

## 云南沃柑二次开花的果实品质分析

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**摘要:**【目的】沃柑是我国面积最大的晚熟柑橘品种,除正常春季开花结果在翌年1—3月成熟外(第一次开花结果),常有较多夏季花,所结果实在翌年6—7月成熟(第二次开花结果)。为此,系统研究沃柑夏花果品质并与春花果比较,以综合评价夏花果质量,为夏花果的利用提供参考。**方法**以云南2种典型气候区的4个果园的沃柑为材料,对春花果和夏花果的外在和内在品质指标进行测定和评价。**结果**连续2 a的结果显示,与春花果相比,夏花果单果质量增大,果面红色度 $a^*$ 显著降低而呈黄色,果皮硬度和厚度增加,但种子数、出汁率、维生素C含量和固酸比无明显高低变化规律,可食率62%以上,可溶性固形物(total soluble solid, TSS)和总酸(total acid, TA)含量显著提高。多数夏花果的蔗糖、葡萄糖、果糖、半乳糖、肌醇、柠檬酸、氨基丁酸、奎宁酸和脯氨酸含量高于春花果,苹果酸、草酸、脂肪酸等含量变化规律性不明显。口感鉴定中78.9%的鉴品小组成员认为夏花果风味优良。夏花果在室内放置1个月无明显异味。**结论**沃柑夏花果果型较大,外观品质略低于春花果,TSS、TA和多数糖酸组分含量高于春花果,夏花果口感风味优良,有探究利用价值。

关键词:沃柑;夏花果;春花果;品质

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## Quality analysis of fruits bore from summer and spring blooms of Orah mandarin (*Citrus reticulata* Blanco) in Yunnan province

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**Abstract:**【Objective】China has energetically developed late-ripening citrus over the last decade. Late-ripening citrus also has a great impact on the market. Orah mandarin (*Citrus reticulata* Blanco) is a late-ripening citrus variety which has been widely planted in China in recent years, and it is extensively cultivated in Yunnan province, China. The climate of Yunnan province is characterized by longer daylength, high diurnal temperature variation, drought spring and rainy summer, under which Orah mandarin is more easily to bloom and bear fruits in the Summer. Fruits derived from the spring blooms (spring fruits) usually mature in January to March of the following year, and fruits derived from the summer blooms (summer fruits) usually mature in June to July of the following year. In China, June to July is the off-season for fresh citrus in fruit market. Therefore, utilization of Orah mandarin summer fruits could not only reduce labor cost for removing summer flowers but also increase fruit incomes and benefit fruit market.【Methods】In this study, 5–7 years old Orah mandarin trees grafted on Ziyang sour orange [*Citrus junos* (Sieb.) Tanaka] rootstocks in Faping orchard of Jinghong city (FP), Wangsi orchard of Menghai county (WS), Chuancheng orchard of Xinping county (CC) and Lizhi orchard of Xinping county (LZ) in Yunnan province were used as materials, and their summer fruits and spring fruits were investigated and measured in 2019—2021. Twelve external quality indicators, seven conventional

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internal quality indicators and sugar as well as acid metabolites indicators were used to assess the fruit quality of the fruits. Single fruit weight, edible rate and juice rate were determined. Fruit shape index and peel thickness were measured by a vernier caliper. Peel firmness was measured by GY-4 fruit firmness meter. Peel smoothness and oil gland were evaluated according to NY/T 2435—2013 (China national industry standard). The soluble solids (TSS) content was measured by the ATAGO PAL-1 digital sugar meter. Vitamine C (Vc) content was measured according to GB 5009.86—2016 (China national standard). Titratable acidity was (TA) measured according to GB/T 12293—1990 (China national standard). The fruit color was measured by Konica Minolta CR-400, and the  $C$ ,  $h$ ,  $L$ ,  $a^*$  and  $b^*$  were calculated. Sugar metabolites were determined and analyzed by GC-MS. Microsoft Office Excel 2016 was used to organize and draw the data; SPSS IBM SPSS Statistics 23.0 was used for variance analysis and multiple comparisons, and the LSD was analyzed by univariate ANOVA to compare the significance level of the differences.

