% gibberellic, against the 15 kg water clusters).

2.2. Experimental design

10 days before flowering, ear pruning was carried out, auxiliary ears were removed, ear tips were pruned 1-2cm, and final ears were left 6-7cm.At the anflorescence stage (from 80% to 2-3 days after anflorescence), the fruit preservation and bulking treatments were performed with plant growth regulators on 10-15 days after anflorescence, along with fungicides and insecticides. Randomized block design was adopted for the experiment.J1: Guoguang Fruit-preserving Formula No. 1, Guoguang Fruit-swelling Formula No. 2 Fruit-puffing; J2: DBY Fruit-preserving, ‘Shine-Muscat’ special gibberellic acid Fruit-puffing;J3: 20mg·L⁻¹GA₃ +3.0mg·L⁻¹TDZ fruit-preserving, 25mg·L⁻¹GA₃ + 3.0mg·L⁻¹CPPU Fruit-puffing; CK1 (routine management):20mg·L⁻¹GA₃+3.0mg·L⁻¹CPPU fruit-preserving,25mg·L⁻¹GA₃+ 3.0mg·L⁻¹CPPU Fruit-puffing, water for fruit-preserving and Fruit-puffing (CK2).Five trees were used as one treatment, and three replicates were set. Samples were collected 70 days after flowering, and the grapes were collected every 10 days until the fruits ripened.

2.3. Determination method

2.3.1. Statistics of fruit russet index. Referring to the method of Zhang Bo et al. [5], classification and russet rate statistics were carried out for each treated fruit during sampling. According to the degree of 'fruit russet', the fruits were graded as follows: the russet-free fruit was graded as 0, the area of 'fruit russet' < 5% was graded as 1, 6% ~ 15% was graded as 2, 16% ~ 25% was graded as 3, and > 25% was graded as 4.Fruit russet index = (grade 0 × A +1 × B +2 × C +3 × D +4 × E) ×100/ (grade 4 × N).Note: A, B, C, D and E are the statistical number of 0-4 grade fruit respectively, and N is the total number of samples.

2.3.2. Determination of phenolic compounds. The contents of total phenols, total flavonoids, flavonols and flavanols were determined according to the method of Yan Juan et al. [6]. Gallic acid was used to make the standard curve, and the total phenol content was expressed by gallic acid equivalent GAE·g⁻¹ FW. Rutin was used to make the standard curve, and the content of total flavonoids was expressed by Rutin equivalent Re·g⁻¹ FW. The standard curve was made by catechin, and total flavanols were represented by catechin equivalent Ce·g⁻¹ FW. Quercetin was used to make the standard curve, and the total flavonol was expressed as quercetin equivalent QE·g⁻¹ FW.

2.3.3. Determination of fruit quality indexes. When the fruits are ripe, samples of the same size, free of diseases and pests, are taken from all directions of the ears, quickly put into prepared ice boxes and
brought back to the laboratory. The content of soluble solids (TSS) in grapes was determined by a
dehandheld saccharometer. The titratable acid content (TA) was determined by acid-base neutralization
titration [7]. Determination of soluble sugar content by anthrone colorimetry [8]; The color of grapes
was measured by chromatimeter.

2.4. Data processing
The experimental data were processed by Microsoft Excel 2016 and Sigma Plot, and related charts
were drawn. SPSS 26.0 software was used for statistical analysis. The significance level of the
difference between the samples was 0.05.

