

# 不同产地灰枣和骏枣干果风味研究

王 超<sup>1</sup>, 吕文秀<sup>1</sup>, 高京草<sup>2</sup>, 贾宇尧<sup>1</sup>, 刘会平<sup>3</sup>, 韩 刚<sup>1\*</sup>

(<sup>1</sup>西北农林科技大学林学院, 陕西杨凌 712100; <sup>2</sup>西北农林科技大学园艺学院, 陕西杨凌 712100;

<sup>3</sup>新疆生产建设兵团第一师二团农业发展服务中心, 新疆阿拉尔 843300)

**摘要:**【目的】选择栽培广泛的灰枣和骏枣2个品种, 研究影响口感的糖酸类物质和影响嗅感的挥发性物质, 比较不同产地枣干果的风味差异。【方法】分别通过蒽酮比色法、酸碱滴定法、液相色谱法、气相色谱串联质谱法测定原产地与主要引栽地枣干果的总糖、总酸、可溶性糖、有机酸及香气物质含量。【结果】不同产地灰枣和骏枣干果的可溶性糖均以蔗糖含量最高(占总糖42.09%~65.33%)、果糖含量次之, 葡萄糖含量最低; 有机酸以苹果酸含量最高(占总酸36.02%~56.94%), 柠檬酸和琥珀酸含量次之, 奎宁酸含量最低; 不同产地灰枣和骏枣共检测到68种挥发性物质, 酸类、酮类、醇类和烃类物质为主要香味物质; 应用主成分分析法进行综合香气品质评价表明原产地香味优于引栽的4个产地。【结论】原产地枣干果低糖高酸的特点导致其糖酸比低于引栽地, 但其香气得分高于引栽地; 不同产地枣干果的风味差异与日照、气温、降水及土壤特性等环境因素高度相关。

**关键词:**枣; 可溶性糖; 有机酸; 香气; 产地

中图分类号:S665.1

文献标志码:A

文章编号:1009-9980(2021)11-1921-09

## Study on dry fruit flavor of Huizao and Junzao jujubes from different habitats

WANG Chao<sup>1</sup>, LÜ Wenxiu<sup>1</sup>, GAO Jingcao<sup>2</sup>, JIA Yuyao<sup>1</sup>, LIU Huiping<sup>3</sup>, HAN Gang<sup>1\*</sup>

(<sup>1</sup>College of Forestry, Northwest Agriculture and Forestry University, Yangling 712100, Shaanxi, China; <sup>2</sup>College of Horticulture, Northwest Agriculture and Forestry University, Yangling 712100, Shaanxi, China; <sup>3</sup>Agricultural Development Service Center of the First Division and Second Regiment of Xinjiang Production and Construction Corps, Alar 843300, Xinjiang, China)

**Abstract:**【Objective】Fruit flavor substances are divided into flavor and aroma substances. The former is perceived through taste. The research focus on flavor is sugar and acid, which determine the two most important flavors of fruit: sweet and acid. Acid is perceived by olfactory sense, and fruits contain a lot of volatile aromatic substances. At present, comprehensive flavor analysis has been carried out on many fruits such as grapes, cherries and so on. For jujube fruit, the research focus is limited to the sugars and acids that affect the taste and aroma substances, thus affecting the sense of smell. Substance analysis lacks comprehensive flavor analysis and systematic research. The fruits of Huizao and Junzao during mature period were studied in this experiment. The sugar, acid and aroma compounds that affected the flavor of jujube fruit were comprehensively analyzed, and their sources (Xinzheng, Henan; Jiaocheng, Shanxi) and four introduced places in Xinjiang (Kashi, Hetian, Ertuan and Wensu) were studied in order to provide a theoretical basis for the flavor evaluation of dried jujube fruit and a reference for the introduction and fine application of desired jujube varieties.【Methods】Determine the total sugar and total acid by spectrophotometry and acid-base titration, respectively; weigh 0.2 g of the dried sample and put into a 10 mL centrifuge tube, add 7.5 mL of 80% ethanol, shake in a water bath at 70 °C for 30 min, cen-

收稿日期:2021-05-06 接受日期:2021-06-28

基金项目:国家重点研发计划(2019YFD1001605);西北农林科技大学科技成果转化推广重点项目(XTG2018-35);杨凌示范区农业科技示范推广能力提升项目(2018-TS43)