【Results】Compared with the spring fruits, the summer fruits of Orah mandarin were more oblate, the single fruit weight was heavier, the peel was harder and thicker, and the peel surface was more coarse. The seed number, juice rate, edible rate, Vc content and solids acid ratio of the summer fruits had no regular change, but the edible rate was over 62% and the juice rate was over 46%. The summer fruits also had significant lower  $a^*$  value and higher  $h$  value; The summer fruits had higher TSS and TA than those of the spring fruits. The analysis of sugar metabolites showed that the soluble sugars in Orah mandarin fruits mainly included sucrose, glucose and fructose, of which the sucrose were the highest. All kinds of sugars in the summer fruits from WS and most kinds of sugar in the summer fruits from FP were significantly higher than those of the spring fruits in 2019—2020. All kinds of sugars in the summer fruits from LZ were higher than those of the spring fruits, while there was no significant difference in 2019—2020. All kinds of sugars in the summer fruits from CC did not significantly regularly changed in 2019—2020. The sucrose content in the summer fruits from all tested orchards was higher than that of the spring fruits in 2020—2021, and most of them had significantly difference. Except for WS, the contents of glucose, fructose and galactose in the summer fruits from other orchards were higher than those of the spring fruits in 2020—2021. The citric acid and malic acid were the two most important acids, which accounted for more than 80% of the total acids in the summer fruits and the spring fruits. The content of citric acid in the summer fruits from all tested orchards was higher than those of the spring fruits in 2020—2021. The contents of oxalic acid, quinic acid and aminobutyric acid in the summer fruits from all tested orchards were not significantly different but most of them were significantly higher than those of the spring fruits in 2020—2021. The content of proline in the summer fruits was higher than that of the spring fruits and the content of other substances had no significant and regular change. More than 78.6% of the consumers expressed good taste for the spring and the summer fruits, and there was no peculiar smell in the summer fruits after 30 days storage at room temperature.

【Conclusion】The summer fruits had lower external quality. The contents of TSS, TA and most of sugar and acid components of the summer fruits were higher than those of the spring fruits. The summer fruits had good taste and would be valuable for research and utilization.

**Key words:** Orah mandarin; Fruits bore from summer bloom; Fruits bore from spring bloom; Quality

果树的二次开花现象在柑橘、葡萄、苹果、梨、桃、李、石榴、蓝莓以及杨桃等树种上都会发生<sup>[1-6]</sup>。二次开花既受遗传特性影响,也受外界环境调控。柑橘类的柠檬、金柑、四季橘和枸橼在遗传上属于容

易成花的类型,每批新梢都可能开花,而柑、橘、橙、柚类通常只有春季一次开花,仅在干旱等特定条件下才偶有二次开花<sup>[2,7]</sup>。多数果树二次开花所结果实质量不佳。例如,梨和苹果的二次花果实小且不能

正常成熟;金柑类的夏花和秋花果实小,商品性差;温州蜜柑、不知火橘橙的夏花或秋花果实异常粗皮味淡,没有商品价值。因此,果树生产中通常控制二次或多次开花<sup>[7-9]</sup>,只有葡萄、柠檬等少数品种利用其多次开花特性,生产错季或反季果品,延长采收期或错峰上市<sup>[2,7,10-12]</sup>。

沃柑(Orah mandarin)是坦普尔橘橙(Temple tangor)与丹西红橘(Dancy tangerine)杂交而来,具有晚熟、丰产、优质、耐贮等优良特性<sup>[13]</sup>,近年在我国得到快速发展,全国已种植近20万hm<sup>2</sup><sup>[14-15]</sup>。沃柑还具有易成花的特点,除在春季第一次开花外,也较易在夏季第二次开花,此现象在我国云南较为常见,生产上习惯抹除夏花和摘除夏花果。然而,近年发现沃柑的夏花果外观和内质都表现良好,这与温州蜜柑、不知火等品种夏花果的粗皮味淡截然不同。因此,我国云南一些沃柑园在夏花果较多时会保留夏花果在翌年夏季采收上市。但是,目前有关沃柑夏花果的研究尚处于空白,不利于了解其特点和生产指导。品质是果实最重要的研究对象和商品指标,其形成受外界因素影响<sup>[7,12,16]</sup>,不同生态环境下的沃柑夏花果质量好坏、与春花果差异大小等还不得而知。为此,笔者在沃柑较易二次开花的云南亚热带山地和热带山地开展夏花果与春花果的形态、品质参数、糖酸组分以及口感风味等品质指标的系统性对比分析,以期为沃柑夏花果的利用提供参考。

## 1 材料和方法

### 1.1 试验材料

云南沃柑主要分布在亚热带山地和热带山地2个典型气候区,试验在这2个典型气候区的4个沃柑园进行:新平县平甸乡的励志沃柑园和传承沃柑园为亚热带山地气候,西双版纳州的勐海王氏沃柑园和景洪发平沃柑园为热带山地气候,4个果园均为资阳香橙砧。新平2个果园海拔分别为1330 m和1450 m,2014年定植,山地黄壤,pH值5.1~5.3;勐海和景洪果园海拔分别为1400 m和850 m,2016年定植,黄红壤,pH值5.5~5.7。新平县城海拔1470 m,年均温16~18 °C,≥10 °C积温5500~6300 °C,5—6月降雨量210~260 mm;勐海县城海拔1700 m,年均温18~19 °C,≥10 °C积温4300~4600 °C,5—6月降雨量89~400 mm;景洪市区海拔580 m,年均温20~23 °C,≥10 °C积温7300~8000 °C,5—6月降雨量

