5TH INTERNATIONAL STRAWBERRY CONGRESS

Thursday

Parallel Session 4: Sustainability & Fruit Quality

Fruit pigmentation is distinctively associated with anthocyanins and VOCs between strawberry cultivars

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September 18, 2025

Strawberry (*Fragaria* × *ananassa* Duch.)

Total 186 cultivars (commonly 18 cultivars)

One of the favorite fruit in Korea

High adoption rate of domestic cultivars (96.3%)

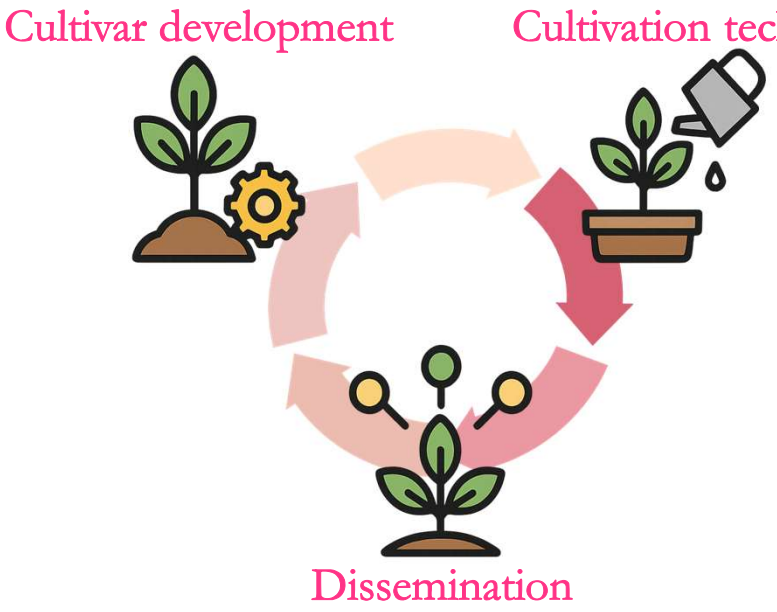
Good source of vitamin C (71 mg/100g FW)

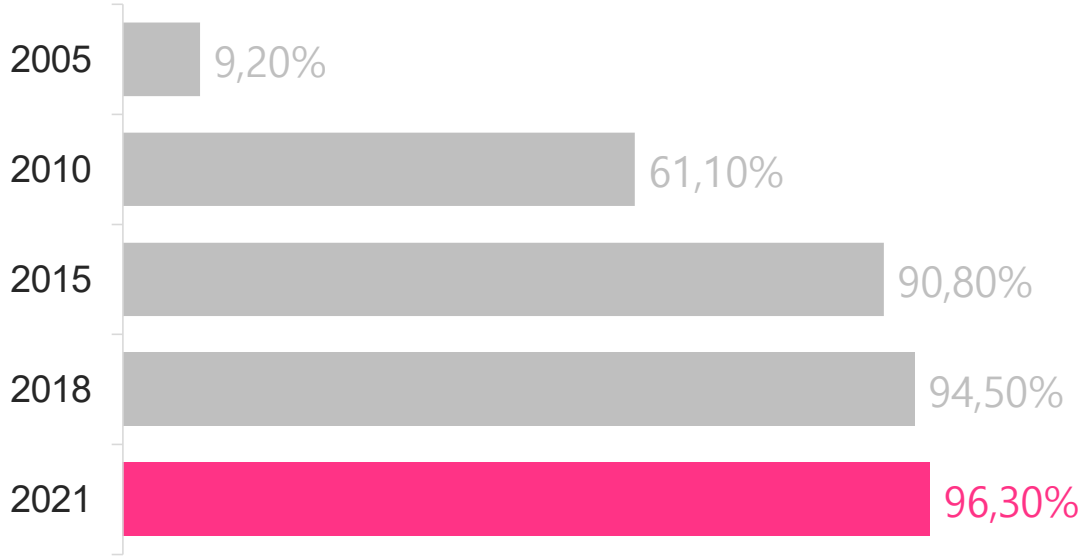
Market share: Seolhyang (84.5%) Kuemsil (4.1%)

Antioxidant properties with low calories

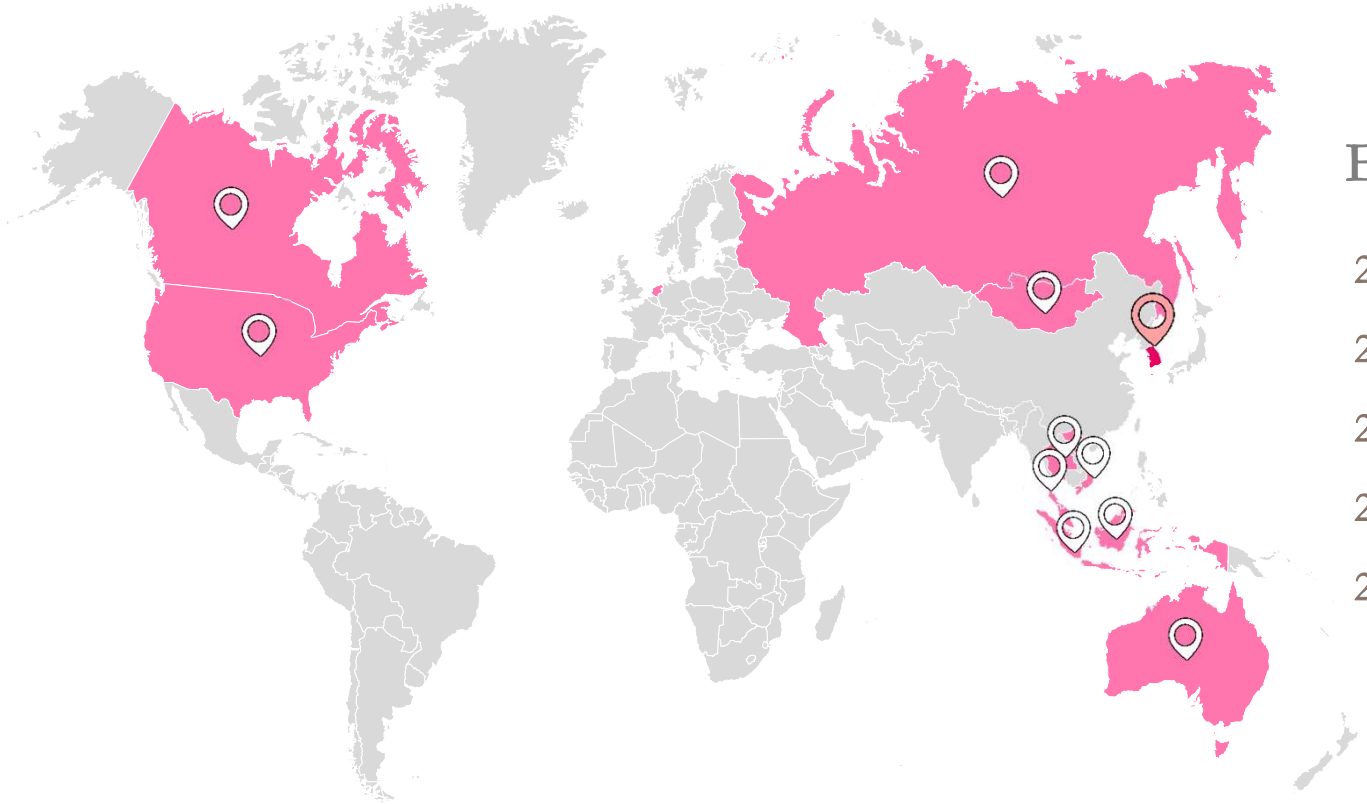
Strawberry (*Fragaria* × *ananassa* Duch.) in Korea

❖ Trends in the Market Share of Korean-Bred Strawberry Cultivars

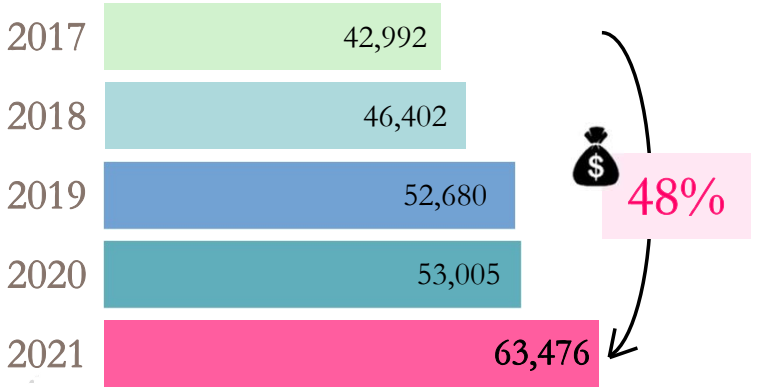




Export of Korean Strawberries



Export strawberries worldwide



※ Unit: 1,000 USD

Hong Kong (34.1%) Singapore (23.7%) Thailand (14.0%) Vietnam (11.6%)

‘Seolhyang’ strawberry

- ‘Akihime’ (♀) × ‘Red Pearl’ (♂)
- Developed in Korea and released in 2005
- ‘Seolhyang’ = Fragrant strawberry blooming in the snow
- Approximately 81% of strawberries are the ‘Seolhyang’ cultivar in Korea
- High productivity and resistant to powdery mildew

https://kberry.kr

‘Cinderella’ strawberry

- ‘Cinderella’ = trademark FIRMMIT.
- Produced by FIRMMIT Co., Ltd., Republic of Korea
- Trademark registration was completed in 2023
- Pineapple flavored white-pink colored strawberry

Usage of fruit based on pigmentation stages

60~70%

- ✓ Long-distance distribution
- ✓ Store 4-6 days
- ✓ Check color pigmentation before distribution

80%

- ✓ Still firm texture
- ✓ Harvest stage for soft-fleshed cultivars
- ✓ Harvest stage for export fruit

90%

- ✓ Suitable for domestic markets, not for export fruit
- ✓ Even firm cultivars, fruit easily discolors during distribution

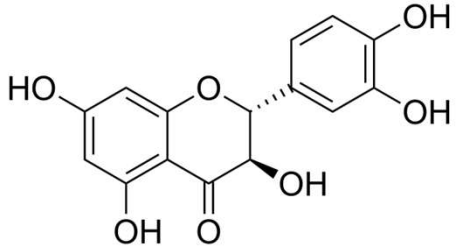
100%

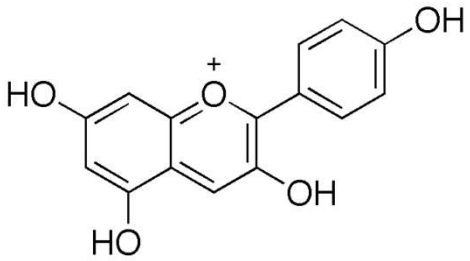
- ✓ Be prone to damage during harvest
- ✓ Discoloration during cooling or sorting
- ✓ Should be carefully handling

