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Assessment of sensory profile and instrumental analyzed attributes influenced by different potassium fertilization levels in three tomato cultivars

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Summary

Sensory properties are an essential quality aspect when the consumption of fresh tomato is under consideration. The flavor of tomato is defined as a combination of taste sensations (sweetness, sourness), aroma (volatile compounds), and texture (firmness, mealiness), some of which are proven to be affected by insufficient nutrient supply – especially potassium (K). This study intends to undertake a holistic assessment of the K fertilization effect on the flavor of tomato by connecting the use of sensorial and instrumental methods. An optimal K supply significantly increased the sensory descriptors sweetness, sourness, and aroma as well as the instrumental estimated color, firmness, total soluble solids (TSS), titratable acids (TA), and dry matter (DM) in a cultivar-specific manner. The volatile organic compounds (VOCs) were not significantly affected by K fertilization. The evaluation by the panelists confirmed the results of the instrumental analyses, by which an increment in the fruit quality with rising K supply could be detected. An optimal K supply of 3.66 g/plant could be suggested to increase tomato flavor in the cocktail cultivars studied: Primavera and Yellow Submarine. Cultivar effects should, therefore, be considered for defining the optimal K fertilizer dose that favors high tomato fruit quality and, hence, better flavor.

Keywords: *Solanum lycopersicum* L., potassium, sensory evaluation, instrumental analyses, volatile organic compounds

Introduction

The tomato is one of the most important vegetables in the world. In 2019, around 181 million tons of tomatoes were produced (FAOSTAT, 2021). The increasing annual demand for tomato can be attributed to its versatility and suitability for several dishes (Adegbola et al., 2019), as well as its fruitfulness in nutrients like minerals and antioxidants (Afzal et al., 2015). In the European Union, 40% of tomatoes are consumed fresh and 60% are processed for different products (European, 2020). Fresh fruits can be described by their extrinsic (e.g. color, shape, and firmness) as well as the intrinsic characteristics (e.g. taste and aroma) (Oltman et al., 2014). The flavor is a complex attribute and derived from the interaction between the volatile compounds, such as hexanal and 2-isobutylthiazole, and non-volatile components like sugar, acids, and minerals (Beckles, 2012). The flavor of tomato is frequently described as a sweet-sour taste accompanying special aromatic aspects like 'fruity' and 'floral' (Baldwin et al., 2008). However, consumers have often complained about the poor flavor of fresh tomato (Tieman et al., 2012). Therefore, the flavor of the tomato needs to be comprehensively considered, and not only for the consumers, but also for the producers (Piombino et al., 2013). Moreover, the extrinsic and intrinsic characteristics of the flavor are remarkably influenced by many factors like weather conditions and the nutrient status of the plant and soil (Mattheis and Fellman, 1999).

This study focused on the effect of potassium (K) nutrition on the flavor of tomato. Being an essential macronutrient, K is involved in many physiological and biochemical processes in plants (Hawkesford et al., 2012). Cellular K plays a role in catalyzing many enzymes, in addition to having major functions in osmotic pressure adjustment (Zörb et al., 2014). Furthermore, sufficient K nutrition reinforces the resistance of the plants against biotic stresses like diseases and insects (Bidari and Hebsur, 2011). K is also involved in the relocation of photosynthetic assimilates to sink organs, resulting in an increment in the sugar content in the cytosol (Lester et al., 2006). Consequently, increasing the K fertilizer dose has demonstrated a positive enhancement on total soluble solids (TSS), titratable acids (TA) (Sonntag et al., 2019), dry matter (DM) (Javaria et al., 2012), and firmness (Lester et al., 2010). Serio et al. (2007) and Taber et al. (2008) could state a significant influence of K supply on the lycopene content and, hence, on skin color. The positive effect of K fertilization on increasing yields and fruit quality has been pointed out by many studies (Afzal et al., 2015; Amjad et al., 2014).

Volatile organic compounds (VOCs) have been considered as sensory indications for flavor preferences (Goff and Klee, 2006). Though around 400 volatile compounds have been detected in tomatoes, only 15-20 compounds, such as hexanal, 2-isobutylthiazole, and 6-methyl-5-hepten-2-one, have been found to characterize the flavor of the tomato (Kanski et al., 2020). Most volatile compounds are derived from essential nutrient precursors like amino acids, carotenoids, and fatty acids (Rambla et al., 2014). Flavor can be measured by instrumental analyses, e.g. TSS, TA, and color, and by sensory evaluation. Several studies investigated the interaction between sensory evaluation and instrumental analyses in tomatoes (Kanski et al., 2020; Tandon et al., 2003). To the best of our knowledge, very few studies (Afzal et al., 2015; Wang et al., 2009) have been measuring the effect of K nutrition on the instrumental and sensory characteristics and their interactions in tomato. Our work attempts to investigate the effect of K fertilization on sensory and physicochemical traits. It also aims to verify whether the results obtained by instrumental methods can be confirmed by the human senses. We hypothesize that: (I) increasing the K supply modifies the values of instrumental analyzed traits and the intensity of sensory quality; (II) the effect of K fertilization on the sensory quality can be recognized by human senses; (III) instrumental analyzed traits will distinctly correlate with sensory quality; and (IV) the effect of K fertilization will be cultivar-dependent.

Materials and methods

Experimental set-up

In summer 2016, an outdoor experiment was conducted with three tomato cultivars. Two cocktail tomato cultivars – Primavera and Yellow Submarine (Kiepenkerl, Everswinkel, Germany) – and one

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salad tomato cultivar – Lyterno F1 (Rijk Zwaan, De Lier, Netherlands) – were chosen. The cocktail cultivars were used in previous experiments and showed a good response to K fertilization (Sonntag et al., 2019). The salad cultivar was chosen based on the breeders' description highlighting this cultivar as being high in lycopene. Therefore, it was expected that Lyterno F1 would respond well to varying K supply as regards its color, which has been shown for high lycopene cultivars by Taber et al. (2008) and Serio et al. (2007). All cultivars were sown on March 30 in planting trays with capacities of 0.1 L. After three weeks, the seedlings were transplanted into 11 cm pots with capacities of 1 L in a greenhouse. Greenhouse conditions comprised 16 hours of daylight, with a mean temperature of 22 °C during the day and 18 °C at night. The soil in the trays and pots was a mixed peat ('A 400', Stender, Schermbeck, Germany). The final transplantation to the outdoor location took place after seven weeks of sowing on May 25. The seedlings were planted into 20 cm Mitscherlich vessels with capacities of 6.2 L filled with peat substrate (Gartentorf, Naturana, Vechta, Germany). Three different concentrations of K – K1 low with 0.5 g K/plant; K2 medium with 2.19 g K/plant; and K3 optimal with 3.66 g K/plant – in the form of liquid K_2SO_4 were applied weekly during the growing season. Nitrogen (N) was applied on a weekly basis along with K – as a mixture of NH_4NO_3 and $Ca(NO_3)_2 \cdot 3H_2O$ – for K3 treatment and every two weeks for K1 and K2 treatments. Another N solution – $(NH_4)_2SO_4$ – was applied for K1 and K2 treatments, alternating with the previous mixture every two weeks to balance the sulfate supply. Other plant macro- and micronutrients were applied at the final transplantation and two more times during the season (Tab. A1). The plants were irrigated with distilled water when required and were pruned to one shoot weekly. They were arranged in a randomized design, with four blocks representing four replicates per cultivar and K level. During harvest, the fruits of each sample were split into three subsamples. One sample set was used for the sensory evaluation by the panelists; the second subsample was used for extraction of VOCs; and the third for instrumental analyses. The number of fruits used for each type of quality analysis is given in the Table A2.

Instrumental analyses

The K concentration, color, firmness, TA, TSS, DM, and volatile compounds were estimated at fruit maturity. Based on the method of Koch et al. (2019), the K concentration was determined by digesting 100 mg fine powder of lyophilized tomato fruits in 4 mL of 65% nitric acid and 2 mL of 30% hydrogen peroxide for 75 min at 200 °C and 40 bar in a microwave (Ethos terminal 660, Milestone, Sorisole, Italy). Subsequently, the samples were analyzed using inductively coupled plasma-optical emission spectrometry (ICP-OES; Vista-RL ICP-OES, Varian, Palo Alto, USA).

