

Evaluation of pomological traits and kernel quality in almond cultivars suitable for commercial cultivation in Central Europe

Ivo Ondrášek*, Eliška Zezulová, Erika Slámová, Tomáš Nečas

Faculty of Horticulture, Mendel University in Brno, Lednice 691 44, Czech Republic

ABSTRACT

This study presents a comprehensive evaluation of the phenological, pomological, and nutritional traits of various almond cultivars based on multi-year observations. The results revealed significant differences among cultivars in flowering and ripening times, stone and kernel weight, shell hardness, and sensory characteristics. The earliest cultivar in terms of both flowering and ripening was 'Zora', while 'Ferrastar' and 'Ferragnes' flowered the latest. 'Gersonskaja' exhibited the highest stone weight (8.8 ± 3.1 g) and shell hardness and 'Suzanne' the softest shell. The highest kernel weight was recorded in *Prunus amygdalus* var. *tenera* (1.6 ± 0.1 g). All evaluated cultivars had sweet kernels, except for the rootstock 'MN-VA-I', which was rated as semi-sweet. 'Ferrastar' received the highest palatability rating, while 'Ferragnes' had the lowest, though still favourable, score. Principal component analysis (PCA) and cluster analysis revealed two main cultivar groups, with 'Gersonskaja' and 'Zora' being the most distinct. The chemical composition of the kernels showed statistically significant differences ($p < 0.05$). 'Genco' exhibited the highest fat content ($61.79 \pm 0.01\%$ FW), while 'Famosa' had the highest soluble protein content ($14.16 \pm 0.79\%$ FW). 'Ferragnes' stood out for its highest levels of phenolic compounds (142.09 ± 0.39 mg) (GAE $\cdot 100$ g⁻¹ FW), flavonoids (85.11 ± 0.35 mg) (CE $\cdot 100$ g⁻¹ FW), and antioxidant capacity (AC) (148.9 ± 1.7 mg) (TE $\cdot 100$ g⁻¹ FW). PCA of the nutritional data confirmed the similarity between 'Ferragnes' and *P. amygdalus* var. *tenera* in terms of secondary metabolite content, whereas 'Gersonskaja' showed the lowest values across most parameters.

Keywords: fat content, flowering, phenology, proteins, ripening, secondary metabolites, taste

Abbreviations: AC, antioxidant capacity; ANOVA, one-way analysis of variance; CE, catechin equivalent; DW, dry weight; FW, fresh weight; GAE, gallic acid equivalent; TE, Trolox equivalent; TFC, total fat content; TFlavC, total flavonoid content; TPC, total phenolic content; TSPC, total soluble protein content.

INTRODUCTION

The almond (*Prunus amygdalus* Batsch., syn. *Prunus dulcis* (Mill.) D.A. Webb) is a stone fruit belonging to the family Rosaceae, genus *Prunus*, subgenus *Amygdalus*. This species is native to Central Asia and western China, with a natural distribution extending from Iran through the Caucasus and eastern Turkey to the eastern Mediterranean region. Almonds are extensively

cultivated in major production areas such as the United States (California), Spain, Italy, Greece, Turkey and India (Janick and Paull, 2008). They have also been successfully introduced and established under Central European conditions, where their chilling requirements are comparable to those of peach or apricot cultivars—typically ranging from 900 to 1200 chilling hours.

*Corresponding author.

e-mail: ivo.ondrasek@mendelu.cz (Ivo Ondrášek).

For reliable and optimal yields in Central Europe, cultivars with a late flowering period are preferred. According to Prudencio et al. (2018), late-flowering almond cultivars generally exhibit very high chilling requirements. In the context of climate change, increasingly mild winters may reduce the theoretical risk of late spring frosts. However, warmer winters can also lead to earlier flowering, which may offset these potential benefits (Di Lena et al., 2018).

Numerous studies have investigated the nutritional value and chemical composition of almond kernels and almond oil (Özcan et al., 2011; Simsek et al., 2018; Barreca et al., 2020; Banjanin et al., 2021; Levent, 2022). The considerable variation in chemical composition depends on cultivation practices, climatic conditions, and, most significantly, almond genotype (Yada et al., 2011). Fat is the main constituent of almond kernels, accounting for 20%–68% of dry weight (DW), and consists primarily of fatty acids such as oleic acid, linoleic acid, and palmitic acid (Hernandez and Sanders, 2024). Almond oil possesses medicinal properties and is widely used in the pharmaceutical and cosmetic industries (Čolić et al., 2019).

In addition, almonds are rich in proteins (10%–35%), carbohydrates (2%–10%), dietary fibre (around 10%), minerals and bioactive compounds (Valdés et al., 2015; Čolić et al., 2019; Yada et al., 2013). The phenolic content in almond kernels ranges from 38.7 to 241 mg GAE · 100 g⁻¹ (Milbury et al., 2006; Levent, 2022). Almond consumption has been linked to improved immune function and the prevention of various diseases, including cardiovascular disorders, diabetes, obesity and oxidative stress. In addition to fresh and dried forms, fermented almonds are also now being consumed (Ahmed et al., 2024).

The significance of almond trees is further emphasised by recent research from Greece analysing bioactive compounds in almond blossoms (Chatzimitakos et al., 2024).

The aim of this study is to provide a comprehensive evaluation of a promising set of almond cultivars, some of which show high potential for reliable performance under commercial cultivation conditions in Central Europe. These findings provide valuable insights for the breeding, cultivation and utilisation of almond cultivars with desirable agronomic and nutritional traits.

MATERIALS AND METHODS

Site of planting and plant material

In total, 14 almond (*P. amygdalus*) cultivars were analysed in this study (Table 1). Each cultivar was represented by five trees grown in an experimental orchard at the Faculty of Horticulture in Lednice, Mendel University in Brno (latitude 48.80°N, longitude 16.80°E; elevation 172 m), where the average annual temperature is 9.7°C. The plantation was established in 2011, GF 677 (*Prunus persica* × *P. amygdalus*) was

Table 1. Origin of evaluated almond varieties.

Variety	Origin
Famosa	Czech; seedling selection from open pollination
Fatima	Czech; seedling selection from open pollination
Ferragnes	France; Cristomorto × Ai
Ferrastar	France; Cristomorto × Ardechoise
Genco	Italy; unknown origin
Gersonskaja	Ukraine; unknown origin
Husle	Czech; seedling selection from open pollination
<i>P. amygdalus</i> var. <i>tenera</i>	Czech; seedling selection from open pollination
MN-VA-1	Czech; seedling selection from open pollination
Nikitsky	Ukraine; Nikitskyi 62 × Nikitskyi 1
Sladkoplodá krajová	Czech; seedling selection
Supernova	Italy; Tuono bud mutation
Suzanne	Czech; seedling selection from open pollination
Zora	Czech; seedling selection from open pollination

chosen as the rootstock. The growing system is a free-standing system, tree spacing 5 m × 3 m.

Phaenological and pomological evaluations were conducted in the years 2017, 2020, 2024 and 2025. For each cultivar, five trees were randomly selected, and data were collected either from five plants or from 10 fruits per tree, depending on the parameter evaluated. All plant material was visibly healthy, vigorous and free from major pests or diseases. Phaenological and pomological traits were assessed according to the UPOV Descriptor Code: PRUNU_DUL (2011) and the Revised Descriptors List for Almond (*P. amygdalus*) by Gülcan (1985). For nutritional analyses, 10 fruits from each cultivar were crushed, and the almond kernels were homogenised using a Pulverisette 2 mill (Fritsch, Germany).