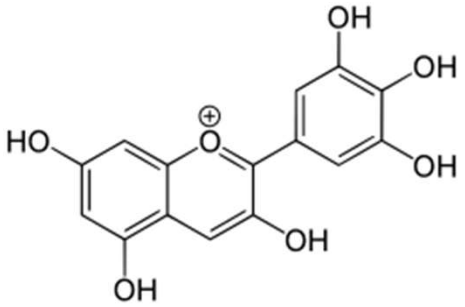
Source: Horticultural and Medicinal Crop Technology Information No. 139

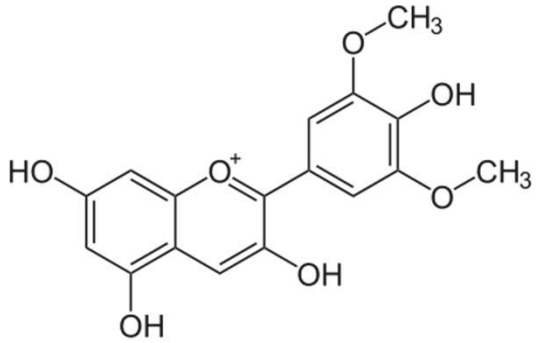
Objectives

1. To compare the metabolic compounds between the SH and CD strawberry cultivars
2. To evaluate the effects of peel pigmentation levels on metabolic patterns in both cultivars
3. To identify cultivar-specific anthocyanin and VOCs that explain the differences in fruit color, aroma, and fruit quality









Materials and Methods

- Plant materials: Strawberry (*Fragaria* × *ananassa* Duch.)
- Cultivars: 'Seolhyang' and 'Cinderella'
- Harvest date: March 11 ('Seolhyang') and 6 ('Cinderella'), 2023
- Pigmentation stages : 0, 50, 75 and 100% of peel red coverage
- Storage condition: 3 °C for 3 days on 100% colored fruit
- Quality evaluation

- Seolhyang

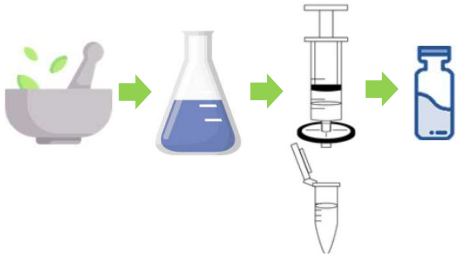
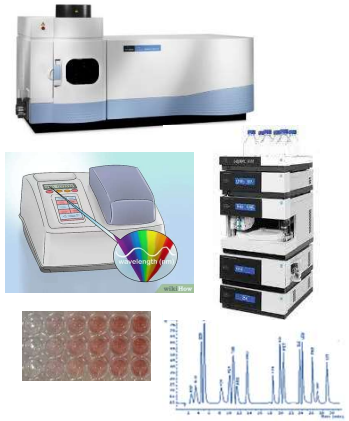
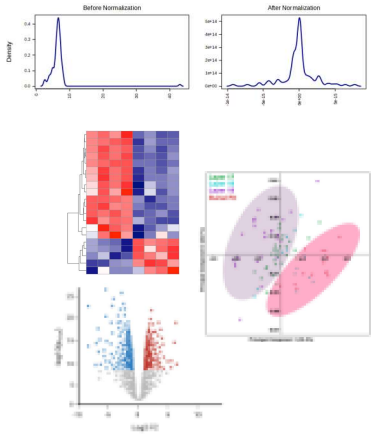
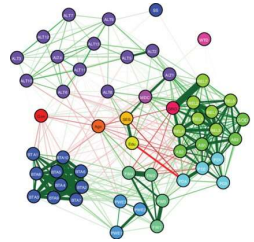
0% 50% 75% 100% 3 d

- Cinderella

0% 50% 75% 100% 3 d

- Fruit quality attributes: Fruit fresh weight, fruit diameter (D), fruit length (L), L/D, ethylene production rate, respiration rate, firmness, SSC, TA, SSC/TA, color variables, and water contents
- Analyses: soluble carbohydrates, organic acids, amino acids, ascorbic acid, phenolic compounds (LC-MS), volatile organic compounds (GC-MS)

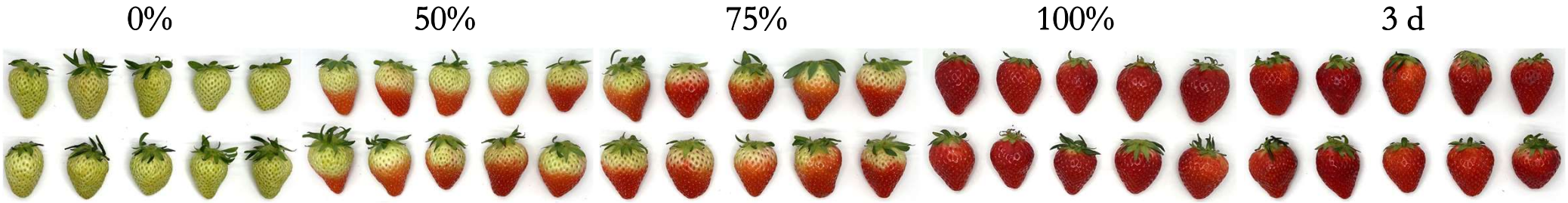
Materials and Methods

Fruit quality assessment	Preparation and extraction	Acquisition	Data analysis	Biochemical interpretation
	 Frozen Freeze-dry 			
◆ **Non-destructive** - Fresh weight - Fruit size - Fruit diameter/length - Peel color - Ethylene production rate - Respiration rate ◆ **Destructive** - Firmness - Soluble solids content (SSC) - Titratable acidity (TA) - Water content	◆ **Primary metabolites** - Soluble carbohydrates - Organic acids - Amino acids ◆ **Secondary metabolites** - Ascorbic acid - Phenolic compounds - Volatile organic compounds (VOCs) - Phytohormones	◆ **Instruments analyses** - High performance liquid chromatography (HPLC) - Gas chromatography (GC) - Gas chromatography-mass spectrometry (GC-MS) - Liquid chromatography-mass spectrometry (LC-MS)	◆ **Data Pre-treatment** - Normalization - Scaling ◆ **Statistical analyses** - ANOVA - Duncan ◆ **Statistical modeling** - Multivariate analyses: PLS-DA, VIP, Volcano plot	◆ **Correlation coefficient-based network analysis** ◆ **Pathway analysis**

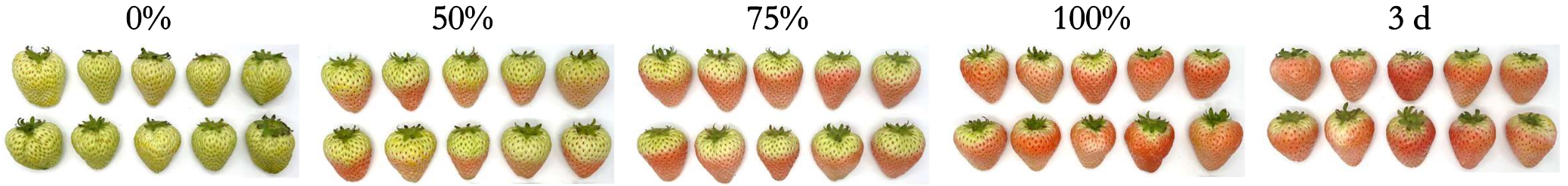
Results

➢ Fruit visual appearances

'Seolhyang' cultivar

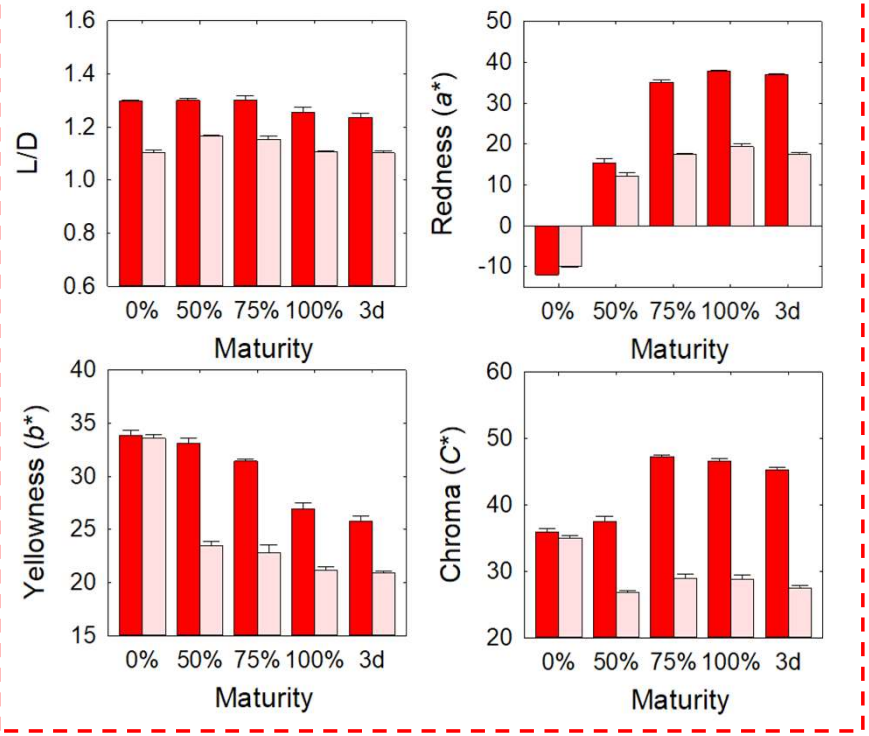


'Cinderella' cultivar

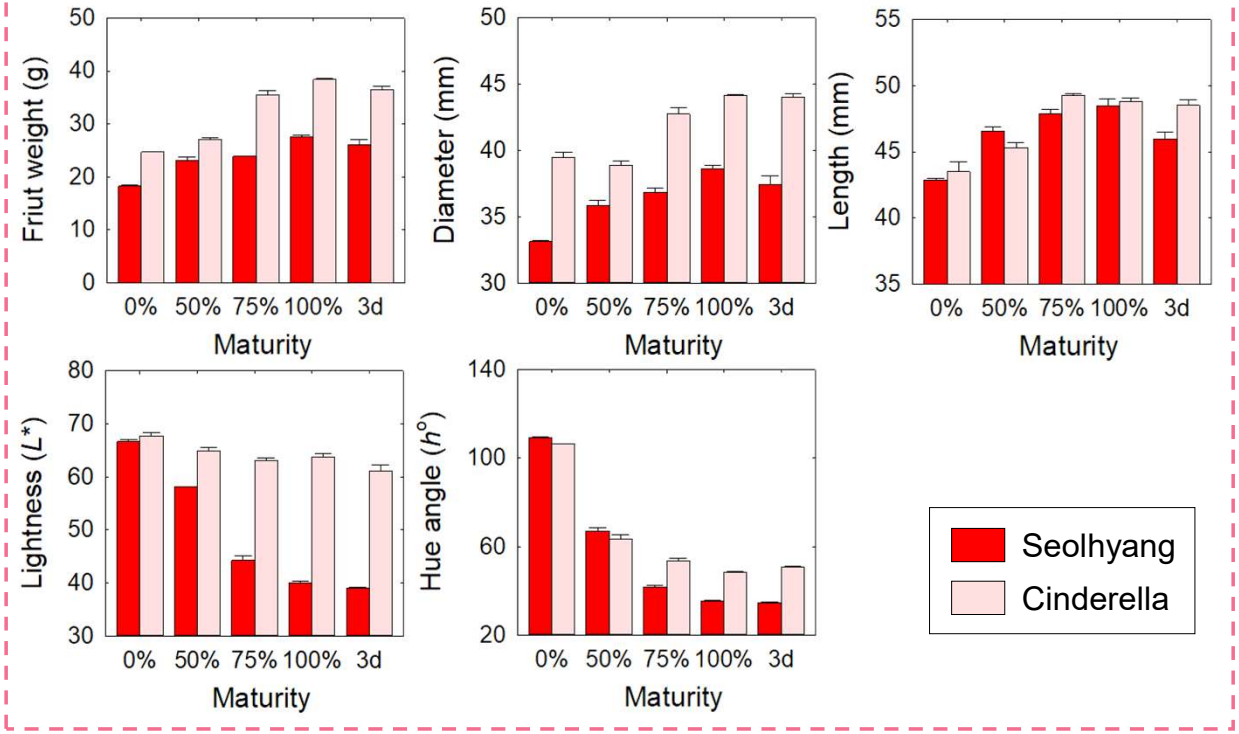


Fruit quality attributes

Upregulated in 'Seolhyang'