120~450 mm。4个果园均采用或参照褚橙果园的技术方案<sup>[17]</sup>,栽培管理方法基本相同。

每个试验果园在采样区保留夏花和夏花果,用于2019—2020年度及2020—2021年度的春花果和夏花果采样分析。新平2个果园春花在3月上旬初花,夏花在5月中旬初花,春花果和夏花果分别在翌年2月中旬和5月下旬调查采样;勐海和景洪果园春花分别在3月上旬和2月中旬初花,夏花分别在5月中旬和上旬初花,春花果和夏花果分别在翌年2月中下旬和6月上旬调查采样。每次在每个果园选结果量中等的沃柑树,采集树冠外围4个方向和中部的果实各1个,3株树共15个果为1个样品,每个果园采集3个样品重复用于品质分析,另外采集部分果实样品用于口感鉴定和室内常温存放试验。

### 1.2 试验方法

1.2.1 果实常规品质测定 使用游标卡尺测量果实纵横径、果皮厚度,电子天平称质量。果皮光滑度和油胞粗细参照NY/T 2435—2013进行评价<sup>[18]</sup>。种子数、出汁率及可食率参照GB 8210—87的方法测定。用KONICA MINOLTA的CR-400色差计测定果皮色差。果实硬度采用硬度计(艾德堡GY-4,探头直径3.5 mm)测定,可溶性固形物(total soluble solid, TSS)含量采用爱拓ATAGO PAL-1折射计测定,总酸(total acid, TA)含量采用NaOH滴定法测定<sup>[19]</sup>,维生素C(Vc)含量采用2,6-二氯酚靛酚法测定<sup>[20]</sup>。固酸比用可溶性固形物含量与总酸含量的比值表示。

1.2.2 果实糖代谢组分测定 采用岛津GC-MS 2010PLUS气相色谱仪对果实糖代谢组分进行测定;样品制备参照朱攀攀<sup>[21]</sup>的方法,测定条件参照He等<sup>[22]</sup>的方法,分流比改为80:1。

1.2.3 口感鉴定与贮运性 参考Obenland等<sup>[23]</sup>的方法对果实感官进行评价,鉴品小组由14名研究生和5名教师共19人组成,2020—2021年度夏花果样品全部到达后,从每个果园的样品中随机选10个果切瓣进行感官品尝测试。风味口感评价分为:1,差;2,一般;3,良;4,优。另外,每个果园选4~5 kg无损伤夏花果置纸箱内在室内进行常温[(26±0.5) °C]贮藏试验至7月10日,了解异味情况。

### 1.3 数据处理与分析

采用Microsoft Office Excel 2016对数据进行整理并作图;使用SPSS IBM SPSS Statistics 23.0进行

方差分析及多重比较,采用单因素ANOVA分析的最小显著性差异法(least-significant difference, LSD)比较差异的显著水平( $\alpha=0.05$ ),表中数据以(平均值±标准误)表示。

## 2 结果与分析

### 2.1 夏花果与春花果外在品质比较

表1结果显示,总体上,2个年度4个果园的沃柑夏花果单果质量、果皮厚度、硬度显著高于春花

果,夏花果比春花果稍扁,果面也稍粗糙。 $L$ 值表示色泽亮度,表2结果显示,2019—2020年度多数夏花果 $L$ 值低于春花果,而2020—2021年度多数夏花果 $L$ 值高于春花果,仅景洪未达到显著差异水平。 $a^*$ 值代表红绿色差,夏花果红色浅,其 $a^*$ 值显著低于春花果。 $b^*$ 值代表黄蓝色差,勐海王氏和景洪发平夏花果 $b^*$ 值均低于春花果,而新平励志和传承的夏花果 $b^*$ 值整体高于春花果。 $C$ 值是色彩饱和度,多数夏花果的 $C$ 值显著低于春花果。 $H$ 值是色相角,从0~

表1 沃柑夏花果与春花果外在品质比较

Table 1 Comparison of external quality of Orah mandarin fruits bore from summer and spring blooms