Phaenological and pomological parameter analysis

The onset of flowering was recorded as the date when 10% of the flowers were fully open. The harvest date was determined when 50% of the fruits on a tree had split.

Pomological traits evaluated included stone keel development, stone shape, kernel size and weight (g), shell colour intensity, shell hardness, kernel taste (bitterness), overall taste quality and kernel-to-stone ratio (%).

All fruit quality assessments, including taste-related traits, were performed by a single experienced

pomologist (the author) using standardised UPOV (2011) descriptor.

Determination of total fat content (TFC)

Crude fat content (%) was determined in three technical replicates using the Soxhlet extraction method with *n*-hexane as the solvent according to the national standard Determination of Fat in Foods (GB 5009.6-2016). A 2 g sample of crushed almonds was placed in a filter paper bag and extracted with 100 mL of *n*-hexane for 1 hr. After extraction, the solvent was evaporated to the constant weight of the residual sample. Fat content (%) was calculated as the ratio of fat weight to sample DW.

Determination of total soluble protein content

Total soluble protein content (TSPC) was analysed following the protocol described by Deans et al. (2018), using the Pierce Bradford Protein Assay Kit (Thermo Fisher Scientific, USA). Reactions were prepared as three technical replicates in a 96-well plate. Standards consisted of six different concentrations of bovine serum albumin (BSA) and one blank containing 0.1 M NaOH. Each reaction mixture included 5 µL of sample or standard and 250 µL of Coomassie reagent. The reactions were incubated at room temperature for 10 min, shaken for 30 s and absorbance was measured at 595 nm using a PowerWave XS microplate reader (BioTek, USA). Results were expressed as grams of soluble protein per 100 g of fresh weight ($\text{g} \cdot 100 \text{ g}^{-1} \text{ FW}$).

Analysis of secondary metabolites

Samples for total phenolic content (TPC), total flavonoid content (TFlavC), and antioxidant capacity (AC) were prepared by extracting 5 g of crushed kernels in 25 mL of 75% methanol overnight. Extracts were filtered through filter paper into 50 mL volumetric flasks, and the volume was adjusted with methanol. Samples were stored in plastic bottles at -20°C until analysis.

The assays were carried out according to the method of Zloch et al. (2004), as described by Mrázová et al. (2021). Each sample was analysed in technical triplicate using a Specord 50 Plus spectrophotometer (Analytik Jena, Germany). TPC results were expressed as milligrams of gallic acid equivalent per 100 g of fresh weight ($\text{mg GAE} \cdot 100 \text{ g}^{-1} \text{ FW}$), TFlavC as milligrams of catechin equivalent per gram of fresh weight ($\text{mg CE} \cdot 100 \text{ g}^{-1} \text{ FW}$) and AC as milligrams of Trolox equivalent per 100 g of fresh weight ($\text{mg TE} \cdot 100 \text{ g}^{-1} \text{ FW}$).

Statistical analysis

Statistical analyses were performed using Statistica 14 software (TIBCO Software Inc., USA). The dataset consisted of measurements obtained for each cultivar over 1 year, with multiple observations per cultivar. Mean values and standard deviations were calculated, and statistical significance among cultivars was

evaluated using one-way analysis of variance (ANOVA), followed by a *post hoc* Tukey HSD test ($p < 0.05$).

Cluster analysis was applied to group cultivars based on similarities in phenological and pomological traits using cultivar mean values. Principal component analysis (PCA) was performed separately on two datasets: (1) phenological and pomological traits and (2) chemical and bioactive compound content. Prior to PCA, all variables were automatically standardised to zero mean and unit variance.

RESULTS

Phaenological and pomological analysis

Based on comprehensive multi-year phenological and pomological evaluations, notable differences among the assessed cultivars were identified (Table 2).

In terms of the average onset of flowering, the earliest blooming cultivar was 'Zora', flowering 18 days earlier than the reference cultivar 'Supernova'. The latest-flowering cultivars were 'Ferrastar' and 'Ferragnes', both blooming approximately 4 days after the reference (Figure 1).

Similarly, 'Zora' was also the earliest maturing cultivar, with harvest occurring approximately 8 days before 'Supernova', while the latest-maturing cultivar was 'Gersonskaja', ripening 5 days after the reference.

The highest stone weight was recorded in 'Gersonskaja' (8.8 g), whereas the lowest was observed in 'Suzanne' (2.44 g). Shell hardness (crackability) followed a similar trend, with 'Gersonskaja' displaying the hardest shell, and 'Suzanne' having the softest shell among the evaluated cultivars.

With respect to kernel weight, the highest value was observed in *P. amygdalus* var. *tenera* (1.61 g), while the lowest was found in 'Fatima' (0.81 g) (Figure 2).

In terms of kernel taste quality, all evaluated cultivars were classified as sweet (score: 3), except for the rootstock 'MN-VA-1', which was rated as semi-sweet (score: 5) due to a slight bitter aftertaste (Figure 3).

Overall taste quality was evaluated using a nine-point hedonic scale. 'Ferrastar' received the highest rating (score: 9), indicating the most favourable taste, while 'Ferragnes' received the lowest score (5), although it still fell within the acceptable taste range.

Cluster analysis based on phenological and pomological traits revealed two main cultivar groups (Figure 4). The cultivars 'Genco', 'Sladkoplodá krajová' and 'Nikitsky' exhibited trait profiles similar to the control cultivar 'Supernova'. In contrast, 'Gersonskaja' and 'Zora' were the most divergent, indicating distinct phenotypic characteristics compared to the rest of the evaluated genotypes. PCA (Figure 5) further confirmed these distinctions. 'Gersonskaja' was characterised by a markedly late flowering period and high stone weight, which contributed significantly to its separation from other cultivars in the PCA space. On the other hand, *P. amygdalus* var. *tenera* and 'Ferrastar' were

Table 2. The evaluated phenological and pomological parameters of different almond cultivars. std. is not shown when all measured values were identical.

Varieties	Date of flowering start ($\pm$ /- days before or after control)		Date of ripening start		Stone weight [g]		Stone shape		Softness of shell		Kernel weight [g]		Shell colour intensity (brown)		Taste		Taste (quality)		Keel	
	$\emptyset$	std.	$\emptyset$	std.	$\emptyset$	std.	$\emptyset$	std.	$\emptyset$	std.	$\emptyset$	std.	$\emptyset$	std.	$\emptyset$	std.	$\emptyset$	std.	$\emptyset$	std.
Famosa	-12.00	8.83	0	0	3.75	0.59	3	0.58	7	3.06	0.91	0.13	4	1	3	1.15	7	-	1	-
Fatima	-8.67	4.62	0	0	3.31	0.32	3	0	4	2.12	0.81	0.02	4	2.12	3	0	8	-	2	-
Ferragnes	4.00	0.71	0	0	4.50	1.73	3	1.26	5	2	1.00	0.29	5	0.96	3	0.5	5	-	1	-
Ferrastar	4.00	1.00	0	-	5.81	0.76	4	-	6	-	1.58	0.12	3	0	3	0	9	-	5	-
Genco	-0.20	0.45	1	1.15	4.83	0.56	4	1	5	2	1.28	0.55	3	1	3	1	8	-	3	-
Gersonskaja	3.50	2.52	5	1.5	8.80	3.06	2	1	3	1.15	1.19	0.73	3	1.73	3	0	8	-	2	-
Husle	-3.00	4.24	0	-	5.59	-	5	-	3	-	0.88	-	5	-	3	0	7	-	2	-
<i>P. amygdalus</i> var. <i>tenera</i>	-12.00	10.58	0	0	3.48	0.06	3	0	8	1.41	1.61	0.14	3	0	3	0	8	-	7	-
MN-VA-1	-12.25	4.57	0	0	4.31	0.84	3	0.58	3	1.53	0.91	0.12	3	1.15	5	1.53	7	-	9	-
Nikitsky	-6.00	-	0	-	4.20	-	3	-	5	-	1.06	-	4	-	3	0	8	-	2	-
Sladkoplodá Krajová	-1.75	2.87	0	0	3.75	0.84	3	0.58	5	1.73	1.41	0.35	5	1	3	0	7	-	2	-
Supernova	0.00	0.00	0	0	4.71	1.26	3	0.82	5	2.08	1.52	0.25	3	0.5	3	1.5	8	-	3	-
Suzanne	-9.50	4.04	1	1.41	2.44	0.41	3	0.58	9	1.15	0.95	0.42	3	1.73	3	0	8	-	5	-
Zora	-17.50	6.56	-8	1.41	4.04	0.72	3	2	5	2.52	1.28	0.45	5	0.58	3	0	8	-	2	-

std., standard deviation.