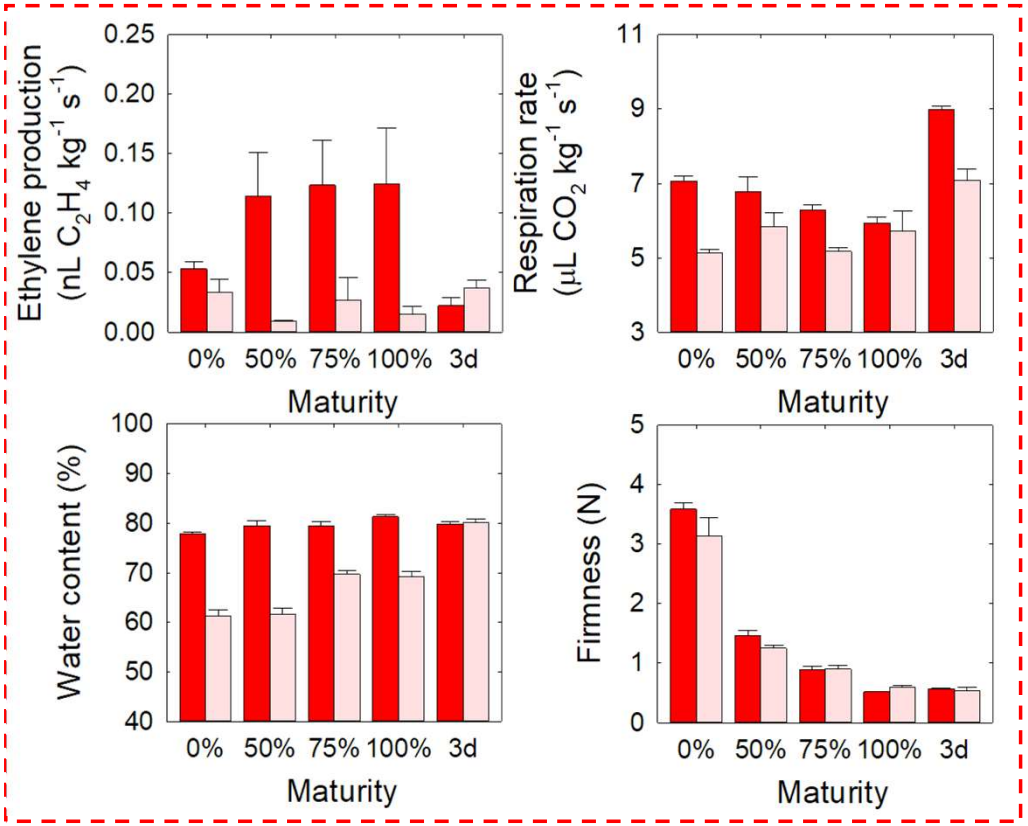


Upregulated in 'Cinderella'

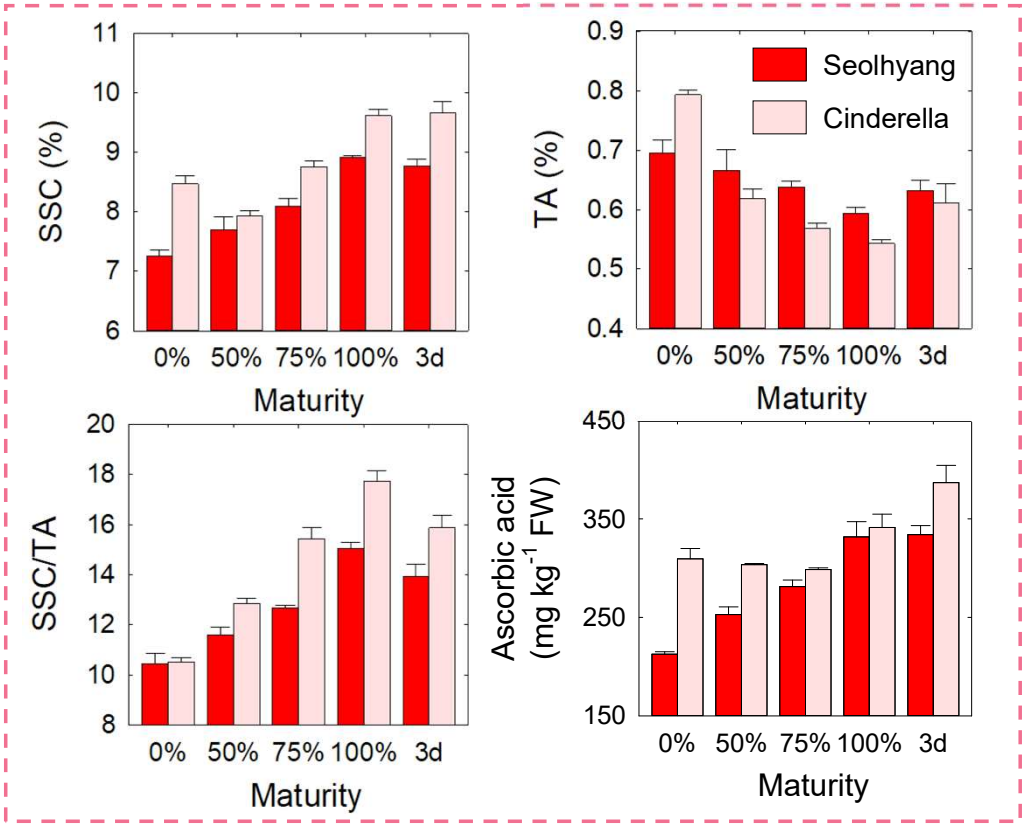


Fruit quality attributes

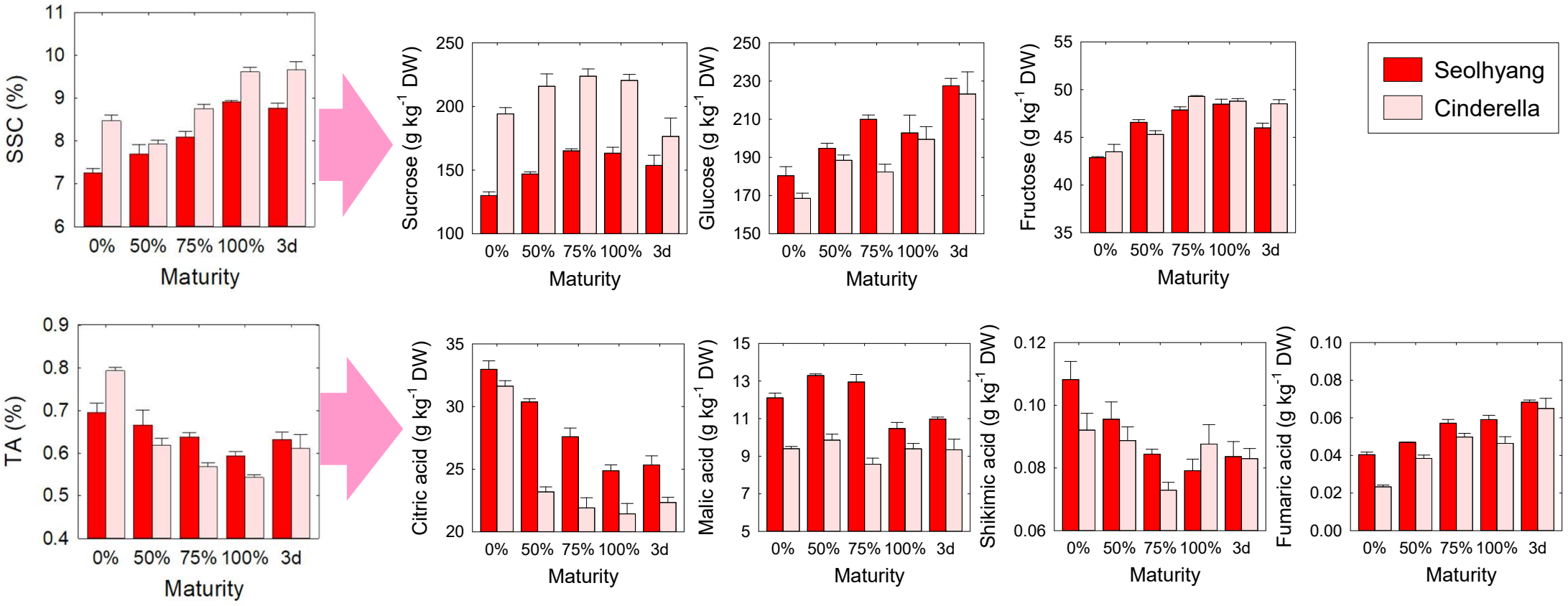
Upregulated in 'Seolhyang'



Upregulated in 'Cinderella'