Fruit color was determined by Minolta Chroma Meter CR-400 (Konica Minolta Optics, Japan) at the two equatorial sides of each fruit in the *Lab* modus, where the *a* value represents the red color intensity of Lyterno and Primavera fruits, while the *b* value represents the yellow color intensity of Yellow Submarine fruits. Afterwards, the firmness was estimated by a penetration test (5 mm staple micro cylinder, speed: 6 mm/s, distance: 6 mm) on the equatorial side of these fruits with a texture analyzer (TA.XT2, Stable Micro System, Surrey, UK).

TSS, TA, and DM were estimated for the same fruits. The fruits were mixed for two minutes with a kitchen blender (MQ 5000 Soup, Braun, Neu-Isenburg, Germany) to achieve a homogenized puree. An amount of 10 g of this puree was dried for estimating DM, and the rest of the puree was centrifuged for 20 minutes at room temperature and at 5000 g (Centrifuge 5804 R, Eppendorf, Hamburg, Germany) to estimate TSS and TA based on Sonntag et al. (2019).

Immediately after harvest, VOCs were extracted from fresh fruits, as described by Ulrich and Olbricht (2013). The fruits were rinsed with distilled water, cut into quarters, and homogenized in a solution with 20% (m/v) NaCl by a kitchen blender (MQ 5000 Soup, Braun, Neu-Isenburg, Germany). The homogenate was centrifuged for 30 minutes at 4 °C and 3000 g (Centrifuge 5804 R, Eppendorf, Hamburg, Germany). To 8 mL of the supernatant and 4 g of NaCl, 16 µL of the internal standard (5 µL octanol + 10 mL ethanol) were added. The samples were vortexed and stored at -20 °C until analysis by gas chromatography – FID, as previously described by Ulrich and Olbricht (2013).

Sensory evaluation

A group of 12 panelists had been trained weekly over two months, resulting in eight training sessions in accordance with the ISO 13299 (2016) sensory analysis guidance (ISO 8586, 2014), by focusing especially on the quantitative descriptive analysis of the type of tomato fruits used in this study. The panel performance was checked after each training session and the result was used for improving the training. The sensory descriptors color and odor intensity, juiciness, sweetness, sourness, bitterness, skin strength, aroma, and aftertaste were elaborated with the sensory panel (Table A3). The scale from 0% (minimum intensity) to 100% (maximum intensity) was used to determine the intensity of all descriptors that were studied. The final sensory evaluation was performed during the second week of August on fully ripe fruits for three consecutive days, with a single cultivar being evaluated each day with respect to sensory fatigue of the panelists. The experimental set-up of the outdoor trial was retained during the sensory evaluation. The replicate samples deriving from the four blocks were evaluated separately by the sensory panel. Overall, each panelist evaluated 12 samples that derived from four field plots multiplied by three fertilization levels. The samples were provided to the panel in a randomized design generated by the EyeQuestion software. The evaluation was accomplished in a sensory laboratory that provided separated booths, in accordance with ISO 8589 (2007). The fruits of cocktail cultivars were cut into halves, while those of the salad cultivar were cut into quarters immediately before being served in transparent plates that were coded with three-digit numbers. The panelists performed the evaluation and the data were acquired digitally using the EyeQuestion software. Between the served samples, the panelists were directed to consume a piece of bread and tap water to naturalize the basic tastes.

Statistical analyses

Statistical analyses were performed mainly by using the SPSS Software, Version 22 (IBM Corporation, New York, United States). Data were proven to be normally distributed with the Shapiro-Wilk test (p<0.05), and the variance homogeneity was verified with Welch's test. General fertilizer effects were tested at the significance level of p<0.05 with one-way ANOVA before separating the means of each fertilization treatment within the cultivars by using Tukey's post-hoc test. In order to connect sensory and physicochemical traits, Pearson's correlation analysis was calculated with SPSS and a principal component analysis (PCA) was calculated with the Statistica Software, Version 13.3 (TIBCO Statistica, Tulsa, United States). The panel performance was calculated by a 2-way ANOVA with assessor and sample as main effects with the Software PanelCheck V1.4.0.

Results

Fruits' K concentration

The fruits' K concentration was significantly influenced by the fertilization level (Tab. 1). As anticipated, the level K1 significantly displayed the lowest values. The supply of the fertilizer level K3 could only significantly raise the K concentrations in the two cocktail tomato cultivars compared to level K2.

Instrumental and sensory determined color

Instrumental analyzed color values increased significantly with rising K fertilization only in the cocktail cultivars, where the color-*b* value (yellow) of Yellow Submarine fruits and the color-*a* value (red) of Primavera fruits were more intense in K3 (Tab. 1). Based on the panelists' evaluation, color intensity was increased significantly only in Primavera (Tab. 3). Consequently, the color values affected by K fertilizations depended remarkably on the cultivar. The principal component analysis (PCA) in three cultivars confirmed the ANOVA results. In the PCA, color intensity and instrumental determined color were located closely to each other in Primavera (Fig. 2) but distanced from each other in Lyterno F1 (Fig. 1) and Yellow Submarine (Fig. 3). Additionally, the correlations of color intensity with the instrumental determined color were low and nonsignificant: color-*a* ($r = 0.23$) and color-*b* ($r = 0.45$) (Tab. A5).

Volatile organic compounds and odor intensity

Around 16 known volatile organic compounds (VOCs) were distinguished in this study and they comprised around 80% of all the detected VOCs (Tab. 2). Most of them were not influenced significantly by K fertilization, while the main variations were related to a

Tab. 1: Mean values and standard deviation of taste-related attributes calculated for each K level (n=4) within the three cultivars Lyterno F1, Primavera, and Yellow Submarine. TSS: total soluble solids, TA: titratable acids. Color-*a*: estimated for Lyterno F1 and Primavera. Color-*b*: determined for Yellow Submarine. n.d. not determined. Letters indicate significant differences at $p<0.05$ between the K treatments. K1 low 0.5; K2 medium 2.19; and K3 optimal 3.66 g/plant.

Instrumental analyzed Attributes	Lyterno F1			Primavera			Yellow Submarine		
	K1	K2	K3	K1	K2	K3	K1	K2	K3
K-content (%)	$1.42^b \pm 0.11$	$2.48^a \pm 0.12$	$2.44^a \pm 0.17$	$1.21^c \pm 0.07$	$2.34^b \pm 0.07$	$2.66^a \pm 0.15$	$1.60^c \pm 0.11$	$2.29^b \pm 0.07$	$2.54^a \pm 0.15$
Color-*a*	$21.09^a \pm 0.92$	$20.32^a \pm 0.7$	$20.77^a \pm 0.71$	$12.16^b \pm 0.45$	$16.81^a \pm 1.72$	$17.67^a \pm 1.25$	n.d.	n.d.	n.d.
Color-*b*	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	$44.82^b \pm 2.71$	$49.48^a \pm 1.33$	$50.24^a \pm 1.94$
Firmness (kg/cm)	$1.21^b \pm 0.34$	$1.59^{ab} \pm 0.08$	$1.79^a \pm 0.32$	$0.69^a \pm 0.03$	$0.82^a \pm 0.09$	$0.70^a \pm 0.11$	$0.75^b \pm 0.01$	$0.95^a \pm 0.10$	$1.03^a \pm 0.14$
TSS (%)	$5.80^b \pm 0.43$	$6.45^{ab} \pm 0.44$	$7.30^a \pm 0.62$	$6.75^b \pm 0.3$	$8.45^a \pm 0.44$	$8.52^a \pm 0.19$	$8.25^b \pm 0.01$	$9.05^b \pm 0.01$	$10.45^a \pm 0.00$
TA (%)	$0.26^c \pm 0.03$	$0.48^b \pm 0.03$	$0.53^a \pm 0.01$	$0.25^b \pm 0.02$	$0.48^a \pm 0.04$	$0.51^a \pm 0.02$	$0.34^c \pm 0.02$	$0.51^b \pm 0.08$	$0.65^a \pm 0.08$
DM (%)	$7.76^a \pm 1.18$	$7.94^a \pm 0.73$	$8.99^a \pm 0.64$	$8.35^b \pm 0.42$	$9.92^a \pm 0.3$	$9.95^a \pm 0.61$	$10.18^b \pm 0.66$	$10.93^b \pm 0.76$	$12.44^a \pm 0.26$

Tab. 2: Mean values and standard deviation of identified and unknown VOCs calculated for each K level (n=4) within the three cultivars Lyterno F1, Primavera, and Yellow Submarine. Values below the limit of detection (LOD) were indicated. Letters indicate significant differences at $p<0.05$ between the K treatments.