年度 Year	果实类型 Fruit type	采样果园 Sample orchard	单果质量 Single fruit weight/g	果形指数 Fruit shape index	果皮硬度 Peel firmness/N	果皮厚度 Peel thickness/mm	果面光滑度 Peel smoothness	油胞粗细 Oil gland
2019—2020	夏花果 Fruits bore from summer blooms	LZ	157.79±1.79 c	0.77±0.01 d	13.69±0.04 c	4.22±0.08 c	中等 Medium	较粗 Coarser
		CC	130.73±2.26 d	0.79±0.01 cd	11.36±0.02 d	4.57±0.05 bc	中等 Medium	较粗 Coarser
		WS	203.43±3.31 a	0.78±0.00 d	16.51±0.02 b	5.97±0.01 a	中等 Medium	较粗 Coarser
		FP	207.86±4.72 a	0.77±0.01 d	18.35±0.06 a	4.60±0.14 bc	粗糙 Rough	较粗 Coarser
	春花果 Fruits bore from spring blooms	LZ	170.00±3.43 bc	0.82±0.01 ab	7.41±0.41 f	4.34±0.12 bc	光滑 Smooth	较细 Finer
		CC	181.23±5.48 b	0.82±0.00 ab	7.83±0.14 f	4.74±0.10 b	光滑 Smooth	较细 Finer
		WS	139.50±0.89 d	0.80±0.00 bc	9.32±0.49 e	3.15±0.06 e	光滑 Smooth	较细 Finer
		FP	134.34±4.30 d	0.83±0.01 a	10.46±0.27 de	3.74±0.23 d	光滑 Smooth	较细 Finer
2020—2021	夏花果 Fruits bore from summer blooms	LZ	241.11±3.31 a	0.82±0.01 abc	16.06±0.36 d	4.28±0.07 c	光滑 Smooth	较粗 Coarser
		CC	184.52±2.48 d	0.79±0.01 c	18.25±0.32 b	5.01±0.11 ab	中等 Medium	较粗 Coarser
		WS	199.10±4.15 bcd	0.75±0.00 d	20.81±0.56 a	5.32±0.18 a	中等 Medium	中等 Medium
		FP	245.70±4.86 a	0.74±0.00 d	17.53±0.33 bc	4.70±0.07 bc	中等 Medium	中等 Medium
	春花果 Fruits bore from spring blooms	LZ	209.60±6.38 b	0.79±0.00 bc	13.52±0.57 e	3.76±0.08 d	光滑 Smooth	较细 Finer
		CC	158.34±1.78 e	0.81±0.00 abc	12.80±0.05 e	2.42±0.07 f	光滑 Smooth	较细 Finer
		WS	188.90±7.09 cd	0.83±0.01 a	16.68±0.54 cd	2.99±0.16 e	光滑 Smooth	较细 Finer
		FP	202.57±2.36 bc	0.83±0.02 ab	15.40±0.02 d	3.20±0.29 e	光滑 Smooth	中等 Medium

注:LZ. 新平励志;CC. 新平传承;WS. 勐海王氏;FP. 景洪发平。同列数据后不同小写字母表示差异显著( $p < 0.05$ )。下同。

Note: LZ. Lizhi orchard of Xinping county; CC. Chuancheng orchard of Xinping county; WS. Wangsi orchard of Menghai county; FP. Faping orchard of Jinghong city, Yunnan province. Different lowercase letters in the same column indicated significant differences ( $p < 0.05$ ). The same below.

180依次分为紫、红、橙、黄、黄绿、绿、蓝绿色,夏花果 $H$ 值显著高于春花果,且接近90。整体上,夏花果和春花果亮度均较高,红色浅且偏黄色。

### 2.2 夏花果和春花果的常规内在品质比较

种子数、出汁率、可食率、TSS、TA和Vc含量是衡量果实品质及果实风味营养最重要的指标。与春花果相比,2个年度的夏花果种子数、可食率、出汁率、固酸比无明显高低变化规律,可食率都超过62%,出汁率超过46%;新平夏花果的出汁率均高于其春花果,勐海王氏和景洪发平夏花果的出汁率均低于其春花果。夏花果TSS和TA含量更高且多数

有显著差异(表3)。

### 2.3 夏花果和春花果的糖代谢组分比较

2.3.1 果实糖组分 表4结果显示,沃柑糖组分主要有蔗糖、葡萄糖和果糖,含量( $\rho$ )分别为37.59~57.48、17.40~31.58和15.60~34.13 mg·mL<sup>-1</sup>;含量较少的糖组分有半乳糖和肌醇,含量分别为3.05~5.55和0.93~1.96 mg·mL<sup>-1</sup>。2019—2020年,勐海王氏夏花果全部糖组分含量、景洪发平多数糖组分含量高于其春花果且有显著差异;新平传承夏花果全部糖组分含量高于其春花果但差异不显著,新平励志果园则无明显变化规律;另外,夏花果果糖占总糖的比

表2 沃柑夏花果与春花果外观色泽比较

Table 2 Peel color comparison of Orah mandarin fruits bore from summer and spring blooms