Stone shape was evaluated according to the following scale: 1 – rounded, 2 – ovate, 3 – oblong, 4 – cordate, 5 – extremely narrow. Softness of shell was evaluated according to the following scale: 1 – extremely hard (very difficult to break, need hammer), 2 – hard (difficult to break, need hammer), 5 – intermediate (broken by hand with effort), 7 – soft (broken by hand), 9 – paper (very thin, easily removed).

Shell colour intensity was evaluated according to the following scale: 1 – extremely light; 3 – light; 5 – intermediate, 7 – dark. Taste was evaluated according to the following scale: 3 – sweet, 5 – intermediate, 7 – bitter.

Taste (quality) was modified kernel taste rating, expressing the taste quality on a scale of 1 to 9, where 9 is the best taste quality of sweet kernels.

Keel development was evaluated according to the following scale: 1 – absent or very weak, 3 – weak, 5 – medium, 7 – strong.

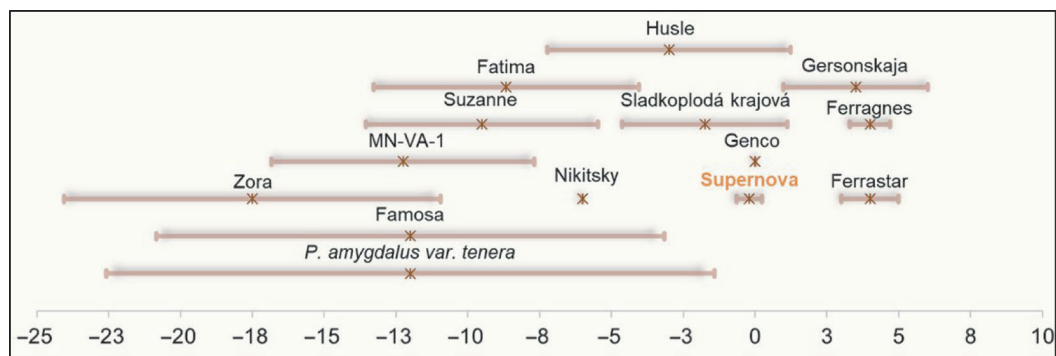


Figure 1. The mean value of the onset of flowering for a range of almond cultivars. The brown lines represent the standard deviation.

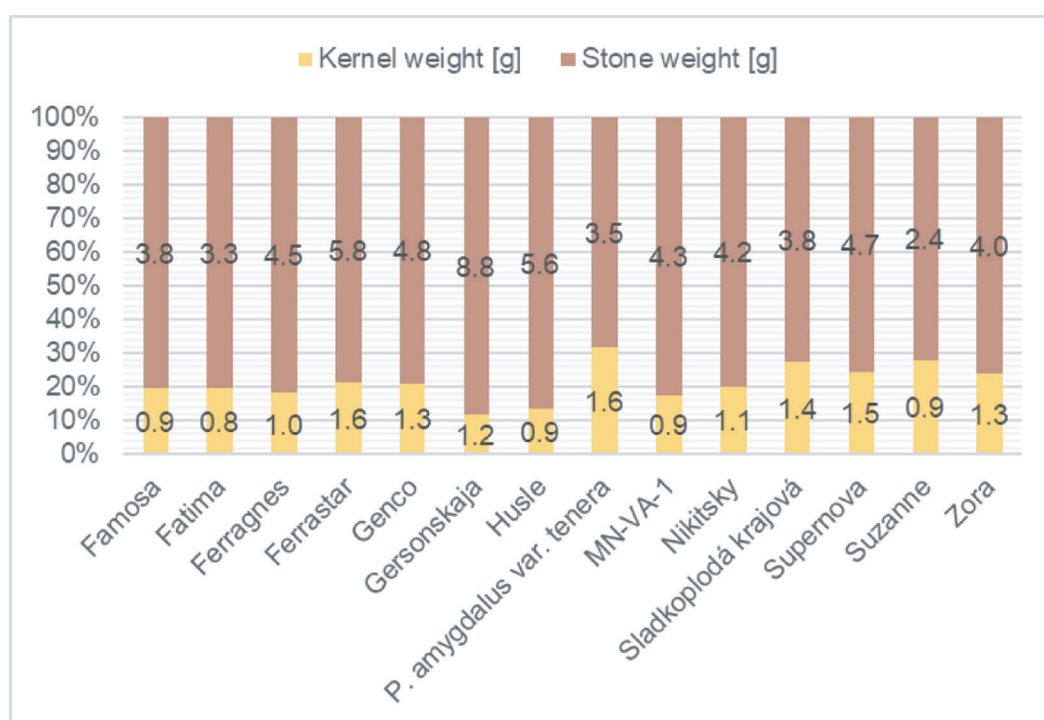


Figure 2. The ratio of almond kernel weight to stone weight, expressed in %.

positioned in the PCA plot as cultivars of high overall quality, exhibiting large kernel weight and easy shell removal, traits desirable for commercial production and processing.

The collection contributes to the promotion of biodiversity and expands the potential for cultivating useful fruit species. Based on multi-year phenological and pomological observations, genotypes and cultivars that are considered promising and recommended for commercial cultivation are those that are self-fertile or partially self-fertile, exhibit late flowering, and, naturally, produce sweet kernels. A brief, comprehensive description, as a result of the performed pomological measurements of the selected varieties, is given as follows:

Supernova

Originating from Italy, this cultivar is a radiomutant of the variety 'Fascionello' (Monastra et al., 1984). Its harvest time coincides with that of the reference cultivar 'Sladkoplodá krajová'. 'Supernova' is characterised by vigorous growth, forming wide and open canopies. Fruiting occurs on both 1-year shoots and spur-bearing structures. This self-fertile cultivar exhibits a mid-late flowering period, approximately 5 days later than 'Sladkoplodá krajová', and consistently produces abundant blooms. The hull is light green, thin and fully dehiscent at maturity. The shell is round-elongated, easily separable from the hull, with an average weight of 3.7 g. The endocarp is classified as 'semi-soft shell'. The kernel, covered by a light brown testa, is medium-sized,



Figure 3. Almonds of analysed cultivars. (A) Famosa, (B) Fatima, (C) Ferragnes, (D) Ferrastar, (E) Genco, (F) Gersonskaja, (G) Husle, (H) MN-VA-1, (I) Nikitskij, (J) Sladkoploda, (K) Supernova, (L) Suzanne, (M) var. *tenera*, (N) Zora.

monoembryonic and of excellent sweet flavour, with an average weight of 1.7 g. 'Supernova' is one of the most suitable cultivars for intensive cultivation systems. Key advantages include high self-fertility, frost resistance, consistent annual yield and superior kernel flavour.