VOCs Identified (%)	Lyterno F1			Primavera			Yellow Submarine		
	K1	K2	K3	K1	K2	K3	K1	K2	K3
hexanal	$32.82^a \pm 4.93$	$19.86^b \pm 6.19$	$19.46^b \pm 2.47$	$40.29^a \pm 7.47$	$40.47^a \pm 1.55$	$39.24^a \pm 1.72$	$27.27^a \pm 2.64$	$26.72^a \pm 2.45$	$27.38^a \pm 1.28$
(E)-2-hexenal	$4.22^a \pm 0.81$	$3.65^{ab} \pm 0.32$	$3.01^b \pm 0.39$	$8.08^a \pm 3.73$	$6.67^a \pm 1.85$	$7.01^a \pm 1.47$	$9.12^a \pm 2.73$	$10.76^a \pm 3.01$	$9.89^a \pm 3.08$
octanal	$5.26^a \pm 0.82$	$4.04^{ab} \pm 0.68$	$3.96^b \pm 0.35$	$4.48^a \pm 1.11$	$3.64^a \pm 0.31$	$4.14^a \pm 1.89$	$1.35^a \pm 0.96$	$1.73^a \pm 0.21$	$1.59^a \pm 0.12$
β-ionone	$1.06^a \pm 0.23$	$0.36^b \pm 0.42$	$0.16^b \pm 0.33$	$1.98^a \pm 0.68$	$1.73^a \pm 0.23$	$1.83^a \pm 0.73$	<LOD	<LOD	<LOD
β-cyclocitral	$0.67^a \pm 0.45$	$0.15^a \pm 0.3$	$0.20^a \pm 0.4$	$1.91^a \pm 0.59$	$1.52^a \pm 0.27$	$1.05^a \pm 0.7$	<LOD	<LOD	<LOD
(Z)-3-hexen-1-ol	$0.42^a \pm 0.51$	$0.18^a \pm 0.36$	$0.61^a \pm 0.43$	$3.04^a \pm 0.28$	$2.41^a \pm 0.39$	$2.63^a \pm 0.57$	$0.38^a \pm 0.47$	$0.57^a \pm 0.66$	$0.81^a \pm 0.71$
linalool	$0.67^a \pm 0.45$	$0.77^a \pm 0.55$	$0.57^a \pm 0.75$	$0.41^a \pm 0.47$	$0.27^a \pm 0.32$	$0.25^a \pm 0.29$	$1.23^a \pm 0.42$	$1.67^a \pm 0.84$	$1.46^a \pm 0.6$
2-isobutyl-thiazole	$17.11^a \pm 3.49$	$27.28^a \pm 7.23$	$27.77^a \pm 7.61$	$11.57^a \pm 1.59$	$11.49^a \pm 1.53$	$11.30^a \pm 2.25$	$24.43^a \pm 3.21$	$22.64^a \pm 4.97$	$23.58^a \pm 4.01$
eugenol	$0.48^a \pm 0.39$	$0.47^a \pm 0.4$	$0.77^a \pm 0.47$	$1.18^a \pm 0.94$	$0.77^a \pm 0.82$	$0.88^a \pm 1.07$	$0.22^a \pm 0.25$	$0.38^a \pm 0.25$	$0.36^a \pm 0.04$
1-hexanol	<LOD	<LOD	<LOD	$1.7^a \pm 0.28$	$1.63^a \pm 0.39$	$1.34^a \pm 0.97$	$0.19^a \pm 0.39$	$0.43^a \pm 0.51$	$0.51^a \pm 0.44$
β-damascenone	$0.31^a \pm 0.36$	$0.86^a \pm 0.77$	$0.66^a \pm 1.11$	$0.86^a \pm 1.05$	$0.64^a \pm 0.81$	$0.68^a \pm 0.78$	$0.75^a \pm 0.67$	$1.50^a \pm 1.09$	$1.71^a \pm 1.17$
(*E*)-geranyl-acetone	$10.19^a \pm 1.99$	$8.05^a \pm 2.2$	$6.98^a \pm 1.29$	$4.58^a \pm 1.83$	$6.32^a \pm 1.69$	$5.94^a \pm 0.75$	<LOD	<LOD	<LOD
6-methyl-5-hepten-2-one	$19.93^a \pm 4.22$	$28.05^a \pm 4.62$	$28.71^a \pm 5.83$	$14.39^a \pm 5.3$	$17.67^a \pm 1.58$	$16.72^a \pm 5.78$	$27.59^a \pm 2.93$	$23.84^a \pm 3.69$	$23.25^a \pm 2.84$
benzaldehyde	$2.84^a \pm 0.79$	$1.82^a \pm 0.59$	$2.51^a \pm 1.01$	$3.07^a \pm 0.85$	$1.99^a \pm 0.64$	$4.29^a \pm 5.21$	$6.62^a \pm 6.52$	$7.37^a \pm 5.54$	$7.00^a \pm 2.18$
citral	$3.81^a \pm 1.39$	$3.20^a \pm 1.17$	$3.09^a \pm 1.29$	$2.25^a \pm 1.14$	$2.83^a \pm 0.61$	$2.29^a \pm 0.93$	<LOD	<LOD	<LOD
methylsalicylate	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	$0.54^a \pm 0.36$	$0.80^a \pm 0.62$	$1.07^a \pm 0.34$
unknown (%)	$18.98^a \pm 1.88$	$17.45^a \pm 3.05$	$15.55^a \pm 3.22$	$22.91^a \pm 3.73$	$20.38^a \pm 4.71$	$22.26^a \pm 12.27$	$23.29^a \pm 7.55$	$22.44^a \pm 7.46$	$17.85^a \pm 1.66$

Tab. 3: Mean values and standard deviation of the sensory evaluation calculated for each K level (n=4) within the three cultivars Lyterno F1, Primavera, and Yellow Submarine. 0 % refers to minimum intensity and 100 % to maximum intensity. Letters indicate significant differences at p<0.05 between the K treatments. K1 low 0.5; K2 medium 2.19; and K3 optimal 3.66 g/plant.

Sensory Descriptors (%)	Lyterno F1			Primavera			Yellow Submarine		
	K1	K2	K3	K1	K2	K3	K1	K2	K3
Color intensity	63.5^{a} ± 12.1	64.2^{a} ± 12.2	64.8^{a} ± 12.7	55.9^{b} ± 12.1	73.2^{a} ± 12.9	73.3^{a} ± 15.3	58.9^{a} ± 11.7	60.5^{a} ± 11.4	58.4^{a} ± 8.4
Odor intensity	39.0^{a} ± 15.5	43.1^{a} ± 17.5	42.6^{a} ± 18.3	49.2^{a} ± 14.6	53.3^{a} ± 13.5	52.5^{a} ± 10.9	52.0^{a} ± 18.9	53.7^{a} ± 16.4	53.8^{a} ± 14.8
Juiciness	67.5^{a} ± 13.9	66.1^{a} ± 15.2	64.7^{a} ± 16.11	78.8^{a} ± 14.1	78.2^{a} ± 14.1	77.5^{a} ± 12.9	72.1^{a} ± 14.5	75.0^{a} ± 14.4	74.7^{a} ± 12.9
Skin strength	56.8^{a} ± 15.7	59.3^{a} ± 14.7	62.4^{a} ± 18.5	58.9^{a} ± 12.5	56.9^{ab} ± 12.5	51.6^{b} ± 10.4	56.7^{b} ± 13.0	55.5^{b} ± 13.1	65.1^{a} ± 12.6
Sweetness	15.1^{a} ± 12.9	13.6^{a} ± 11.7	12.5^{a} ± 8.1	33.9^{b} ± 15.5	40.0^{ab} ± 15.6	43.7^{a} ± 16.9	50.7^{b} ± 17.1	57.2^{ab} ± 15.7	59.7^{a} ± 13.4
Sourness	17.6^{a} ± 12.5	20.4^{a} ± 14.4	21.9^{a} ± 13.1	16.3^{b} ± 12.3	25.2^{a} ± 11.8	28.4^{a} ± 15.3	20.3^{b} ± 13.0	29.3^{a} ± 14.1	35.3^{a} ± 13.8
Bitterness	8.2^{a} ± 9.7	7.1^{a} ± 8.1	8.8^{a} ± 11.3	10.1^{a} ± 12.8	7.0^{a} ± 8.7	6.3^{a} ± 6.1	9.87^{a} ± 11.5	9.06^{a} ± 9.7	12.35^{a} ± 14.7
Aroma	32.7^{a} ± 18.3	32.0^{a} ± 17.5	37.6^{a} ± 17.3	36.6^{b} ± 14.4	52.9^{a} ± 14.6	56.2^{a} ± 14.2	46.01^{b} ± 17.8	53.7^{ab} ± 18.8	57.4^{a} ± 17.2
Aftertaste	31.7^{a} ± 14.0	35.7^{a} ± 15.1	36.4^{a} ± 15.5	39.0^{a} ± 16.8	42.8^{a} ± 14.0	44.3^{a} ± 13.5	43.2^{a} ± 14.4	46.7^{a} ± 13.1	49.3^{a} ± 14.4