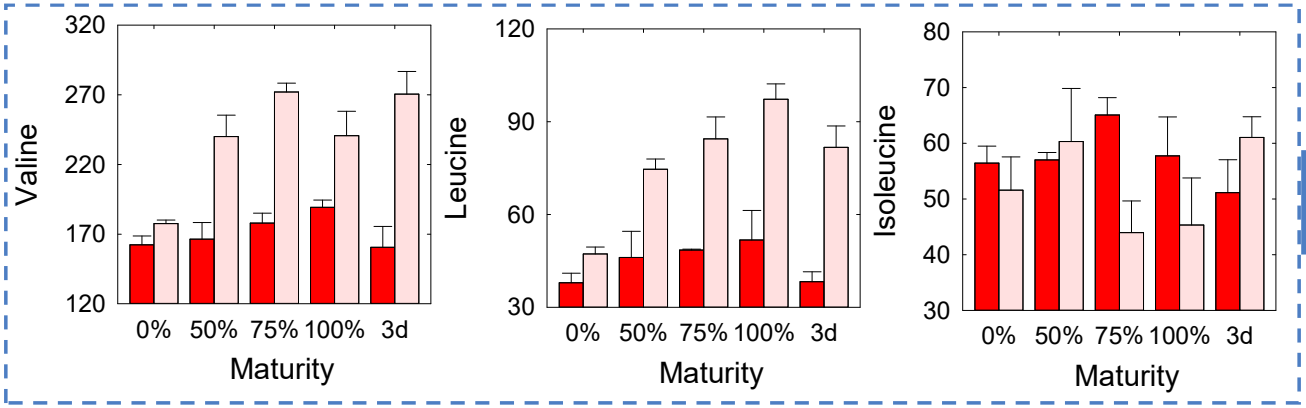


Soluble carbohydrates and organic acids



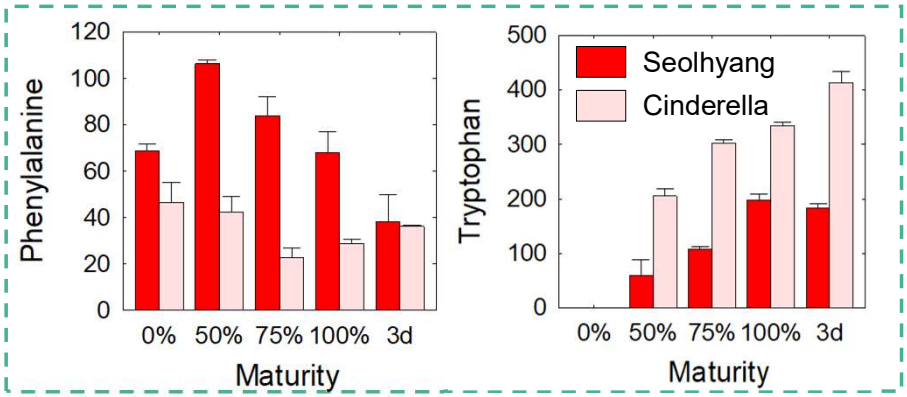
Amino acids (mg kg^{-1} DW)

Branched-chain amino acids



Precursors to
branched-chain volatile esters

Aromatic amino acids

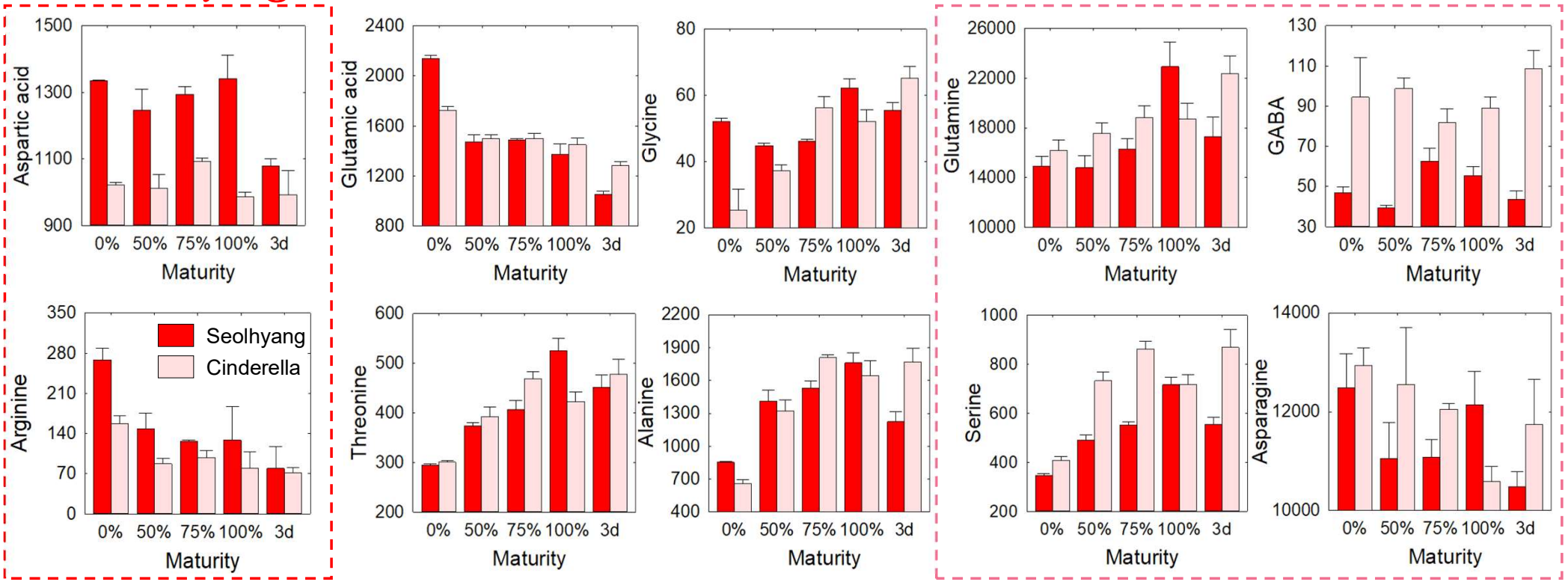


Precursors for secondary metabolites,
including pigments and flavor compounds

Amino acids (mg kg^{-1} DW)

Upregulated in 'Seolhyang'

Upregulated in 'Cinderella'

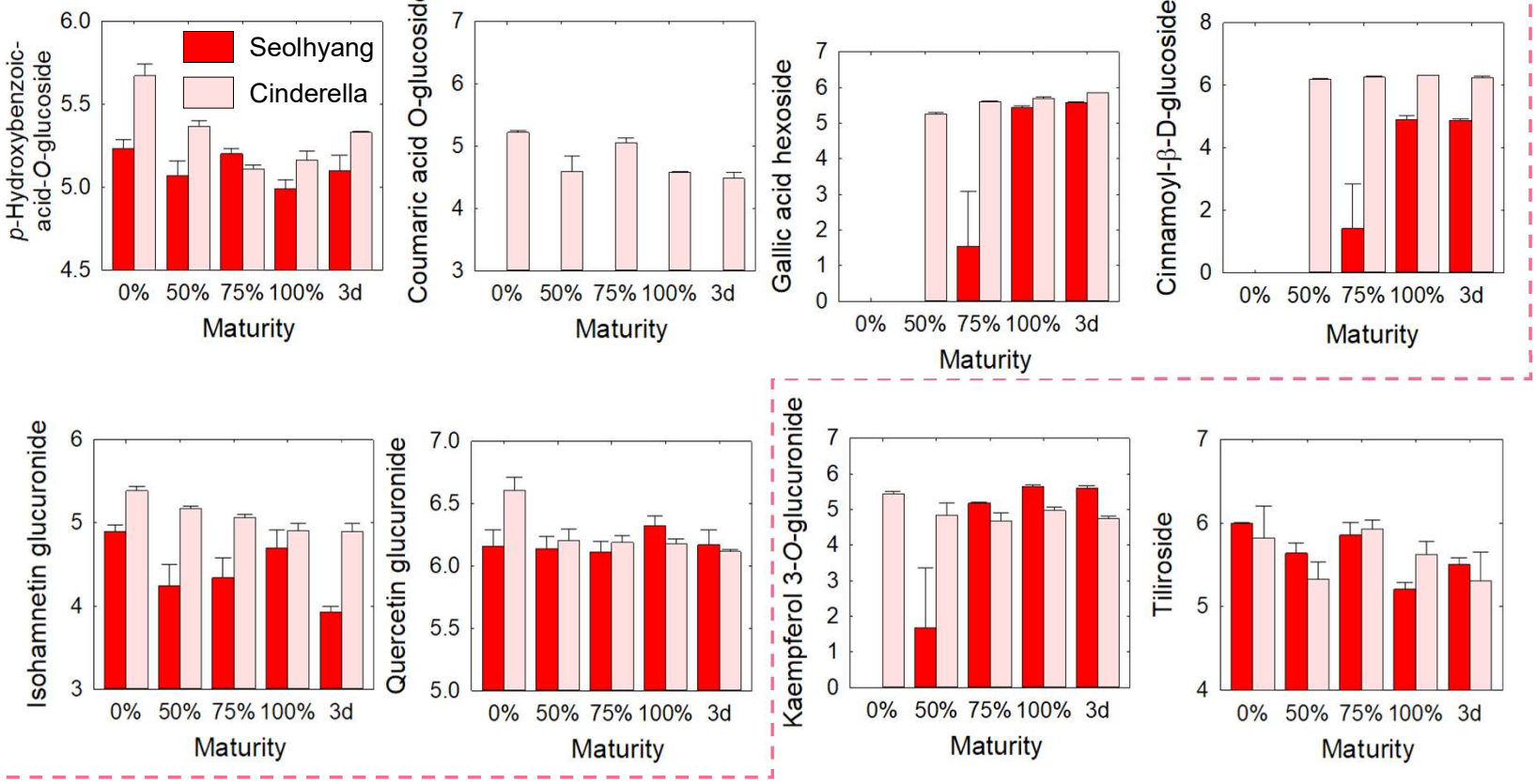


Phenolic compounds

Upregulated in 'Cinderella'

Phenolic acids

Flavonol

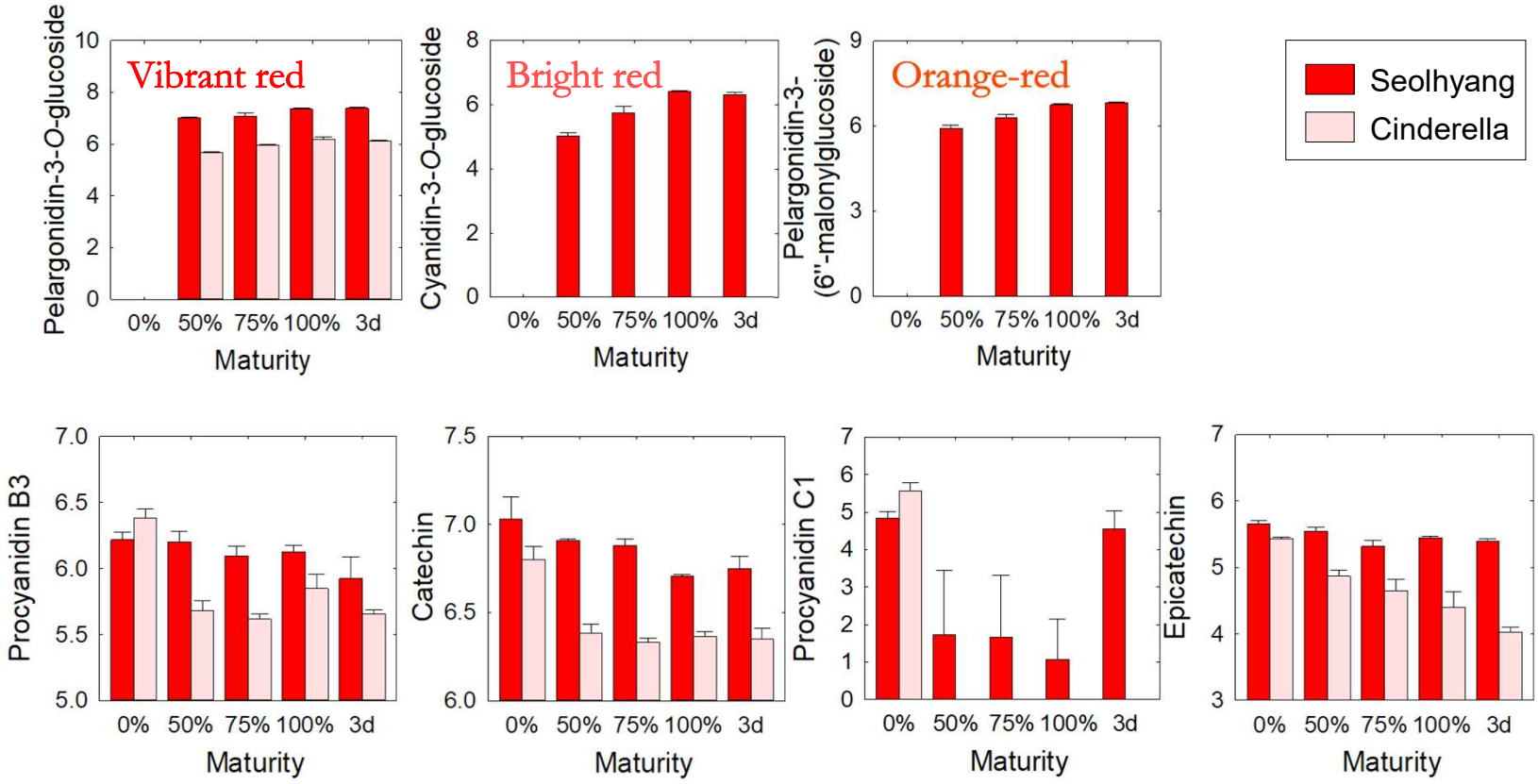


Phenolic compounds

Upregulated in 'Seolhyang'