Genco

An Italian cultivar of unknown seedling origin (Monastra et al., 1984). Its harvest time coincides with that of 'Sladkoploda krajová' and 'Supernova'. It exhibits vigorous growth and forms a wide, dense canopy.

Fruiting primarily occurs on spur-bearing shoots. 'Genco' is a self-fertile cultivar with a mid-late flowering period, approximately 5 days later than 'Sladkoploda krajová'. It consistently produces profuse flowering. The hull is thick and opens at full maturity. The shell is heart-shaped, easily separable from the hull, and has an average weight of 5.2 g. The endocarp is semi-soft, and bi-embryony is common. The kernel is medium-sized, sweet and weighs on average 2.1 g. This cultivar features excellent kernel flavour and is well-suited for marginal cultivation areas.

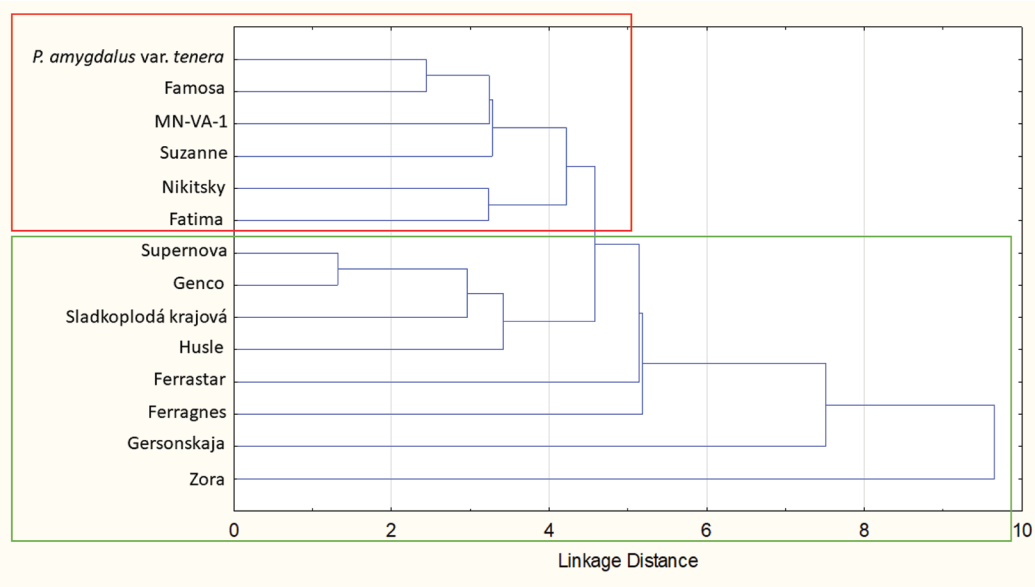


Figure 4. Diagram of cluster analysis based on phenological and pomological parameters of different almond cultivars. The rectangles represent two main clusters differed by the analysis.

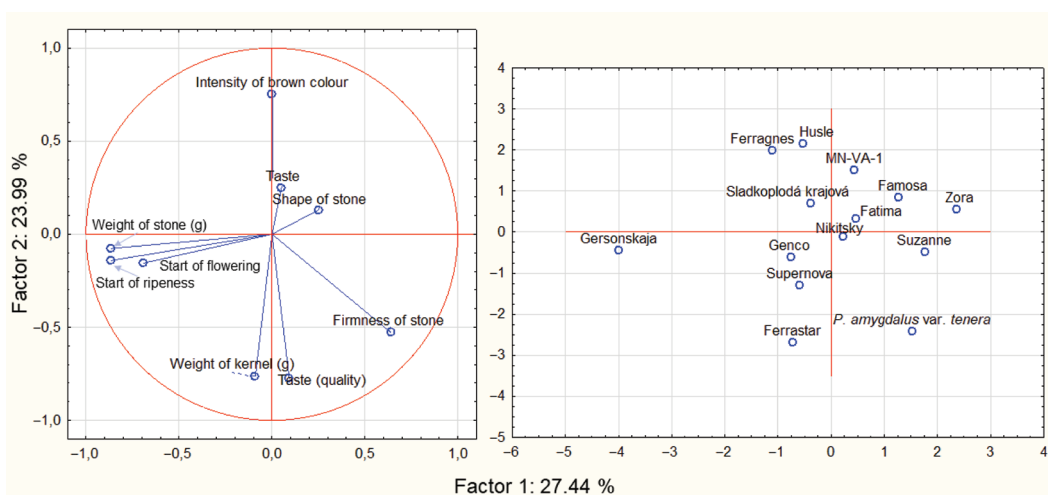


Figure 5. The projection of the cases on the PC1 × PC2 plane was obtained from the PCA of pomological and phaenological parameters of different almond cultivars. PCA, principal component analysis.

Ferragnes

A French cultivar developed by INRA from the cross 'Cristomoro' × 'Ai' (Monastra et al., 1984). Its harvest time is synchronised with 'Supernova'. 'Ferragnes' has moderate vigour and a dense, wide canopy. It produces abundant fruiting along the full length of annual shoots. The cultivar is notable for its very late and relatively extended flowering period, starting approximately 10 days after 'Sladkoplodá krajová'. As a cross-pollinated cultivar, it requires compatible late-flowering pollinators. The hull is light green at maturity and fully dehiscent. The shell is globular, semi-soft, light brown, smooth and corky in texture, with an average weight of 4.4 g. The kernel is relatively large, typically monoembryonic, well-filling the shell, with

a light brown testa and excellent sweet flavour. With outstanding kernel quality, 'Ferragnes' is suitable for a wide range of applications.

MN-VA-1

A rootstock cultivar of Czech origin, selected from sweet-seeded seedlings. Its harvest occurs approximately 2 weeks after 'Sladkoplodá krajová'. It exhibits weak growth with upright, relatively dense canopies. Fruiting is predominantly on spur-bearing shoots. This partially self-fertile cultivar flowers early, approximately 5 days before 'Sladkoplodá krajová'. It consistently shows very abundant flowering. The hull is light green and partially open at maturity. The shell is elongated, separates very easily from the hull, and weighs on average of 4.3 g.

The endocarp is semi-soft, with a wrinkled and sparsely porous surface. The kernel, enveloped in a light brown testa, is small, semi-sweet and weighs about 1.0 g. Due to its regular yield, it is mainly used as a generative rootstock for other almond cultivars. Its small, upright growth habit may also be advantageous in specific cultivation systems (Ondrášek, 2022).

Suzanne

A Czech selection from seedling populations. Its harvest time aligns with that of 'Supernova'. This cultivar exhibits moderate vigour, forming open to semi-upright, relatively dense canopies. Fruiting is mainly on spur-bearing shoots. It is a very early-flowering cultivar, beginning approximately 12 days before 'Sladkoplodá krajová'. It regularly produces abundant flowers, although its pollination characteristics have not been reliably confirmed. The hull is light green and fully dehiscent at maturity. The shell is elongated, prone to opening (cracking), and partially separable from the hull, with an average weight of 2.4 g. It features a 'paper shell' endocarp, the softest shell type. The endocarp surface is wrinkled and sparsely porous. The kernel, covered with a light brown testa, is of excellent sweet flavour, with an average weight of 1.4 g, and exhibits a partial tendency to bi-embryony (Ondrášek, 2022).

