

Deconstructing the flavor release from cooking with olive oil

Case Study: Zeytinyağlı Fasulye

Zeynep Delen Nircan

Pat O'Hara

May 6, 2026

Colmar, France



<https://www.refikaninmutfagi.com/tarifler/zeytinyagli-taze-fasulye/>

Cuisine evolves over centuries if not millennia

Πλακί - پلاکی - Pilaki - Zeytinyağlı



- The word pilaki is from the ancient **Greek** word for flat pan and included protein or vegetables sauteed in olive oil.
- **Romans** served it with fish or mussels for during Lent.
- **Ottoman** elite served vegetable pilaki with beans and leeks and tomatoes added.
- Today **Turkey**: pilaki is served as a cold starter or side dish.

A. Ottoman Elite Cuisine

The Culinary Culture
of the Ottoman Palace & Istanbul
During the Last Period of the Empire

Özge Samancı*

A Generic Recipe

INGREDIENTS

6 tablespoons **olive oil**
2 **onions**
1.1 kg green **beans**
4 large **tomatoes**
2 teaspoons sugar
2 teaspoons salt

PREPARATION (regional variation)

Peel the strings, cut beans in half.
Peel and grate tomatoes.
Cook onions in oil until they lose color.
Add beans and tomato.
Add sugar and salt.
Close the lid cook until beans are yellow and soft.
Cook some more with lid open.



<https://www.refikaninmutfagi.com/tarifler/zeytinyagli-taze-fasulye/>

Same recipe - Regional differences



Method 1 - Whole onion placed in the center of pan, beans surround, tomatoes on top.

Method 2 - All ingredients added at the same time

Method 3 — Onions sauteed first, tomatoes added, other ingredients added

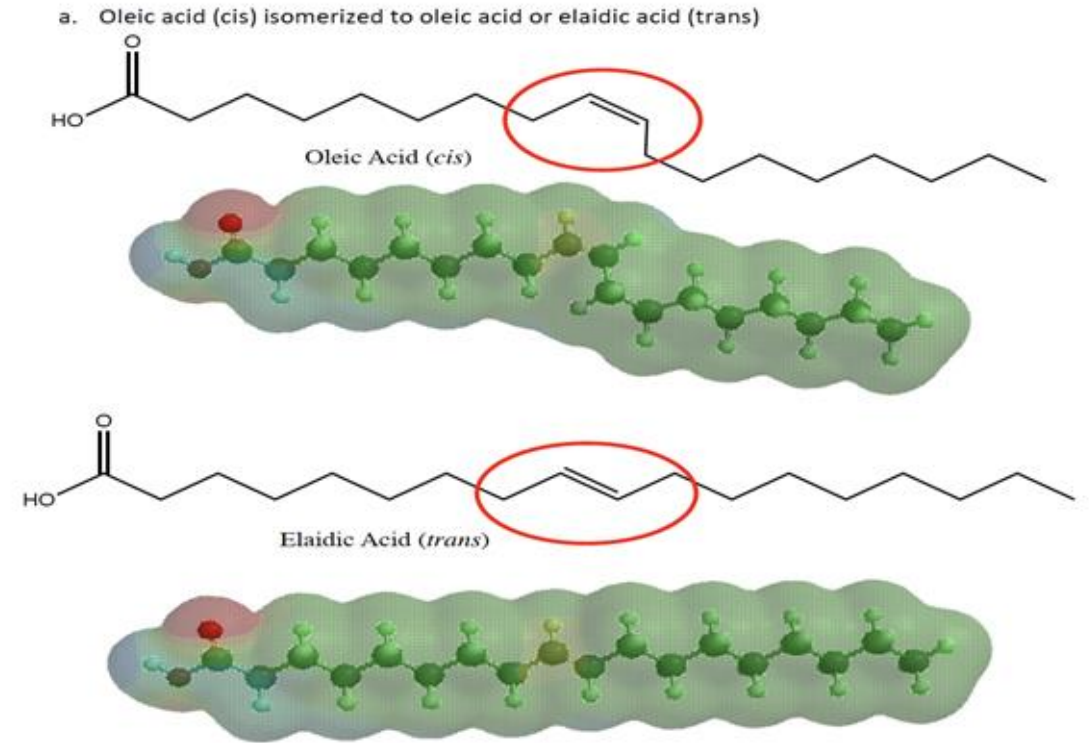


Olive Oil's major component is oleic acid



Oleic acid is a liquid at room temperature with a cis double bond and leaves a neutral soft taste on the palate. It is considered a healthy oil.

