

基于主成分分析的不同品种柑橘制汁适应性研究

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摘要:【目的】为了筛选出适合生产NFC果汁的柑橘品种,以浙江地区主栽的19个柑橘品种为原料,进行了各个品种的制汁适应性研究。【方法】采用常规方法分析了各个柑橘品种的出汁率、果肉率等品质特性,以及柑橘汁的维生素C、可溶性固形物、可滴定酸、可溶性糖、总酚、总黄酮等营养理化指标,对比了不同品种柑橘之间的差异,然后采用主成分分析法(PCA)建立了柑橘品质评价体系,作为评价不同品种柑橘汁综合品质的依据。【结果】不同柑橘品种的品质存在显著差异,‘红美人’‘山下红’‘宫川’‘天草’‘尾张温州蜜柑’等品种出汁率高,具有较大的果汁加工潜力,但其总黄酮、总酚、维生素C这3项指标含量略低,因此口感有所欠缺。经由主成分分析,从9项原始指标提取出3个主成分,累计方差贡献率达到86.728%。以3个主成分及单个主成分所对应的特征值占所提取主成分总的特征值之和的比例作为权重,构建了柑橘综合品质评价模型,作为筛选适合制作柑橘汁的柑橘品种的方法。【结论】根据该评价模型计算浙江地区19个柑橘品种的综合得分,可将不同品种的柑橘分为三类。分值较高的是‘冰糖橙’‘纽荷尔脐橙’‘瓯柑’,分值较合适的是‘丽椪2号’‘山下红’‘满头红’‘鸡尾葡萄柚’‘中育橙’。通过该评价体系,可以较为便捷地选取出营养价值较高且风味口感较好的柑橘品种。同时考虑果肉率、出汁率等因素,可以提供直观的柑橘品质评价,为企业选取适合柑橘汁制备原料品种提供依据。

关键词:柑橘;制汁;筛选;理化指标;主成分分析(PCA);适应性;评价体系

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Study on suitability of different citrus varieties of for juice manufacturing based on principal component analysis

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Abstract:【Objective】Fruit and vegetable juice has a broad prospect for development as a nutritious and healthy drink. In 2015, the output value of fruit and vegetable juice in China reached 120 billion yuan, and is increasing at a rate of 7%-15% per year. Development and production of nutritious juice products has become an important development direction in fruit and vegetable processing industry. Citrus juice accounts for two thirds of juice produced. But at present, the variety of citrus juice is very narrow and dominated by orange juice. Besides sweet orange, our country has a rich citrus resource, especially Satsuma mandarin. In Japan, studies have been carried out on the function and processing of Satsuma mandarin, and some products have been commercialized. However, there are few studies on the NFC juice processed from different citrus varieties in Zhejiang. In order to select citrus varieties suitable for manufacturing NFC orange juice, 19 citrus cultivars produced in Zhejiang province were evaluated for suitability for juice production.【Methods】At present, there are many methods of evaluating citrus

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juice, and each method has its advantages and disadvantages. Fresh mature fruit samples were collected from four directions of tree canopy from mid-November to mid-December. A part of the samples were used for weighing and juicing, and the pulp recovery and juice recovery were determined at the same time. The processed juice were stored in a cryogenic refrigerator (-18 °C). The determinations of 6 parameters were carried out according to national standards or Ministry of Agriculture Standards. The quality characteristics analyzed included juice recovery, pulp recovery, and nutritional phyto-chemical components in citrus juice including vitamin C (VC), total soluble solid (TSS), titratable acidity (TA), soluble sugar (SS), total phenols (TP) and total flavonoids (TF). Then, principle component analysis (PCA) was applied to evaluate the overall quality of NFC juice made from different citrus varieties.【Results】The pulp recovery of 'Niponicum' and 'Citrus Hybrid' was higher than 80%. 11 varieties had a pulp recovery between 70% and 80%. The lowest pulp recovery was found in 'Aliquam', which was 63.09%. 'Niponicum' had the highest juice yield (68.50%). There were 4 varieties with juice yield higher than 60%, including 'Satsuma Mandarin' 'Miyagawa Wase' 'Citrus Hybrid' and 'Owari'. There were 13 varieties with juice yields ranging from 50% to 60%. The juice yield of 'Aliquam' was the lowest, being only 36.84%. There was a significant influence of variety on the taste of the citrus juice. The taste of *Citrus Sinensis* Osbeck was very sweet because of its highest ratio of total soluble solid to titratable acidity (44.24) and low acidity. The fruits were generally high in vitamin C, total phenols and total flavonoids. The contents of vitamin C in 'Newhall Navel' and 'Aliquam' were higher, being 78.26 mg · 100mL⁻¹ and 74.90 mg · 100mL⁻¹, respectively. *Citrus Suavissima* had the highest content of total phenols and total flavonoids, but 'Haruka Tangelo' had the lowest content. The results showed that there were significant differences in quality traits of the juice among varieties. 'Niponicum' 'Satsuma Mandarin' 'Miyagawa wase', Citrus Hybrid and 'Owari' showed good yield. However, the contents of vitamin C, total phenols and total flavonoids in their juice were relative low, leading to plain flavor. Principal component analysis showed that the characteristic values of the top three principal components were all higher than 1, and the rates of variance contribution to the three principal components were 38.267%, 35.615% and 12.846%, respectively. The accumulative variance contribution rate of three principle components extracted from nine origin indices reached 86.728%, illustrating that the three principal components reflected the most parts of the original variables. The first factor reflected total soluble solid, soluble sugar, vitamin C, and total sugar; the second factor titratable acidity, RTT, and pH; and the third the total phenols and total flavonoids. The comprehensive evaluation function was $F=0.38267\times F1+0.35615\times F2+0.12846\times F3$. The comprehensive quality evaluation model of citrus was constructed using the proportion of the eigenvalues corresponding to the three principal components and the sum of the extracted principal components' eigenvalues, which was used for screening citrus varieties suitable for making juice. The top 5 were *Citrus Sinensis* Osbeck, 'Newhall Navel', *Citrus Suavissima*, Ponkan and Satsuma Mandarin.【Conclusion】The 19 citrus varieties could be divided into three categories. *Citrus Sinensis* Osbeck, 'Newhall Navel' and *Citrus Suavissima* had the high grades. 'No. II Li Png', Satsuma Mandarin, 'Red Sene', 'Cocktail Citrus Paradisi' and 'Aliquam Zhongyu' were intermediate. Through this evaluation, citrus varieties with high nutritional value and good flavor and taste can be selected conveniently. At the same time, the pulp recovery, juice recovery and other factors provide an intuitive evaluation of citrus quality and provide a reference for selecting suitable raw material varieties for juice processing.