Chemical composition analysis

The obtained data of the main chemical composition of kernels of different almond cultivars are mentioned

in Table 3. The variation of bioactive content among the samples was determined as significant ($p < 0.05$). The total fat content (TFC) was the predominant component with an overall average $53 \pm 5\%$ FW, ranged from $45.2 \pm 1.8\%$ (Husle) to $61.79 \pm 0.01\%$ FW (Genco). Soluble protein content (TSPC) showed greater variability, averaging $9.05 \pm 2.95\%$ FW with the lowest value recorded in Ferragnes ($4.96 \pm 0.03\%$ FW) and the highest in Famosa ($14.16 \pm 0.79\%$ FW). Kernel moisture content was relatively stable across cultivars, averaging $4.0 \pm 0.3\%$ FW and ranging from $3.37 \pm 0.03\%$ FW to $4.44 \pm 0.03\%$ FW, when the moisture of *P. amygdalus* var. *tenera* ($11.66 \pm 0.06\%$ FW) was determined as an outlier based on exploratory data analysis (boxplot), and thus was not included in the calculation of the average value.

Considerable differences were also found in phenolic-related parameters. TPC averaged 64 ± 33 mg (GAE) $\cdot 100$ g⁻¹ FW, ranged from 22.70 ± 0.09 mg (GAE) $\cdot 100$ g⁻¹ FW (Gersonskaja) to 142.09 ± 0.39 mg (GAE) $\cdot 100$ g⁻¹ FW (Ferragnes). A similar trend was observed for TFlavC, which varied between 13.1 ± 0.8 mg (CE) $\cdot 100$ g⁻¹ FW (Sladkoplodá krajová) and 85.1 ± 0.4 mg (CE) $\cdot 100$ g⁻¹ FW (Ferragnes), with a mean value of 41 ± 22 mg (CE) $\cdot 100$ g⁻¹ FW. Antioxidant capacity (TAC) differed markedly among cultivars, ranging from 18.7 ± 0.2 mg (TE) $\cdot 100$ g⁻¹ FW (Gersonskaja) to 149 ± 2 mg (TE) $\cdot 100$ g⁻¹ FW, with the highest TAC observed in Ferragnes and an overall average of 61 ± 37 mg (TE) $\cdot 100$ g⁻¹ FW.

Table 3. Chemical and bioactive content of almond cultivars.

Variety	TFC (% FW)	TSPC (% FW)	Moisture (% FW)	TPC (mg GAE $\cdot 100$ g ⁻¹ FW)	TFlavC (mg CE $\cdot 100$ g ⁻¹ FW)	TAC (mg TE $\cdot 100$ g ⁻¹ FW)
Famosa	45.81 ± 1.00 a*	14.16 ± 0.79 e	4.44 ± 0.03 e	75.16 ± 0.20 h	49.72 ± 0.06 i	72.4 ± 0.20 f
Fatima	54.61 ± 0.37 bcd	8.30 ± 0.12 c	3.74 ± 0.08 ab	53.91 ± 0.02 f	42.07 ± 0.17 h	54.5 ± 0.60 e
Ferragnes	50.32 ± 1.48 ab	4.96 ± 0.03 a	4.23 ± 0.12 cde	142.09 ± 0.39 k	85.11 ± 0.35 l	148.9 ± 1.70 i
Ferrastar	58.48 ± 3.68 cd	10.90 ± 0.10 d	3.73 ± 0.01 ab	84.83 ± 0.17 i	49.96 ± 0.08 i	71.5 ± 0.50 f
Genco	61.80 ± 0.01 c	6.19 ± 0.14 ab	3.37 ± 0.03 a	53.84 ± 0.19 f	35.02 ± 0.15 g	49.3 ± 0.20 d
Gersonskaja	54.83 ± 0.45 bcd	11.24 ± 0.50 d	4.03 ± 0.03 bcde	22.70 ± 0.09 a	16.27 ± 0.05 b	18.7 ± 0.20 a
Husle	45.20 ± 1.84 a	13.44 ± 0.25 e	4.41 ± 0.11 de	53.07 ± 0.47 f	18.24 ± 0.17 c	24.6 ± 0.50 b
<i>P. amygdalus</i> var. <i>tenera</i>	50.69 ± 0.04 bc	8.33 ± 0.18 c	11.66 ± 0.06 f	121.16 ± 0.34 j	80.85 ± 0.83 k	126.4 ± 0.70 h
MN-VA-1	53.74 ± 0.90 bc	8.16 ± 0.21 c	4.10 ± 0.01 bcde	84.57 ± 0.14 i	60.46 ± 0.04 j	88.8 ± 0.70 g
Nikitsky	56.21 ± 0.25 bcd	6.41 ± 0.10 ab	3.95 ± 0.07 bc	46.85 ± 0.23 e	25.59 ± 0.04 d	39.8 ± 0.30 c
Sladkoplodá krajová	58.20 ± 0.72 cd	5.24 ± 0.01 a	3.74 ± 0.08 ab	29.28 ± 0.05 b	13.05 ± 0.83 a	23.7 ± 0.60 b
Supernova	51.95 ± 0.64 abc	10.66 ± 0.02 d	4.02 ± 0.07 bcd	55.67 ± 0.07 g	43.11 ± 0.09 h	56.8 ± 0.20 e
Suzanne	56.79 ± 0.65 bcd	6.97 ± 0.13 bc	3.76 ± 0.01 ab	39.11 ± 0.05 d	28.01 ± 0.09 e	37.1 ± 0.50 c
Zora	50.29 ± 0.20 ab	11.81 ± 0.25 d	4.00 ± 0.14 bcd	37.91 ± 0.06 c	30.42 ± 0.21 f	39.8 ± 0.20 c

*Values within each column followed by different letters are significantly different at $p < 0.05$.

GAE, gallic acid equivalent; TFC, total fat content; TFlavC, total flavonoid content; TPC, total phenolic content; TSPC, total soluble protein content.

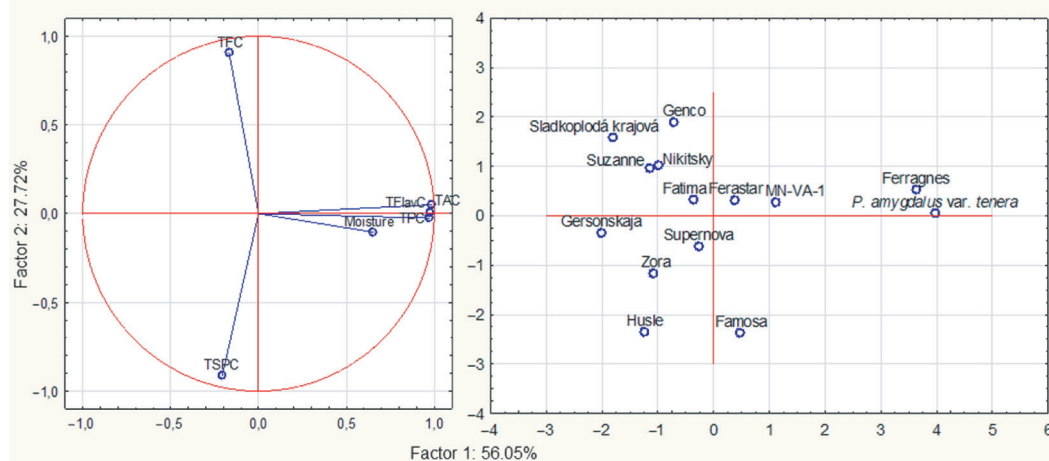


Figure 6. The projection of the cases on the factor plane 1×2 provided by the PCA of selected nutritional parameters of different almond cultivars. PCA, principal component analysis.