Elaidic acid is a solid at room temperature with a trans double bond. It can be generated from oleic acid at high temp ($>120^{\circ}\text{C}$). It leaves a waxy taste on the palate and is an unhealthy trans fat.



OLIVE OIL (EVOO)

Phenolic & Volatile Stability Under Heat

COLD / FRESH (≤27°C)	WARM SAUTÉ (80–100°C)	HIGH HEAT (130–180°C)	FRYING (>180°C)
----------------------	-----------------------	-----------------------	-----------------

Compound	Cold	Sauté	Hot	Fry	Flavor Note & Behavior
(E)-2-Hexenal	●●●	●●	●	—	Dominant fresh green odorant; volatilizes above ~90°C
Hexanal	●●	●●	●●	●●	Fatty-green; decreases with heat but new hexanal from oxidation
cis-3-Hexenol	●●	●	—	—	Floral-green leaf alcohol; reduces on heating
α-Farnesene	●●	●●	●	—	Woody-citrus terpene; heat stable below 150°C
Guaiacol	●	●	●●	●●●	Smoky-woody-phenolic; thermal degradation product
Octanal / Nonanal	—	●	●●	●●●	Thermal oxidation markers; increase with heat
(E)-2-Octenal	—	—	●	●●●	Thermal oxidation marker; rises at >180°C
1-Penten-3-one	—	●	●●	●●	Marker of thermal oxidation in EVOO
Trans-2-decenal	—	—	●	●●●	Secondary oxidation aldehyde; frying indicator

Oleocanthal (OC)	Oleacein (OA)	Hydroxytyrosol	Lignans (Pinoresinol)
90°C: ~0% loss 170°C: ~50% loss <i>TRPA1 pungency; first-order kinetics</i>	90°C: ~0% loss 170°C: ~50% loss <i>Throat burn; degrades parallel to OC</i>	90°C: 25–50%↓ 170°C: 70%+ ↓ <i>Major antioxidant; rapid degradation</i>	90°C: Stable 170°C: Stable <i>Heat-stable; last phenolics retained</i>

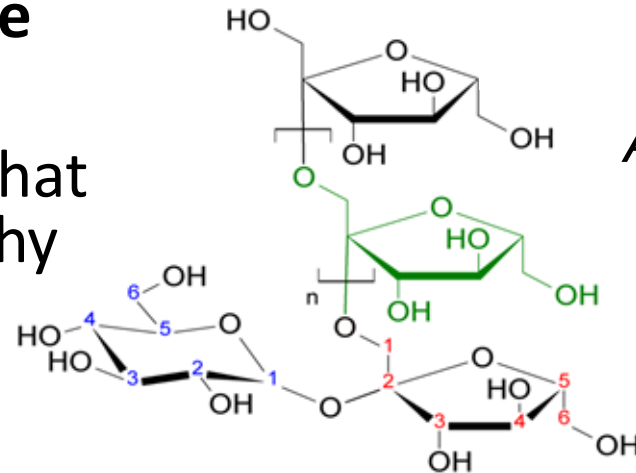
Refs: Brenes et al. (2002) J. Agric. Food Chem. · doi:10.1021/jf020506w | Attya et al. (2010) Food Chem. · doi:10.1016/j.foodchem.2010.07.001 | Zanoni et al. (2015) PMC · doi:10.3390/foods4030428 | Bubola et al. (2024) PMC · doi:10.3390/foods13213509

Onion Background

- Originated in Central Asia
- The name comes from the Latin word for a large pearl or unity.
- Layers of the onion are the swollen bases of the leaves.
- Layers contain 90% water and 10 % carbohydrates chains of **fructose sugars (inulin)**.
- Inulin is a soluble dietary fiber that encourages the growth of healthy intestinal bacteria.



