

Effects of bagging treatment on fruit quality and pesticide residues of 'Donghong' kiwifruit

Xuelian SANG, Zhixin LI, Wenlin ZHANG,
Jianmin TANG, Dengwei JUE*

Chongqing University of Arts and Sciences, College of Landscape Architecture and Life Science, Yongchuan 402160, Chongqing, China;
anyue1220@126.com; lizhexin_8903@163.com; zhangwenlin88519@126.com; Tangjmjy@163.com;
juedengwei@126.com (*corresponding author)

Abstract

In this study, the effects of bagging treatment on fruit appearance and internal quality, including fruit shape index, single fruit weight, fruit vitamin C, soluble solids, titratable acid, chlorophyll and carotenoid content, were studied by using 'Donghong' kiwifruit as experimental material. Meanwhile, the pesticide residues of bagged and non-bagged (NB) kiwifruit were compared and analyzed. Results showed that the pericarp color of bagged kiwifruit is lighter in green than that of NB group, with uniform color, cleaner appearance and no scabs and spots. Single fruit weight and transverse meridians of bagged kiwifruits were significantly increased. Interestingly, we found single bagging treatment had little effect on the internal quality of 'Donghong' kiwifruit. After pesticide treatment, the fruit shape of kiwifruit was rounder, significantly increased the weight, chlorophyll content of fruit, and decreased the content of vitamin C and carotenoids. In addition, bagging + pesticide treatment had additive effect on these characters. After bagging, the residues of pyraclostrobin and β -cypermethrin in 'Donghong' kiwifruit were significantly lower than those in the control. However, the residue of difenoconazole residues did not show significant difference. Bagging treatment has the ability to improve the appearance and reduce the residue of some pesticides. Meanwhile, the application of some pesticides can improve the single fruit weight and fruit quality. Therefore, bagging is a scientific and effective cultivation method in the green production of 'Donghong' kiwifruit.

Keywords: bagging; 'Donghong' kiwifruit; fruit quality; pesticide residues

Introduction

Kiwifruit (*Actinidia deliciosa*), known as the "king of fruit", are widely preferred by consumers due to their flavor and high value of nutrient compounds (such as vitamin C) (Niu *et al.*, 2023). Although, the kiwifruit industry first developed in New Zealand, kiwifruit is native to China and China has become the world's largest producer and consumer (Zhong *et al.*, 2021). In the past 44 years, more than 150 new kiwifruit cultivars, including 'Hongyang', 'Xuxiang', 'Cuixiang', 'Donghong', 'Guichang', 'Jinyan' and 'Miliang 1', were bred by using wild germplasm resources in China (Zhong *et al.*, 2021). Among these cultivars, 'Donghong' was selected from the F1 offspring of open-pollinated kiwifruit 'Hongyang' at Wuhan Botanical Garden, Chinese

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Academy of Sciences (Zhong *et al.*, 2016). Compared with ‘Hongyang’, the main Chinese red-fleshed kiwifruit cultivar, ‘Donghong’ has a better resistance to soft rot, and better performance under other stress, such as *Pseudomonas syringae* PV. *actinidiae* (Psa) of kiwifruit, heat and drought.

Chongqing is located in the eastern monsoon area south of Qinling Mountains-Huaihe River, with large temperature difference between day and night, abundant rainfall and abundant solar and thermal resources, which is very suitable for kiwifruit planting (Liao *et al.*, 2021). Because of its high nutritional value, ‘Donghong’ has also become the preferred fruit tree variety for the development of mountain economic agriculture in Chongqing. However, the rainy and humid climate in Chongqing makes ‘Donghong’ kiwifruit more vulnerable to diseases such as Psa and *Pseudopeziza medicaginis*.

Pesticide treatment is an indispensable part of modern agriculture, which is recognized by all countries with developed agriculture. Like other crops, in order to reduce the impact of diseases and pests such as Psa and *pseudopeziza medicaginis*, chemical pesticides, such as pesticides and fungicides, are used in kiwifruit production (Pang *et al.*, 2019). However, the application of these chemical pesticides may bring certain hidden dangers to the quality and safety of kiwifruit. Therefore, the cultivation of ‘Donghong’ kiwifruit needs to be healthier and environmentally friendly, such as bagging.