作者简介:王超,男,在读硕士研究生,研究方向为枣树栽培生理与果实品质。Tel:18710931355,E-mail:Wangchao\_916@163.com

\*通信作者 Author for correspondence. Tel:13772195939,E-mail:zxphg@nwsuaf.edu.cn

trifuge at 8000  $r \cdot min^{-1}$  10 min, take the supernatant in a 25 mL glass test tube, repeat 3 times, dilute the volume (80% ethanol) to 25 mL and shake well. Take 10 mL (8 mL) into a 50 mL centrifuge tube, dry at 55 °C, add 10 mL (8 mL) redistilled water to dissolve, filter with 0.45 um filter, it was the test solution. The soluble sugar was determined by high performance liquid chromatography, using COSMOSIL Packed Column 5NH2-MS column (4.6ID×150 nm), the detector was RI Detector L-2490 differential detector, and the mobile phase was acetonitrile: water (80:20), the standard products were sucrose, fructose and glucose; the organic acid was determined by ultra-high performance liquid chromatography, the acid was determined with a C18 column and a UV detector, the mobile phase was a potassium dihydrogen phosphate solution with pH=2.4, and the standard product was malic acid, citric acid, succinic acid and quinic acid. Determination of aroma substances was performed by the gas chromatography-tandem mass spectrometry, and the chromatographic mass spectrometry acquisition conditions were as follows: Chromatographic column: HP-5MS (30 m $\times$ 0.25 mm $\times$ 0.25 mm); carrier gas: helium (0.83 mL $\cdot$ mL $^{-1}$ ); sample inlet temperature: 250 °C; solution delay: 3 min; program temperature rise: hold at 60 °C for 1 min, increase to 250 °C at a rate of 10 °C $\cdot$ min $^{-1}$  and hold for 1 min, then increase to 280 °C at a rate of 20 °C $\cdot$ min $^{-1}$  and hold for 1 min, and finally increase at a rate of 10 °C $\cdot$ min $^{-1}$  to 315 °C and keep for 4 min; split mode: 10:1; mass spectrometry conditions: transmission line temperature 280 °C, electron energy 70 eV, ion source temperature 250 °C, quadrupole temperature 150 °C, acquisition mode MRM. SPME sampling parameters: aging temperature 250 °C, aging time 5 min, heating temperature 60 °C, heating time 10 min, adsorption time 20 min, desorption time 5 min, aging time 5 min after sample injection. 【Results】The soluble sugar contents of Huizao and Junzao dried fruits from different origins were the highest (accounting for 42.09%-65.33% of total sugar), followed by fructose, and glucose content was the lowest; organic acid had the highest content of malic acid (accounting for 36.02%-56.94%), followed by citric acid and succinic acid, with the lowest content of quinic acid; the high sugar and low acid characteristics of the 4 kinds of jujube fruits in Xinjiang, which led to a higher sugar-acid ratio than the original place, making them a better taste. A total of 68 aroma substances were detected in Huizao jujube and jujubes from different origins. The main aroma substances that affected the aroma of dried jujube fruits were acids, ketones, alcohols and hydrocarbons. The comprehensive evaluation of aroma quality by principal component analysis showed that the flavor from the original producing area was better than that of the four introducing areas. The flavor difference in dried jujube from different areas may be closely related to environmental factors such as sunshine, temperature, precipitation and soil characteristics. The results can provide reference for the introduction and fine application of desired jujube varieties in Xinjiang. 【Conclusion】(1) The contents of soluble sugar and organic acid in dried jujube fruits from different areas were different. Sucrose was the main soluble sugar and malic acid was the main organic acid. Planting land can result in the jujube dried fruit flavor being better than the original place. (2) The main aroma components affecting the aroma quality of dried jujube were acids, ketones, alcohols and hydrocarbons; the content of aroma components changed greatly, mainly for acids and ketones. The comprehensive aroma scores of jujube and sour jujubes from different producing areas were higher than those from the introduction areas. (3) The flavor differences in dried jujube from different producing areas may be closely related to environmental factors such as sunshine, temperature, precipitation and soil characteristics. Further study on the key environmental factors affecting the aroma of dried jujube is of great significance to improve the aroma of dried jujube in cultivation area.

**Key words:** Jujube; Soluble sugar; Organic acids; Aroma; Habitats

枣(*Ziziphus jujuba* Mill.)为鼠李科(Rhamnaceae)枣属(*Ziziphus*)植物,在我国栽培历史悠久,黄河中下游是最早的栽培中心<sup>[1]</sup>,后渐及南北各地,并引种栽植到国外50多个国家。进入21世纪,由于新疆自然条件优异,兴起了以灰枣和骏枣两个品种为主向新疆沙漠、戈壁规模化引种栽培的热潮<sup>[2]</sup>,使新疆红枣种植面积达到46.67余万hm<sup>2</sup>,占全国1/3,尤其是新疆和田、阿克苏、喀什等地为其主栽区,枣产品的市场竞争力越来越大,引起人们对枣干果风味的关注和研究。

前人针对不同产地枣干果风味中的糖酸类物质已经开展了大量研究,张萍等<sup>[3]</sup>对南疆6个灰枣栽培区及其原产地枣干果营养品质进行分析,表明新疆各产地枣干果糖含量显著高于原产地河南新郑;张颖等<sup>[4]</sup>对26个栽培产地、42个栽培枣品种的观测表明,新疆枣干果总糖含量显著高于其他产地,主要贡献来自蔗糖;贺润平等<sup>[5]</sup>比较不同产地金昌1号糖酸类物质时表明新疆枣干果糖酸比最高,品质最佳。关于枣干果风味组成中香气物质也有一些报道,但多集中于品种间<sup>[6]</sup>及干制方式<sup>[7]</sup>、烘干温度<sup>[8]</sup>等的影响。

而针对产地不同引起枣干果香气物质的差异仅有少量的研究,邓红等<sup>[9]</sup>在5个产地的不同品种上得出,品种、产地的不同均是红枣香气成分存在差异的原因。总体来说,相较于在其他果树上进行的风味研究,如葡萄<sup>[10]</sup>、樱桃<sup>[11]</sup>等,枣干果风味研究仅从影响口感的糖酸类物质或影响嗅感的香气物质进行分析,缺乏综合性的风味分析和系统性的研究。

笔者在本研究中选择全国栽培广泛的灰枣和骏枣两个品种,测定其原产地(河南新郑市、山西交城县)与主要引栽的新疆4个产地(和田洛浦县、喀什疏勒县、阿克苏二团、阿克苏温宿县)枣干果的总糖、总酸、可溶性糖、有机酸及香气物质,探寻不同产地枣干果的风味特性差异,以期为枣干果风味评价提供理论依据,为优良枣品种引进新疆及其精准应用提供参考。

## 1 材料和方法

### 1.1 材料

供试材料灰枣和骏枣果实样品采集地见表1。于2018年10月,分别在各采集地选择典型立地条件

表1 样品采集地及其气候、土壤特点

Table 1 Sample collection site and its climate and soil characteristics

样品 Sample	采集地 Collection place	经纬度 Latitude and longitude	气候类型 Climate type	土壤类型 Soil type
灰枣、骏枣 Huizao, Junzao	新疆和田地区洛浦县 Luopu County, Hotan Region, Xinjiang	78°00'~0°30'E, 34°22'~38°27'N	暖温带干旱荒漠性气候 Warm temperate arid desert climate	壤质沙土 Loamy sand
灰枣、骏枣 Huizao, Junzao	新疆阿克苏二团 Aksu Second Regiment, Xinjiang	79°39'~82°01'E, 39°30'~41°27'N	暖温带大陆性气候 Warm temperate continental climate	砂质黏土 Sandy clay
灰枣、骏枣 Huizao, Junzao	新疆喀什地区疏勒县 Shule County, Kashgar Prefecture, Xinjiang	71°39'~79.52' E, 35°28'~40°16'N	温带大陆性气候 Temperate continental climate	粉(砂)壤土 Silt (sand) loam
灰枣、骏枣 Huizao, Junzao	新疆阿克苏地区温宿县 Wensu County, Aksu Prefecture, Xinjiang	79°28'~81°30'E, 40°52'~42°15'N	暖温带大陆性干旱气候 Warm temperate continental arid climate	砂土 Sand
灰枣 Huizao	河南省新郑市 Xinzheng City, Henan Province	113°30'~113°54'E, 34°16'~34°39'N	暖温带大陆性季风气候 Warm temperate continental monsoon climate	褐土 Cinnamon
骏枣 Junzao	山西省交城县 Jiaocheng County, Shanxi Province	111°24'~112°17'E, 37°28'~37°54'N	暖温带大陆干旱性气候 Warm temperate continental arid climate	褐土 Cinnamon