For the data on the nutritional content of different almond cultivars, PCA was provided, when the variability of the data was visualised (Figure 6). The eigenvalue of Factor 1 and Factor 2 was 56.05% and 27.72%, respectively. The analysis showed the similarity of the cultivars 'Ferragnes' and *P. amygdalus* var. *tenera*, which reached a high content of the secondary metabolites. The cultivars 'Husle' and 'Famosa' showed to be rich in TSPC, and the cultivars 'Genco' and 'Sladkoplodá krajová' were rich in TFC. The cultivars in the middle of the graph showed to be average in all of analysed nutritional components, and the 'Gersonskaja' was the lowest of the values.

DISCUSSION

Many scientific studies also focus on phenological, pomological or morphological evaluation of almond genotypes or cultivars from various geographic regions. As mentioned in the Introduction and in the final summary, late-flowering cultivars are of particular importance for practical cultivation—not only from a Central European perspective, but also in regions with significant almond production potential. Giordani et al. (2017) evaluated a large set of almond genotypes and cultivars of Afghan origin (56 entries) and described the characteristic of very early flowering as a disadvantage in terms of reliable commercial cultivation. Similarly, in our multi-year evaluation of phenological data, cultivars such as 'Ferragnes', 'Ferrastar', 'Genco' and 'Supernova' were identified as medium or late-flowering. These findings are consistent with those of Calle et al. (2025), who also classified 'Genco' late-flowering and noted its higher tolerance to low temperatures, as previously reported by Viti et al. (1994). When comparing morphological characteristics of fruits (or kernels), samples grown under our climatic conditions showed similar average values for parameters such as kernel weight, shell hardness, frequency of double kernels,

and overall taste quality. For 'Supernova' and 'Genco' our measured traits closely aligned with those reported by Calle et al. (2025), who described a kernel weight of 1.5 g for 'Supernova' and 1.2 g for 'Genco'. Similar to our findings, they also reported a high frequency of double kernels in the cultivar 'Genco'. As an example of variability in morphological evaluation results, we can highlight shell hardness for 'Ferrastar' and 'Ferragnes'. Calle et al. (2025) classified 'Ferrastar' as having very hard shells and 'Ferragnes' as hard-shelled. In contrast, our evaluation classified both cultivars as having medium shell hardness.

Almond kernel is known to be rich of oil content vary between 45% and 62% FW (48 to 67% DW), when most of the results originate from Turkey (Özcan et al., 2011; Yilidrim et al., 2016; Simsek, 2018), similar values were also detected in studies from Morocco (Ibourki et al., 2022) and Italy (Barreca et al., 2020). These results correspond to our results, when ranged from 48 to 64% DW. Results of Levent (2022) and Banjanin et al. (2021) determined lower content 35.37% DW on average and 37.6%–49.1% DW, respectively. These values are comparably similar to TFC in wild species of almonds analysed in Hosseinzadeh et al. (2019). TFC of 'Supernova' can be compared in results by from Banjanin et al. (2021) (44.8% DW) and Yildirim et al. (2016) (62% DW), while in our study it was 54.04% DW. TFC can be compared also in 'Ferragnes' and 'Ferrastar', which reached 60.9% DW and 57.4% DW, respectively (Yildirim et al., 2016), and in our study, it was 52.5% DW and 60.7% DW. The results confirmed the influence of growing conditions, including geographical location and climatic conditions.

Almond kernels were considered a protein-rich food (Roncero et al., 2020). According to the studies the proximate value of the second most important component protein ranges from 14% to 25% (Summo et al., 2018; Banjanin et al., 2021; Ibourki et al., 2022). The results of TSPC in our study ranged from 5.2% to

14.2%. The cultivar 'Ferragnes' has the lowest TSCP 4.96%. Drogoudi et al. (2013) reached similar results, when 'Ferragnes' reached 11%. Conversely, in other studies, the value reached 18.9% (Levent, 2022) and 18.1% (Asad and Malik, 2024). In most studies, the Kjeldahl method of protein content analyses related to total content of nitrogen, with nitrogen-to-protein conversion factor of 6.25 is used (Rampáčková et al., 2021), despite in our study, the Pierce Bradford Protein Assay was used, and as same as TFC, protein content can be influenced by the horticulture and actual climatic conditions.

The moisture of the fruits is important for enzymatic activities, but it allows the microorganisms and microbial spoilage to grow. Thus, the dry almond kernels are offered in the markets (Simsek et al., 2018). In various studies, the moisture content reached from 3% to 5% (Simsek and Demirkiran, 2010; de Oliveira Sousa et al., 2011). These results correspond with our study, when the value ranged from 3.37% to 4.44%, except for the outlier *P. amygdalus* var. *tenera* (11.66%). The results of moisture content confirmed the genotype influence (Yada et al., 2011).

Phenolic compounds of food have an important impact on human health. In our study the significant variable groups were detected in analysed genotypes ranged from 22.7 to 142.1 mg GAE · 100 g⁻¹ FW. Barreira et al. (2008) determined that similar values in almond kernels ranged from 90 to 163 mg GAE · 100 g⁻¹. Özcan and Uslu (2022) compared TPC in bitter almonds (18.7 mg GAE · 100 g⁻¹) with four known sweet almond cultivars ranged from 8.8 to 109.8 mg GAE · 100 g⁻¹, when the highest TFC was analysed at 'Ferragnes'. The similar results were obtained in our study, when 'Ferragnes' reached the highest TFC in comparison with other cultivars (142 mg GAE · 100 g⁻¹). Abe et al. (2010) analysed TPC in roasted almond kernels and determined similar results 114 mg GAE · 100 g⁻¹. TPC of microwave dried almonds in Çolak et al. (2024) reached lower values ranged from 11.6 to 17.1 mg · 100 g⁻¹ in microwave dried almonds.

Flavonoids are mainly found in the almond skin and the predominant polyphenol in almond kernels is catechin followed by chlorogenic acid and naringenin (Yildirim et al., 2016). Oliveira et al. (2018) analysed 16.1–28.2 mg CE · 100 g⁻¹ in almonds. The analysis of Portugal almonds (Oliveira et al., 2019) brought the results ranged from 12.88 to 19.49 mg CE · g⁻¹ and similar results reached Barreira et al. (2008) ranged from 6.2 to 25.02 mg CE · g⁻¹, which is hundred times less, than in previous study and also from results of our study (13.1–85.1 mg CE · 100 g⁻¹).

The total amount of phenolics has an impact on total AC. Summo et al. (2018) analysed TAC in almond kernels between 12.69 and 60.99 µmol TE · g⁻¹, which corresponds to 317.62–1,526.52 mg TE · 100 g⁻¹. The similar results were detected in wild almond kernels in Iran 372–463 mg TE · 100 g⁻¹ (Hosseinzadeh et al.,

2019). Oliveira et al. (2019) determined lower values in Portugal almonds between 0.50 and 3.72 mg TE · 100 g⁻¹. In our study, the range of TAC in fresh almond kernels was 18.7–148.9 mg TE · 100 g⁻¹.

CONCLUSIONS

The commercial cultivation of almond trees was purposefully tested in the Czech Republic beginning in the 1950s. Compared to currently available cultivars, the varieties used at that time exhibited certain characteristics that were not sufficiently reliable for consistent fruit production. These included self-fertility, early flowering time and relatively low fruit set. In the study, the variability of pomological and phenological traits, as well as the kernel nutritional composition, was obtained for different almond cultivars. The results have shown promising varieties with the potential for expansion in commercial cultivation in the Czech Republic, primarily due to their long-term and stable productivity, late flowering period and kernel quality. The significance of the almond gene pool collection lies, among other things, in the long-term conservation of diverse genetic resources. These may gradually gain greater importance for kernel production as growing conditions evolve, particularly under drier and warmer climate scenarios.