年度 Year	果实类型 Fruit type	采样果园 Sample orchard	色差值 Color difference value					
			L	a*	b*	C	H	
2019—2020	夏花果 Fruits bore from summer blooms	LZ	74.31±0.60 b	6.90±0.20 e	69.71±0.77 cd	70.21±0.79 cd	84.51±0.16 b	
		CC	69.96±0.14 c	2.87±1.78 f	64.07±0.32 e	64.07±0.32 e	89.76±0.06 a	
		WS	74.52±0.53 b	14.51±0.57 c	73.65±0.29 ab	75.09±0.21 ab	78.85±0.46 cd	
		FP	69.99±0.46 c	10.73±1.27 d	66.50±1.10 d	67.47±1.21 d	80.98±1.06 c	
	春花果 Fruits bore from spring blooms	LZ	70.74±0.77 c	27.09±1.26 a	68.82±0.81 cd	74.09±0.34 ab	68.46±1.13 e	
		CC	71.61±0.77 c	24.20±0.86 b	68.89±1.14 cd	73.18±0.84 abc	70.52±0.91 e	
		WS	77.49±0.24 a	16.07±0.48 c	74.56±0.24 a	76.32±0.32 a	77.82±0.32 d	
		FP	74.72±1.04 b	16.96±0.34 c	70.99±2.01 bc	73.04±1.96 bc	76.53±0.41 d	
	2020—2021	夏花果 Fruits bore from summer blooms	LZ	81.17±0.23 a	7.44±0.24 d	76.56±0.44 a	77.06±0.54 a	84.05±0.91 c
		CC	79.50±0.33 b	5.22±0.12 e	75.42±0.40 a	75.61±0.42 ab	86.34±0.33 b	
		WS	78.97±0.20 b	1.71±0.06 f	72.68±0.65 bc	72.75±0.69 d	89.07±0.26 a	
		FP	75.61±0.26 d	15.41±0.58 c	72.87±0.47 b	74.55±0.56 bc	78.06±0.40 d	
	春花果 Fruits bore from spring blooms	LZ	73.51±0.07 f	27.28±0.28 a	68.74±0.36 d	74.01±0.44 cd	68.34±0.12 f	
		CC	74.52±0.22 e	26.21±0.41 a	71.16±0.46 c	75.87±0.18 ab	69.76±0.66 f	
		WS	76.79±0.33 c	20.12±0.63 b	73.11±0.56 b	75.99±0.42 ab	74.54±0.54 e	
		FP	76.39±0.22 bd	19.39±0.21 b	73.58±0.15 b	76.17±0.18 a	75.20±0.10 e	

表3 沃柑夏花果与春花果内质比较

Table 3 Comparison of internal quality of Orah mandarin fruits bore from summer and spring blooms

年度 Year	果实类型 Fruit type	采样果园 Sample	种子数 Seed number	出汁率 Juice rate/%	可食率 Edible rate/%	w(可溶性 固形物) Soluble solid content/%	w(可滴定酸) Titratable acidity/%	ρ(维生素C) Vitamin C content/ (mg·100 mL <sup>-1</sup> )	固酸比 Solid acid ratio	
2019—2020	夏花果 Fruits bore from summer blooms	LZ	20.72±0.56 ab	55.62±0.70 a	72.46±0.41 a	13.77±0.07 b	0.61±0.00 bc	18.05±0.26 bc	22.70±0.13 b	
		CC	26.67±0.58 a	52.01±0.15 bc	69.41±0.53 ab	13.47±0.35 bc	0.79±0.03 a	20.96±0.12 a	16.98±0.30 de	
		WS	25.67±3.39 a	49.45±0.37 cd	66.22±0.24 b	15.87±0.18 a	0.75±0.03 a	20.39±1.03 a	21.16±0.49 bc	
		FP	14.60±3.06 b	46.70±1.35 d	68.76±1.49 b	15.37±0.43 a	0.53±0.01 cd	12.82±0.98 d	29.08±0.92 a	
	春花果 Fruits bore from spring blooms	LZ	21.00±1.16 ab	52.91±0.75 ab	69.42±0.54 ab	13.10±0.06 bc	0.45±0.01 d	20.05±0.49 ab	29.25±0.38 a	
		CC	20.69±1.77 ab	50.01±0.97 c	68.51±0.95 b	12.56±0.39 cd	0.34±0.03 e	17.75±0.81 c	29.05±0.84 a	
		WS	17.00±3.71 b	55.14±0.32 a	69.19±0.36 ab	11.90±0.44 d	0.64±0.03 b	20.35±0.27 a	18.81±1.73 cd	
		FP	17.68±0.41 b	51.67±0.96 bc	66.60±1.93 b	11.97±0.25 d	0.80±0.04 a	21.50±0.44 a	15.01±0.61 e	
	2020—2021	夏花果 Fruits bore from summer blooms	LZ	9.71±0.15 f	59.24±0.54 a	71.05±0.82 b	13.93±0.3 b	0.38±0.01 bc	15.82±0.34 c	36.53±0.47 b
		CC	14.83±0.29 d	51.73±1.84 bcd	67.55±0.29 d	15.17±0.15 a	0.79±0.10 a	23.23±1.54 a	19.88±2.39 ef	
		WS	16.67±0.48 c	51.90±0.58 bcd	62.81±0.43 e	12.83±0.27 c	0.82±0.06 a	24.41±0.89 a	15.78±0.96 f	
		FP	18.13±0.22 b	54.19±1.98 abc	69.02±0.19 cd	14.47±0.09 ab	0.49±0.02 b	18.69±0.29 b	29.91±1.64 cd	
	春花果 Fruits bore from spring blooms	LZ	14.17±0.10 d	46.42±2.79 d	70.44±0.28 bc	12.10±0.15 c	0.27±0.01 c	16.02±0.39 c	45.30±2.01 a	
		CC	11.94±0.65 e	49.15±2.20 cd	73.92±0.56 a	14.20±0.15 b	0.42±0.01 bc	11.06±0.62 d	33.96±0.48 bc	
		WS	28.11±0.20 a	60.35±1.85 a	74.91±0.84 a	12.50±0.21 c	0.50±0.03 b	17.55±0.68 bc	25.20±1.48 de	
		FP	12.00±0.58 e	55.96±2.18 ab	70.41±0.26 bc	12.93±0.43 c	0.46±0.06 b	16.78±0.34 bc	28.53±2.58 cd	