3. Results and discussion

3.1. Statistics of fruit russet index and determination of lignin in ‘Shine Muscat’ grape in different
fruit-preserving and puffing-fruit formulations
The fruit russet index of ‘Shine Muscat’ grapes was collected from 70 days after anthesis (Figure 1).
At 70 d and 80 d after anthesis, none of the treatments produced fruit rust. At 90 d after anthesis, J1,
CK1 and CK2 began to produce fruit rust, and the fruit rust index increased rapidly with fruit ripening.
At 110 d after anthesis, the fruit rust index of J1, CK1 and CK2 was 23.7%, 42.3% and 47.8%,
respectively. Fruit rust began to appear in J2 and J3 treatment at 100 d after anthesis, and the fruit rust
index of J2 and J3 treatment at 110 d after anthesis was 8.5% and 3.9%, respectively, which was
negligible. The highest lignin content in CK2 pericarp was 51.86mg/g·DW, and there was no
significant difference in lignin content between CK2 and CK1, compared with J1, J2 and J3, the lignin
content of CK2 increased by 16.88%, 18.70% and 42.33%, respectively. The content of lignin in the
peel of CK1 was 49.83mg/g·DW, which was significantly higher than that of J2 and J3. The content
of lignin in the peel of CK2 was 81.81mg/g·DW, respectively, which was significantly higher than
that of other treatments at fruit ripening stage. These results indicated that the accumulation of lignin
led to the formation of fruit rust, and hormone regulation could inhibit the accumulation of lignin to a
certain extent and thus effectively inhibit the formation of fruit russet.

3.2. Effects of different fruit-preserving and puffing-fruit formulations on phenolic compounds in
grape skins of ‘Shine Muscat’ grape
As shown in Table 1, the total phenol content in the peel of different fruit-preserving and puffing-fruit
formulations was different at fruit maturity stage. The total phenol content in the peel of CK2
treatment was significantly higher than that of other treatments, and increased by 26.5%, 38.3%,
44.2% and 14.7%, respectively, compared with J1, J2, J3 and CK1. The content of total flavonoids in
pericarp of CK2 treatment was significantly higher than that of other treatments at fruit ripening stage,
and the order of total flavonoids content from large to small was CK2>CK1 > J1> J2> J3, content of
total flavonoids in pericarp of J1 and J2 treatment had no significant difference. Fruit maturation CK2 handle peel flavonoids and flavanol content were significantly higher than other processing, CK2 handle peel flavonol content relative J1, J2, J3 and CK1 increased by 16.8%, 22.3%, 27.5% and 3.4%, respectively, each processing peel flavanol content according to the order from big to small order is CK2 > CK1 > J1 > J2 > J3, CK1 and J1 flavanol content had no significant difference of the skin. In conclusion, the contents of total phenols, flavonols and flavanols in fruit peel of CK2 treatment were significantly higher than those of other treatments at fruit ripening stage.

Table 1. Effects of the phenolic compound of ‘Shine Muscat’ grape pericarp in different fruit-preserving and puffing-fruit formulations

| Treatment | Total phenol content (mg GAE·g⁻¹ FW) | Total flavonoids (mg RE·g⁻¹ FW) | Flavonol content (mg CE·g⁻¹ FW) | Flavanol content (mg QE·g⁻¹ FW) |
|-----------|--------------------------------------|----------------------------------|----------------------------------|----------------------------------|
| J1        | 38.86±1.06c                          | 3.75±0.09c                       | 1.55±0.04c                       | 15.34±0.58b                     |
| J2        | 35.54±1.50d                          | 3.64±0.15c                       | 1.48±0.02d                       | 14.54±0.18c                     |
| J3        | 34.08±0.09d                          | 2.79±0.03d                       | 1.42±0.01d                       | 13.73±0.29d                     |
| CK1       | 42.86±0.34b                          | 4.25±0.06b                       | 1.75±0.02b                       | 16.00±0.16b                     |
| CK2       | 49.15±0.56a                          | 5.29±0.11a                       | 1.81±0.03a                       | 18.04±0.09a                     |

3.3. Effects of different fruit-preserving and puffing-fruit formulations on the fruit quality of grapes

Appearance quality and inner quality of ‘Shine Muscat’ grape fruits were measured at the fruit ripening stage. The results are shown in Table 2 and Table 3. The single fruit weight of J3 treatment was significantly higher than that of other treatments, up to 14.32g, followed by the single fruit weight of J2 treatment, which was 12.66g, and the single fruit weight of CK2 was the least, only 9.30g. The longitudinal and transverse diameters of J2 treatment were significantly larger than those of CK2, but there was no significant difference compared with other treatments. There was no significant difference in fruit shape index among all treatments. The brightness value of J3 treatment was significantly higher than that of CK2, but there was no significant difference compared with other treatments. There was no significant difference in the red saturation of all treatments, and the yellow saturation of J2 and J3 was significantly higher than that of other treatments.