Key words: Citrus; Juice manufacturing; Dressing by screening; Phytochemical properties; Principal component analysis(PCA); Adaptive; Evaluation system

柑橘(*Citrus reticulata* Blanco)属芸香科柑橘亚科,是橘、柑、橙、柚等的总称,主要分布在热带、亚热带^[1]。中国是柑橘的重要原产地之一,有4000多年的栽培历史,柑橘资源丰富,优良品种繁多^[2]。我国主要的柑橘产区有浙江、福建、湖南、四川、广西、湖北等10个省(市、区)^[3]。2016年我国柑橘面积246.67多万hm²,产量约3 700万t,高居世界第一,占世界水果的26%。

柑橘色泽鲜艳、果汁量大、酸甜可口,含有糖类、有机酸、氨基酸、维生素、膳食纤维等多种营养成分和类胡萝卜素、多酚、总黄酮等活性物质,具有一定的营养价值和药用价值^[4]。随着我国果蔬深加工产业的迅速发展和人民生活水平的不断提高,人们对水果加工产品的需求日益多样化^[5]。果蔬汁作为一类营养健康的食品,2015年我国果蔬汁产值达1 200亿元,且每年以7%~15%的速度增长,发展前景广阔,研制营养丰富的果蔬汁产品已成为果蔬加工产业重要的发展方向,其中柑橘汁占果汁总量的2/3,但目前柑橘汁品种非常单一,基本上为橙汁^[6],其他柑橘品种在NFC果汁制汁相关的研究较为缺乏。

笔者旨在通过测定不同品种柑橘汁的9项理化性质,并结合数据对比和主成分分析,建立一套柑橘品质评价体系,帮助筛选出综合品质较好的柑橘品种,为柑橘汁的制取和复配提供一定的理论依据。

1 材料和方法

1.1 材料与试剂

本实验所用柑橘均采摘于浙江衢州,当天运至浙江省农业科学院食品所实验室,剔除损伤果,选择色泽相对均匀的新鲜果实榨汁并置于-18℃冰箱保存,用于品质指标测定分析。本实验采集的柑橘品种共19个,具体见表1。

主要试剂:氢氧化钠、基准邻苯二甲酸氢钾、酚酞、抗坏血酸、草酸、碳酸氢钠、2,6-二氯靛酚、高岭土、3,5-二硝基水杨酸、酒石酸钾钠、苯酚、亚硫酸钠、葡萄糖、没食子酸、福林酚、碳酸钠、芦丁、亚硝酸钠、硝酸铝,以上试剂均为分析纯。

1.2 仪器与设备

SKG A8大口径原汁机,广东艾诗凯奇智能科技有限公司;实验室pH计FE20,梅特勒-托利多仪器(上海)有限公司;Quick-BrixTM 90便携式糖度计,梅特勒-托利多仪器(上海)有限公司;CR-400手持色

表1 试验用柑橘品种

Table 1 Test material

序号 Number	品种 Cultivar	类别 Classification
1	中晚熟温州蜜柑(尾张)Owari	温州蜜柑
2	宫川温州蜜柑 Miyagawa Wase	Citrus unshiu
3	山下红温州蜜柑 Satsuma Mandarin	
4	满头红 Red Sene	朱红橘 Citrus reticulata Blanco
5	椪柑 Ponkan	柑 Citrus
6	瓯柑 Citrus Suavissima	
7	丽椪2号(无籽椪柑)No.II Li Png	
8	香橙 Aliquam	杂柑 Tangerine hybrids
9	爱媛28(红美人)Niponicum	
10	胡柚 Citrus Paradisi	
11	鸡尾葡萄柚 Cocktail .C. Paradisi	
12	春香 Haruka Tangelo	
13	甜橘柚 Dulce Tangelo	
14	天草(象山红)Citrus Hybrid	
15	高橙 Aliquam High	
16	纽荷尔脐橙 Newhall Navel	橙 Citrus sinensis
17	冰糖橙 Citrus Sinensis Osbeck	
18	中育橙 Aliquam Zhongyu	
19	塔罗科血橙 Blood Orange	

差仪,日本柯尼卡美能达公司;紫外可见分光光度计UV-1800,日本岛津公司;电子天平 AL104-IC,梅特勒-托利多仪器(上海)有限公司;CJJ78-1磁力加热搅拌器;Anke LXJ-II B低速大容量离心机,上海安亭科学仪器厂。

1.3 试验方法

从各个品种的柑橘样品中随机抽取30~50个果实,称量总重,去皮后称量果肉重,计算各个品种的果肉率;然后采用SKG原汁机榨汁后称量汁重,计算各个品种柑橘汁的出汁率。果汁榨好后用100目滤布过滤,分装在50 mL灭菌离心管中,密封贮藏在-18℃的冷库中备用。

采用CR-400手持色差仪进行色泽的测定,用L*、a*、b*值的模式对果汁颜色进行测定和评价。根据CIE Lab颜色系统进行分析,L*值为明度,反映色泽的亮度程度;a*值的正数代表红色,负数代表绿色;b*值的正数代表黄色,负数代表蓝色^[7]。可溶性固形物(TSS)采用手持糖度计测定;有效酸度(pH)测定;可滴定酸(TA)参照国标GB/T 12456-2008《食品中总酸的测定》测定;维生素C参照国标GB 5009.86-2016《食品中抗坏血酸的测定(2,6-二氯靛酚滴定法)》测定;可溶性糖参照NY/T 2742-2015《水果及制品可溶性糖的测定(3,5二硝基水杨酸(3,5-Dinitro-salicylic acid,DNS)比色法)》测定。将柑橘汁稀释50

倍,准确吸取1 mL于25 mL具塞刻度试管中,各加水至2 mL,加入2 mL 3,5二硝基水杨酸试剂,置沸水浴中加热5 min。取出冷却定容。在540 nm处测定吸光值;总黄酮含量采用分光光度法(芦丁法)^[8-10]测定;总酚含量采用改进后的Folin-Ciocalteu比色法测定^[11-12];总糖含量采用苯酚硫酸法测定。

1.4 数据处理

本试验每个评价指标均重复测定3次,结果所示数据均为3次平行试验的平均值±标准偏差。采用Excel 2010,SPSS 21.0对数据进行分析处理。

2 结果与分析

2.1 不同品种的果肉率、出汁率

各品种柑橘的果肉率和出汁率如图1、图2所示。

示。从图1、图2可以看出,不同品种柑橘的果肉率和出汁率有一定差异。从图1可以看出,在果肉率方面,‘红美人’‘天草’的果肉率在80%以上,分别为87.69%、83.98%;‘血橙’‘山下红’‘宫川’‘中育橙’‘满头红’‘丽椪’‘冰糖橙’‘鸡尾葡萄柚’‘尾张温州蜜柑’‘椪柑’‘纽荷尔脐’橙11个品种的果肉率为70%~80%;果肉率最低的为香橙,仅为63.09%。从图2可以看出,在出汁率方面,‘红美人’的出汁率最高,达到68.50%;‘山下红’‘宫川’‘天草’‘尾张温州蜜柑’四个品种的出汁率均高于60%,分别为65.47%、64.22%、64.09%、62.15%;‘春香’‘胡柚’‘高橙’‘纽荷尔脐橙’‘瓯柑’‘冰糖橙’‘甜橘柚’‘鸡尾葡萄柚’‘香橙’‘椪柑’‘中育橙’‘满头红’‘丽椪’这些品种的出汁率在50%到60%不等;而‘香橙’的出汁