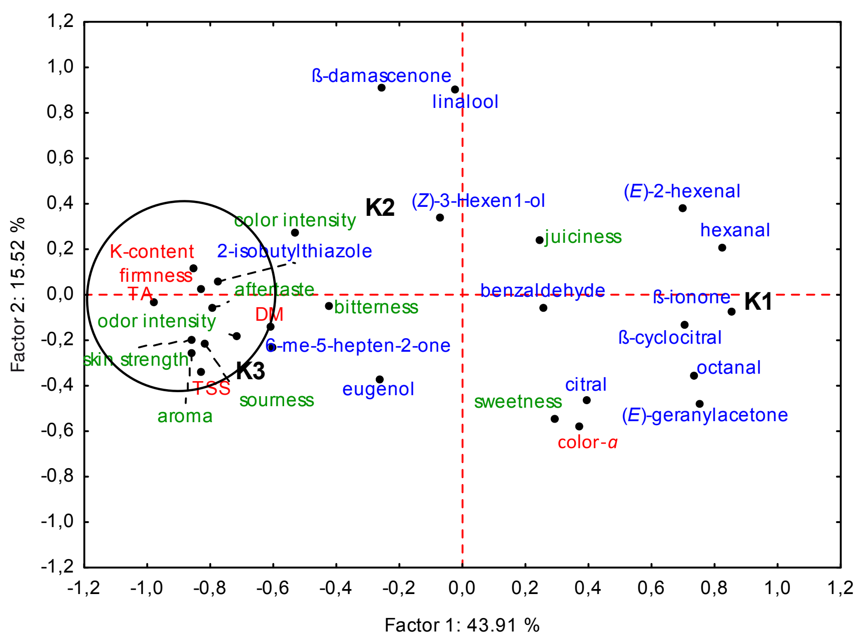

Fig. 1: Principal component analysis (PCA) of the sensory evaluation (green), metric data (red), and VOCs (blue) for mature fruits of cv. **Lyterno F1** with K supply as an independent variable. K1: 0.5, K2: 2.19, and K3: 3.66 g/plant weekly K dose, TA: titratable acidity, TSS: total soluble solids. Color intensity: estimated by the panelists. Color-*a*: measured by Minolta Chroma-Meter.

cultivar effect. For instance, in Lyterno F1, hexanal, (*E*)-2-hexanal, octanal, and ß-ionone decreased significantly with rising K supply, while these compounds exhibited no alterations as regards K levels in Primavera and Yellow Submarine. In addition, some of the detected VOCs were only found in red-colored cultivars, e.g. ß-ionone, ß-cyclocitral, and (*E*)-geranylacetone, or only in yellow-colored cultivars like methylsalicylate (Tab. 2). Odor intensity was not affected by K application along the cultivars that were studied. These observations could be visualized with the previously mentioned PCA plots (Fig. 1, 2, and 3), in which the odor intensity and most of the VOCs were less related to K3. Interestingly, odor intensity correlated in a significantly positive manner with only a few compounds – in particular, ß-ionone (r = 0.57**), (*E*)-2-hexenal (r = 0.64**), and benzaldehyde (r = 0.40**) (Tab. A5).

Texture parameters

Similar to the VOCs, the cultivar background influenced the textural parameters analyzed by instruments or evaluated by the panelists. The firmness determined by a texture analyzer increased significantly only in Lyterno F1 and Yellow Submarine with rising K levels (Tab. 1). In terms of the sensory descriptors, skin strength increased significantly in Yellow Submarine, while a significant reduction in Primavera was found (Tab. 3). On the other hand, juiciness did not exhibit any significant alterations with K fertilization (Tab. 3). In Fig. 1 and 3 of the PCA plot, the firmness and skin strength exhibited a significant increase with K application and were associated closely with K3.

Overall, the firmness correlated in a positively significant manner with skin strength (r = 0.42**), while juiciness did not significantly correlate either with firmness or with skin strength (Tab. A5).

Relationship between instrumental analyses and taste attributes

TSS and TA positively increased with rising K fertilization in the three cultivars (Tab. 1). DM was significantly rising in the cocktail cultivars, while in Lyterno F1 only a positive trend was observed (Tab. 1). From the panelists' perspective, sweetness and sourness

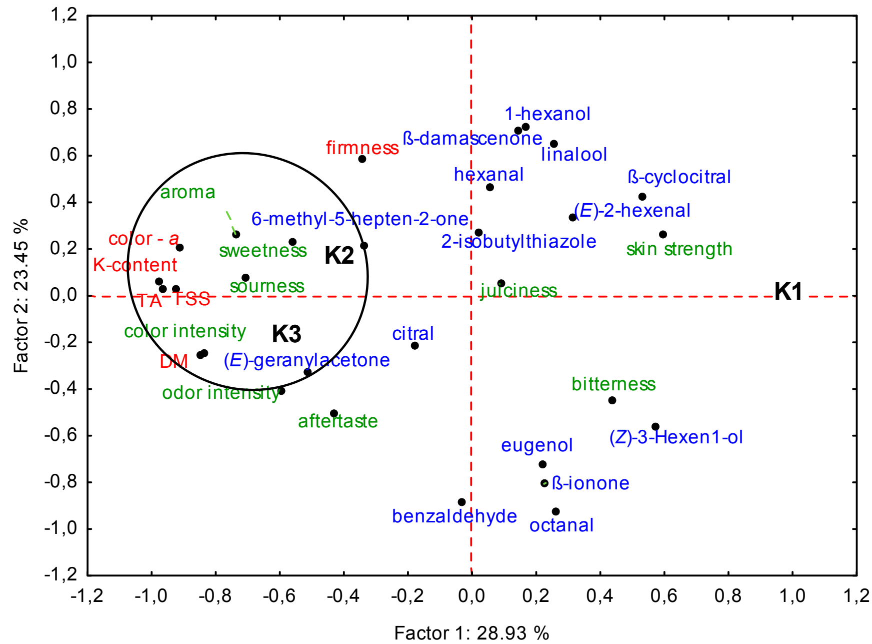

Fig. 2: Principal component analysis (PCA) of the sensory evaluation (green), metric data (red), and VOCs (blue) for mature fruits of cv. **Primavera** with K fertilization as an independent variable. K1: 0.5, K2: 2.19, and K3: 3.66 g plant^{-1} weekly potassium fertilization dose, TA: titratable acidity, TSS: total soluble solids. Color intensity: estimated by the panelists. Color – *a*: measured by Minolta Chroma-Meter.