下管理良好的枣园,每个品种随机选择5株生长健康的结果树(3~5年生),每株于上层分东南西北各随机选取5个完熟期果实共20个,每个品种合计100个果实,带回实验室,室内(温度15~25℃,相对湿度45%~70%)条件下进行阴干至含水量23%左右,将样品分为2份,1份去核后用匀浆机粉碎用于香气物质的测定;另1份去核后用液氮研磨用于糖酸类物质的测定。

### 1.2 方法

1.2.1 糖酸类物质的测定 可溶性糖(蔗糖、果糖、葡萄糖)<sup>[12]</sup>、有机酸(苹果酸、柠檬酸、琥珀酸、奎宁酸)含量的<sup>[13]</sup>测定采用高效液相色谱法,称取烘干样品0.2 g于10 mL离心管中,加入7.5 mL 80%乙醇,70℃水浴振荡30 min,8000 r·min<sup>-1</sup>离心10 min,取上清液于25 mL玻璃试管中,重复3次,定容(80%乙醇)至25 mL摇匀。取10 mL(8 mL)至50 mL离心管中,55℃烘干,加10 mL(8 mL)重蒸水溶解,0.45 um滤头过滤,即为待测液。采用COSMOSIL Packed

Column 5NH<sub>2</sub>-MS 色谱柱(4.6ID×150 nm), 检测器为RI Detector L-2490 示差检测器测定糖,流动相为  $V_{乙腈}:V_水=80:20$ , 标品为蔗糖、果糖和葡萄糖;用C<sub>18</sub>柱和紫外检测器测定酸,流动相为pH=2.4的磷酸二氢钾溶液,标品为苹果酸、柠檬酸、琥珀酸和奎宁酸。

可溶性糖/有机酸含量( $\text{mg} \cdot \text{g}^{-1}$ )=各糖/酸类物质浓度( $\text{mg} \cdot \text{mL}^{-1}$ )×定容体积(mL)/样品质量(g)。

总糖、总酸含量测定分别采用蒽酮比色法<sup>[14]</sup>、酸碱滴定法<sup>[14]</sup>,3次重复。

**1.2.2 挥发性物质的测定** 采用气相色谱(Gas Chromatography, GC)和串联质谱(Tandem mass spectrometry, MS/MS)联用方法测定;色谱质谱采集条件-色谱柱:HP-5MS(30 m×0.25 mm×0.25 mm);载气:氮气(0.83 mL·mL<sup>-1</sup>);进样口温度:250 °C;溶液延迟:3 min;程序升温:60 °C保持1 min,以10 °C·min<sup>-1</sup>速度升至250 °C并保持1 min,然后再以20 °C·min<sup>-1</sup>速度升至280 °C并保持1 min,最后以10 °C·min<sup>-1</sup>速度升至315 °C并保持4 min;分流模式:10:1;质谱条件:传输线温度280 °C,电子能量

70 eV,离子源温度250 °C,四级杆温度150 °C,采集模式为多反映监测模式(multiple reaction monitoring, MRM)。固相微萃取(soild-phase microextraction, SPME)进样参数:老化温度250 °C,老化时间5 min,加热温度60 °C,加热时间10 min,吸附时间20 min,解析时间5 min,进样后老化时间5 min。

利用MWDB数据库自动检索各组分,参考文献及标准谱对机检结果进行核对和确认,按面积归一法计算各组分相对质量分数<sup>[15]</sup>。

### 1.3 数据处理

利用SPSS 19.0软件进行统计分析和主成分分析,数据均以均值±标准差(mean±SD)表示,糖酸含量比较采用单因素方差分析(ANOVA),差异显著水平均为0.05,绘图采用Excel 2016软件。

## 2 结果与分析

### 2.1 糖酸类物质

**2.1.1 不同产地枣干果糖类物质** 从表2可以看出,灰枣、骏枣原产地及其不同引栽地枣干果中可溶

表2 不同产地枣干糖组分及含量

Table 2 Sugar composition and content of dried jujube from different Habitats (mg·g<sup>-1</sup>)

品种 Variety	产地 Habitats	可溶性糖 Soluble sugar			总糖 Total sugar
		果糖 Fructose	葡萄糖 Glucose	蔗糖 Sucrose	
灰枣 Huizao	二团 Ertuan	160.50±22.54 a	122.42±11.53 a	457.97±15.10 b	830.85±24.68 b
	喀什 Kashi	127.75±13.89 b	99.42±27.13 b	402.14±15.60 c	865.42±24.04 ab
	和田 Hotan	134.12±39.26 b	117.60±17.52 ab	573.89±20.57 a	878.49±18.72 a
	温宿 Wensu	169.56±11.79 a	115.57±7.43 ab	461.44±12.49 b	841.09±44.14 b
	新郑 Xinzheng	126.84±29.70 b	85.98±4.77 b	416.02±13.44 c	822.37±17.05 b
骏枣 Junzao	二团 Ertuan	124.71±27.28 b	112.49±22.43 a	400.85±13.83 b	747.21±23.48 ab
	喀什 Kashi	181.24±13.52 a	124.98±42.92 a	318.04±19.95 c	755.67±22.79 ab
	和田 Hotan	108.23±22.53 b	97.54±13.45 b	486.29±38.79 a	790.26±24.76 a
	温宿 Wensu	139.02±18.06 ab	97.80±15.20 b	366.65±20.76 bc	728.99±24.38 ab
	交城 Jiaocheng	98.73±6.55 b	89.26±15.98 b	306.12±24.72 c	715.16±47.08 b

注:同列不同小写字母表示差异显著( $p < 0.05$ )。下同。

Note: Different small letters in the same column indicate significant difference at  $p < 0.05$ . The same below.