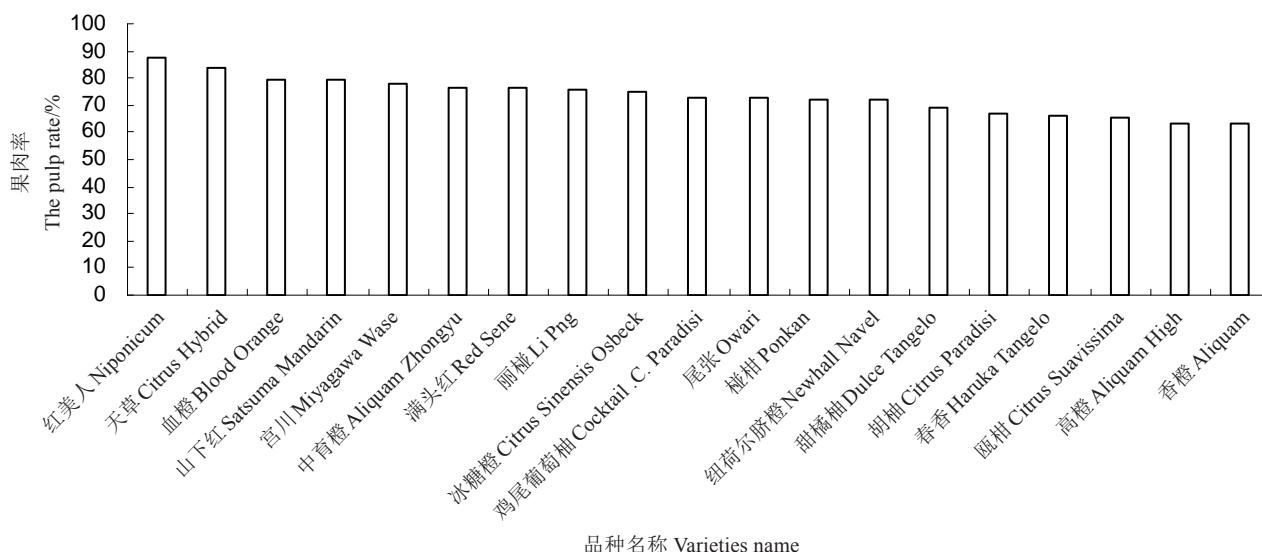


图1 不同柑橘品种的果肉率

Fig. 1 The pulp recovery of different citrus varieties

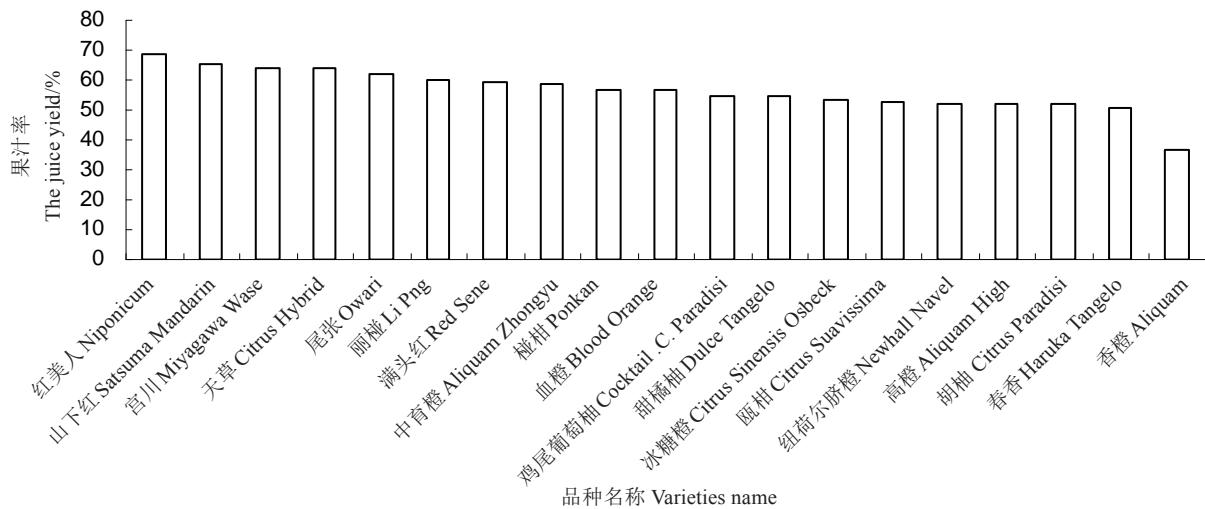


图2 不同柑橘品种的出汁率

Fig. 2 The juice recovery of different citrus varieties

率最低,只有36.84%。因此,从出汁率的角度考虑,除‘香橙’之外,其他品种柑橘都有较大的制汁潜力。

2.2 不同品种柑橘的色泽比较

果实的色泽是评定外观品质的一个重要指标。Wei^[13]等认为产品的色泽是区分其商业等级的基础,并且色素及其他特定成分的含量能表征产品的质量指数。不同品种柑橘汁的色度结果如表1所示。由表2可以得出,不同柑橘汁的L*值为48~74,‘香橙’汁偏白色,其表征亮度的L*值最高,血橙汁的亮度最低,原因可能是里面含量含有一定量的花色苷或胡萝卜素的缘故^[14];‘丽椪’‘血橙’‘瓯柑’‘宫川’‘椪柑’‘山下红’‘满头红’这7个品种柑橘汁的a*为正值,表征其为红色偏向,‘天草’‘香橙’‘冰糖橙’等12个品种柑橘汁的a*为负值,表征其为绿色偏向;所有品种柑橘汁的b*均为正值,表明柑橘果汁均为黄色偏向。

2.3 不同品种的理化指标分析

柑橘汁中含有的可溶性固形物、可滴定酸等成分会对其口感风味产生重要影响^[15]。各品种柑橘汁的pH值、可溶性固形物、可滴定酸、可溶性糖等成分含量测定结果如下表3所示。由表3可知,各个品种柑橘汁的pH值和可滴定酸、可溶性固形物、可溶性糖含量均存在一定差异。比较各个品种的可滴定酸和可溶性糖含量可得,‘香橙’的可滴定酸含量最高,可溶性糖的含量最低,而‘冰糖橙’的可滴定酸含量