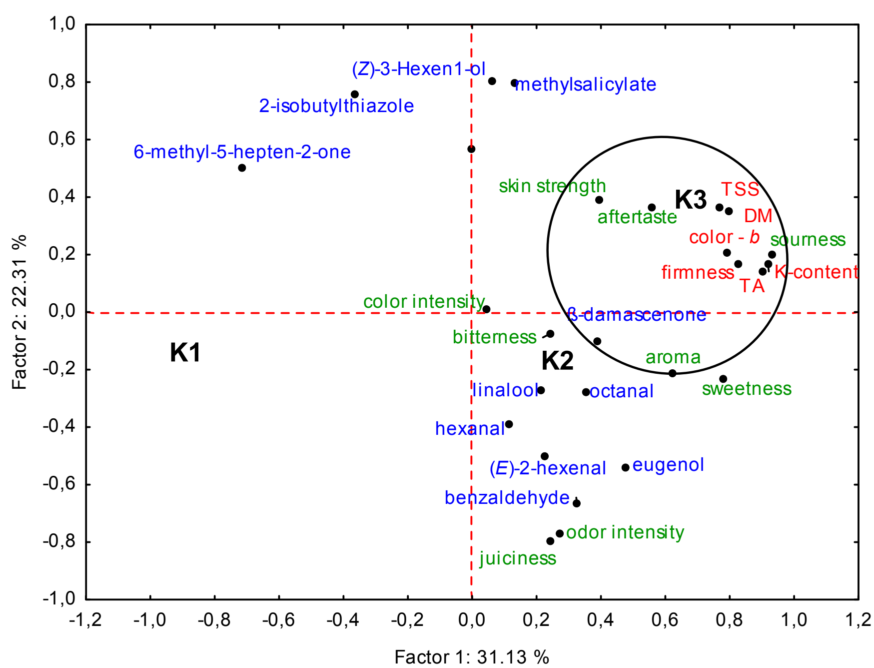

Fig. 3: Principal component analysis (PCA) of the sensory evaluation (green), metric data (red), and the VOCs (blue) for mature fruits of cv. **Yellow Submarine** with K fertilization as an independent variable. K1: 0.5, K2: 2.19, and K3: 3.66 g plant^{-1} weekly potassium fertilization dose, TA: titratable acidity, TSS: total soluble solids. Color intensity: estimated by the panelists. Color – *b*: measured by Minolta Chroma-Meter.

increased significantly with higher K levels, though only in the cocktail cultivars (Tab. 3). Apparently, the cultivar effect was evident in the instrumental and sensory determined taste attributes. For instance, in Lyterno F1, TSS, TA, sourness, and DM grouped with optimal K3, while sweetness was decreased with rising K dose; consequently, it dissociated from K3 and approached the low K1 (Fig. 1). Sweetness correlated significantly positively with TSS ($r = 0.81^{**}$); likewise, sourness with TA ($r = 0.76^{**}$) and DM correlated in a significantly positive manner as well with TSS ($r = 0.95^{**}$), TA ($r = 0.63^{**}$), sweetness ($r = 0.79^{**}$), and sourness ($r = 0.63^{**}$) (Tab. A5).

Retronasal attributes (aroma)

The aroma of the fruits was finally estimated by the panelists at the end of the sensory evaluation represented by aftertaste and aroma for red-colored cultivars – Primavera and Lyterno F1 – and for Yellow

Submarine as well. Application of K increased aftertaste in the studied cultivars though not significantly (Tab. 3). Aroma increased with rising K supply; significantly in Primavera and Yellow Submarine and not significantly in Lyterno F1. These observations were visually acknowledged by PCA plots (Fig. 1, 2, and 3). Aftertaste was associated with K3 in all cultivars. In the same way, aroma (Fig. 1, 2, and 3) were linked to K3, confirming the ANOVA results.

Correlations among aroma, and the instrumental attributes as well as the VOC's were identified. Aroma associated in a significantly positive manner with TSS ($r = 0.83^{**}$), TA ($r = 0.51^{**}$), DM ($r = 0.74^{**}$), sweetness ($r = 0.82^{**}$), sourness ($r = 0.67^{**}$), odor intensity ($r = 0.76^{**}$), hexanal ($r = 0.44^{*}$), and (*E*)-2-hexenal ($r = 0.48^{**}$).

Discussion

In the present study, the effects of different K applications on the instrumental as well as the sensory descriptors on three different cultivars were investigated. In all cultivars, increasing K fertilization to the optimal level significantly ameliorated the K concentrations in the fruits (Tab. 1). This confirmed our outcomes in the previous research (Daoud et al., 2020), in which the fruit's content of K and the yield of the cocktail tomatoes used in this study were significantly increased by K fertilization. As a major macronutrient, the plants manage to maintain K concentrations in a specific range even under deficient K conditions (Zörb et al., 2014). A constant limitation of K nutrition, however, leads to a decrease in K concentrations; in contrast, sufficient K application increases K concentrations (Sonntag et al., 2019; Zörb et al., 2014), which was confirmed by our results as well (Tab. 1).

Effect of K fertilization on instrumental and sensory determined color

The color is the most important external property for the evaluation of tomato fruits (López Camelo and Gómez, 2004). In our study, a positive significant effect of K fertilization was exhibited (Tab. 1 and 3) and compatible results were found between the red color intensity and the instrumental analyzed red color measurement in Primavera. In Lyterno F1 as well, the panelists confirmed the instrumental analyzed color measurement, in which no significant effect of K supply was revealed. Fertilization of K has a positive effect on the color intensity, as has been demonstrated by several researches (e.g. Afzal et al., 2015; Sonntag et al., 2019). Arias et al. (2000) demonstrated high significant correlations between carotenoids content in tomato and color-*a* and color-*b*, such that in this context, a positive increment of K fertilization on lycopene and phytoene in tomato was confirmed (Taber et al., 2008).

In Yellow Submarine, the sensory analysis of color intensity showed no significant effect of K, which contradicted the instrumental analyzed color evaluation. Yellow tomatoes are not as widely common as the red ones, and one can presume that the panelists in this matter were not able to differentiate between the yellow color intensity among K fertilization levels, because of their slight experience of yellow tomato consumption. In line with this, the assessor effect on results of sensory descriptor color was proven to be significant for all cultivars (Tab. A4), indicating a higher variation between the panelists' evaluation compared to the samples derived of different K fertilizer levels.

All in all, the instrumental and the sensory color attribute affected by K fertilization was cultivar-dependent, as the K fertilization significantly increased the instrumental analyzed color in the cocktail cultivars, while in the salad cultivar, no significant effect was detected. Accordingly, several studies pointed out the remarkable cultivar effect on color values under K application (Javaria et al., 2012; Sonntag et al., 2019).

The instrumental analyzed color did not correlate with the color intensity of sensory results and also Csambalik et al. (2014) did not find that as well in their study on cherry tomatoes.

Effect of K fertilization on volatile organic compounds and sensory determined aroma

The VOCs were analyzed by GC-FID to gain deeper insights into the possible changes in the aroma of tomato fruits by differing K supply. In combination with the instrumental analysis of VOCs, the odor intensity as a sensory descriptor was estimated by panelists. Of all the VOCs determined, only four were influenced significantly – although negatively – by K application in the salad cultivar 'Lyterno F1'.

The volatile compounds in tomatoes are derived from secondary metabolites such as fatty acids, phenolics, amino acids, and carotenoids (Rambla et al., 2014). Hexanal and (*E*)-2-hexanal, which are being formed from the degradation of fatty acids, showed a significant decrease with increasing K fertilization in Lyterno F1. That could have been caused by the changes in the peroxidation of the fatty acids under stress conditions (K deficiency), as was observed by Wang et al. (2013). In addition, these compounds are classified as green leafy volatiles as they have the fresh aroma of cut grass (Klee, 2010). Presumably, under sufficient K supply, the fruits developed to the full ripe stage better than under K-deficiency and lessened the green grass odor; as was stated, K provokes early maturity of fruits (Varis and George, 1985).