FUNDING

This study was supported by the Ministry of Agriculture of the Czech Republic, Subsidy Programme No. 6.2.10/MZE-62216/2022-13113.

AUTHOR CONTRIBUTIONS

I.O. conceptualisation, data curation, supervision. E.Z. data curation, formal analysis, writing – original draft, writing – review and editing, methodology, statistical analysis. E.S. data curation, formal analysis, writing – original draft, writing – review and editing, methodology, statistical analysis. T.N. formal analysis.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

- ABE, L. T., LAJOLO, F. M., AND GENOVESE, M. I. (2010). Comparison of phenol content and antioxidant capacity of nuts. *Ciência e Tecnologia de Alimentos*, 30(Suppl. 1), 254–259, <http://doi.org/10.1590/S0101-20612010000500038>.
- AHMED, I. A. M., ALJUHAIMI, F., ÖZCAN, M. M., USLU, N., AND ALBAKRY, Z. (2024). The effect of fermentation on the oil content, fatty acid profile and bioactive compounds of fresh and fermented almond kernels. *Journal of Oleo Science*, 73(12), 1447–1455, <https://doi.org/10.5650/jos.ess24151>.

- ASAD, M., AND MALIK, A. (2024). Almond varieties: nutritional and chemical composition and health benefits and culinary application. In R. A. Marc, C. C. Mureşan and A. N. Postolache (Eds.), *Nut Consumption and its Usefulness in the Modern World* (pp. 39–61). London, UK: IntechOpen, <https://doi.org/10.5772/intechopen.1005139>.
- BANJANIN, T., NIKOLIC, D., USLU, N., GÖKMEN, F., ÖZCAN, M. M., MILATOVIC, D., ZEC, G., BOŠKOV, Đ, AND DURSUN, N. (2021). Physicochemical properties, fatty acids, phenolic compounds, and mineral contents of 12 Serbia regional and commercial almond cultivars. *Journal of Food Processing and Preservation*, 45(1), e15015, <https://doi.org/10.1111/jfpp.15015>.
- BARRECA, D., NABAVI, S. M., SUREDA, A., RASEKHIAN, M., RACITI, R., SILVA, A. S., ANNUNZIATA, G., ARNONE, A., TENORE, G. C., SÜNTAR, İ, AND MANDALARI, G. (2020). Almonds (*Prunus dulcis* Mill. D. A. Webb): A source of nutrients and health-promoting compounds. *Nutrients*, 12(3), 672, <https://doi.org/10.3390/nu12030672>.
- BARREIRA, J. C., FERREIRA, I. C., OLIVEIRA, M. B. P., AND PEREIRA, J. A. (2008). Antioxidant activity and bioactive compounds of ten Portuguese regional and commercial almond cultivars. *Food and Chemical Toxicology*, 46(6), 2230–2235, <https://doi.org/10.1016/j.fct.2008.02.024>.
- CALLE, A., APARICIO-DURÁN, L., BATLLE, I., EDUARDO, I., AND MIARNAU, X. (2025). Review of agronomic and kernel quality traits of 273 almond cultivars. *Genetic Resources and Crop Evolution*, 72, 3783–3828, <https://doi.org/10.1007/s10722-024-02183-0>.
- CHATZIMITAKOS, T., ATHANASIADIS, V., KOTSOU, K., MAKRYGIANNIS, I., BOZINO, E., AND LALAS, S. I. (2024). Evaluation of the nutritional value of *Prunus dulcis* blossoms and the antioxidant compounds of their extracted oil using green extraction method. *Applied Sciences*, 14(5), 2001, <https://doi.org/10.3390/app14052001>.
- ÇOLAK, A. M., GUNDOĞDU, M., BERK, S. K., SAHİN, T., AND CANAZ, M. (2024). Agromorphological genetic identification of almond genetic resources regarding physicochemical properties in Turkey. *Research Square* [Preprint], <https://doi.org/10.21203/rs.3.rs-4363310/v1>.
- ČOLIĆ, S., ZEC, G., NATIĆ, M., AND FOTIRIĆ-AKŠIĆ, M. (2019). Almond (*Prunus dulcis*) oil. In M. F. Ramadan (Ed.), *Fruit Oils: Chemistry and Functionality* (pp.149–180). Cham: Springer, https://doi.org/10.1007/978-3-030-12473-1_6.
- DEANS, C. A., SWORD, G. A., LENHART, P. A., BURKNESS, E., HUTCHISON, W. D., AND BEHMER, S. T. (2018). Quantifying plant soluble protein and digestible carbohydrate content, using corn (*Zea mays*) as an exemplar. *Journal of Visualized Experiments*, (138), e58164, <https://doi.org/10.3791/58164>.
- DE OLIVEIRA SOUSA, A. G., FERNANDES, D. C., ALVES, A. M., DE FREITAS, J. B., AND NAVES, M. M. V. (2011). Nutritional quality and protein value of exotic almonds and nut from the Brazilian Savanna compared to peanut. *Food Research International*, 44(7), 2319–2325, <https://doi.org/10.1016/j.foodres.2011.02.013>.
- DI LENA, B., FARINELLI, D., PALLIOTTI, A., PONI, S., DEJONG, T. M., AND TOMBESI, S. (2018). Impact of climate change on the possible expansion of almond cultivation area pole-ward: A case study of Abruzzo, Italy. *The Journal of Horticultural Science and Biotechnology*, 93(2), 209–215, <https://doi.org/10.1080/14620316.2017.1357433>.
- DROGOUDI, P. D., PANTELIDIS, G., BACCHETTA, L., DE GIORGIO, D., DUVAL, H., METZIDAKIS, I., AND SPERA, D. (2013). Protein and mineral nutrient contents in kernels from 72 sweet almond cultivars and accessions grown in France, Greece and Italy. *International Journal of Food Sciences and Nutrition*, 64(2), 202–209, <https://doi.org/10.3109/09637486.2012.728202>.
- GIORDANI, E., BERTI, M., AND YAQUBI, M. (2017). Phenotypic characterisation of almond accessions collected in Afghanistan. *Advances in Horticultural Science*, 30(4), 207–216, <https://doi.org/10.13128/ahs-20346>.
- GÜLCAN, R. (1985). *Descriptor list for almond (Prunus amygdalus)* (revised). Rome: IBPGR Secretariat.
- HERNANDEZ, E. M., AND SANDERS, T. A. B. (2024). Specialty oils: functional and nutraceutical properties. In T. A. B. Sanders (Ed.), *Functional Dietary Lipids: Food Formulation, Consumer Issues, and Innovation for Health* (2nd ed., pp. 69–97). Cambridge and Kidlington, UK: Woodhead Publishing/Elsevier. <https://doi.org/10.1016/B978-0-443-15327-3.00002-1>.
- HOSSEINZADEH, M., MOAYEDI, A., MOGHADDAS, H. C., AND REZAEI, K. (2019). Nutritional, anti-nutritional, and antioxidant properties of several wild almond species from Iran. *Journal of Agricultural Science and Technology*, 21(2), 369–380.
- IBOURKI, M., AIT BOUZID, H., BIJLA, L., AISSA, R., SAKAR, E. H., AINANE, T., GHARBY, S., AND EL HAMMADI, A. E. (2022). Physical fruit traits, proximate composition, fatty acid and elemental profiling of almond [*Prunus dulcis* Mill. DA Webb] kernels from ten genotypes grown in southern Morocco. *OCL*, 29, 9, <https://doi.org/10.1051/ocl/2022002>.
- JANICK, J., AND PAULL, R. E. (2008). *The encyclopedia of fruit and nuts*. Wallingford, UK: CABI, <https://doi.org/10.1079/9780851996387.0000>.
- LEVENT, O. (2022). A detailed comparative study on some physicochemical properties, volatile composition, fatty acid, and mineral profile of different almond (*Prunus dulcis* L.) varieties. *Horticulturae*, 8(6), 488, <https://doi.org/10.3390/horticulturae8060488>.
- MILBURY, P. E., CHEN, C., DOLNIKOWSKI, G. G., AND BLUMBERG, J. B. (2006). Determination of flavonoids and phenolics and their distribution in almonds.