Allium cepa (Lily Family)





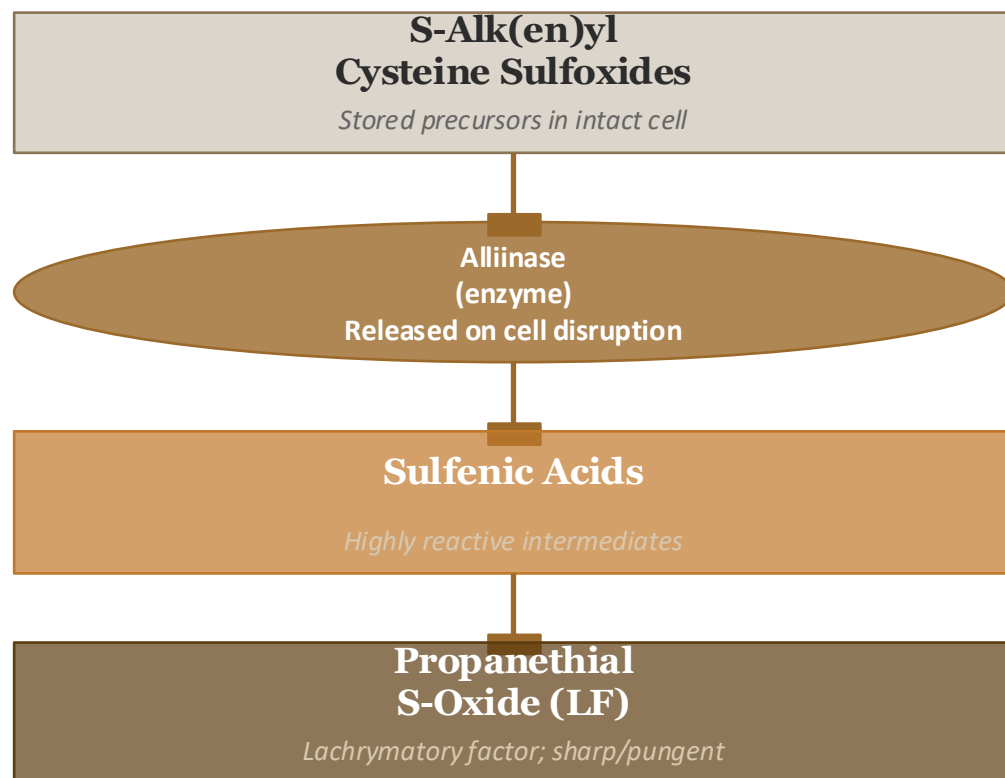
INTACT CELL

CUTTING/DISRUPTION

SAUTÉ (80–120°C)

CARAMELIZATION (>130°C)

ENZYMATIC PATHWAY ON DISRUPTION



LF also dimerizes → cepaenes & zwiebelanes (characteristic onion base note)

FLAVOR COMPOUNDS DURING COOKING

Propanethial S-oxide (LF) Sharp, lachrymatory, pungent	↑ cut, ↓ on heat
Dipropenyl thiosulfinate Onion/garlic sulfurous	↑ cut, transforms
Propanethiol Pungent sulfur — dominant after 60 min	↑↑ sauté
Dipropyl disulfide Cooked onion, milder sulfur	↑ sauté
Methional Cooked potato, sulfurous savory (Strecker)	↑ Maillard
Methylpyrazines Nutty, roasted, toasty	↑↑ caramel
Furfural / HMF Caramel-sweet, slightly bitter	↑↑ caramel
Diacetyl / Acetoin Buttery-creamy top note	↑ caramel

Green Bean Background

Phaseolus Vulgaris

- Green beans are a legume, high in value as an alternative, inexpensive protein source.
- Many family names in ancient Rome came from...
 - Fabius (from fava beans)
 - Lentulus (from lentil)
 - Piso (from peas)
 - Cicero (from chickpeas)
- Green Bean: originated in Central America and the Andes region of North America
- Flavor of raw bean: fiber, sugars, protein - amino acids
- Flavor of cooked bean grassy notes from C6 volatile hexene compounds, umami mushroom flavors from octenol, flowery terpene (linalool)



Ayşekadın*



Çalı

GREEN BEANS

Highest Lipoxygenase Activity of Any Vegetable → Cooking Evolution



VOLATILE COMPOUND EVOLUTION

Compound	Raw	Boil	Braise	Aroma
(Z)-3-Hexenal	●●●	●	—	Intense fresh cut grass
(E)-2-Hexenal	●●	●●	●	Pungent leaf aldehyde
cis-3-Hexenol	●●	●●	●●	Floral-green leaf alcohol
Hexanal	●●	●●●	●●	Fatty-green, cut grass
1-Penten-3-one	●●●	●	—	Pungent grassy/green
1-Penten-3-ol	●●	●	—	Earthy, mushroom
2-Isobutylthiazole	●	●●	●●	Green tomato leaf
Methoxypyrazines	●	●	●●	Green pepper, earthy
Dimethyl sulfide	—	●	●●	Cooked vegetable, savory
Furfural	—	●	●●	Caramel-sweet