表2 不同柑橘品种的色度

Table 2 The color parameters of juice of made from different citrus varieties

品种 Cultivar	L*	a*	b*
尾张 Owari	54.17±0.03	7.42±0.10	46.88±0.05
宫川 Miyagawa Wase	51.50±0.10	3.95±0.09	41.17±0.19
山下红 Satsuma Mandarin	51.46±0.74	3.27±0.72	40.59±1.37
满头红 Red Sene	53.07±0.91	2.54±0.89	40.12±1.80
椪柑 Ponkan	59.60±0.18	3.51±0.16	46.36±0.19
瓯柑 Citrus Suavissima	54.86±0.03	4.43±0.08	47.88±0.02
丽椪2号 No.II Li Png	57.50±0.13	4.92±0.13	46.51±0.16
香橙 Aliquam	73.35±0.09	-7.19±0.05	30.65±0.16
红美人 Niponicum	48.21±0.28	-6.60±0.01	27.72±0.51
胡柚 Citrus Paradisi	60.42±0.09	-9.45±0.02	37.23±0.10
鸡尾葡萄柚 Cocktail C. Paradisi	60.34±0.10	-9.49±0.02	35.70±0.14
春香 Haruka Tangelo	60.74±0.06	-10.09±0.05	27.24±0.06
甜橘柚 Dulce Tangelo	57.15±0.03	-6.11±0.02	41.25±0.01
天草 Citrus Hybrid	54.53±0.27	-1.28±0.17	42.46±0.39
高橙 Aliquam High	51.85±0.03	-7.24±0.01	34.27±0.03
纽荷尔脐橙 Newhall Navel	69.46±0.18	-8.73±0.03	51.47±0.10
冰糖橙 Citrus Sinensis Osbeck	68.63±0.07	-8.95±0.01	53.68±0.01
中育橙 Aliquam Zhongyu	66.72±0.06	-7.90±0.05	46.93±0.70
血橙 Blood Orange	48.02±0.01	4.85±0.02	36.65±0.01

最低,可溶性糖的含量最高。水果中酸和糖的含量对其风味有很大影响。随着水果的成熟,其中的可溶性糖含量升高而酸的含量减少,水果风味得到较大提升,因此,常用可溶性固形物与可滴定酸含量的比值(简称固酸比)来评价水果果实风味和成熟程度。相关文献^[16-17]报道,当柑橘汁的固酸比在12~20时,其口感最为适宜。

表3 不同柑橘品种的理化指标

Table 3 Phytochemical indexes of juice made from different citrus varieties

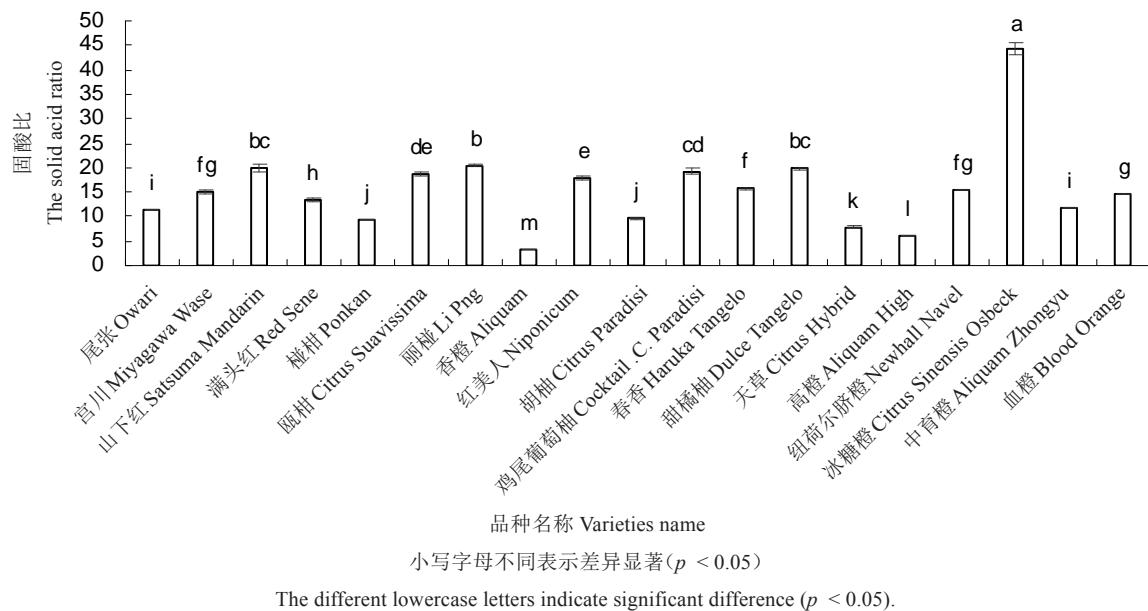
品种 Cultivar	pH	ρ (可滴定酸) Titratable acid content/(g·L ⁻¹)	w(可溶性固形物) Soluble solids content/%	ρ (可溶性糖) Soluble sugar content/(g·L ⁻¹)
尾张 Owari	3.30±0.01 m	10.27±0.14 f	11.6±0.06 g	57.05±1.20 e
宫川 Miyagawa Wase	3.46±0.01 k	7.25±0.19 h	11.0±0.06 h	63.74±0.41 c
山下红 Satsuma Mandarin	3.49±0.01 j	0.63±0.02 ij	12.4±0.06 e	66.31±0.66 b
满头红 Red Sene	3.45±0.01 k	10.17±0.19 f	13.5±0.12 d	48.62±0.86 g
椪柑 Ponkan	3.13±0.01 n	14.98±0.06 d	14.1±0.06 c	57.33±1.33 e
瓯柑 Citrus Suavissima	3.86±0.01 c	6.40±0.07 i	11.9±0.06 f	46.43±1.04 h
丽椪2号 No.II Li Png	3.79±0.01 e	5.80±0.07 k	11.8±0.06 f	56.22±0.83 e
香橙 Aliquam	2.91±0.01 q	35.05±0.32 a	11.9±0.10 f	39.96±0.70 i
红美人 Niponicum	3.83±0.01 d	5.40±0.19 l	9.7±0.10 k	41.17±0.12 i
胡柚 Citrus Paradisi	3.31±0.01 m	10.21±0.14 f	9.9±0.06 j	32.33±0.66 k
鸡尾葡萄柚 Cocktail C. Paradisi	3.63±0.01 h	5.99±0.16 jk	11.5±0.06 g	50.01±1.00 f
春香 Haruka Tangelo	3.71±0.01 g	6.34±0.04 i	9.9±0.06 j	32.35±0.40 k
甜橘柚 Dulce Tangelo	3.99±0.01 b	4.78±0.07 m	9.4±0.06 l	36.38±0.19 j
天草 Citrus Hybrid	2.97±0.01 p	15.85±0.11 c	12.4±0.10 e	59.68±0.33 d
高橙 Aliquam High	3.01±0.01 o	17.56±0.04 b	10.6±0.06 i	49.82±0.39 fg
纽荷尔脐橙 Newhall Navel	3.51±0.01 i	10.29±0.06 f	15.8±0.12 a	67.52±0.53 b
冰糖橙 Citrus Sinensis Osbeck	4.18±0.01 a	3.33±0.10 n	14.7±0.06 b	100.68±0.49 a
中育橙 Aliquam Zhongyu	3.33±0.01 l	11.61±0.06 e	13.6±0.06 d	57.31±1.36 e
血橙 Blood Orange	3.73±0.01 f	7.55±0.10 g	11.0±0.06 h	50.63±0.61 f

注:同列小写字母不同表示差异显著($p < 0.05$)。下同。

Note: Different lowercase letters indicate significant difference ($p < 0.05$). The same below.