The bagging technique, which was first utilized in Japan in the 20th century for pears and grapes, has many benefits for fruit growing, such as keeps the surface of the fruit smooth, bright and pollution-free, and improves the commodity value with significant benefits with a sort of shield-a physical barrier around the fruit (Sharma *et al.*, 2014b). At present, bagging technology has been widely used in various fruit production, including kiwifruit. Bagging is an important part of green and efficient cultivation technology of kiwifruit. Previous studies showed that bagging technology applied in kiwifruit production had the following advantages (Yang *et al.*, 2019; Xu *et al.*, 2022):

- 1) Reducing pests and diseases;
- 2) Improve the appearance quality of fruit;
- 3) Prevent sunburn;
- 4) Reduce fruit drop and other advantages

However, the detailed effects of bagging treatment on fruit quality and pesticide residues of ‘Donghong’ kiwifruit is still limited. In the present study, the study of analyzing the effects of bagging treatment on fruit quality and pesticide residues of ‘Donghong’ kiwifruit was performed. Based on the results of this study, we found that bagging treatment has the ability to improve the appearance of ‘Donghong’ kiwifruit and reduce the residue of some pesticides.

Materials and Methods

Plant materials and treatment

Kiwifruit (*Actinidia chinensis* cv. ‘Donghong’), grown in kiwifruit experiment base of Chongqing University of Arts and Sciences, were used in this study. This experiment base is located in Cucumber Mountain, Yongchuan District, Chongqing City, with an average altitude of 600m (105.56E, 29.7N). It belongs to the subtropical monsoon climate. The average annual temperature of this region is 17.3 °C, the annual rainfall is 898 mm, the total sunshine throughout the year is 1145 hours, the maximum temperature is 37.5 °C, and the minimum temperature is 1 °C. The fruit bag is a dark yellow single-layer bag with a length of 16×11cm wide. The bagging time was June 1, 2020, and the samples were collected on September 1, 2020. During bagging, the young fruit is suspended in the middle of the fruit bag to avoid mechanical damage to the fruit handle. The pesticides sprayed are mainly the bactericide benzopyrazole ester (30% difenoconazole, 10% pyraclostrobin) and the insecticide β -cypermethrin, which are applied once before bagging and twice after bagging (diluted by 1/1200 for using).

Three nine-year-old trees with the same growth trend and similar flowering period of female flowers were selected for fruit observation or collection. Three fruits were collected from the east, south, west and north of the upper middle part of each tree. The phenotype and pesticide residues of the samples were measured immediately after taken back to the laboratory. The fruit quality of these samples was determined after the fruits naturally softened. B and NB represent bagging and non-bagging respectively. 1 and 2 represent pesticides treatment and non-pesticides treatment respectively, as shown in the following table:

Table 1. Different treatment methods

| Treatments | Groups |
|------------|---------------------------------------|
| B1 | bagging+ pesticides treatment |
| B2 | bagging+ non-pesticides treatment |
| NB1 | non-bagging+ pesticides treatment |
| NB2 | non-bagging +non-pesticides treatment |

Fruit quality

Fruit weight was determined by using a Lichen YP-B model digital scale, with a capacity of 0.01-2000 g. Fruit vertical diameter and horizontal diameter was determined by using an Delixi vernier caliper, with a capacity of 0.01-15 cm. The content of total soluble solids (TSS) was measured with manual digital refractometer (Pal-1, Atago). The titratable acidity in % of malic acid was obtained by using NaOH titration method (Tyl and Sadler, 2017). The content of vitamin C was determined by 2, 6- dichloro-indophenol titration method (Huang *et al.*, 2017). The dry matter weight of fruit was determined by referring to the method of Jordan *et al.* (2000). The method of extraction and determination of chlorophyll and carotenoids was followed by the description of Xia *et al.* (2021).

Pesticide residues detection

The analytical standards, pyrazolone, beta cypermethrin and difenoconazole were purchased from Dr. Ehrenstorfer GmbH (Augsburg, Germany). Acetonitrile and formic acid were HPLC grade obtained from the Dikema Company, Inc. (Beijing, China). Analytical grade of sodium chloride (NaCl) and anhydrous MgSO₄ were purchased from Beijing Chemical Company (Beijing, China). Ultra-pure water was obtained from Guangzhou Watson's Food & Beverage Co., (Guangzhou, China). Primary secondary amine (PSA) was obtained from Angela Technologies Inc. (Tianjin, China). Kobayashi Bag KM-2 was purchased from Qingdao Kobayashi Bag Mfg. Co., Ltd. (Shandong, China).