Similarly, ß-ionone – derived from the apocarotenoids (Rambla et al., 2014) – decreased significantly by K supply but only in Lyterno F1. Apocarotenoids are derived from carotenoids by oxidative cleavage. The cleavage of carotenoid induces rapidly under stress conditions when a non-enzymatic process catalyzed by reactive oxygen species (Ramel et al., 2012). Taking this into account, the studied plants were exposed to stress conditions represented by K deficiency (K1), thus, the production of ß-ionone increased in Lyterno F1 at deficient K supply. The cultivar effect was evident for the VOCs, which was confirmed by Wang et al. (2018) and Kanski et al. (2020), as they found differences in aroma profile among different tomato cultivars.

Odor intensity correlated in a significantly positive manner with ß-ionone, (*E*)-2-hexenal, and benzaldehyde. Vogel et al. (2010) pointed out that ß-ionone has fruity and floral perceptions, which can be positively associated with the acceptability of tomato flavor. The significant correlation of (*E*)-2-hexenal with odor intensity is in agreement with Baldwin et al. (1998), they found a high positive significant correlation ($r = 0.62^{**}$) between (*E*)-2-hexenal and the overall aroma intensity in seven tomato salad cultivars. Benzaldehyde is described as having a peach-like/fruitiness perception (Baldwin et al., 2015; Selli et al., 2014), and it belongs to the group of phenolic volatiles in tomato fruits (Rambla et al., 2014). In our study, benzaldehyde correlated in a significantly positive manner with odor intensity. Baldwin et al. (2015) also found a positive significant correlation of benzaldehyde with tomato flavor along a seven-year study with 38 tomato cultivars.

Effect of K fertilization on instrumental and sensory determined texture

With the sense of touch, either when the product is picked up by hand or is bitten off in the mouth and is chewed, the textural parameters of vegetables and fruits can be perceived. Physiologically, the texture of fruits and vegetables is derived from their turgor pressure, and the combination of individual plant cell walls and the middle lamella, which holds the cells together Valente et al. (2011). In this context, it has been stated that K supply can result in an enhancement of the tissue firmness (Sonntag et al., 2019; Tong et al., 1999) by increasing the osmotic potential as a result of the increment of cytosolic K and the accumulation of photosynthetic assimilates (Lester et al., 2006).

Instrumental determined firmness increased with optimal K dose (K3) in Lyterno F1 and Yellow Submarine. Accordingly, the sensory descriptor skin strength rose significantly in Yellow Submarine and showed a similar – although not significant – trend in Lyterno F1. However, we observed the opposite effect in Primavera (Tab. 3). Consequently, the results of Javaria et al. (2012) and Tavallali et al. (2018) could be confirmed by our findings that the positive effect of K on the tissues firmness and skin strength was partly revealed. The instrumental determined firmness and the sensory parameter skin strength are highly positive correlated (0.42^{**}). Hence, the effect of K fertilization on the texture in this study has been confirmed by instruments as well as by human senses. Thus, the second hypothesis – the effect of K fertilization on the sensory properties can be recognized by the human senses – can be demonstrated.

Juiciness is one of the most important sensory characteristics and a favorable attribute in most food products (meat, fruits, and vegetables). It is highly correlated to the texture of the plant tissues, in which the juiciness is associated with the cell turgor (Valente et al., 2011). K has been pointed out to be essential to cell turgor and the accumulation of photosynthetic products into the plant cell (Kanai et al., 2011). Nonetheless, our results exhibited no significant effect of K on juiciness. Chaïb et al. (2007) stated that the firmest tomato fruits with a strengthened skin were less juicy. Accordingly, juiciness correlated in a significantly negative manner with firmness and skin strength in the salad tomato (Lyterno F1). It has to be considered that the descriptor juiciness was elaborated by the sensory panel to distinguish juicy fruits from other fruits with less juiciness and more granular dry tissues. It can be assumed – based on the evaluation by the panel – that fruits of salad cultivars appeared to have a generally more granular tissue than those of cocktail cultivars.

The cultivar effect was also noticeable for the instrumental determined firmness (Tab. 1 and 3). Our results confirm that the texture is a complex attribute, which can be affected highly by the genetic background of the cultivars (Chaïb et al., 2007).

Effect of K fertilization on instrumental and sensory determined taste

The taste of tomatoes is mainly derived from reducing sugars, organic acids, and bitter compounds. However, as it is abundant in relatively high concentrations, the higher impact is related to sugar (2.6 g 100 g/FM) (Kader, 2008; Verheul et al., 2015). Many studies have demonstrated that rising K supply increases the contens of sugar and organic acids (Asri and Sönmez, 2010; Sonntag et al., 2019). In line with this, K dose exhibited a positive significant impact on TSS and TA contents in the three cultivars (Tab. 1). Likewise, the sensorial sweetness and sourness increased significantly with high K fertilization, though only in Primavera and Yellow Submarine, but not in Lyterno F1 (Tab. 3). In this context, Kanski et al. (2020) found in their study on three tomato cultivars and two breeding lines that TSS and TA as well sweetness and sourness were highly influenced by the genetic background of the cultivars.

Taking into account the correlations between the instrumental and sensorial attributes, TSS and TA correlated highly positive with sweetness (0.81^{**}) and sourness (0.76^{**}) respectively. Therefore, the outcomes of Kanski et al. (2020) could be confirmed by our findings, as they proved a high positive correlation between TSS and sweetness as well as between TA and sourness.

Apart from TSS and TA, DM is considered to exert a strong influence on tomato taste as it is correlated positively with sugars like fructose and glucose (Chapagain and Wiesman, 2004; Kanski et al., 2020). The positive effect of K was stated to increase DM in tomato fruits (Constán-Aguilar et al., 2014; Javaria et al., 2012), which is because of the function of K in translocating and accumulating the assimilated 'sugar' in the cytosol (Hawkesford et al., 2012). We were able to prove these previous findings, as we showed that increasing the supply of K increased the DM values in the cocktail cultivars but not in the salad one. Here, the water content in the cells and the type of the cultivar have a prominent effect on DM content (Beckles, 2012). Interestingly, DM correlated in a significantly positive manner not just with TSS ($r = 0.95^{**}$) and TA ($r = 0.63^{**}$) but also with sweetness ($r = 0.79^{**}$) and sourness ($r = 0.63^{**}$), which could lead to a new approach to enhance cocktail tomato taste under sufficient K fertilization.

The bitter taste is desirable in some products like coffee and beer (Goff and Klee, 2006). However, the bitter taste in tomato is not much of a favorite as far as consumers are concerned (You and van Kan, 2021). Interestingly, the sensory evaluation in the present study exhibited no significant increment of K supply on the bitterness. The sweet compounds have been reported to restrain the bitter taste (Beckles, 2012), which is compatible with our findings in Primavera, in which K can increase sweet taste and reduce bitter taste. Moreover, bitterness had neither positive nor negative significant correlations with any instrumental analyzed or sensorial attributes.

Effect of K fertilization on retronasal attributes (aroma)

Tomato flavor is defined by several studies as a complex impression caused by sugar content, organic acids, bitter compounds, and volatile compounds percepted retronasally (Auerswald et al., 1999; Baldwin et al., 2015; Kanski et al., 2020). In our study, the descriptors aroma and aftertaste correlated in a significantly positive manner with TSS ($r = 0.76^{**}$), TA ($r = 0.46^{**}$), sweetness ($r = 0.71^{**}$), and sourness ($r = 0.68^{**}$), which are in line with the previous studies of Baldwin et al. (2015) and Kanski et al. (2020). The positive correlations between TSS, sweetness and aroma intensity found in the present study are also in accordance with the findings made in the case of strawberries (Schwieterman et al., 2014; Ulrich and Olbricht, 2016). However, aroma correlated positively with odor intensity but negatively with hexanal and (*E*)-2-hexenal. This was surprising; hexanal and (*E*)-2-hexenal together comprised a high percentage (in Lyterno F1: 22–37%, in Primavera: 36-48%) of the known detected VOCs, and were expected to be associated with aroma. Rambla et al. (2014) reported that the VOCs – hexanal and (*E*)-2-hexenal – have the most abundant volatile compounds produced in tomato fruits. Nevertheless, the influence of these compounds on tomato flavor has been a matter of discussion. Some researchers observed a diminution in the effect of these compounds on tomato flavor and no effect on consumer liking (Chen et al., 2004; Tieman et al., 2012). In our findings, these two compounds were decreased with rising K fertilization and seem not to contribute to the aroma (Tab. 5A). Instead, the sugar and acid content seemed to be more relevant for this descriptor.