图3为不同柑橘汁的固酸比,由图3可知,‘冰糖橙’汁的值最高,高达44.24,因此其口感非常甜,但缺乏一定的酸度;‘丽椪’‘山下红’‘甜橘柚’‘鸡尾葡萄柚’‘瓯柑’‘红美人’‘春香’‘纽荷尔脐橙’,

‘宫川’‘血橙’‘满头红’的固酸比位于最佳固酸比区域,分别为:20.42、19.90、19.73、19.25、18.65、17.96、15.66、15.32、15.14、14.62、13.32;而‘胡柚’‘天草’‘椪柑’‘香橙’‘高橙’5个品种的值均在10以



品种名称 Varieties name

小写字母不同表示差异显著($p < 0.05$)The different lowercase letters indicate significant difference ($p < 0.05$).

图3 不同柑橘品种的固酸比

Fig. 3 The ratio of soluble solids to acid in juice made from different citrus varieties

下,酸感较强。

2.4 不同品种的营养品质比较

柑橘果实中含有丰富的维生素C、总黄酮、总酚、总糖等营养物质,其含量也影响着柑橘汁的风味。

表4所示为不同品种柑橘汁的维生素C、总黄酮、总酚、总糖含量测定结果。从表4可以看出,不同品种柑橘汁的总酚、总黄酮、维生素C、总糖含量均存在较大差异。‘瓯柑’‘香橙’‘满头红’‘纽荷尔脐橙’‘冰糖

表4 不同柑橘品种的营养指标

Table 4 The nutritional parameters of different citrus varieties

品种 Cultivar	$\rho(\text{维生素C})$ Vitamin C/(mg·L ⁻¹)	$\rho(\text{总酚})$ Total phenols/(mg·L ⁻¹)	$\rho(\text{总黄酮})$ Total flavonoids/(mg·L ⁻¹)	$\rho(\text{总糖})$ Total soluble solid/(mg·L ⁻¹)
尾张 Owari	265.85±5.78 n	650.75±0.30 g	166.41±0.08 ef	91.13±0.75 efg
宫川 Miyagawa Wase	265.53±3.29 n	653.92±1.47 g	172.65±0.24 e	85.33±0.56 g
山下红 Satsuma Mandarin	325.99±3.28 l	745.77±3.02 de	190.38±0.20 d	88.59±0.47 fg
满头红 Red Sene	448.96±5.68 h	1 082.91±3.32 a	195.53±0.15 cd	98.80±0.23 cd
椪柑 Ponkan	380.76±5.77 j	723.73±1.89 e	168.71±0.46 ef	103.18±0.49 c
瓯柑 Citrus Suavissima	318.43±3.36 l	1 101.28±1.64 a	350.47±0.47 a	89.36±0.25 fg
丽椪 2号 No.II Li Png	274.76±3.35 m	788.09±1.55 d	201.82±1.21 c	94.55±0.17 def
香橙 Aliquam	749.02±3.28 b	1 087.39±2.41 a	257.79±0.47 b	56.90±0.19 k
红美人 Niponicum	242.19±3.28 o	563.08±0.69 h	141.22±0.12 g	71.98±0.20 hij
胡柚 Citrus Paradisi	419.00±8.61 i	725.50±2.89 e	256.91±0.62 b	70.37±0.24 ij
鸡尾葡萄柚 Cocktail C. Paradisi	467.04±3.24 g	677.23±2.20 fg	253.03±0.87 b	91.60±0.26 efg
春香 Haruka Tangelo	181.11±3.34 p	428.66±0.97 j	103.49±0.18 i	78.75±0.13 h
甜橘柚 Dulce Tangelo	245.66±3.32 o	473.76±0.67 i	122.66±0.16 h	65.42±0.12 k
天草 Citrus Hybrid	696.51±10.88 d	709.16±2.30 ef	189.25±0.32 d	92.41±0.23 defg
高橙 Aliquam High	370.95±5.80 k	720.69±2.25 ef	255.88±0.68 b	78.07±0.46 h
纽荷尔脐橙 Newhall Navel	782.55±3.27 a	988.90±1.38 b	200.23±0.41 c	123.46±0.26 b
冰糖橙 Citrus Sinensis Osbeck	542.94±3.19 e	885.39±5.19 c	198.38±0.61 cd	131.81±0.26 a
中育橙 Aliquam Zhongyu	708.09±3.33 c	884.38±1.92 c	162.23±0.29 f	98.03±0.25 cde
血橙 Blood Orange	504.33±3.36 f	789.61±2.54 d	194.34±0.46 cd	74.93±0.16 hi

‘橙’的总酚含量排在前五位,分别为1 101.28、1 087.39、1 082.91、988.90、885.39 mg·L⁻¹;而总黄酮含量前五位的是‘瓯柑’‘香橙’‘胡柚’‘高橙’‘鸡尾葡萄柚’,其含量分别为350.47、257.79、256.91、255.88、253.03 mg·L⁻¹;‘瓯柑’的总酚含量和总黄酮含量均为最高。‘纽荷尔脐橙’‘香橙’‘中育橙’‘天草’‘冰糖橙’5个品种的维生素C含量相对较高,其含量均在500 mg·L⁻¹以上;‘冰糖橙’‘纽荷尔脐橙’‘椪柑’3个品种的总糖含量均在100 mg·L⁻¹以上,分别为131.81、123.46、103.18 mg·L⁻¹。

表5 不同柑橘品种的相关系数矩阵
Table 5 Correlation matrix among analyzed parameters

相关系数 Correlation	pH	可滴定酸 Titratable acid	可溶性固形物 Total soluble solid	可溶性糖 Soluble sugar	固酸比 The solid acid ratio	维生素C Vitamin C	总酚 Total phenols	总黄酮 Total flavonoids	总糖 Total sugar
pH	1								
可滴定酸 Titratable acid	-0.801	1							
可溶性固形物 Total soluble solid	-0.085	0.101	1						
可溶性糖 Soluble sugar	0.201	-0.218	0.716	1					
固酸比 The solid acid ratio	0.843	-0.673	0.237	0.626	1				
维生素C Vitamin C	-0.398	0.533	0.626	0.301	-0.17	1			
总酚 Total phenols	-0.156	0.385	0.629	0.265	-0.029	0.602	1		
总黄酮 Total flavonoids	-0.159	0.272	0.108	-0.015	-0.099	0.245	0.645	1	
总糖 Total sugar	0.231	-0.335	0.84	0.809	0.539	0.301	0.319	-0.016	1

pH呈负相关,可溶性糖与可溶性固形物呈正相关;固酸比与pH、可溶性糖呈正相关,与可滴定酸呈负相关;维生素C、总酚与可滴定酸、可溶性固形物、可溶性糖都呈正相关。因大部分的检验系数都较高(>0.3),本次分析中所用的9个指标适合进行因子分析^[18]。