- Journal of Agricultural and Food Chemistry*, 54(14), 5027–5033, <https://doi.org/10.1021/jf0603937>.
- MONASTRA, F., CRISAFULLI, A., MARCHESE, F., ONDRADU, G., PAVIA, R., AND RIVALTA, L. (1984). *Étude pomologique de 70 variétés d'amandier d'origine différente*. GREMPA, Colloque 1983. Paris: CIHEAM, 27–37 (Options Méditerranéennes, Série Études, No. 1984-II).
- MRÁZOVÁ, M., RAMPÁČKOVÁ, E., ŠNURKOVIČ, P., ONDRÁŠEK, I., NEČAS, T., AND ERCIŞLI, S. (2021). Determination of selected beneficial substances in peach fruits. *Sustainability*, 13, 14028, <https://doi.org/10.3390/su132414028>.
- OLIVEIRA, I., MEYER, A. S., AFONSO, S., AIRES, A., GOUFO, P., TRINDADE, H., AND GONÇALVES, B. (2019). Phenolic and fatty acid profiles, α -tocopherol and sucrose contents, and antioxidant capacities of understudied Portuguese almond cultivars. *Journal of Food Biochemistry*, 43, e12887, <https://doi.org/10.1111/jfbc.12887>.
- OLIVEIRA, I., MEYER, A., AFONSO, S., RIBEIRO, C., AND GONÇALVES, B. (2018). Morphological, mechanical and antioxidant properties of Portuguese almond cultivars. *Journal of Food Science and Technology*, 55, 467–478, <https://doi.org/10.1007/s13197-017-2955-3>.
- ONDRÁŠEK, I. (2022). Collection and evaluation of almond genetic resources: an overview of the current status. In L. Papoušková (Ed.), *Využití genetických zdrojů rostlin ve šlechtění: Sborník referátů ze semináře pořádaného 8. prosince 2021 on-line v rámci RGZ 2021* (p. 131). Prague: Výzkumný ústav rostlinné výroby, v.v.i. ISBN 978-80-7427-380-3.
- ÖZCAN, M. M., ÜNVER, A., ERKAN, E., AND ARSLAN, D. (2011). Characteristics of some almond kernel and oils. *Scientia Horticulturae*, 127(3), 330–333, <https://doi.org/10.1016/j.scienta.2010.10.027>.
- ÖZCAN, M. M., AND USLU, N. (2022). Effect of variety on bioactive properties, phytochemicals and nutrients of almond kernels. *Erwerbs-Obstbau*, 65(4), 981–988, <https://doi.org/10.1007/s10341-022-00762-y>.
- PRUDENCIO, ÁS., DICENTA, F., AND MARTÍNEZ-GÓMEZ, P. (2018). Monitoring dormancy transition in almond [*Prunus dulcis* (Miller) Webb] during cold and warm mediterranean seasons through the analysis of a DAM (Dormancy-Associated MADS-Box) gene. *Horticulturae*, 4(4), 41, <https://doi.org/10.3390/horticulturae4040041>.
- RAMPÁČKOVÁ, E., GÖTTINGEROVÁ, M., GÁLA, P., KISS, T., ERCIŞLI, S., AND NEČAS, T. (2021). Evaluation of protein and antioxidant content in apricot kernels as a sustainable additional source of nutrition. *Sustainability*, 13(9), 4742, <https://doi.org/10.3390/su13094742>.
- RONCERO, J. M., ÁLVAREZ-ORTÍ, M., PARDO-GIMÉNEZ, A., RABADÁN, A., AND PARDO, J. E. (2020). Review about non-lipid components and minor fat-soluble bioactive compounds of almond kernel. *Foods*, 9(11), 1646, <https://doi.org/10.3390/foods9111646>.
- SIMSEK, M., AND DEMIRKIRAN, A. R. (2010). Determination of superior almond genotypes in Diyarbakir central districts. *Agricultural Journal*, 5(3), 173–180, <https://makhillpublications.co/files/published-files/mak-aj/2010/3-173-180.pdf>.
- SIMSEK, M., GULSOY, E., YAVIC, A., ARIKAN, B., YILDIRIM, Y., OLMEZ, N., ERDOGMUS, B., AND BOGUC, F. (2018). Fatty acid, mineral and proximate compositions of various genotypes and commercial cultivars of sweet almond from the same ecological conditions. *Applied Ecology and Environmental Research*, 16(3), 2957–2971, https://doi.org/10.15666/aecer/1603_29572971.
- SUMMO, C., PALASCIANO, M., DE ANGELIS, D., PARADISO, V. M., CAPONIO, F., AND PASQUALONE, A. (2018). Evaluation of the chemical and nutritional characteristics of almonds (*Prunus dulcis* (Mill.) D.A. Webb) as influenced by harvest time and cultivar. *Journal of the Science of Food and Agriculture*, 98(15), 5647–5655, <https://doi.org/10.1002/jsfa.9110>.
- UPOV (2011). *Almond. Guidelines for the Conduct of Tests for Distinctness, Uniformity and Stability*. UPOV, Geneva, Switzerland. UPOV Code: PRUNU_DUL.
- VALDÉS, A., VIDAL, L., BELTRÁN, A., CANALS, A., AND GARRIGÓS, M. C. (2015). Microwave-assisted extraction of phenolic compounds from almond skin byproducts (*Prunus amygdalus*): A multivariate analysis approach. *Journal of Agricultural and Food Chemistry*, 63(22), 5395–5402, <https://doi.org/10.1021/acs.jafc.5b01011>.
- VITI, R., BARTOLINI, S., AND GIORGELLI, F. (1994). Effect of low temperatures on flower buds of several almond cultivars. *Acta Horticulturae*, 373, 193–200, <https://doi.org/10.17660/ActaHortic.1994.373.27>.
- YADA, S., HUANG, G., AND LAPSLEY, K. (2013). Natural variability in the nutrient composition of California-grown almonds. *Journal of Food Composition and Analysis*, 30(2), 80–85, <https://doi.org/10.1016/j.jfca.2013.01.008>.
- YADA, S., LAPSLEY, K., AND HUANG, G. (2011). A review of composition studies of cultivated almonds: Macronutrients and micronutrients. *Journal of Food Composition and Analysis*, 24(4–5), 469–480, <https://doi.org/10.1016/j.jfca.2011.01.007>.
- YILDIRIM, A., AKINCI-YILDIRIM, F., SAN, B., AND SESLI, Y. (2016). Total oil content and fatty acid profile of some almond (*Amygdalus communis* L.) cultivars. *Polish Journal of Food and Nutrition Sciences*, 66(3), 173–178, <https://doi.org/10.1515/pjfn-2015-0032>.
- ZLOCH, Z., ČELAKOVSKÝ, J., AND AUJEZDSKÁ, A. (2004). *Stanovení obsahu polyfenolů a celkové antioxidační kapacity v potravinách rostlinného původu*. Plzeň: Ústav hygieny Lékařské fakulty UK Plzeň.