性糖均以蔗糖含量最高,其次为果糖含量,葡萄糖含量稍低于果糖含量,其中蔗糖含量超过其他可溶性糖2倍,是枣干果中最主要的可溶性糖。2个品种的3种可溶性糖含量在不同产地间均存在显著差异,其中葡萄糖含量总体上变幅较小,而果糖与蔗糖含量在个别产地表现突出,如温宿产地灰枣的果糖含量、温宿和喀什产地骏枣的果糖含量均显著高于其他产地,以及和田产地灰枣和骏枣的蔗糖含量均显

著高于其他产地,尤其是后者使得该产地灰枣和骏枣总糖含量均处于最高水平,表明蔗糖对该产地灰枣和骏枣总糖含量贡献最大。

**2.1.2 不同产地枣干果酸类物质** 从表3可以看出,不同产地灰枣和骏枣干果中,有机酸均以苹果酸含量最高,是枣干果中最主要的有机酸;柠檬酸、琥珀酸含量次于苹果酸,奎宁酸含量最低,此外,总酸含量皆以原产地枣干果最高。苹果酸、柠檬酸、奎宁

表3 不同产地枣干果酸组分及含量

Table 3 Components and contents of dried fruit acids of jujube from different habitats (mg·g<sup>-1</sup>)

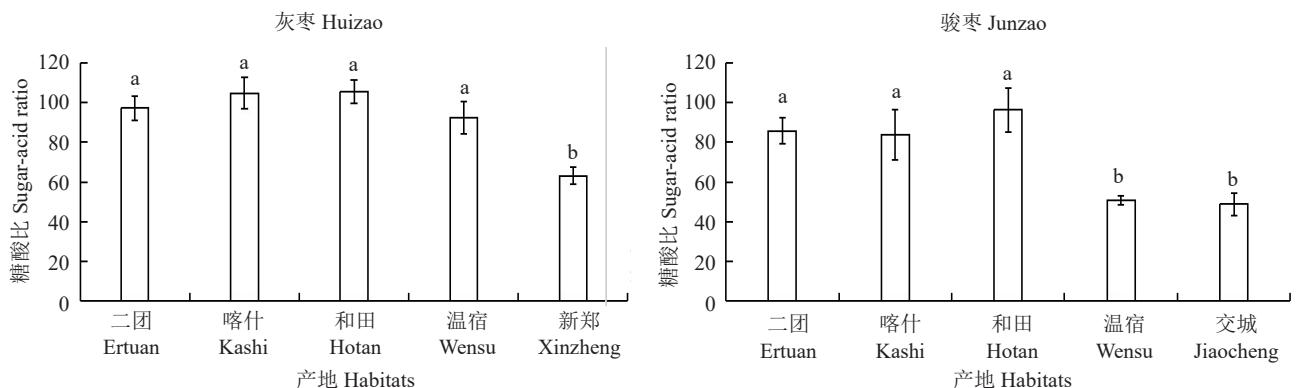
品种 Variety	产地 Habitats	有机酸 Organic acids				总酸 Acid value
		苹果酸 Malic acid	柠檬酸 Citric acid	奎宁酸 Quinic acid	琥珀酸 Succinic acid	
灰枣 Huizao	二团 Ertuan	4.88±0.67 a	1.60±0.31 ab	0.80±0.07 ab	1.69±0.33 ab	8.57±0.33 b
	喀什 Kashi	4.35±0.30 b	1.08±0.19 b	0.63±0.02 b	2.06±0.20 ab	8.31±0.64 b
	和田 Hotan	4.20±0.37 b	2.01±0.21 a	0.76±0.17 ab	1.73±0.28 ab	8.36±0.59 b
	温宿 Wensu	4.23±0.62 b	1.29±0.10 ab	0.84±0.03 a	2.03±0.79 a	9.13±0.46 b
	新郑 Xinzheng	5.16±0.49 a	1.95±0.31 a	0.73±0.12 ab	1.89±0.85 b	13.06±0.71 a
骏枣 Junzao	二团 Ertuan	4.42±0.89 abc	1.95±0.19 b	1.03±0.06 a	2.24±0.19 a	8.75±0.39 b
	喀什 Kashi	4.59±0.40 bc	0.97±0.08 c	0.73±0.11 b	1.50±0.22 b	9.18±1.18 b
	和田 Hotan	4.38±0.17 c	1.55±0.28 bc	0.67±0.02 b	1.56±0.16 b	8.29±0.78 b
	温宿 Wensu	5.75±0.15 a	2.80±0.23 a	0.81±0.14 a	1.61±0.25 b	14.37±1.18 a
	交城 Jiaocheng	5.32±0.15 ab	1.95±0.19 b	0.61±0.16 b	2.07±0.04 ab	14.77±1.42 a

酸、琥珀酸及总酸含量均存在显著差异,尤其是总酸含量,新郑灰枣、交城骏枣分别高出引栽地30.09%~36.37%、2.71%~43.87%。

### 2.1.3 不同产地枣干果糖酸比

通过总糖与总酸相

比计算得出的糖酸比作为一项综合指标,可反映枣果实最重要的甜酸味,除各糖酸组分含量外,其高低在很大程度上决定果实风味<sup>[16]</sup>。图1显示,新郑灰枣糖酸比显著低于其他产地灰枣,其余4个产地差



不同小写字母表示在  $p < 0.05$  差异显著。下同。

Different small letters indicate significant difference at  $p < 0.05$ . The same below.