对原始数据进行因子分析,分析结果见表6。

表6 解释的总方差
Table 6 Total variance explained

成分 Compo- nent	初始特征值 Initial eigenvalues			提取平方和载入 Extraction sums of squared loadings		
	特征值 Eigen- value	方差 Variance/ %	累积 Cumu- lative/%	特征值 Eigen- value	方差 Vari- ance/%	累积 Cumu- lative/%
	3.444	38.267	38.267	3.444	38.267	38.267
1	3.444	38.267	38.267	3.444	38.267	38.267
2	3.205	35.615	73.882	3.205	35.615	73.882
3	1.156	12.846	86.728	1.156	12.846	86.728
4	0.447	4.963	91.691			
5	0.353	3.925	95.616			
6	0.238	2.648	98.264			
7	0.099	1.096	99.36			
8	0.034	0.379	99.739			
9	0.023	0.261	100			

3 不同品种柑橘品质性状的主成分分析

通过多项单一指标的对比,各个品种均存在优劣,难以选择出适合制取柑橘汁的主要品种,因此需要建立一套合理的整体评价体系。

对pH、可滴定酸、可溶性固形物、可溶性糖、维生素C、总酚、总黄酮、总糖等9个指标进行相关系数分析,以确定这些指标是否适合进行因子分析,相关系数矩阵如表5所示。从表5可以看出,可滴定酸与

由表6可知,根据特征值大于1的原则提取了3个因子,这3个因子共解释了原有变量总方差的86.728%(80%~85%以上较佳,可代表原品质性状的绝大部分信息)^[19]。总体上,这3个因子能反映原有变量的信息,因子分析效果较理想。这3个因子的特征值分别为:3.444、3.205、1.156,各因子的方差贡献率分别为38.267%、35.615%、12.846%,累积贡献率达86.728%。

因子负荷矩阵旋转后的表7可知,第一个主成分与可溶性固形物、可溶性糖、维生素C、总糖呈很大的正相关,第一个因子主要解释这4个变量;第二个主成分与pH、固酸比呈很大的正相关,与可滴定酸呈很大的负相关,第二个因子主要解释这3个变量;第三个主成分与总酚、总黄酮呈很大的正相关,这主要是功能活性成分方面的指标,第三个因子主要解释这2个变量^[20]。

表8是根据回归算法计算出来的成分得分函数的系数,根据该表可得因子得分函数:

$$F_1 = -0.069 X_1 + 0.018 X_2 + 0.317 X_3 + 0.292 X_4 + 0.076 X_5 + 0.205 X_6 + 0.039 X_7 - 0.181 X_8 + 0.301 X_9$$

表7 旋转后的因子负荷矩阵
Table 7 Rotated component matrix

	成分 Component		
	1	2	3
pH	0.023	0.941	-0.019
可滴定酸 Titratable acid	-0.035	-0.885	0.265
可溶性固形物 Total soluble solid	0.938	-0.120	0.200
可溶性糖 Soluble sugar	0.867	0.271	-0.001
固酸比 The solid acid ratio	0.408	0.854	-0.005
维生素C Vitamin C	0.585	-0.545	0.322
总酚 Total phenols	0.434	-0.212	0.807
总黄酮 Total flavonoids	-0.072	-0.054	0.941
总糖 Total sugar	0.900	0.281	0.013

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 5 iterations.

$$F_2=0.368 X_1-0.3 X_2-0.091 X_3+0.033 X_4+0.304 X_5-0.207 X_6+0.028 X_7+0.159 X_8+0.037 X_9$$

$$F_3=0.157 X_1+0.029 X_2-0.04 X_3-0.098 X_4+0.086 X_5+0.027 X_6+0.457 X_7+0.667 X_8-0.091 X_9$$

表8 成分得分系数矩阵

Table 8 Component score coefficient matrix

	成分 Component		
	1	2	3
pH	-0.069	0.368	0.157
可滴定酸 Titratable acid	0.018	-0.300	0.029
可溶性固形物 Total soluble solid	0.317	-0.091	-0.040
可溶性糖 Soluble sugar	0.292	0.033	-0.098
固酸比 The solid acid ratio	0.076	0.304	0.086
维生素C Vitamin C	0.205	-0.207	0.027
总酚 Total phenols	0.039	0.028	0.457
总黄酮 Total flavonoids	-0.181	0.159	0.667
总糖 Total sugar	0.301	0.037	-0.091

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

Component Scores.

根据这3个因子得分函数自动计算各样本的3个因子得分见表9。三个因子按各自的方差贡献率加权相加为综合得分,其计算公式为: $F=0.382\ 67\times F_1+0.356\ 15\times F_2+0.128\ 46\times F_3$,结果如表9。

根据根据 F 值的大小可分为如下几类^[18]:

第一类:较为合适($F \geq 0.5$):‘瓯柑’‘纽荷尔脐橙’‘冰糖橙’。

第二类:一般($0 \leq F < 0.5$):山下红、满头红、丽椪、鸡尾葡萄柚、中育橙。

第三类:较为不合适($F < 0$):‘尾张’‘宫川’‘椪柑’‘香橙’‘红美人’‘胡柚’‘春香’‘甜橘柚’‘天草’‘高橙’‘血橙’。

根据 F 值的排名可知前五位分别是‘冰糖橙’‘纽荷尔脐橙’‘瓯柑’‘丽椪2号’‘山下红’,因此经过主成分分析建立的评价体系可知,能够选用合适的柑橘品种作为果汁制备原料。上述9项指标主要体现了不同品种柑橘的营养价值和口感的不同,通过该评价体系,可以较为便捷的选取出营养价值较高且风味口感较好的柑橘品种。同时从大规模制取柑橘汁的角度出发,考虑种植面积及产量、果肉率、出汁率等指标,可为提高柑橘汁制备提供更多依据。