例高于春花果,为21.32%~23.27%。2020—2021年,4个果园夏花果蔗糖含量均高于其春花果,且大部分差异显著;除勐海王氏果园外,其余果园夏花果的葡萄糖、果糖及半乳糖含量均高于春花果,部分差异显著,而肌醇含量无显著高低变化规律。除勐海王氏果园外,其余3个果园葡萄糖和果糖占总糖的比

例均高于春花果。果糖甜度高于蔗糖,比例升高有利于改善口感风味。

2.3.2 果实有机酸组分 表5显示,柠檬酸和苹果酸是沃柑果实中最主要的2种酸,比例超过80%。总体而言,2019—2020年度夏花果的柠檬酸和氨基丁酸含量高于春花果,夏花果柠檬酸和氨基丁酸分

表4 沃柑夏花果和春花果中的糖组分含量比较

Table 4 Comparison of soluble sugar components of Orah mandarin fruits bore from summer and spring blooms

(mg·mL<sup>-1</sup>)

年度 Year	果实类型 Fruit type	采样果园 Sampling orchard	蔗糖 Sucrose	葡萄糖 Glucose	果糖 Fructose	半乳糖 Galactose	肌醇 Inositol	糖总量 The total sugar	
2019— 2020	夏花果 Fruits bore from summer blooms	LZ	52.83±2.87 a	23.76±1.90 cde	24.66±2.02 ab	3.68±0.22 ab	1.63±0.12 ab	106.34±5.28 ab	
		CC	46.45±2.52 a	25.26±1.19 bcd	21.72±2.47 abc	4.24±0.29 a	1.84±0.18 a	99.02±4.68 abc	
		WS	54.90±1.79 a	28.19±1.22 abc	23.91±2.96 ab	3.69±0.14 ab	1.55±0.26 ab	112.11±5.72 a	
		FP	49.90±3.86 a	31.58±1.74 a	26.54±1.73 a	3.70±0.02 ab	1.54±0.10 ab	114.05±7.40 a	
	春花果 Fruits bore from spring blooms	LZ	51.67±2.76 a	28.58±1.30 ab	23.29±2.26 ab	3.20±0.21 b	1.45±0.17 b	108.19±5.32 ab	
		CC	46.20±4.97 a	22.51±0.34 def	19.19±0.14 bc	3.90±0.08 a	1.30±0.09 ab	93.10±4.66 bc	
		WS	47.92±0.87 a	18.91±1.11 f	15.60±1.02 c	3.05±0.11 b	0.93±0.08 c	86.41±2.32 c	
		FP	50.20±4.06 a	19.24±1.20 ef	15.88±1.22 c	4.24±0.30 a	1.50±0.09 b	91.07±2.43 bc	
	2020— 2021	夏花果 Fruits bore from summer blooms	LZ	49.08±0.76 bc	24.31±1.18 abc	31.97±1.54 abc	5.10±0.23 ab	1.63±0.12 ab	112.09±3.32 ab
		CC	53.40±0.45 abc	25.95±0.71 a	32.53±0.80 ab	5.55±0.06 a	1.84±0.18 a	119.27±1.90 a	
		WS	54.36±1.34 ab	18.44±1.36 de	23.13±1.65 ef	3.97±0.18 cde	1.55±0.26 ab	101.44±3.11 bc	
		FP	57.48±0.97 a	25.00±1.00 ab	34.13±1.42 a	5.31±0.27 ab	1.54±0.10 ab	123.46±3.73 a	
	春花果 Fruits bore from spring blooms	LZ	37.59±1.47 d	17.40±1.20 e	22.56±2.16 f	3.88±0.43 d	1.48±0.27 ab	82.91±3.83 d	
		CC	48.90±3.72 bc	21.90±1.48 bcd	28.03±1.42 bcd	4.83±0.31 abc	1.96±0.17 a	105.62±6.96 bc	
		WS	46.13±4.71 c	20.92±1.40 cde	27.24±1.87 cde	4.51±0.29 bcd	1.80±0.09 a	100.59±1.28 bc	
		FP	49.68±0.55 abc	18.02±0.66 de	22.68±0.84 f	3.80±0.14 d	1.16±0.04 b	95.35±1.14 cde	

注:n=3. 下同。 Note: n=3. The same below.