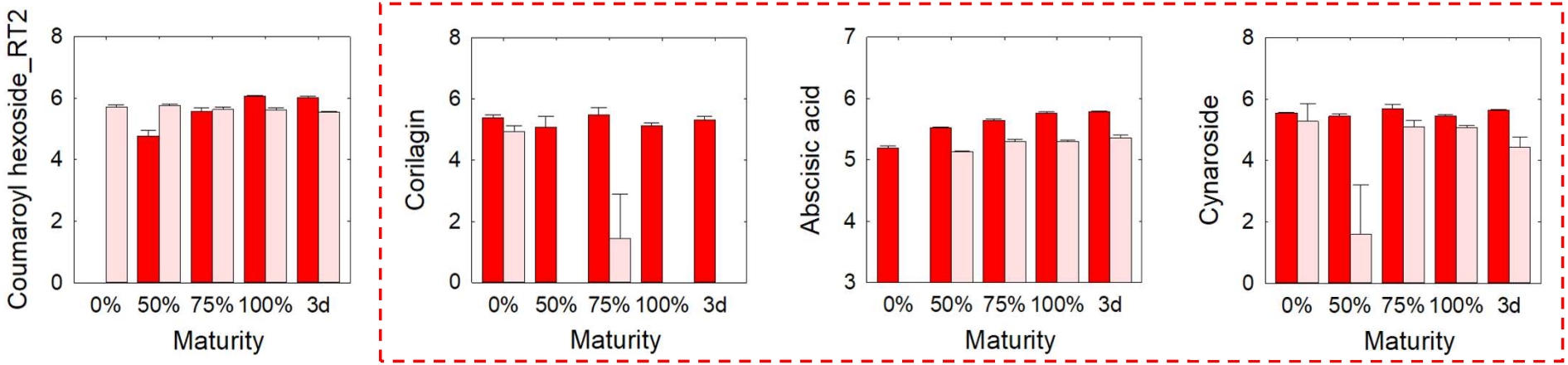
Anthocyanins

Flavan-3-ol



Phenolic and non-phenolic compounds

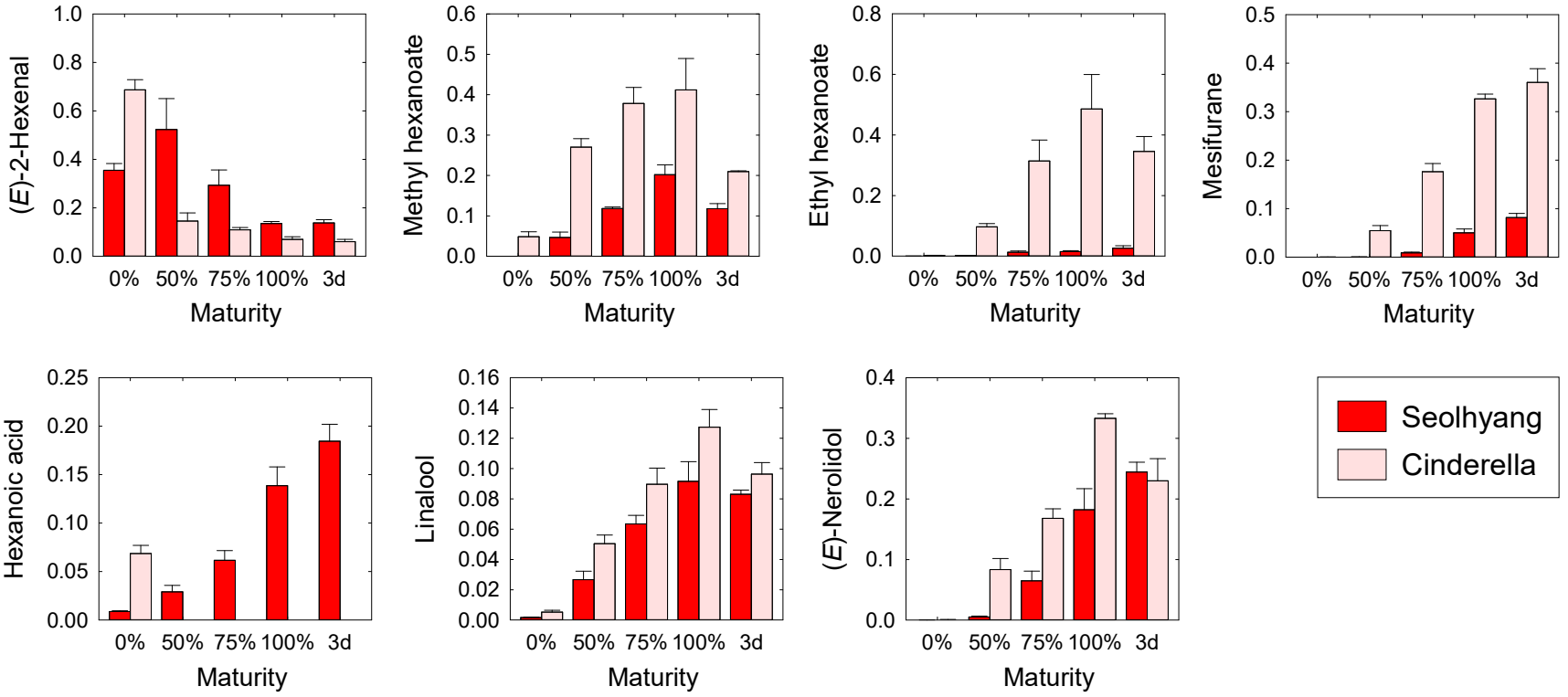
Upregulated in 'Seolhyang'



Phenolic acids | Ellagitannins | Plant hormone | Flavones

- A total of 19 phenolic compounds were detected through LC-MS profiling.
- Comprised of 3 anthocyanins, 4 flavon-3-ols, 4 flavonols, 6 phenolic acids, 1 ellagitannin, and 1 plant hormone.

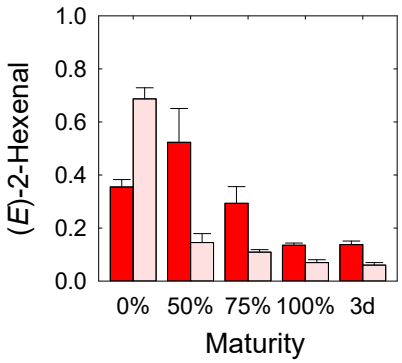
Volatile organic compounds (VOCs)

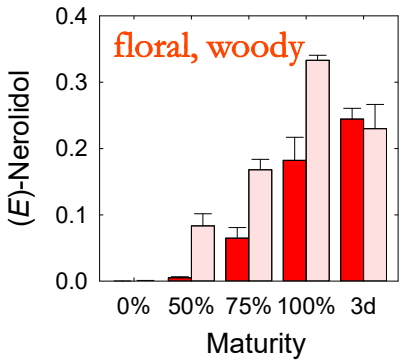


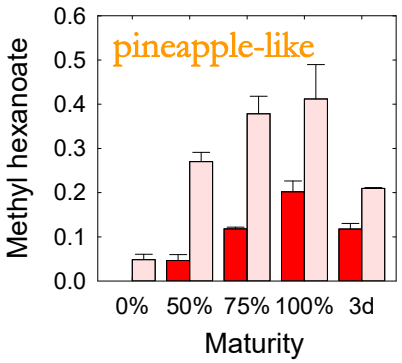
Group	#
Esters	26
Alcohols	14
Aldehydes	12
Ketones	9
Terpenes	5
Acids	3
Others	5
Total	**74**

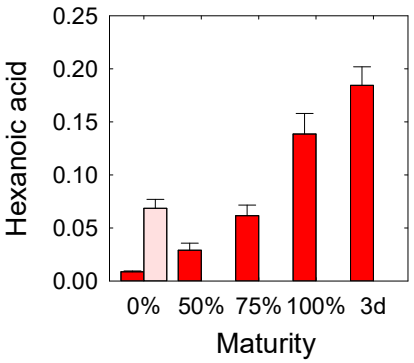
Volatile organic compounds (VOCs)