表9 各品种的因子得分

Table 9 Factor score of each variety

品种 Cultivar	FAC1_1	FAC2_1	FAC3_1	F	综合评价 Comprehensive score	
					FAC1_1	FAC2_1
尾张 Owari	-0.11	-0.26	-0.86	-0.22	12	
宫川 Miyagawa Wase	-0.06	0.23	-0.68	-0.07	10	
山下红	0.32	0.41	-0.25	0.22	5	
Satsuma Mandarin						
满头红 Red Sene	0.55	-0.19	0.60	0.18	6	
椪柑 Ponkan	0.40	-0.93	-0.84	-0.15	11	
瓯柑 Citrus Suavissima	-0.57	1.25	2.78	0.53	3	
丽椪2号 No.II Li Png	-0.16	0.88	0.16	0.31	4	
香橙 Aliquam	-0.63	-2.35	1.45	-0.84	19	
红美人 Nipponicum	-1.10	0.72	-0.85	-0.25	13	
胡柚 Citrus Paradisi	-1.05	-0.22	0.70	-0.49	17	
鸡尾葡萄柚	-0.44	0.57	0.51	0.18	7	
Cocktail .C. Paradisi						
春香 Haruka Tangelo	-1.07	0.39	-1.69	-0.47	16	
甜橘柚 Dulce Tangelo	-0.78	0.89	-1.13	-0.31	14	
天草 Citrus Hybrid	0.27	-1.42	-0.60	-0.34	15	
高橙 Aliquam High	-0.04	-0.92	0.36	-0.55	18	
纽荷尔脐橙	2.07	-0.46	0.23	0.62	2	
Newhall Navel						
冰糖橙	2.03	1.98	0.27	1.65	1	
Citrus Sinensis Osbeck						
中育橙	0.64	-0.84	-0.35	0.03	8	
Aliquam Zhongyu						
血橙 Blood Orange	-0.40	0.25	0.19	-0.04	9	

4 讨论

柑橘汁品质指标主要包括果肉率、出汁率、色泽、pH、可溶性固形物、可滴定酸、可溶性糖、维生素C、总酚、总黄酮、总糖,这些指标既相互独立又密切联系,共同影响着柑橘汁的营养风味。殷艳^[21]对5个杂柑品种果实品质及制汁特性进行了研究,对不同杂柑品种中天草的出汁率、可溶性固形物及可滴定酸、可溶性糖指标等多项指标进行对比分析,选出了果汁风味浓郁且果汁滋味和香气品评分数较高的杂

柑品种。王贵元等^[22]分析荆州地区6个柑橘品种果形、单果质量、果形指数、可食率、维生素C含量等理化指标进行分析,为柑橘品种的筛选提供一定思路。

因此本文对不同品种柑橘的单项指标测定结果进行对比分析:不同品种柑橘汁的品质指标差异较大,从出汁率和果肉率的角度出发,‘红美人’的出汁率和果肉率最高,而‘香橙’的果肉率和出汁率最低的;从柑橘色泽的测定结果可知‘尾张温州蜜柑’‘宫川’‘山下红’‘冰糖橙’在色泽方面相对较好;‘香橙’‘高橙’‘天草’‘椪柑’等品种中可滴定酸的含量相对较高;‘冰糖橙’‘纽荷尔脐橙’中的可溶性固形物和可溶性糖的含量都较高;‘瓯柑’的总酚、总黄酮含量最高;‘纽荷尔脐橙’‘香橙’‘中育橙’‘天草’‘冰糖橙’5个品种的维生素C含量相对较高,其含量均在500 mg·L⁻¹以上,而‘冰糖橙’‘纽荷尔脐橙’‘椪柑’3个品种的总糖含量则地域200 mg·L⁻¹以上,分别为131.81、123.46、103.18 mg·L⁻¹。

杨水芝等^[20]开展酸橙株系品质分析时采用主成分分析筛选出适合加工型的酸橙株系,为了综合评价不同柑橘的制汁适应性,对19个柑橘品种的9个品质性状进行主成分分析,从分析结果看,提取的3个主成分累计方差贡献率达到86.728%。根据每个指标对每个主成分的贡献率计算得到柑橘汁品质评价综合得分模型。综合得分较高的‘冰糖橙’‘纽荷尔脐橙’这两个品种属于橙类,甜度高、口感易被大众接受,但其产量小、价格高不适合大量生产NFC果汁;‘瓯柑’‘椪柑’‘宫川’‘尾张温州蜜柑’等品种产量大但风味欠缺,需和冰糖橙、纽荷尔脐橙加以复配,提高口感风味。利用主成分分析可对各个品种柑橘进行综合评价,剔除不重要的评价指标,保留重要信息,也能避免重复信息的干扰,与李伟等^[23]对不同品种杨梅果实综合品质评价时采用的方法一致。

5 结 论

对浙江地区19个品种柑橘的品质指标进行了测定,在单个指标的对比未能得出合理的结果下,对19个柑橘品种的9个品质性状进行主成分分析,并建立了基于主成分分析的柑橘品质评价模型。从分析结果可知,共提取了3个主成分,累计方差贡献率达到86.728%。经过该模型的计算,综合得分较高的‘冰糖橙’‘纽荷尔脐橙’属于橙类,其优点是甜度高、口感易被大众接受,适合作为制取NFC果汁。由于浙

江地区主产‘宫川’‘尾张’等品种,产量大、风味欠缺,而冰糖橙产量少、价格高。因此,考虑成本因素和大规模的生产所需,可与‘椪柑’‘宫川’‘尾张温州蜜柑’等产量大但风味欠缺的几种柑橘进行复配。此外,利用主成分分析可对各个品种的柑橘进行综合评价,同时考虑多项指标因素,可以提供直观的柑橘品质评价,为企业选取适合柑橘汁制备原料品种提供依据。

参考文献 References:

- [1] 丁晓波,张华,刘世尧,廖益均,周志钦.柑橘果品营养学研究现状[J].园艺学报,2012,39(9):1687-1702.
DING Xiaobo, ZHANG Hua, LIU Shiya, LIAO Yijun, ZHOU Zhiqin. Current status of the study in citrusnutriology[J]. Acta Horticulturae Sinica, 2012, 39(9):1687-1702.
- [2] 单杨.我国柑橘工业现状及发展趋势[J].农业工程技术(农产品加工业),2014(4):13-17.
SHAN Yang. Present situation and development trend of citrus industry in China [J]. Agricultural Engineering Technology (Agricultural Products Processing Industry), 2014(4): 13-17.
- [3] 董美超,李进学,周东果,岳建强,高俊燕.柑橘品种选育研究进展[J].中国果树,2013(6): 73-78.
DONG Meichao, LI Xuejin, ZHOU Dongguo, YUE Jianqiang, GAO Junyan. Research progress of citrus variety breeding[J]. China Fruits, 2013(6): 73-78.
- [4] KOCA U, BERHOW M A, FEBRES V J, CHAMP K I, CARRILLO-MENDOZA O, MOORE G A. Decreasing unpalatable flavonoid components in Citrus: the effect of transformation construct [J]. Physiologia plantarum, 2009, 137(2): 101-114.
- [5] 张珉,钟晓红.柑橘功能性成分研究进展[J].中国农学通报,2009,25(11): 137-140.
ZHANG Min, ZHONG Xiaohong. Advance in study of functional components in citrus[J]. Chinese Agricultural Science Bulletin, 2009, 25(11): 137-140.
- [6] 单杨.中国柑橘工业的现状、发展趋势与对策[J].中国食品学报,2008(1): 1-8.
SHAN Yang, Present situation, development trend and countermeasures of citrus industry in China[J]. Journal of Chinese Institute of Food Science and Technology, 2008(1): 1-8.
- [7] 韩斯,孟宪军,汪艳群,李斌,李冬男.不同品种蓝莓品质特性及聚类分析[J].食品科学,2015,36(6): 140-144.
HAN Si, MENG Xianjun, WANG Yanqun, LI Bin, LI Dongnan. Quality properties and cluster analysis of different blueberry cultivars[J]. Food Science, 2015, 36(6): 140-144.
- [8] 王菁,蒲彪,伍红梅.柑橘果皮中主要功能性成分含量测定[J].食品工业科技,2010,31(3): 367-369.
WANG Jing, PU Biao, WU Hongmei. Determination of the main functional components in citrus peels [J]. Science and Technolo-