图1 不同产地枣干果糖酸比

Fig. 1 Sugar-acid ratio of dried jujube from different Habitats

异不显著,以和田、喀什灰枣最高;温宿、交城骏枣糖酸比显著低于其他产地,其他3个产地差异不显著,以和田骏枣糖酸比最高。

## 2.2 香气物质

2.2.1 不同产地枣干果挥发性物质 水果的挥发性香气物质主要包括酯类、醇类、醛类、羧基化合物和一些杂环化合物,这些香气成分能反应果品的风味特征<sup>[7]</sup>。表4所示,不同产地灰枣和骏枣干果中共检测出68种挥发性物质,包括酸类(14)、酮类(10)、醇类(8)、酯类(7)、醛类(19)、烃类(5)和其他类物质(5)。2个品种枣干果所含香气物质种类最多的物

质皆为醛类,其次为酸类和酮类,但所含香气物质种类在各组分间差异不大,仅在醇类、醛类、烃类和其他类物质稍有不同;灰枣、骏枣干果所含香气物质含量在不同产地间存在差异,含量最多的皆为酸类物质,其次是酮类、酯类和醛类物质。

主成分分析可以克服风味成分的单一相对含量评价弊端<sup>[17-18]</sup>。笔者以灰枣、骏枣干果中的酸类、酯类、酮类、醇类、醛类和烃类这6种香气物质进行主成分分析,综合考量其主要香气成分。从表5可以看出,灰枣、骏枣干果香气物质中前2项主成分的特征值均大于1,且累计贡献率分别达到82.997%、

表4 不同产地枣干果香气种类及含量

Table 4 Aroma components and contents of dried jujube fruits from different habitats

%

品种 Variety	产地 Habitats	酸类 Acids	酮类 Ketones	酯类 Esters	醇类 Lcohols	醛类 Dehydes	烃类 Olefins	其他 Other
灰枣 Huizao	二团 Ertuan	57.73(14)	14.34(10)	15.12(7)	1.33(7)	4.90(18)	0.51(4)	6.07(5)
	喀什 Kashi	68.24(14)	10.31(10)	9.59(7)	1.02(6)	4.93(18)	0.49(4)	5.41(5)
	和田 Hotan	60.91(14)	15.69(10)	10.43(7)	1.21(6)	7.42(18)	0.44(4)	3.90(5)
	温宿 Wensu	56.59(14)	13.12(10)	15.34(7)	1.30(6)	7.09(18)	0.56(4)	6.00(5)
骏枣 Junzao	新郑 Xinzheng	57.44(14)	23.88(10)	8.51(7)	1.69(6)	4.93(19)	0.71(5)	2.84(4)
	二团 Ertuan	53.79(14)	23.86(10)	11.49(7)	1.05(6)	6.28(18)	0.71(5)	2.82(5)
	喀什 Kashi	64.94(14)	18.49(10)	6.10(7)	1.06(6)	7.01(19)	0.58(4)	1.82(5)
	和田 Hotan	59.67(14)	22.70(10)	5.57(7)	1.09(6)	8.89(19)	0.37(5)	1.72(5)
	温宿 Wensu	51.14(14)	28.26(10)	7.57(7)	1.43(7)	7.89(19)	0.95(4)	2.76(5)
交城 Jiaocheng	交城 Jiaocheng	45.47(14)	36.12(10)	8.17(7)	2.19(8)	4.59(19)	1.10(5)	2.37(5)

注: \*括号内数值代表香气物质种类。

Note: \*The value in brackets represents the type of aroma substance.

表5 不同产地枣干果香气成分的主成分分析

Table 5 Principal component analysis of aroma components of dried jujube fruits from different habitats

品种 Variety	成分因子 Component factor	特征值 Eigenvalues	方差贡献率 Variance contribution rate/%	累计贡献率 Cumulative contribution rate/%
灰枣 Huizao	1	3.271	54.501	54.501
	2	1.709	28.487	82.997
骏枣 Junzao	1	4.341	72.345	72.345
	2	1.057	17.612	89.957

89.957%，这表明前2个主成分可以基本反映所有变量的原有信息，故可将前2个主成分作为数据分析的有效成分。

从表5、表6可以看出，灰枣第一主成分的贡献率占总变异系数的54.510%，主要反映酮类、醇类、烃类3类香气物质的变异系数，第二主成分的贡献率占变异系数的28.487%，主要反映酸类、酯类、醛类3类香气物质的变异系数；骏枣第一主成分的贡献率占总变异系数的72.345%，主要反映酸类、酮

表6 香气主成分的特征向量和载荷矩阵

Table 6 The eigenvector and loading matrix of the principal components of aroma

香气成分 Aroma components	灰枣 Huizao				骏枣 Junzao			
	PC1		PC2		PC1		PC2	
	特征向量 Feature vector	载荷值 Load value						
$X_1$	-0.360	-0.652	-0.576	-0.753	-0.452	-0.943	0.009	0.009
$X_2$	0.521	0.941	-0.074	-0.096	0.455	0.947	0.238	0.245
$X_3$	-0.129	-0.234	0.642	0.840	0.220	0.458	-0.853	-0.876
$X_4$	0.548	0.992	0.090	0.117	0.435	0.906	0.389	0.400
$X_5$	-0.164	-0.297	0.479	0.627	-0.387	-0.806	0.254	0.261
$X_6$	0.505	0.913	-0.112	-0.146	0.449	0.935	0.028	0.029

注:  $X_1$  酸类,  $X_2$  酮类,  $X_3$  酯类,  $X_4$  醇类,  $X_5$  醛类,  $X_6$  烃类。Note:  $X_1$  is acids,  $X_2$  is ketones,  $X_3$  is esters,  $X_4$  is alcohols,  $X_5$  is aldehydes, and  $X_6$  is hydrocarbons.