Samples (10 ± 0.1 g) were weighed into a 50 mL Teflon centrifuge tube. Then, 10 mL acetonitrile was added to extract pesticide. The tubes were capped and stirred for 5 min. 2 g NaCl and 4 g MgSO₄ were added and vortexed vigorously for 2 min. The tubes were immediately centrifuged (5000 rpm) for 3 min and then 2 mL of the upper layer (acetonitrile) was transferred into a 5 mL centrifuge tube, which contained an amount of sorbent (30 mg PSA and 150 mg MgSO₄). The extracts were vortexed for 1 min and subsequently centrifuged for 2 min at 5000 rpm. The supernatant was filtered by a 0.22 µm nylon syringe filter and transferred to an auto-sampler vial for the UPLC-MS/MS injection.

The Waters UPLC-MS/MS system consisted of a Waters Acquity UPLC system and a Waters (Milford, MA, USA) Xevo TQD triple quadrupole tandem mass spectrometer equipped with an electrospray ionisation (ESI) source were used in this study. The gradient program and the multiple reaction monitoring (MRM) mode were performed according to the methodology of Xu *et al.* (2018).

The method was validated according to "GB 23200.8—2016 determination of 500 pesticides and related chemical residues in fruits and vegetables by gas chromatography-mass spectrometry".

Data analysis

SPSS 17.0 and SigmaPlot 12.0 software are used for data statistics, analysis and mapping.

Results

Comparative analysis on phenotype and taste of 'Donghong' kiwifruit under bagging and non-bagging treatment

As shown in Figure 1 and Table 2, the pulp of these four treated groups is sweet, with a lot of juice. The shape of the fruit is regular and beautiful, with the fruit core is bright red, as the sun radiates around. Since belongs to the dark green hairless variety, the overall fruit surface of 'Donghong' is smoother. After bagging, the pericarp color of 'Donghong' is lighter than NB group, and the color is more uniform, without spots and scabs. Meanwhile, the ripening fruit of bagging group are sweeter, with the lower acidity. After the treatment of pesticides, the fruit is significantly larger and tends to be short and round, with the deeper color and cleaner fruit surface. However, there is no significant difference in the taste of fruits.



Figure 1. Bagging treatment of 'Donghong' kiwifruit phenotype

Table 2. Effects of bagging on the phenotype and taste of 'Donghong' kiwifruit

| Treatments | Fruit shape | Skin color | Fruit surface | Fruit core | Pulp taste |
|------------|----------------|--------------------------------|---------------|------------|------------------|
| B1 | Short cylinder | Green brown, uniform color | clean | Bright red | Sour sweet juicy |
| NB1 | Long cylinder | Yellow brown, uniform color | clean | Bright red | Sour sweet juicy |
| B2 | Short cylinder | Dark green brown, uneven color | spots | Bright red | Sour sweet juicy |
| NB2 | Long cylinder | Green brown, uneven color | scabs | Bright red | Sour sweet juicy |

Fruit quality analysis of different treatment group

Similar to the changes in the phenotype, we found that the bagging treatment can significantly affect the horizontal meridian, single fruit weight, and dry material weight of the 'Donghong' kiwifruit, while the impact on indicators such as vertical and fruit shape index are less. As shown in Table 3, compared to the non-bagging group (NB2), the single fruit weight of non-bagging group (B2) group 'Donghong' kiwifruit increased significantly, with an increase of 18.61% (about 10.7g). The average transverse diameter increased by 8.63% (about 0.36cm). The weight of dry matter was reduced by 1.75%. The vertical period was increased by 0.29cm, and the fruit shape index decreased by 0.03, but there was no significant difference. Compared with the B2, the single fruit weight of non-bagging+ pesticides treatment group (NB1) group 'Donghong' kiwifruit increased significantly, with an increase of 28.99% (about 16.67g). The weight was reduced by 12.57%. There is no significant difference in changes in vertical and fruit shaped indexes. Meanwhile, among the four groups of treatment, the bagging+ pesticides treatment group (B1) has the most influence on the physiological indicators of 'Donghong' kiwifruit. Compared with non-bagging+ non-pesticides treatment group (NB2), the single fruit weight and horizontal of B1 group increased by 45.43% (26.12g) and 19.18% (0.8cm), respectively, while their dry matter weight and fruit shape index decreased by 2.86% and 0.17, respectively. These results indicate that single bagging treatment and pesticides treatment can significantly increase the single fruit weight and transverse meridian of 'Donghong' kiwifruit, while has the opposite effect on transverse longitude and dry matter weight. In addition, the impact of baggage+ pesticides treatment has a significant additive effect on these indicators.