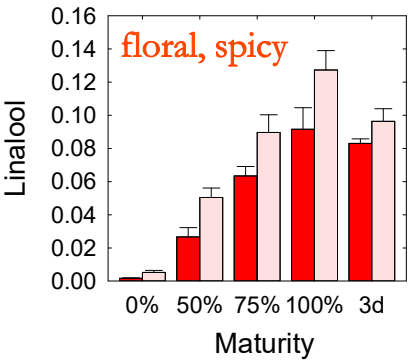
❖ Major VOCs in 'Seolhyang' cultivar



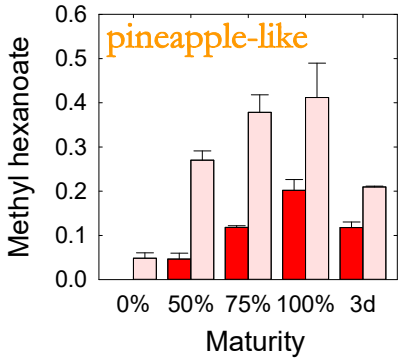


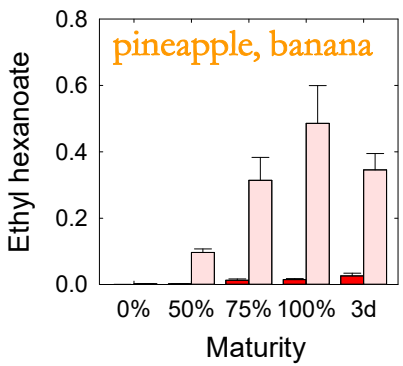


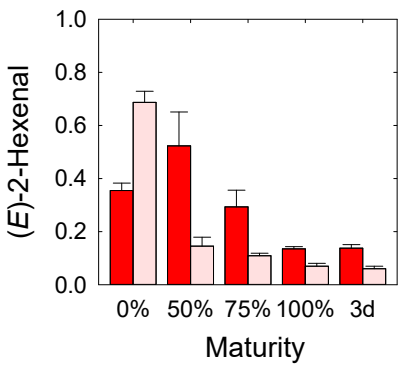


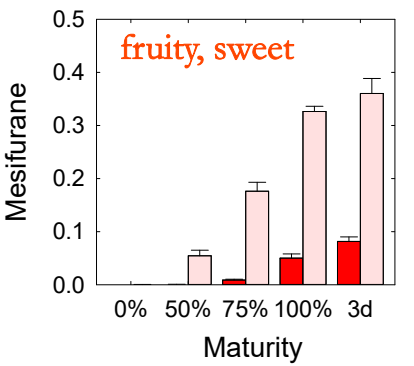


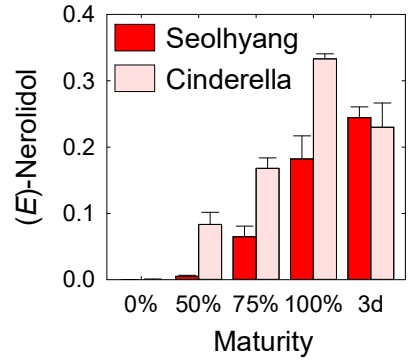
❖ Major VOCs in 'Cinderella' cultivar





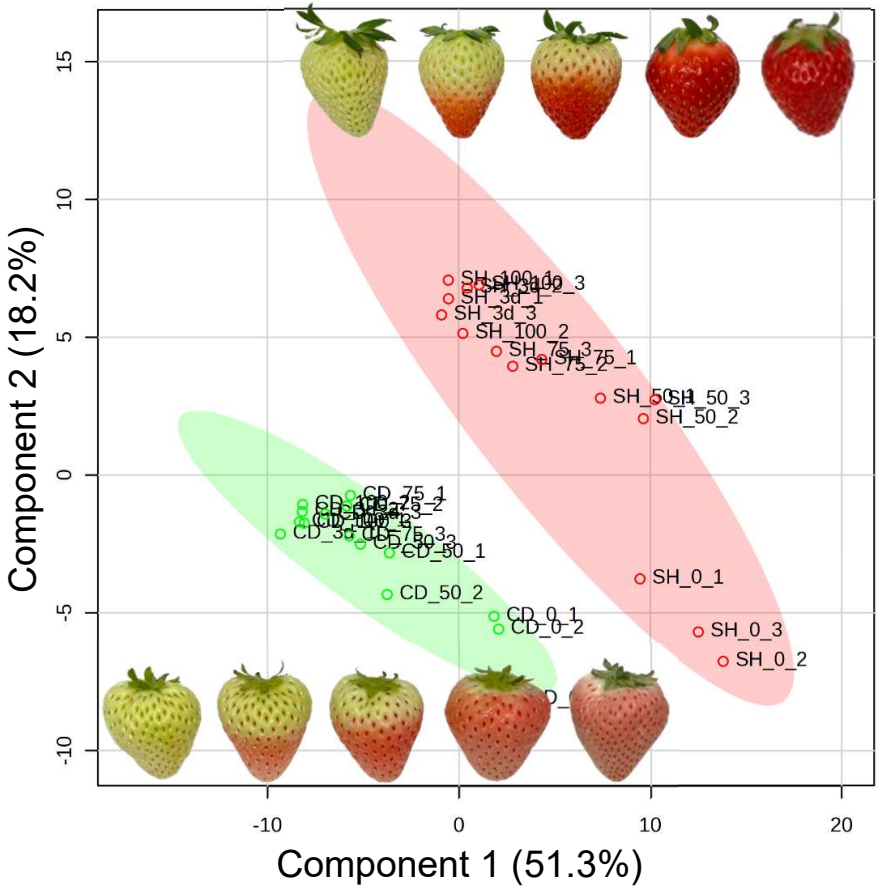


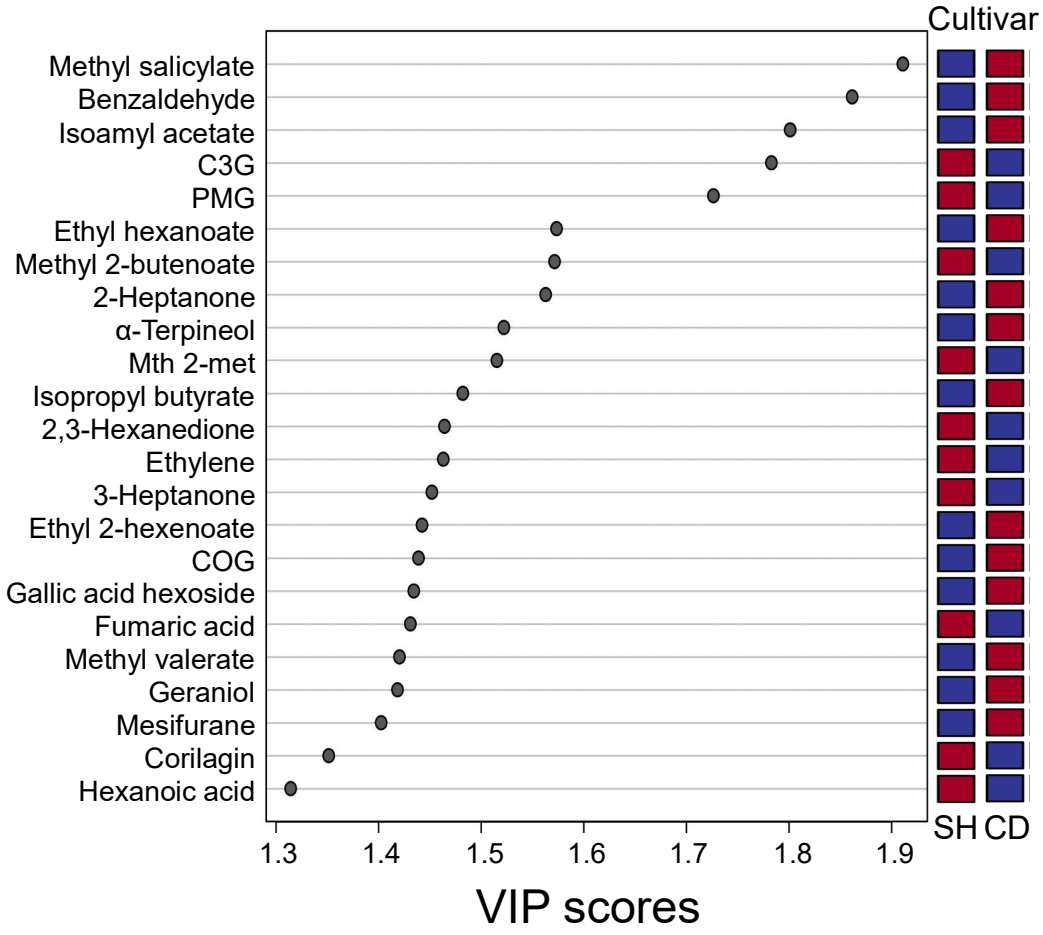




Partial least-squares discriminant analysis (PLS-DA)