- gy of Food Industry, 2010, 31(3): 367-369.
- [9] HANDIQUE J G, BORUAH M P, KALITA D. Antioxidant activities and total phenolic and flavonoid contents in three indigenous medicinal vegetables of north-east India[J]. Natural Product Communications, 2012, 7(8): 1021-1023.
- [10] 贾莹莹,赵晋彤,韩香玉,李苏苏.紫外分光光度法测定绵马贯众总黄酮含量[J].亚太传统医药,2018,14(4):48-49.
- JIA Yingying, ZHAO Jintong, HAN Xiangyu, LI Susu. Determination of the total flavonoids content of Dryo-pteridis Crassirhizomatis Rhizoma by ultraviolet spectroscopy[J]. Science and Technology of Food Industry, 2018, 14(4):48-49.
- [11] 曹少谦,刘亮,潘思轶.血橙果汁贮藏过程中品质变化研究[J].食品科学,2011,32(2):297-301.
- CAO Shaoqian, LIU Liang, PAN Siyi. Quality changes of blood orange juice during storage[J]. Food Science, 2011, 32(2): 297-301.
- [12] SURVESWARAN S , CAI Y Z, CORKE H, SUN M. Systematic evaluation of natural phenolic antioxidants from 133 Indian medicinal plants [J]. Food Chemistry, 2007, 102(3): 938-953.
- [13] WEI X, CHEN C X, Yu Q B, G A, Y Y, L G L, Jr GMITTER F G. Comparison of carotenoid accumulation and biosynthetic gene expression between Valencia and Rohde Red Valencia sweet oranges[J]. Plant Science, 2014, 227: 28-36.
- [14] 米佳,禄璐,戴国礼,何昕孺,李晓莺,闫亚美,秦昱.枸杞色泽与其类胡萝卜素含量和组成的相关性[J].食品科学,2018,39(5): 81-86.
- MI Jia, LU Lu, DAI Guoli, HE Xinru, LI Xiaoying, YAN Yamei, QIN Ken. Correlations between skin color and carotenoid contents in wolfberry [J]. Food Science, 2018, 39(5): 81-86.
- [15] 程相,陈家旭,吴文鑫.应用多元统计分析葡萄、葡萄酒理化指标与葡萄酒质量的相关性[J].中外葡萄与葡萄酒,2013(4): 43-47.
- CHENG Xiang, CHEN Jiaxu, WU Wenxin. Multivariate statistical analysis of the correlation between grape, physicochemical indicators of grape wine and quality of grape wine[J]. Sino-Oceanside Grapevine & Wine, 2013(4): 43-47.
- [16] 周煜棉,蔡小林,潘介春,刘红红.龙眼成熟过程中外观色泽与品质变化及其相关性分析[J].江苏农业科学,2018,46(7): 189-193.
- ZHOU Yumian, CAI Xiaolin, PAN Jiechun, LIU Honghong. The change of appearance color and quality and its correlation analysis in the process of longan maturation[J]. Jiangsu Agricultural Sciences, 2018, 46(7): 189-193.
- [17] 李娜,刘颖平,尤毅娜,王睿,邓红,孟永宏,郭玉蓉.香橙果汁产品配方的研发[J].食品科技,2015,40(1): 117-121.
- LI Na, LIU Yingping, YOU Yina, WANG Rui, DENG Hong, MENG Yonghong, GUO Yurong. The development of product formulation for orange juice[J]. Food Science and Technology, 2015, 40(1): 117-121.
- [18] 赵娜.温州蜜柑汁品质特性及复配改进研究[D].华中农业大学,2013.
- ZHAO Na. The study on quality characteristics and blending improvements of juice satsuma mandarins [D]. Huazhong Agricultural University, 2013.
- [19] 白沙沙,毕金峰,王沛,公丽艳,王轩.不同品种苹果果实品质分析[J].食品科学,2012,33(17):68-72.
- BAI Shasha, BI Jinfeng, WANG Pei, GONG Liyan, WANG Xuan. Fruit quality analysis of different apple varieties[J]. Food Science, 2012, 33(17): 68-72.
- [20] 杨水芝,周长富,龚碧涯,李高阳,李绮丽,单杨,余应弘.湖南野生酸橙株系的品质分析及评价[J].食品工业科技,2017,38(16): 43-49.
- YANG Shui芝, ZHOU Changfu, GONG Biya, LI Gaoyang, LI Qili, SHAN Yang, YU Yinghong. Quality analysis and evaluation of Citrus aurantium L. wild strains from Hunan province[J]. Science and Technology of Food Industry, 2017, 38(16): 43-49.
- [21] 殷艳.杂柑的果实品质及果汁加工工艺的研究[D].长沙:中南林业科技大学,2007.
- YIN Yan. Study on the fruit quality and juice processing technology of hybrid oranges.[D]. Changsha: Central South University of Forestry and Technology, 2007.
- [22] 王贵元,倪丽.荆州地区6个柑橘品种成熟期果实品质的比较[J].天津农业科学,2014,20(1): 99-101.
- WANG Guiyuan, NI Li. Comparative of the fruit quality of six varieties of citrus in the Jinzhou area[J]. Tianjin Agricultural Sciences, 2014, 20(1): 99-101.
- [23] 李伟,郜海燕,陈杭君,吴伟杰,房祥军.基于主成分分析的不同品种杨梅果实综合品质评价[J].中国食品学报,2017,17(6): 161-171.
- LI Wei, GAO Haiyan, CHEN Hangjun, WU Weijie, FANG Xiangjun. Comprehensive assessment on different varieties of *Myrica rubra* based on principle component analysis[J]. Journal of Chinese Institute of Food Science and Technology, 2017, 17(6):161-171.