COOKING EFFECT ON LOX ENZYME

Raw / Disrupted	LOX maximally active; enzyme released from chloroplasts; C6 green volatiles surge
60–70 °C	LOX begins denaturation; C6 aldehydes start declining; alcohols accumulate via ADH
80–100 °C (Blanch/Boil)	Majority of LOX denatured; green volatile production arrested; dimethyl sulfide emerges
100–130 °C (Slow Braise)	Amino carbonyl & Strecker reactions begin; furfural, pyrazines build; residual cis-3-hexenol anchors 'cooked green' note

Refs: De Lumen et al. (1978) J. Food Sci. · doi:10.1111/j.1365-2621.1978.tb02396.x | Ulrich et al. (2001) Eur. Food Res. Technol. · doi:10.1007/PL00005517 | Buttery et al. (1994) J. Agric. Food Chem.

Tomato Background

- Originated in the Americas as far back as 3500 BCE.
- Brought to Europe and Ottoman in 17th century.
- Sugar content in cell walls is lower (3%) than in other fruits(10-15%).
- Non-volatile acids exist in jelly.
- High level of vitamin C.
- Aromatic sulfur compounds (like meat)



*Lycopersicon
esculentum*

Aztec “tomatl” means plump fruit.



TOMATO

Flavor Origins & Cooking Transformations

RAW / INTACT	CELL DISRUPTION	GENTLE HEAT (60–90°C)	SUSTAINED COOKING (>100°C)
LOX / Fatty Acid Pathway	Carotenoid Cleavage (CCD1)	Amino carbonyl / Strecker (Heat)	
(Z)-3-Hexenal ↓ cook Intense green/grassy — high raw, drops on heating	β-Ionone ↑ ripe/heat Sweet/floral — from β-carotene oxidation; key aroma	2-Methylbutanal ↑↑ cook Malty/chocolatey; Strecker from isoleucine	
Hexanal ↑ cook Fatty-green; rises with lipid oxidation under heat	Geranial (Citrал-A) ↑ heat Lemon-citrus; from lycopene; enhances sweetness	3-Methylbutanal ↑↑ cook Malty/cocoa; Strecker from leucine	
(E)-2-Hexenal ~→ Pungent green; isomerizes from Z-3-hexenal	6-Methyl-5-hepten-2-one ↑ heat Citrus-floral ketone; from phytoene/lycopene	Phenylacetaldehyde ↑ cook Honey/rose; Strecker from phenylalanine	
cis-3-Hexenol ↓ cook Leaf alcohol; converts to hexenyl acetate	Pseudoionone ↑ heat Floral-woody; carotenoid cleavage product	Furfural ↑ cook Caramel-sweet; from pentose sugar dehydration	
1-Penten-3-one ↓ cook Pungent grassy; reduced enzymatically	Geranyl acetone ↑ heat Floral-rose; C13 carotenoid fragment	Methyl salicylate ↑ cook Wintergreen; phenylpropanoid pathway	

doi:10.3389/fpls.2023.1144113

doi:10.1093/jxb/eru250

doi:10.1016/j.foodchem.2018.02.133

KEY: Green LOX-volatiles dominate raw tomato aroma; heat shifts profile toward β-ionone (sweet/floral), Strecker aldehydes (malty), and furfural (caramel) → cooked tomato complexity

Warm green beans with meat and tomato paste



- In the winter, concentrated tomato paste is used for cooking vegetables with ground beef.
- Onions are sauteed in EVOO, concentrated tomato paste is added before other ingredients are added.
- This creates conditions (high temperature, low water) for amino carbonyl reactions and Strecker degradation of the abundant amino acid methionine.
- Sautéing tomato paste generates a lot more methional.



Olive Oil in Pilaki is an Infusion Medium

- The dish is cooked covered at low heat.
- Long and slow cooking allows the oil to absorb and carry volatiles from all the ingredients, integrating them into a unified aromatic whole.
- Always served at room temperature so that fat-soluble aroma compounds fully dispersed through the oil are released slowly.
- The olive oil role is fundamentally different from a sauté context.