Table 3. Effects of bagging on physiological indexes of 'Donghong' kiwifruit

| Treatments | Vertical diameter/cm | Horizontal diameter/cm | Single fruit weight/g | Dry matter weight/% | Fruit shape index |
|------------|----------------------|------------------------|-----------------------|---------------------|-------------------|
| B1 | 5.65±0.09a | 4.97±0.09c | 83.62±0.31d | 15.12±0.06a | 1.14±0.04a |
| NB1 | 5.56±0.06a | 4.64±0.06b | 74.17±0.48c | 15.72±0.08b | 1.20±0.03ab |
| B2 | 5.78±0.03a | 4.53±0.10b | 68.20±1.31b | 16.23±0.11c | 1.28±0.03ab |
| NB2 | 5.49±0.10a | 4.17±0.03a | 57.50±0.55a | 17.98±0.12d | 1.31±0.05b |

Note: After the same column of data, different lowercase letters indicate significant differences ($P < 0.05$)

As shown in Table 4, the chlorophyll content and titratable acid content in B1 were lower than that in B2, with 11.54% (0.6 ug/g) and 0.09% reduction, respectively. While the content of vitamin C, carotenoids, TSS and solid acid ratio in B1 increased by 6.33% (0.14 ug/g), 1.63% and 46.03% respectively compared with that in B2. Meanwhile, the content of vitamin C, carotene content and solid acid ratio in NB1 were lower than that in NB2 with 6.33% (0.14 ug/g), 44.09% (0.97 ug/g) and 5.28% reduction, respectively. While the content of chlorophyll, titratable acid, and TSS were higher in NB1, and the chlorophyll content has significant differences (increased by 13.46%). In addition, among these four treatments, B1 had the higher vitamin C content, carotene content, TSS content, and solid acid ratio, while the chlorophyll content and titratable acid content are significantly lower. These results indicate that the fruit of B1 has the best fruit quality.

Table 4. Effects of bagging on fruit quality of 'Donghong' kiwifruit

| Treatments | Vitamin C content (ug/g) | chlorophyll content (ug/g) | Carotenoid content (ug/g) | Titratable acid content (%) | TSS content (%) | Solid acid ratio |
|------------|--------------------------|----------------------------|---------------------------|-----------------------------|-----------------|------------------|
| B1 | 2.35±0.03a | 4.60±0.15a | 2.47±0.09a | 0.24±0.02a | 17.78±0.09a | 75.22±9.18a |
| NB1 | 2.07±0.02b | 5.90±0.15b | 1.23±0.03c | 0.36±0.01b | 16.52±0.20b | 45.54±1.53b |
| B2 | 2.14±0.01bc | 5.33±0.12c | 2.03±0.12b | 0.32±0.02b | 16.34±0.09b | 51.51±4.35b |
| NB2 | 2.21±0.02c | 5.20±0.15c | 2.20±0.06ab | 0.33±0.02b | 16.15±0.20b | 48.08±2.82b |

Comparative analysis on pesticide residue of 'Donghong' kiwifruit under bagging and non-bagging treatment

During the cultivation of kiwifruit, spraying pesticides can reduce the effects of pests and diseases on the yield and quality of kiwifruit. However, the pesticide residues of kiwifruit are harmful to human body. In this study, we also carried out an analysis of bagging treatment on the impact of pesticide residues of kiwifruits. As shown in Figure 2, difenoconazole residue was detected in these four groups. Among these four groups, the difenoconazole residue in the fruits of B2 group is the lowest, with only 0.010mg/kg. Followed by 0.08mg/kg in NB2 group. The residues of difenoconazole in kiwifruit of B1 and NB1 group was 0.12mg/kg. These results indicated that bagging treatment had little effect on the residue of difenoconazole.