表5 沃柑夏花果和春花果的有机酸组分含量比较

Table 5 Comparison of organic acid components of Orah mandarin fruits bore from summer and spring blooms

(mg·mL<sup>-1</sup>)

年度 Year	果实类型 Fruit type	采样果园 Sampling orchard	柠檬酸 Citicric acid	苹果酸 Malic acid	草酸 Oxalic acid	氨基丁酸 Aminobutyric acid	奎宁酸 Quinic acid	酸总量 The total acid
2019— 2020	夏花果 Fruits bore from summer blooms	LZ	3.68±0.72 bc	1.52±0.09 bc	0.35±0.04 bc	0.24±0.01 c	0.06±0.01 bc	5.84±0.62 c
		CC	5.20±0.26 a	1.53±0.17 bc	0.37±0.01 ab	0.23±0.00 c	0.07±0.01 bc	7.38±0.20 a
		WS	4.73±0.51 ab	1.83±0.13 b	0.15±0.05 d	0.34±0.03 b	0.07±0.01 bc	7.12±0.50 ab
		FP	3.58±0.33 bc	1.00±0.10 d	0.24±0.05 cd	0.46±0.03 a	0.09±0.01 bc	5.36±0.22 cd
	春花果 Fruits bore from spring blooms	LZ	2.67±0.31 cd	1.34±0.07 cd	0.25±0.02 cd	0.09±0.01 de	0.15±0.02 a	4.49±0.21 d
		CC	1.85±0.26 d	1.05±0.05 d	0.19±0.02 d	0.08±0.01 de	0.04±0.00 c	3.20±0.25 e
		WS	2.43±0.24 cd	2.90±0.08 a	0.46±0.02 a	0.13±0.01 d	0.06±0.02 bc	5.98±0.32 bc
		FP	4.29±0.24 ab	2.98±0.18 a	0.40±0.00 ab	0.05±0.01 e	0.09±0.01 b	7.81±0.17 a
	2020— 2021	夏花果 Fruits bore from summer blooms	1.30±0.25 bc	2.09±0.04 a	0.30±0.02 b	0.12±0.01 c	0.11±0.00 bc	3.93±0.19 c
		CC	5.49±0.15 a	1.10±0.13 b	0.36±0.01 ab	0.20±0.02 ab	0.26±0.05 a	7.40±0.08 a
		WS	6.16±0.84 a	1.44±0.03 b	0.43±0.01 ab	0.14±0.01 c	0.16±0.03 b	8.32±0.82 a
		FP	2.16±0.08 b	2.29±0.03 a	0.37±0.03 ab	0.22±0.01 a	0.08±0.01 c	5.12±0.04 b
	春花果 Fruits bore from spring blooms	LZ	0.85±0.09 c	1.43±0.08 b	0.30±0.04 ab	0.13±0.02 c	0.08±0.01 bc	2.79±0.18 d
		CC	1.48±0.07 bc	2.05±0.18 a	0.31±0.04 ab	0.16±0.03 bc	0.10±0.00 bc	4.10±0.19 bc
		WS	1.97±0.23 bc	2.18±0.21 a	0.43±0.10 ab	0.15±0.01 bc	0.10±0.02 bc	4.83±0.11 bc
		FP	1.27±0.02 bc	2.13±0.04 a	0.47±0.01 a	0.17±0.02 abc	0.10±0.01 bc	4.13±0.08 bc

别占总酸的66.39%~70.39%和3.07%~8.60%, 均高于春花果; 励志和传承夏花果的苹果酸和草酸含量高于春花果, 而王氏和发平低于春花果; 4个果园苹果酸和草酸占总酸的比例均低于春花果; 奎宁酸则无明显高低变化规律。2020—2021年, 4个果园夏

花果的柠檬酸含量均高于春花果, 占总酸33.17%~74.14%, 苹果酸和草酸无明显高低变化规律; 夏花果的奎宁酸及氨基丁酸的含量与春花果相比差异不显著或较显著。2个年度的结果表明, 多数夏花果的氨基丁酸含量显著高于其春花果, 最高的是其春

花果的9.2倍(2019—2020年景洪发平果园)。氨基丁酸是一种天然的非蛋白质氨基酸,在哺乳动物中可以抑制神经递质在神经中枢中的运输,氨基丁酸在人体紧张状态下可以抑制多巴胺的释放,进而影响人体的各种情绪及学习能力<sup>[24]</sup>,夏花果中较高含量的氨基丁酸有一定保健价值。

**2.3.3 果实氨基酸与脂肪酸组分** 对沃柑果实脯氨酸、腐胺、棕榈酸单甘油酯和丙三醇4种成分进行测定,发现这4种物质的含量都很低,鲜果汁中4种成分总含量在0.27~1.97 mg·mL<sup>-1</sup>之间;夏花果这4种成分含量0.47~1.97 mg·mL<sup>-1</sup>,高于春花果的0.27~1.01 mg·mL<sup>-1</sup>。总体上,氨基酸类的脯氨酸含量高于腐胺,脂肪类的棕榈酸单甘油酯含量高于丙三醇。与春花果相比,多数夏花果中的脯氨酸和丙三醇含量显著高于春花果,腐胺含量显著低于春花果,棕榈酸单甘油酯含量则无明显高低变化规律。腐胺有强烈臭味<sup>[25]</sup>,果实中腐胺低含量对果实风味是有利的。