类、醇类、醛类、烃类5类香气物质的变异系数，第二主成分的贡献率占变异系数的17.612%，仅反映酯类物质的变异系数。载荷数主要反映各变量与主成分之间的相关系数<sup>[7]</sup>，从表6可知灰枣第一主成分与酮类、醇类、烃类呈显著正相关，第二主成分与酯类、醛类呈显著正相关，与酸类呈显著负相关；骏枣第一主成分与酸类、醛类呈显著负相关，与酮类、醇类、烃

类呈显著正相关。综合分析各成分作用的大小，可以认为酸类、酮类、醇类和烃类是影响枣干果香气品质的主要成分。

2.2.2 枣干果香气评价 经主成分分析提取的2个主成分几乎反映了6种香气的全部变量信息，各变量信息在2个主成分上的权系数较高，从而可用 $Z_1$ 、 $Z_2$ 这2个新的综合指标代替原来的6个指标，对不同

产地枣干果样品进行分析,得出香气物质的线性关系式。

$$\text{灰枣: } Z_1 = -0.360X_1 + 0.521X_2 - 0.129X_3 + 0.548X_4 - 0.164X_5 + 0.505X_6;$$

$$Z_2 = -0.576X_1 - 0.074X_2 + 0.642X_3 + 0.090X_4 + 0.479X_5 - 0.112X_6;$$

$$\text{骏枣: } Z_1 = -0.452X_1 + 0.455X_2 + 0.220X_3 + 0.435X_4 - 0.387X_5 + 0.449X_6;$$

$$Z_2 = 0.009X_1 + 0.238X_2 - 0.853X_3 + 0.389X_4 + 0.254X_5 + 0.028X_6.$$

式中: $Z_1, Z_2$ 分别表示综合主成分值, $X_1, X_2, \dots, X_6$ 分别表示6种香气成分标准化后的相对含量。然后以第一、第二主成分贡献率 $\alpha_1, \alpha_2$ 作为权数,建立香气综合评价模型 $F = Z_1 \times \alpha_1 + Z_2 \times \alpha_2$ ,计算综合评价指标的分值F(表7)。主成分综合得分可以有效反映红枣的香气品质<sup>[7]</sup>,从表7可以看出,灰枣中,新郑灰枣在第一主成分上得分最高,二团灰枣在第二主成分上得分最高,喀什灰枣在第一、第二主成分中均得分最低,综合排序位列第五,灰枣原产地新郑枣干果香气综合得分高于新疆4个引栽地;骏枣中,交城骏枣在第一主成分上得分最高,和田骏枣在第二主成分上得分最高,综合排序以骏枣原产地交城枣干果得分高于新疆四个引栽地。由此表明,灰枣、骏枣在

表7 香气物质标准化后主成分得分及排序

Table 7 Principal component score and ranking after standardization of aroma substances

品种 Variety	产地 Habitats	$Z_1$	排序 Sort	$Z_2$	排序 Sort	F	排序 Sort
灰枣 Huizao	二团 Ertuan	0.391	2	0.553	2	0.371	3
	喀什 Kashi	-0.276	5	-0.492	5	-0.291	5
	和田 Hotan	0.024	4	0.443	3	0.139	4
	温宿 Wensu	0.292	3	1.031	1	0.453	2
	新郑 Xinzheng	1.545	1	-0.132	4	0.805	1
骏枣 Junzao	二团 Ertuan	0.220	3	-0.664	5	0.042	3
	喀什 Kashi	-0.515	4	0.090	4	-0.357	4
	和田 Hotan	-0.590	5	0.333	1	-0.368	5
	温宿 Wensu	0.401	2	0.195	3	0.324	2
	交城 Jiaocheng	1.435	1	0.281	2	1.087	1

不同产地间的香气物质经主成分分析表现出明显的差异,均以原产地枣干果香气得分最高,因此原产地枣干果香气品质优于引栽地。

### 3 讨论

#### 3.1 产地对枣干果糖酸类物质的影响

糖酸类物质在果实中主要呈现甜味和酸味,通过味觉影响人们的感官评价。产地对枣干果糖酸类物质种类影响较小,其中可溶性糖以蔗糖为主<sup>[12,19]</sup>,有机酸以苹果酸为主<sup>[20]</sup>,但不同产地枣干果糖酸类物质含量存在差异。新疆地区日照充足、昼夜温差大易于蔗糖积累,导致其枣干果中蔗糖含量显著高于其他产地<sup>[4]</sup>,张任等<sup>[21]</sup>的研究表明枣干果中可溶性总糖、总酸含量与温度显著相关,温度升高有助于增大糖酸比,进而提升口感,另外光强、光质也对甜酸度具有促进作用。此外,新疆枣园大多数营造在改造的戈壁滩上,土壤盐渍化是影响枣树生长和生产的主要因素<sup>[22]</sup>,但其对果实风味提升具有促进作用。位杰等<sup>[23]</sup>研究表明,适度的复合盐碱胁迫能够增加枣干果中可溶性糖含量,降低有机酸含量,进而增大糖酸比,提升口感。因此,由原产地引入新疆栽培后,土壤、气候等环境条件的不同也会导致果干果风味发生变化。周丽等<sup>[22]</sup>研究表明和田地区红枣成熟期降雨量少、气温高、空气相对湿度低(38.55%~41.90%),无霜期长(210.05~240.8 d),生长季≥10 °C积温高(4320.78~4545.02 °C),光热资源丰富,是中、晚熟品种灰枣、骏枣的最佳优生区。本研究结果与其一致,和田骏枣、和田灰枣总糖、蔗糖含量最高,其糖酸比值高于其他产地,这也导致和田灰枣、骏枣甜酸口味优于其他产地。

#### 3.2 产地对香气物质的影响

不同产地灰枣、骏枣挥发性物质种类差异较小,仅在醇类、醛类、烃类和其他类香气物质上略有不同,但其香气物质含量差异较大,尤其是酸类物质和酮类物质,两者含量接近总香气物质的70%,其中新郑灰枣、交城骏枣的酸类物质含量相较于新疆4个引栽地较低,主成分分析显示酸类物质与香气综合得分呈显著负相关,即酸类物质含量越低,香气得分越高;酮类物质作为枣干果香气中一类重要的呈香物质<sup>[24]</sup>,易被红枣中的其他酶转化为醇类、酯类等香气物质,且酮类物质与香气综合得分呈显著正相关,因此酮类物质含量对香气品质具有重要作用,新郑