Different from the residue of difenoconazole, the residues of pyraclostrobin in bagging treatment group (B1 and B2) were very low, with 0.01 mg/kg and 0 mg/kg, respectively. While there were 0.24 mg/kg and 0.09 mg/kg detected in the fruits of NB1 group and NB2 group. The results showed that bagging treatment could significantly reduce the residual content of pyrazolidide (about 95.83%).

Similar to pyraclostrobin, the residues of β -cypermethrin in the bag group (B1 and B2) were very low, with 0.11 mg/kg and 0 mg/kg, respectively. However, the residual in the non-bagging groups (NB1 and NB2) were quite high, with 0.48 mg/kg detected in the fruits of NB1 group and 0.22 mg/kg detected in the fruits of the NB2 group. The result shows that bagging treatment can significantly reduce the residual amount (about 77.08%).

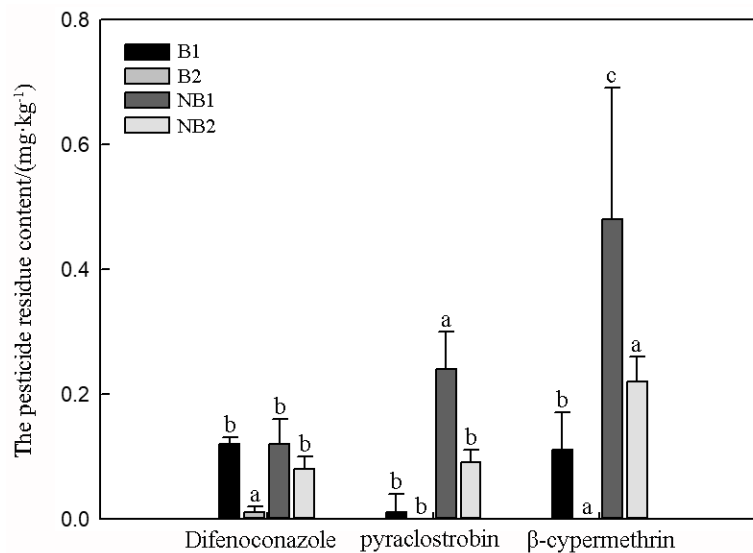


Figure 2. Effects of bagging on pesticide residues in 'Donghong' kiwifruit

Discussion

Bagging is one of the most important techniques for producing high-quality fruits and has many benefits for fruit production, including reduce the incidence of disease, insect pests, bird damage, reduce pesticide residue, and keeps pericarp smoothness (Bentley *et al.*, 1992; Hofman *et al.*, 1997; Amarante *et al.*, 2002; Sharma *et al.*, 2014a). This technique has been widely used in China, Australia, Japan, and the United States for the cultivation of peach, apple, pear, grape, loquat and so on (Sharma *et al.*, 2014b; Tran *et al.*, 2015). Previous studies shown that bagging treatment have different degrees of effects in terms of fruit appearance and quality (Zhong *et al.*, 2002; Wang *et al.*, 2020). In this study, the appearance of the bagged 'Donghong' kiwifruit

has indeed improved. The green color of fruit pericarp after bagging treatment is lighter than the non-bagging group. Meanwhile, the fruit pericarp after bagging treatment is cleaner, and there is no scabs and spots. The micro-environment after bagging which can prevent the impact of adverse environmental factors such as sunburning, rain, germ, insect pests, and mechanical damage on the development of kiwifruits is the mainly reason for these benefits. In addition, bagging can provide a relatively moderate high temperature environment for the fruit, resulting in accelerating the breathing rate of the fruit and a strong cell division (Huang, 2010). Consistent with previous study, we also found that after bagging treatment, the single fruit weight and horizontal meridian of 'Donghong' kiwifruit had significantly improved (Wang *et al.*, 2020).