**2.3.4 果实口感风味和贮运性** 夏花果甜酸适中,肉脆化渣,果汁丰富,口感鉴定认为风味优良(优或良)的占比78.9%,认为风味一般的占比21.1%。贮运性方面,夏花果采收后,次日用普通快递发送,3~4 d到达,2个年度16批次果实样品到达时的伤腐率为4.4%~8.9%,均为采收或运输途中的机械损伤果,因气温较高,部分果实开始伤口腐烂。夏花果在室内存放至7月10日,少量果实口感有轻微异味,大部分果实无异味。

### 3 讨 论

柑橘的花芽分化受内因和外因的综合影响,内因主要有遗传因素、树体养分和激素水平<sup>[26-29]</sup>,外因主要有低温和干旱<sup>[30-32]</sup>。世界多数产区柑橘的花芽分化在秋冬低温期完成,在春季开花结果<sup>[33]</sup>;热带地区的柑橘缺乏低温,干旱是诱导花芽分化的主要因素<sup>[2,7,34]</sup>,旱季过后的雨季柑橘开花。干旱诱导花芽分化的重要机制是细胞液浓缩,糖和氨基酸等养分浓度升高,脱落酸和乙烯等促进花芽分化的内源激素增加<sup>[7]</sup>。云南沃柑比其他区域沃柑更容易形成夏花,主要与云南日照长、昼夜温差大和春旱气候有关,这些因素均有利于养分积累和促花激素的升高,尤其是上一年度结果较少当年又有较严重春旱时,常出现较多夏花果,有时超过春花果产量。2019—2020年度对夏花果较多的植株调查统计发现,夏花

果平均株产质量新平励志果园28.2 kg、传承果园12.5 kg、王氏果园24.7 kg、发平果园13.4 kg。

柑橘为亚热带水果,通常在年均温17~20℃、成熟季节相对干旱少雨环境下品质才优良,过高的温度则粗皮大果、肉糙味淡<sup>[35]</sup>。柑橘的夏花果因夏季温度高、养分充足,幼果细胞分裂和生长旺盛而成粗皮大果,在海南热带和南宁等南亚热带环境的温州蜜柑、脐橙等也因为温度高而质量不佳。但是,沃柑果实对温度的反应则与大多数柑橘品种不同,即使在海南和南宁也能表现出良好的外观和内质,云南夏季二次开花果实品质也依然优良。沃柑的这种耐热特性可能与其杂交亲本的起源有关,坦普尔橘橙起源于热带雨林气候的牙买加<sup>[36]</sup>,丹西红橘起源于热带气候的摩洛哥<sup>[37]</sup>,这种原产热带气候的品种对高温有良好适用性。但是,目前对沃柑果实在高热量环境下生理生化和细胞分裂分化等尚无研究,其不形成粗皮大果、风味不变淡的机制尚不清楚;另外,夏橙等晚熟柑橘果实春季气温回升后,果实会褪色返青,并且果皮恢复生长而变粗<sup>[38-39]</sup>,但沃柑成熟果实挂树到7月份仍无明显返青,仅是果面红色消褪转为黄色,2021-09-15景洪发平沃柑园遗留在树上的零星夏花果仍保持黄色光滑,且风味远好于同期上市的早熟温州蜜柑,说明高温并不能使沃柑成熟果实果皮恢复叶绿素的合成,也不会使糖酸大量下降和果面变粗,其机制有待研究。

从本研究结果看,云南沃柑夏花果质量总体上与春花果相近,只是果皮颜色、厚度和硬度稍逊,果实大部分内质指标无显著差异,TSS、果糖和氨基丁酸等部分指标更优。氨基丁酸是一种对人体保健有益的功能成分,其含量的升高对品质是有利的。但目前沃柑生产上普遍采用抹除夏花、摘除夏花果的管理方法,有必要根据具体情况进行调整,如果春花果比较少、夏花比较多,可以保留夏花结果,维持树体总挂果量在30~40叶·果<sup>-1</sup>的适宜水平,这样既可以省去抹夏花、摘夏果的劳动成本,也能增加产量和效益。6—7月为柑橘市场淡季,销售压力小、价格高<sup>[40-41]</sup>,沃柑夏花果在此期上市,可填补市场空档。近几年的6—7月,云南沃柑夏花果的销售价格普遍要比1—4月销售的春花果高50%左右。云南开发利用沃柑夏花果的自然条件较好,在目前广西等地沃柑产量大、销售越来越困难的大背景下,利用夏花果不失为错峰上市和增加效益的有效手段。不过,

要大规模开发利用夏花果,还有待研究抑制春季开花、促进夏季开花的高效方法,使夏花果成为主要目标产量。

## 4 结 论

沃柑夏花果单果质量增大,果皮黄色,厚度和硬度较高,外观品质略低于春花果,可溶性固形物、总酸和多数糖酸组分含量高于春花果。夏花果口感风味优良,有研究利用价值。

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