灰枣、交城骏枣酮类物质含量显著高于新疆4个引栽地,尤其是交城骏枣,其酮类物质含量接近喀什骏枣的2倍。此外,特殊香气成分可能导致香气得分差异,如交城骏枣中检测到的苯甲醇在新疆4个引栽地皆未检测到,苯甲醇具有花香、甜味<sup>[11]</sup>,阈值较低,对枣干果香味十分重要。杨洋等<sup>[10]</sup>对山东、宁夏、新疆3个产地赤霞珠葡萄风味差异研究表明,不同产地的风土条件和地域性决定葡萄果实香气物质具有差异性;邱爽等<sup>[11]</sup>对5个产地红灯樱桃香气物质研究的结果表明,不同产地红灯樱桃的香气成分及含量存在差异,年日照时数、年积温以及降水量等环境生态因子是造成差异的重要原因。秦召等<sup>[25]</sup>表明枣树种植区域气候的差异会影响果实成熟过程中不同种类香气物质的合成代谢,进而影响香气物质种类及含量的差异,最终导致不同产地枣干果香味受到影响。综上,灰枣、骏枣香气物质含量在不同产地间存在差异,尤其以酸类物质和酮类物质差异最显著;原产地枣干果香气优于引栽地可能是由不同产地环境条件差异所致。

## 4 结 论

(1)不同产地枣干果可溶性糖、有机酸含量间存在差异,其中可溶性糖以蔗糖为主,有机酸以苹果酸为主,原产地枣干果低糖高酸的特点导致其糖酸比低于引栽地,这导致新疆引栽地枣干果风味优于原产地。(2)影响枣干果香气品质的主要香气物质种类为酸类、酮类、醇类和烃类;香气物质含量差异较大,主要表现在酸类和酮类物质上。不同产地灰枣、骏枣香气综合得分均表现为原产地高于引栽地。(3)不同产地枣干果的风味差异可能与日照、气温、降水及土壤特性等环境因素高度相关,进一步研究影响枣干果香味的关键环境因子对引栽地枣干果香味提升具有重要意义。

## 参考文献 References:

- [1] 曲泽洲,王永惠.中国果树志·枣卷[M].北京:中国林业出版社,1993:23-37.  
QU Zezhou, WANG Yonghui. Chinese fruit tree records: Jujube[M]. Beijing: China Forestry Publishing House, 1993: 23-37.
- [2] 李新岗.中国枣产业[M].北京:中国林业出版社,2015.  
LI Xingang. Chinese jujube industry[M]. Beijing: China Foresty Publishing House, 2015.
- [3] 张萍,史彦江,宋锋惠,桌热木·塔西,吴正保.南疆灰枣主要营养品质性状的变异及相关性研究[J].果树学报,2011,28(1):77-81.  
ZHANG Ping, SHI Yanjiang, SONG Fenghui, Zhuoremu · Taxi, WU Zhengbao. Investigation on variation and correlation of the main nutrition quality traits of *Ziziphus jujube* cv. Huizao from south of Xinjiang[J]. Journal of Fruit Science, 2011, 28(1): 77-81.
- [4] 张颖,郭盛,严辉,段金廒.不同产地不同品种大枣中可溶性糖类成分的分析[J].食品工业,2016,37(8):265-270.  
ZHANG Ying, GUO Sheng, YAN Hui, DUAN Jiniao. Analysis of soluble carbohydrate in different cultivars of jujube fruits collected from different producing areas[J]. Food Industry, 2016, 37(8):265-270.
- [5] 贺润平,李捷,赵飞,孔维娜.山西省枣品种在不同产地的品质比较[J].山西农业科学,2010,38(11):20-21.  
HE Runping, LI Jie, ZHAO Fei, KONG Weinna. Quality comparison of Shanxi jujube strains cultivated at various production sites[J]. Journal of Shanxi Agricultural Sciences, 2010, 38(11): 20-21.
- [6] 张富县,李娜,李妙清,翁子甯.三种红枣香气成分的分析及模块香精的调配[J].食品工业科技,2018,39(12):222-226.  
ZHANG Fuxian, LI Na, LI Miaoqing, WENG Zining. Analysis of aroma components of three red dates and the blending of modular flavors[J]. Science and Technology of Food Industry, 2018, 39(12):222-226.
- [7] 闫忠心,鲁周民,刘坤,焦文月,赵佳奇.干制条件对红枣香气品质的影响[J].农业工程学报,2011,27(1):389-392.  
YAN Zhongxin, LU Zhoumin, LIU Kun, JIAO Wenye, ZHAO Jiaqi. Effects of drying conditions on aroma quality of jujube[J]. Transactions of the Chinese Society of Agricultural Engineering, 2011, 27(1):389-392.
- [8] 吕姗,凌敏,董浩爽,孟明佳,曹真,刘孟军,敖常伟.烘干温度对大枣香气成分及理化指标的影响[J].食品科学,2017,38(2):139-145.  
LÜ Shan, LING Min, DONG Haoshuang, MENG Mingjia, CAO Zhen, LIU Mengjun, AO Changwei. Effect of drying temperature on aroma components and physical and chemical indexes of jujube[J]. Food Science, 2017, 38(2):139-145.
- [9] 邓红,王玉珠,史乐伟,贺小化,孟永宏,郭玉蓉.清涧红枣香气成分的分析鉴定[J].食品研究与开发,2013,34(24):201-205.  
DENG Hong, WANG Yuzhu, SHI Lewei, HE Xiaohua, MENG Yonghong, GUO Yurong. Analysis and identification of aroma components for the Qingjian date[J]. Food Research and Development, 2013, 34(24):201-205.
- [10] 杨洋,张亚红,李鹏,胡泽军,张晓丽.三个产地‘赤霞珠’葡萄果实风味物质差异性研究[J].中外葡萄与葡萄酒,2020(5):6-11.  
YANG Yang, ZHANG Yahong, LI Peng, HU Zejun, ZHANG Xiaoli. Difference of flavor compounds in berries of ‘Cabernet