It was a consensus of the panel that the typical tomato aroma could be attributed to red-colored cultivars; Lyterno F1 and Primavera, while the flavor of Yellow Submarine was different. Aroma of red-colored cultivars did not match the flavor of the yellow cultivar. In which, the panel described the aroma of Yellow Submarine as having a spicy flavored fruit.

Increasing K supply resulted in a significant increase in the descriptor aroma in Yellow Submarine. Some VOCs mainly characterize the spicy aroma in tomato puree (Viljanen et al., 2011) – for instance, 4-methyl-1,5-heptadiene and 6-methyl-3,5-heptadien-2-one. In our study, however, these substances were not detected. Among the determined VOCs, eugenol was stated to be associated with the smoky aroma in fresh tomato fruits (Tikunov et al., 2013). It was supposed that the attribute aroma described by the panelists in this research is closely related to the attribute smoky. Nonetheless, eugenol did not significantly correlate with the aroma as it was found by Tikunov et al. (2013). The reason for this finding might be the effect of K on eugenol, because K fertilization was reported to increase eugenol concentrations (Sensch et al., 2000), which was consistent with our results.

Remarkably, the panelists were able to detect the positive increment of optimal K fertilization on aroma; this can enhance the possibilities of a new approach in increasing tomato flavor with rising K application.

Conclusion

In this study, the effect of K on instrumental determined and sensory traits could be demonstrated. In this context, the following conclusions are drawn: (I) Optimal K3 application – 3.66 g/plant – increased the instrumental analyzed attributes and some of the sensory descriptors, such as sweetness, sourness, and aroma. Nevertheless, it did not significantly increase the identified VOCs. (II) The panelists were able to distinguish between the three K fertilization levels, as confirmed by the instrumental analyses. (III) Sugars (sweetness and TSS), acids (sourness and TA), and odor attributes (odor intensity, hexanal, and (*E*)-2-hexenal) were positively associated with aroma and aftertaste. (IV) The cultivar background had a fundamental influence on both instrumental analyzed and sensory attributes and, finally, on tomato flavor. In this study, cocktail cultivars – Primavera and Yellow Submarine – exhibited higher aftertaste and aroma compared to salad cultivar Lyterno F1.

Consequently, optimal K supply – 3.66 g/plant – could be suggested to increase tomato flavor in the studied cocktail cultivars. The flavor of the tomato is a complex perception and is affected by many factors from seed-sowing to the harvest, which needs further investigations to elucidate it comprehensively.

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Conflict of interest

No potential conflict of interest was reported by the authors.

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Supplementary material

Table A1. Application of Fertilization during the growing season (May–September 2017) for the cultivars studied.

Fertilization	Chemical	g plant^{-1}	Application
K1	K_2SO_4	0.5	weekly
K2	K_2SO_4	2.19	weekly
K3	K_2SO_4	3.66	weekly
N	$Ca(NO_3)_2 + NH_4NO_3$	9.22 + 1.56	weekly for level K3, second week for levels K1 and K2
	$(NH_4)_2SO_4$	2.32	Second week for levels K1 and K2 (to balance the Sulfate)
Mg	$MgSO_4•7H_2O$	19	Three times per growing season:
Fe	Fe-EDTA	0.71	-final transplanting 24.05.2016
Mixture of micronutrients	$MnCl_2•4H_2O + ZnSO_4•7H_2O + CuSO_4•5H_2O + Na_2MoO_4•2H_2O + H_3BO_3$	0.26 + 0.05 + 0.02 + 0.0005 + 0.21	-second time 16.07.2016 -third time 26.08.2016
P	$Ca(H_2PO_4)_2 •xH_2O$	17.70	one time at final transplanting
S	K_2SO_4 and $(NH_4)_2SO_4$	Sufficient supply by K and N fertilization	

Table A2. Number of fruits used from each cultivar for the conducted analyses; TSS: total soluble solids; TA: titratable acids; and DM: dry matter.

Instrumental Analyses	Lyterno F1	Primavera	Yellow Submarine
Aroma extraction	3 to 5	8 to 10	8 to 10
Sensory evaluation	4 to 6	12 to 24	12 to 24
TSS, TA, and DM	2 to 3	4 to 6	4 to 6
Firmness and minerals extraction	6 to 10	15 to 20	15 to 20
Color	15 to 20	35 to 40	35 to 40

Table A3. classification of descriptors according to the kind of sensory impression. The evaluation order was established by the panel and is not equal to order of the classification. Detailed information is given on the evaluation instructions for the panel. A scale from 0-100% intensity with a setting of anchors inside (e.g. for 50% color intensity) was used.

Sensory impression	**Order**	**Descriptor**	**Evaluation instructions**
Appearance	1	color intensity	A self-made reference template with a color standard representing 50% color intensity either for red or for yellow fruits was used by the panelists. The evaluation was carried out on the fruit skin and not on the cross-sectional view of the fruit.
Smell (orthonasal olfactory impression)	2	odor intensity	Odor intensity is defined as the smell of the freshly sliced fruit.
Tactile or haptic impression	3	juiciness	The juiciness of the fruit is represented mainly by the mesocarp, placenta, and myxotesta (pulp and jelly) after biting in. These fruit parts had to be mixed by slight chewing. ’Weak‘ is defined as a granular dry tissue. ’Strong‘ is defined either crispy and fresh but watery tissue or a very soft and watery / liquid tissue of a ripe to overripe tomato.
	8	skin strength	’Weak‘ means that the peel is easily broken during chewing. ’Medium‘ (50 %) means that a peel residue is clearly recognizable. ’Strong‘ also means that a peel residue is clearly recognizable and moreover the peel appears to be very thick.
Taste (gustatory impression)	4	sweetness	For evaluating the taste, it was not differentiated between jelly and pulp. The fruit parts had to be mixed by slight chewing. To compare with samples, the reference fruits were provided with a defined sweetness and sourness. Sweetness was calculated based on the total soluble solids that were measured with a refractometer in advance, while sourness was calculated based on the titratable acidity.
	5	sourness	without instruction
	6	bitterness	without instruction
Retronasal smell (aroma)	7	aroma	Taking into account the sensory differences between yellow and red-fruited cultivars, the panel was trained with both, a yellow-fruited cultivar (cultivar Yellow Nugget) and a red-fruited cocktail tomato cultivar (biologically produced date tomato, cultivar unknown) from a local supermarket set as a standard for the aroma.
Aftertaste	9	aftertaste	The intensity of aftertaste was evaluated half a minute after swallowing.

Table A4. 2-Way ANOVA of sensory data showing the main effects of assessor (n=12) and sample (n= 4) deriving of K fertilization level (n= 3) and the interaction of factors assessor*sample. F-values are displayed, and the significance value is indicated by asterisks (*, **, *** significant at p ≤ 0.05, 0.01, 0.001; n.d. not determined).