Table 2. Effect of different fruit-preserving and puffing-fruit formulations on the fruit appearance quality of ‘Shine Muscat’ grape

| Treatment | Single fruit weight (g) | Longitudinal diameter (mm) | Transverse diameter (mm) | Fruit Index | Lightness (L*) | a value (a*) | b value (b*) |
|-----------|-------------------------|----------------------------|--------------------------|-------------|----------------|-------------|-------------|
| J1        | 10.45±0.61c             | 27.03±1.06ab               | 23.40±1.73ab             | 1.16±0.08a  | 50.68±3.69ab   | -3.82±1.62a | 17.75±2.82b |
| J2        | 12.66±0.56b             | 30.93±2.55a                | 25.34±1.03a              | 1.17±0.13a  | 54.84±3.22ab   | -5.57±0.39a | 25.26±2.60a |
| J3        | 14.32±0.48a             | 29.77±0.60ab               | 25.64±2.12ab             | 1.16±0.12a  | 51.35±2.97a    | -4.26±1.49a | 22.16±1.63a |
| CK1       | 10.77±1.13c             | 28.56±1.59ab               | 24.14±2.08a              | 1.18±0.05a  | 48.83±2.30ab   | -3.91±0.98a | 16.46±3.65b |
| CK2       | 9.30±0.48c              | 27.11±1.70b                | 27.11±1.70b              | 1.16±0.03a  | 47.71±2.89b    | -3.87±1.23a | 17.41±1.88b |

There was no significant difference in the soluble solids of all treatments at fruit ripening stage, and the order from large to small was J3>CK2 >CK1> J1> J2. The soluble sugar content of J3 and CK2 treatments was higher, 16.46% and 16.26%, respectively, which were significantly higher than that of other treatments. J2 treatment had the highest titratable acid content, which was significantly higher than CK1 treatment, and had no significant difference with other treatments. Solid acid ratio is an important index to evaluate grape fruit flavor and maturity, the higher the ratio, the better the fruit flavor. The ratio of solid to acid in CK1 treatment was the highest, followed by J3 treatment, and the carbohydrate-acid ratio in descending order was CK1>J3> J2>CK2>J1. These results indicated that J3 treatment had better fruit appearance and internal quality than other treatments.
Table 3. Effect of different fruit-preserving and puffing-fruit formulations on the fruit interior quality of ‘Shine Muscat’ grape

| Treatment | Soluble solids (%) | Soluble sugar (%) | Titrateable acid(%) | Solid-acid ratio | Sugar-acid ratio |
|-----------|--------------------|-------------------|--------------------|------------------|-----------------|
| J1        | 18.77±2.46a        | 14.78±0.12c       | 0.38±0.02ab        | 49.16±4.16ab     | 38.99±2.39a     |
| J2        | 18.03±1.32a        | 13.45±0.14d       | 0.43±0.02a         | 42.48±3.11b      | 31.72±1.74b     |
| J3        | 19.90±2.09a        | 16.46±0.21a       | 0.39±0.03ab        | 50.58±2.34ab     | 42.20±3.90a     |
| CK1       | 19.30±0.54a        | 15.77±0.07b       | 0.36±0.03b         | 54.02±3.69a      | 44.17±3.32a     |
| CK2       | 19.57±0.99a        | 16.26±0.06a       | 0.42±0.03ab        | 47.21±2.73ab     | 39.33±2.78a     |

4. Conclusion
Through the treatment of ‘Shine Muscat’ grape with fruit-preserving and puffing-fruit formulations, the results showed that J3 treatment significantly decreased the fruit russet index, but significantly increased the fruit weight, brightness value, yellow saturation and soluble sugar content of ‘Shine Muscat’ grapes. The content of phenolic compounds in pericarp was decreased by different formulas, which indicated that the formation of fruit russet was closely related to the accumulation of phenolic compounds. The content of lignin in the pericarp was decreased by different treatments at fruit ripening stage, and the content of lignin in J3 treatment was the lowest, which indicated that it inhibited lignin production.

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