Fruit bagging can improve the internal quality of fruits (Liao *et al.*, 2019). For example, the sugar contents in bagged mango fruits were increased (Nadeemet *et al.*, 2022). By using white-colored bags, soluble solid contents, chlorophyll and anthocyanins of peach fruit were increased (Kim *et al.*, 2008). However, the response to bagging varies according to the fruits considered. For instance, bagging has a non-significant effect on soluble sugars but decreases organic acids in pear fruits (Huang *et al.*, 2009). For kiwifruit (three lines of *Actinidia eriantha* germplasm resources 'G19', 'G21' and 'G28'), bagging significantly improve fruit appearance and flesh color, reduced the content of chlorophyll, carotenoid and AsA, while did not affect the content of soluble solid, dry matter, soluble sugar and titrable acid (Liao *et al.*, 2019). However, Liu *et al.* (2022) found that the contents of soluble solids (SSC), soluble sugar (SS), ascorbic acid (AsA), chlorophyll and carotenoid in the fruit shading by bagging (FSB) fruit were significantly reduced by using *A. eriantha* 'Ganlv 1' as material. In the present study, we found that there was a small impact on the quality of 'Donghong' kiwifruit only under bagging treatment. However, the B1 could increase the vitamin C content, carotene content, TSS content, and solid acid ratio, while the chlorophyll content and titrable acid content of fruit are significantly down-regulated. Thus bagging+ chemical pesticide treatment has an additional effect on these traits. This additional effect of bagging+ chemical pesticide treatment mainly caused by the growth promoting effect of pyraclostrobin on crops (Zhang *et al.*, 2022). previous studies shown that the combination of difenoconazole and pyraclostrobin reduced the incidence of watermelon *Colletotrichum* and increased watermelon production (Wang *et al.*, 2016). By using brassinolide and pyraclostrobin can reduce the occurrence of rice, bananas, rapeseed diseases, improve the quality of crops, and increase yield (Lu *et al.*, 2020).

The pesticide is an indispensable material in kiwifruit production. It can reduce loss from pests and disease during the cultivation of kiwifruit, but it leads to serious agricultural environmental problems and the agricultural product quality safety problems. Bagging is an effective way to reduce fruit pesticide residues (Wang *et al.*, 2021). Fruit bagging reduced the hazard quotient and the dietary risk of four pesticides in apple (Xu *et al.*, 2018). The residues of cyhalothrin and carbendazim in bagged "cuiguan" pear were significantly reduced (Lin *et al.*, 2008). Consistent with these studies, in this study, the residue of pyraclostrobin and β -cypermethrin in the bagged 'Donghong' is significantly reduced, indicating that bagging can effectively prevent pesticides from penetrating and reduce pesticides directly on kiwifruits. However, different from pyraclostrobin and β -cypermethrin, there is no difference in pesticide residues between bagged and non-bagged groups after using difenoconazole. This difference may be caused by two reasons: on the one hand, the content of difenoconazole sprayed before bagging is high and it is not easy to decompose; on the other hand, the micro-environment enclosed by bagging is not conducive to the elution and dispersion of difenoconazole on fruit surface. However, the pesticide residues detected in this study are kept within the safe range (Mao *et al.*, 2021). Therefore, in order to reduce the problem of pesticide residues, it is necessary to select appropriate cultivation methods (bagging and application time) according to different pesticide characteristics during kiwifruit production.

Conclusions

In the present study, the effects of bagging treatment on fruit quality and pesticide residues of 'Donghong' kiwifruit were studied. Our results shown that bagging treatment can improve the appearance of the 'Donghong' kiwifruit, with uniform color, cleaner appearance and no scabs and spots. bagging + chemical pesticide treatment had additive effect on the internal quality of fruits, including increased the vitamin C content, carotene content, TSS content, and solid acid ratio, and decreased the chlorophyll content and titrable acid content. Meanwhile, bagging significantly reduced the residues of pyrazolone and β -cypermethrin, while the residue of difenoconazole residues did not show significant difference. This study provides useful information for the scientific cultivation of 'Donghong' kiwifruit.

Authors' Contributions

Conceptualization: XS; Data curation: XS and DJ; Formal analysis: DJ and XS; Funding acquisition: DJ and XS; Investigation: WZ and ZL; Methodology: DJ and XS; Resources: JT; Software: DJ and XS; Visualization; Writing-original draft: DJ; Writing-review and editing: DJ and XS. All authors read and approved the final manuscript.

Ethical approval (for researches involving animals or humans)

Not applicable.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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