	Lyterno F1			Primavera			Yellow Submarine		
Sensory descriptor	**Assessor**	**Sample**	**Assessor* sample**	**Assessor**	**Sample**	**Assessor* sample**	**Assessor**	**Sample**	**Assessor* sample**
Color intensity	12.81***	0.24	1.36	5.41***	26.41***	1.76*	7.49***	1.33	0.39
Odor intensity	18.06***	1.8	0.97	8.55***	2.38	0.84	22.88***	0.5	0.99
Juiciness	10.71***	0.7	1.12	28.37***	0.37	1.26	84.73***	5.79**	0.32
Skin strength	5.73***	2.02	0.85	5.86***	6.26**	1.18	3.56**	7.23**	1.61
Sweetness	6.87***	0.62	2.82***	8.37***	6.33**	1.32	4.63**	3.77*	2.13**
Sourness	12.15***	2.22	1.17	4.44**	8.49**	2.6***	7.36***	17.97***	1.56
Bitterness	8.85***	0.68	0.87	7.97***	1.94	5.43***	9.82***	1.4	1.41
Aroma	30.6***	4.79*	0.97	8.29***	28.37***	2.53***	21.26***	12.31***	1.22
Aftertaste	39.59***	6.19**	0.62	11.31***	2.15	2.51***	28.24***	8.68**	0.56

Table A5. Pearson correlations between the studied attributes.

	color Intensity	odor intensity	juiciness	skin strength	sweetness	sourness	bitterness	aroma	aftertaste
odor intensity	0.04	1.000							
juiciness	0.16	0.58**	1.000						
skin strength	-0.28*	-0.08	-0.327*	1.000					
sweetness	-0.15	0.79**	0.496**	-0.060	1.000				
sourness	0.17	0.52**	0.197	0.140	0.564**	1.000			
bitterness	-0.26	0.14	0.147	0.392**	0.234	0.198	1.000		
aroma	0.44*	0.76**	0.540**	-0.109	0.824**	0.686**	-0.045	1.000	
aftertaste	0,23	0.69**	0.453**	-0.001	0.712**	0.682**	0.257	0.529**	1.000
K_content	0.42**	0.23	-0.070	0.145	0.114	0.686**	-0.047	0.501**	0.331*
color_a	0.23	-0.62**	-0.691**	0.052	-0.640**	0.042	-0.250	-0.249	-0.436*
color_b	0.45	0.027	0.115	0.287	0.652*	0.811**	0.171	n.d.	0.736**
firmness	0.06	-0.522**	-0.579**	0.422**	-0.636**	-0.040	0.015	-0.386*	-0.335*
TSS	0.09	0.672**	0.268	0.133	0.808**	0.743**	0.102	0.828**	0.758**
TA	0.23	0.360*	-0.044	0.302*	0.282	0.759**	0.038	0.512**	0.457**
DM	0.01	0.644**	0.230	0.172	0.785**	0.631**	0.117	0.740**	0.734**
hexanal	0.21	0.293*	0.620**	-0.480**	0,259	-0.056	-0.223	0.436*	0.224
(*E*)-2-hexenal	-0.34	0.642**	0.436**	-0,183	0.745**	0.374*	0.036	0.477**	0.433**
octanal	0.28	-0.481**	-0.069	-0,082	-0.669**	-0.468**	-0.050	-0.431*	-0.534**
6-methyl-5-hepten-2-one	-0,23	-0.181	-0.618**	0.425**	-0.132	0.025	0.211	-0,280	-0,057
(*Z*)-3-hexen-1-ol	0.28	0.297*	0.516**	-0.180	0.173	-0.044	-0.067	0.522**	0,238
isobutylthiazole_2	-0.19	-0.285*	-0.545**	0.435**	-0.172	0.116	0.089	-0.361*	0,004
benzaldehyde	-0.05	0.397**	0.382*	-0.081	0.495**	0.312*	0.373	-0.116	0.422**
linalool	-0.44*	0.188	-0,131	0.058	0.349*	0.190	-0.007	-0.290	0,138
citral	-0.17	-0.316	-0.431*	0.044	-0,337	-0.255	0.228	-0.329	-0,311
ß-damascenone	-0.26	0.194	0.077	0.030	0.276	0.263	-0.189	0.093	0,134
(*E*)-geranylacetone	0.04	-0.575**	-0.556**	-0.219	-0.527**	-0.324	-0.197	-0.49**	-0.489**
ß-ionone	0.11	0.568**	0.589**	-0.536**	0.701**	-0.019	0.126	0.31	0.356*
eugenol	0.21	0.179	0.238	0.040	-0.123	-0.044	0.197	0.13	0.088
ß-cyclocitral	-0.67	-0,192	-0.156	0.760**	0.072	-0.491	0.241	-0.08	-0.698**
1-hexanol	0.27	-0.393*	0.285	0.003	-0.531**	-0.287	-0.239	0.075	-0.297
methylsalicylate	0.03	-0.41	-0.577*	0.064	-0.313	0.361	-0.253	n.d.	0.523*

Table A5. Continue

	K_content	color_a	color_b	Firmness	TSS	TA	DM	hexanal	(*E*)-2-hexenal	octanal	6-methyl-5-hepten-2-one	(*Z*)-3-hexen-1-ol
color_a	0.407*	1.000										
color_b	0.666*	n.d.	1.000									
Firmness	0.281	0.701**	0.616*	1.000								
TSS	0.489**	-0.238	0.681*	-0.304*	1.000							
TA	0.886**	0.372*	0.679*	0.285*	0.676**	1.000						
DM	0.392**	-0.226	0.625*	-0.267	0.955**	0.627**	1.000					
hexanal	-0.285*	-0.620**	0.163	-0.670**	0.023	-0.334*	-0.047	1.000				
(*E*)-2-hexenal	-0.028	-0.635**	-0.077	-0.544**	0.568**	0.150	0.566**	0.278	1.000			
octanal	-0.204	0.004	0.011	0.139	-0.637**	-0.364*	-0.622**	0.131	-0.578**	1.000		
6-methyl-5-hepten-2-one	0.264	0.571**	-0.477	0.478**	-0.014	0.243	0.024	-0.821**	-0.293*	-0.326*	1.000	
(*Z*)-3-hexen-1-ol	-0.102	-0.855**	0.154	-0.533**	0.099	-0.183	0.045	0.729**	0.086	0.296*	-0.654**	1.000
2-isobutylthiazole_2	0.196	0.601**	0.081	0.632**	0.079	0.302*	0.142	-0.837**	-0.187	-0.349*	0.615**	-0.676**
benzaldehyde	-0.022	-0.175	0.060	-0.216	0.416**	0.164	0.446**	-0.053	0.347*	-0.165	-0.149	-0.151
linalool	0.086	0.235	-0.004	0.045	0.270	0.241	0.359*	-0.273	0.602**	-0.633**	0.252	-0.476**
citral	-0.021	0.342	n.d.	0.155	-0.377*	-0.100	-0.333	-0.399*	-0.615**	0.305	0.661**	-0.467*
ß_damascenone	0.223	-0.081	0.116	-0.037	0.272	0.336*	0.296*	-0.002	0.622**	-0.471**	-0.060	-0.122
(*E*)-geranylacetone	-0.066	0.664**	n.d.	0.296	-0.456*	-0.162	-0.410*	-0.419*	-0.608**	0.462*	0.397*	-0.645**
ß-ionone	-0.281	-0.699**	n.d.	-0.858**	0.327	-0.334	0.309	0.697**	0.601**	0.346*	-0.634**	0.800**
eugenol	-0.131	-0.369*	0.379	-0.037	-0.103	-0.097	-0.095	0.257	-0.025	0.492**	-0.482**	0.442**
ß-cyclocitral	-0.454	-0.472	n.d.	0.086	-0.443	-0.494	-0.421	-0.242	0.190	-0.192	0.359	0.153
1-hexanol	-0.044	-0.082	0.311	-0.267	-0.411*	-0.284	-0.519**	0.691**	-0.548**	0.431*	-0.384*	0.772**
methylsalicylate	0.438	n.d.	0.183	0.480	0.281	0.198	0.300	-0.150	-0.186	-0.286	0.198	0.786**

Table A5. Continue

	2-isobutylthiazole	benzaldehyde	linalool	citral	ß_damascenone	(*E*)-geranylacetone	ß_ionone	eugenol	ß_cyclocitral	1-hexanol
benzaldehyde	-0.012	1.000								
linalool	0.316*	0.193	1.000							
citral	0.018	-0.225	-0.220	1.000						
ß_damascenone	0.076	-0.004	0.812**	-0.546**	1.000					
(*E*)-geranylacetone	0.212	0.011	-0.130	0.658**	-0.447*	1.000				
ß-ionone	-0.830**	0.392*	-0.356*	-0.085	-0.160	-0.260	1.000			
eugenol	-0.263	0.117	-0.431**	-0.317	-0.353*	-0.255	0.366*	1.000		
ß-cyclocitral	0.271	-0.715**	0.238	0.226	0.124	-0.272	-0.008	-0.454	1.000	
1-hexanol	-0.620**	-0.631**	-0.648**	0.208	-0.234	-0.137	-0.630*	-0.044	0.619*	1.000
methylsalicylate	0.543*	-0.667*	-0.087	n.d.	0.071	n.d.	n.d.	0.438	n.d.	0.752**