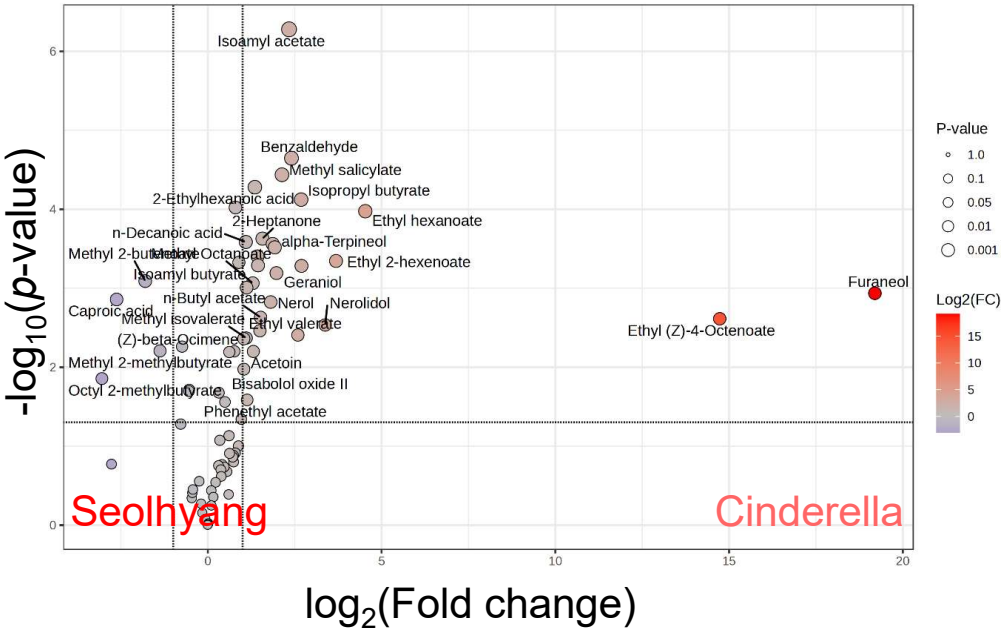
❖ Cultivar comparison



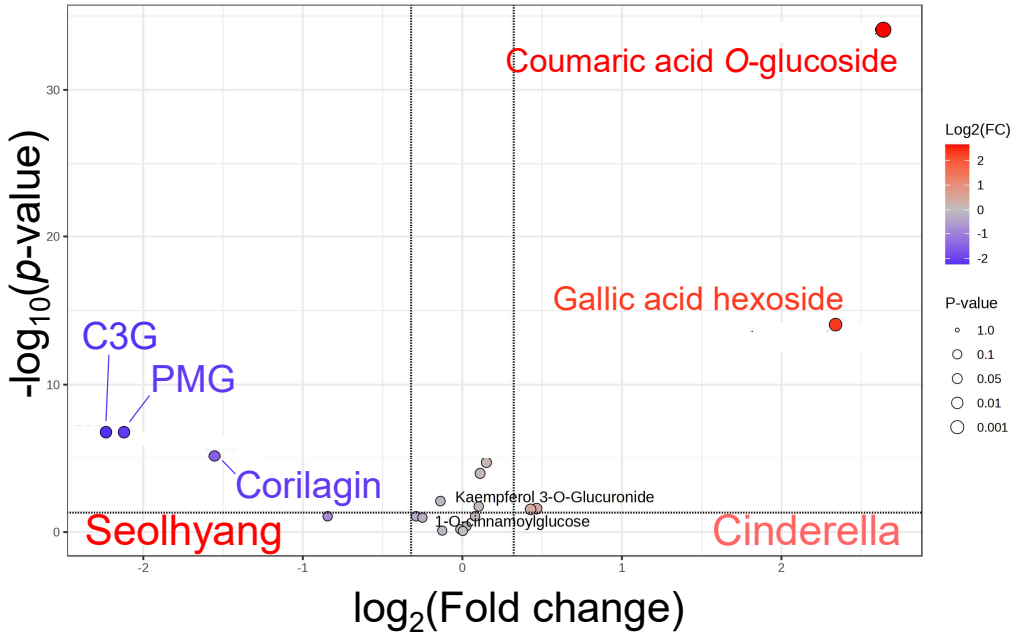


Volcano plots of VOCs and phenolic compounds

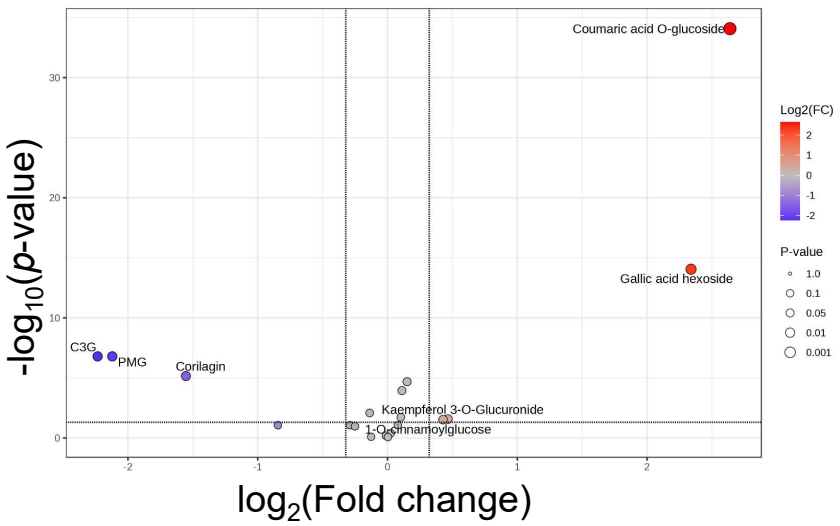
VOCs



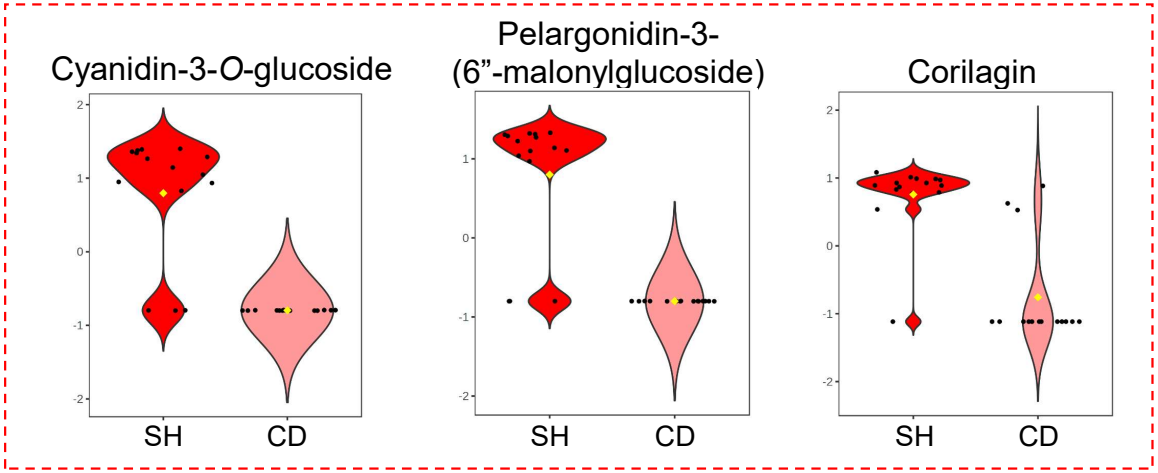
Flavonoids



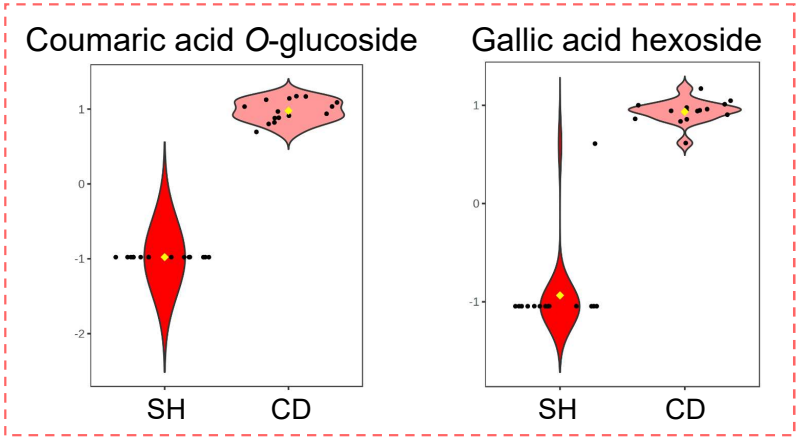
❖ Volcano plots of flavonoids



Seolhyang



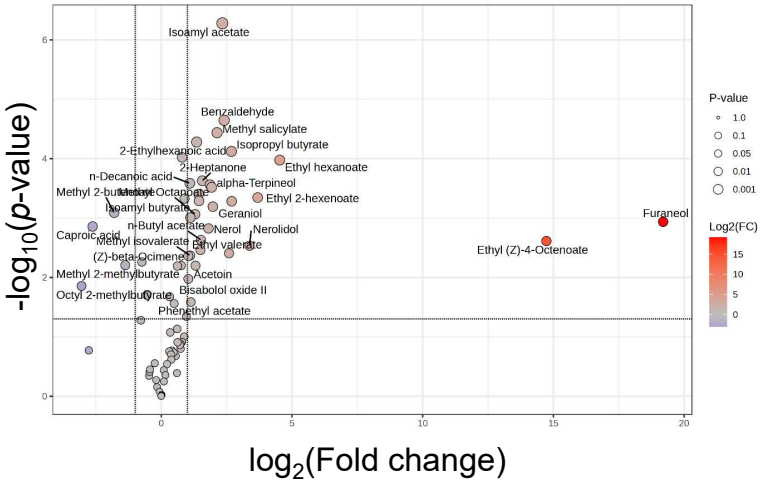
Cinderella

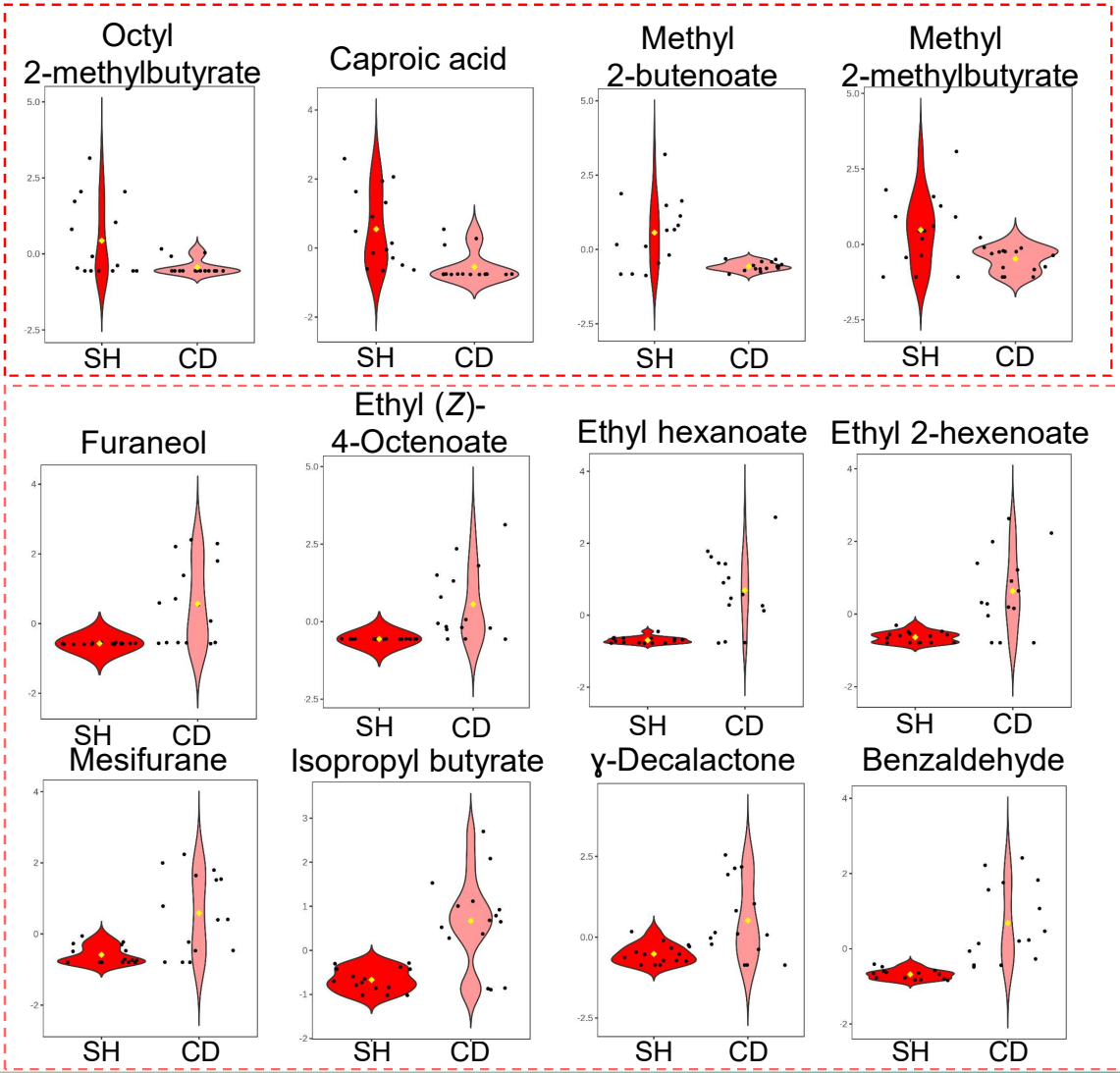


❖ Volcano plots of VOCs

Seolhyang

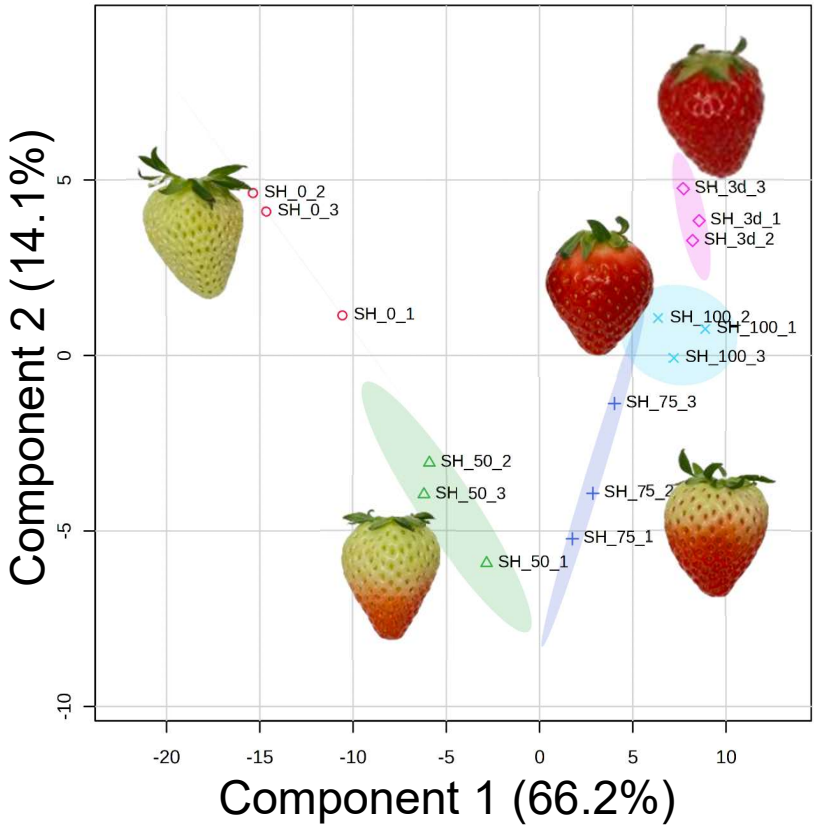
Cinderella

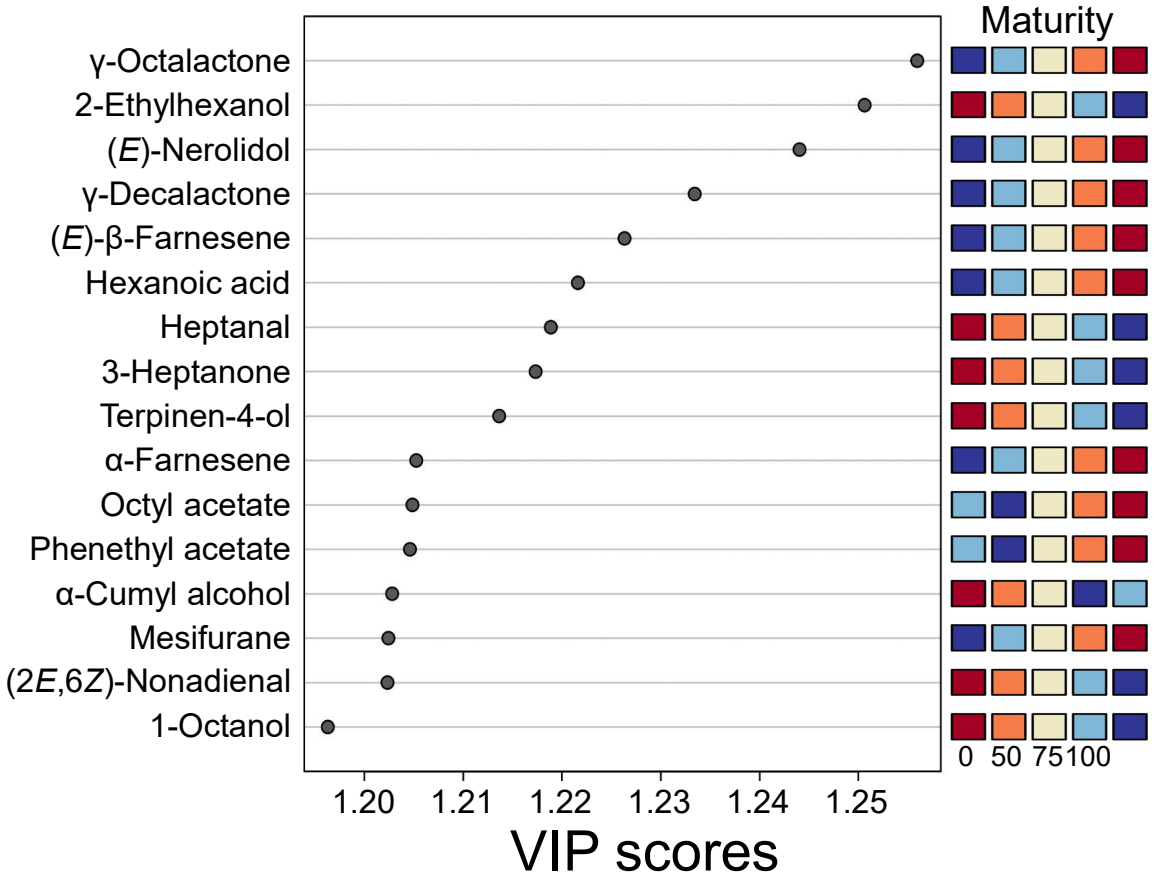




❖PLS-DA depending on fruit pigmentation stages

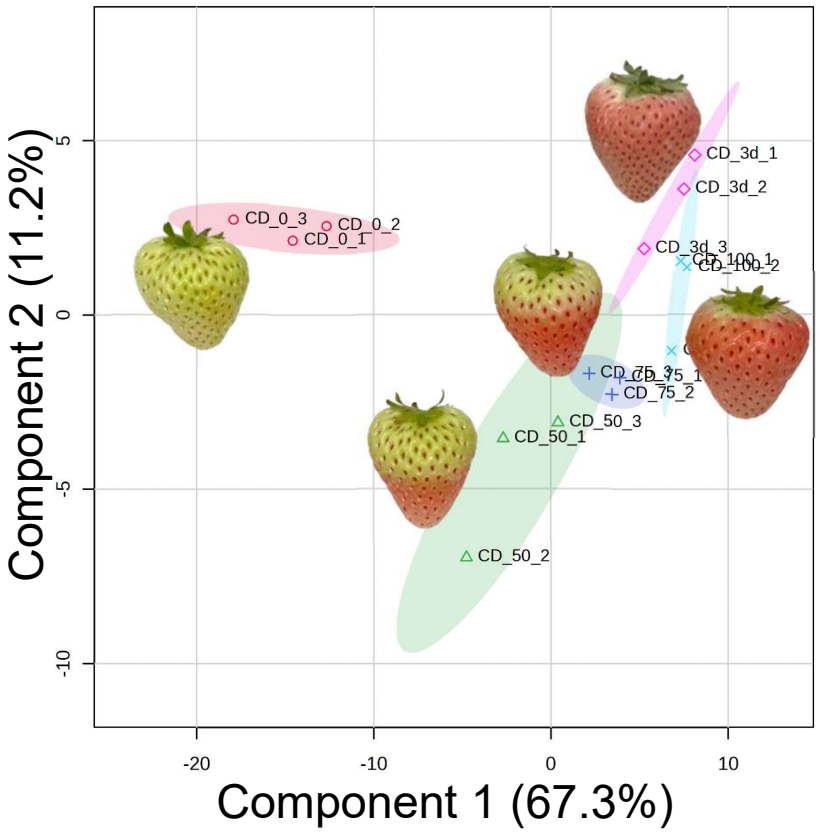
Seolhyang

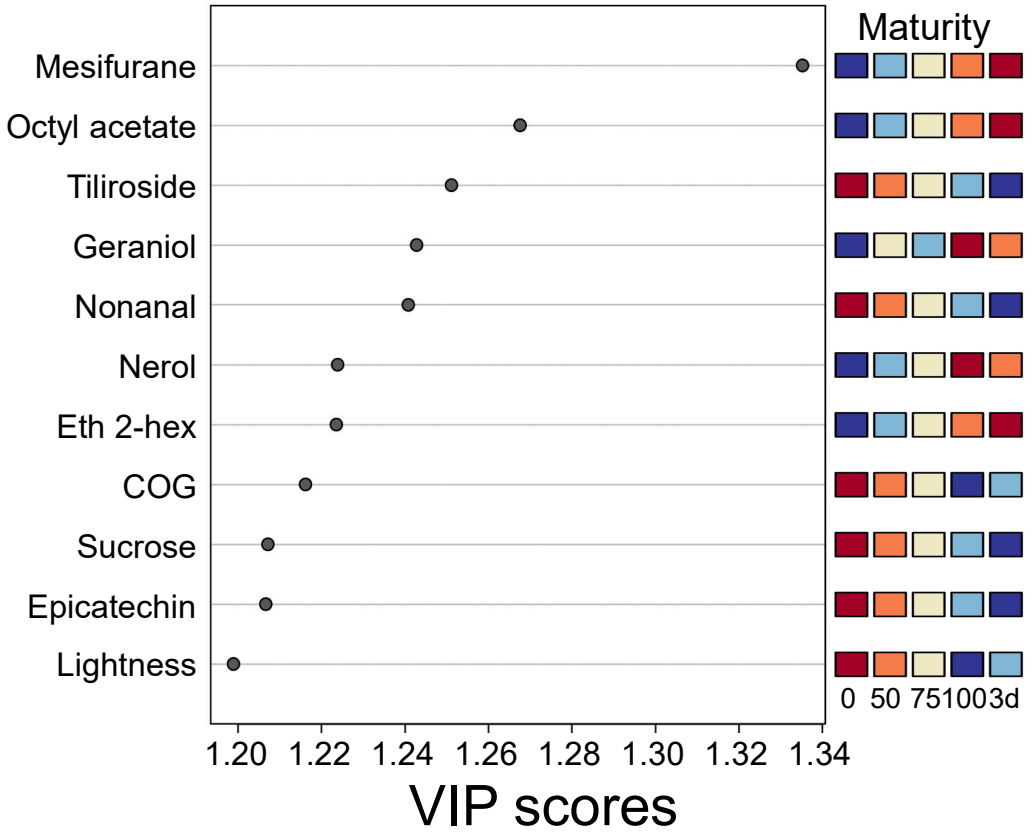




❖ PLS-DA depending on fruit pigmentation stages

Cinderella





Conclusion

	Seolhyang	Cinderella
		
Anthocyanin	Cyanidin-3-*O*-glucoside Pelargonidin-3-*O*-glucoside Pelargonidin-3-(6”-malonylglucoside)	Pelargonidin-3-*O*-glucoside
VOCs	Fatty acid-derived esters octyl 2-methylbutyrate, methyl 2-butenoate, methyl 2-methylbutyrate	Short-chain esters Ethyl hexanoate, ethyl 2-hexenoate, isopropyl butyrate Branched-chain esters / lactones Isoamyl acetate / ɣ-decalactone

Conclusion

- The SH cultivar accumulates high levels of anthocyanins, which gives a vivid red color.
- The CD cultivar has higher concentrations of VOCs, resulting in a distinctive sweet-fruity aroma.
- The divergent metabolic profiles indicate that the SH is beneficial for enhancing visual attributes and anthocyanin contents.
- On the other hand, CD cultivar offers potential for breeding programs aimed at improving aromatic characteristics (VOCs).
- This approach can inform breeding programs to enhance both the fruit appearance and flavor profiles of future strawberry cultivars.

Acknowledgements

중앙대학교 CHUNG-ANG UNIVERSITY

- Dr. Hyowon Park
- Dr. Jinhee Lee
- Ms. Si-Eun Byeon
- Ms. Theint Thandar Latt
- Mr. Jiwon Park
- Mr. Joohyuk Jo

IPET

- Supported by the Korea Institute of Planning and Evaluation for Technology in Food, Agriculture and Forestry (IPET) funded by Ministry of Agriculture, Food and Rural Affairs (MAFRA)
- Grant No. 322052052HD030

Thank you for your attention!

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