- Sauvignon' among production regions[J]. Sino-Overseas Grape-vine & Wine, 2020(5):6-11.
- [11] 邱爽,刘畅,谢美林,杨丽丽,魏阳吉,李景明. 不同产区‘红灯’樱桃香气成分与产地生态因子相关性分析[J]. 食品工业科技, 2021, 42(11):240-247.
- QIU Shuang, LIU Chang, XIE Meilin, YANG Lili, WEI Yangji, LI Jingming. Correlation analysis between aroma components and ecological factors of ‘Hongdeng’ cherry in different producing areas[J/OL]. Science and Technology of Food Industry: 2021, 42(11):240-247.
- [12] 高京草,哈力娜·哈麦拉,韩刚,李宁. 不同枣品种果实中主要糖分及其含量特征[J]. 北方园艺, 2017(16):31-36.
- GAO Jingcao, Halina Hamaili, HAN Gang, LI Ning. Characteristics of main sugar and its contents in different jujube cultivars[J]. Northern Horticulture, 2017(16):31-36.
- [13] 马倩倩,吴翠云,蒲小秋,王德,孙亚强. 高效液相色谱法同时测定枣果实中的有机酸和Vc含量[J]. 食品科学, 2016, 37(14):149-153.
- MA Qianqian, WU Cuiyun, PU Xiaoqiu, WANG De, SUN Ya-qiang. Simultaneous determination of organic acids and Vc in jujube fruits by high performance liquid chromatography[J]. Food Science, 2016, 37(14):149-153.
- [14] 高俊凤. 植物生理学实验指导[M]. 北京:高等教育出版社, 2006:199-200.
- GAO Junfeng. Plant physiology experiment guidance[M]. Beijing: Higher Education Press, 2006: 199-200.
- [15] FRAGA C G, CLOWERS B H, MOORE R J. Signature-discovery approach for sample matching of a nerve-agent precursor using liquid chromatography-mass spectrometry, XCMS, and chemometrics[J]. Analytical Chemistry, 2010, 82(10): 4165-4173.
- [16] 段敏杰,伊洪伟,杨丽,武峥,王进. 不同砂梨品种果实糖酸组分及含量分析[J]. 南方农业学报, 2020, 51(9):2236-2244.
- DUAN Minjie, YI Hongwei, YANG Li, WU Zheng, WANG Jin. Sugar and acid compositions and their contents in different Pyrus pyrifolia varieties[J]. Journal of Southern Agriculture, 2020, 51(9):2236-2244.
- [17] 刘莎莎,张宝善,孙肖园. 红枣香味物质的主物质分析[J]. 食品工业科技, 2015, 36(20):72-76.
- LIU Shasha, ZHANG Baoshan, SUN Xiaoyuan. Principal components analysis of flavor compositions in *Zizyphus jujuba*[J]. Science and Technology of Food Industry, 2015, 36(20): 72-76.
- [18] 陈恺,李琼,周彤,付冰,李瑾瑜,李焕荣. 不同干制方式对新疆哈密大枣香气物质的影响[J]. 食品科学, 2017, 38(14):158-163.
- CHEN Kai, LI Qiong, ZHOU Tong, FU Bing, LI Jinyu, LI Huan-rong. Effects of different drying methods on aroma components of Xinjiang Hami jujube[J]. Food Science, 2017, 38(14): 158-163.
- [19] 薛晓芳,赵爱玲,王永康,隋串玲,任海燕,李登科,梁萍. 不同枣品种果实品质分析及综合评价[J]. 中国果树, 2016(3):11-15.
- XUE Xiaofang, ZHAO Ailing, WANG Yongkang, SUI Chuan-ling, REN Haiyan, LI Dengke, LIANG Qian. Analysis and comprehensive evaluation of fruit quality of different jujube varieties[J]. China Fruits, 2016(3):11-15.
- [20] 赵爱玲,薛晓芳,王永康,隋串玲,任海燕,李登科. 枣果实糖酸组分特点及不同发育阶段含量的变化[J]. 园艺学报, 2016, 43(6):1175-1185.
- ZHAO Ailing, XUE Xiaofang, WANG Yongkang, SUI Chuan-ling, REN Haiyan, LI Dengke. The sugars and organic acids composition in fruits of different Chinese jujube cultivars of different development stages[J]. Acta Horticulturae Sinica, 2016, 43 (6):1175-1185.
- [21] 张任,张鹏程,邬欢欢,张学东. 气象因子对南疆地区骏枣果实品质的影响[J]. 中国农业科技导报, 2018, 20(7):113-122.
- ZHANG Ren, ZHANG Pengcheng, WU Huanhuan, ZHANG Xuedong. Impact of meteorological factors on fruit quality of Jun jujube in Southern Xinjiang[J]. Journal of Agricultural Science and Technology, 2018, 20(7):113-122.
- [22] 周丽,杨伟志,王长柱,李新岗. 新疆红枣优生区研究[J]. 果树学报, 2015, 32(3):453-459.
- ZHOU Li, YANG Weizhi, WANG Changzhu, LI Xingang. Superior production region of Chinese jujube in Xinjiang[J]. Journal of Fruit Science, 2015, 32(3):453-459.
- [23] 位杰,王合理,吴翠云,张琦,蒋媛,李湘钰. 复合盐碱胁迫对灰枣果实内在品质的影响[J]. 干旱地区农业研究, 2015, 33 (3):144-147.
- WEI jie, WANG Heli, WU Cuiyun, ZHANG Qi, JIANG Yuan, LI Xiangyu. Effects of mixed salt-alkali stress on internal quality of *Zizyphus jujuba* ‘Huizao’[J]. Agricultural Research in the Arid Areas, 2015, 33(3):144-147.
- [24] 王林祥,刘杨岷,袁身淑,汤坚. 天津红枣香气成分的分离与鉴定[J]. 无锡轻工业学院学报, 1995(1):49-56.
- WANG Linxiang, LIU Yangmin, YUAN Shenshu, TANG Jian. Isolation and identification of flavor of Tianjin jujuba[J]. Journal of Wuxi University of Light Industry, 1995(1):49-56.
- [25] 秦召,吴月娇,谷令彪,刘华敏,庞会利,田海英,何保江,屈展,秦广雍. 大枣香气成分研究进展[J]. 香料香精化妆品, 2015 (5):63-67.
- QIN Zhao, WU Yuejiao, GU Lingbiao, LIU Huamin, PANG Hui-li , TIAN Haiying, HE Baojiang, QU Zhan, QIN Guangyong. The research progress on jujube aroma components[J]. Flavour Fragrance Cosmetics, 2015(5):63-67.