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Evaluation of the Effects of Cultivar and Location on the Interaction of Lentil Seed Characteristics with Optimal Cooking Time

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Abstract: The most important product of the lentil crop (*Lens culinaris* Medik) is the seeds. The main seed characteristics are their size, color, and the cooking time required to make them edible. Cultivar, location of cultivation, and their interaction are the primary factors of raw or cooked seed characteristics. The study examined the impact of five different lentil cultivars (Dimitra, Elpida, Thessalia, Samos, and 03-24L), as influenced by the cultivation environment in four different zones or nine different locations in Central-Northern Greece, on cooking time. The optimal cooking time (OCT) was calculated by cooking the seeds for 0–60 min to determine the percentage of cooked seeds using the penetration test. OCT was associated with the characteristics of both raw (mass of 1000 seeds, external color, and the percentage of mature/immature seeds) and cooked (color and organoleptic characteristics of the cooking media as well as mass increase and hardness and organoleptic characteristics of the seeds) seeds for 30 min. Depending on location, each cultivar had a different mass of 1000 seeds; Elpida had the highest mass (63.9 g), and Dimitra had the lowest (33.1 g). This was linked to OCT, which was among the highest (57.5 min) for Elpida, lowest (49 min) for Dimitra, and intermediate for Thessalia, Samos, or 03-24L. The average OCT was 55.9 min for all samples. The seed from the five locations with the shortest OCT was considered appropriate for human consumption. Two locations yielded seeds with intermediate OCT, while the other two produced the highest OCT; these were recommended for processing or propagation. In this study, the cultivar factor had a greater effect on raw seed characteristics, while the location factor had a greater effect on cooked seed characteristics and OCT than either the location, the cultivar factor, or the cultivar x location interaction.

Keywords: genotype; seed quality; optimal cooking time; *Lens culinaris* Medik; texture analysis; organoleptic method; lentil seed traits

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1. Introduction

Lentil (*Lens culinaris* Medik.; Fabaceae) is considered the major crop among cool-season pulses produced globally. The lentil crop's main product is its seeds, which are used for human consumption worldwide. Lentil seed is known for its high protein content [1], as well as other nutrients such as carbohydrates, fiber, vitamins, and minerals [2–5], and its reputation as a particularly nutritious food. Its significance originates in its impact on the diet and well-being of the general public, particularly for women (who require folate as a nutrient for childbearing), the elderly (who require low fat and cholesterol), and vegetarians/vegans (who require plant-based proteins) [5,6].

Lentil seeds are always consumed in cooked form around the world; they are primarily consumed as a soup with whole seeds [7], but they are also consumed after decortication and/or splitting [8], as well as ground to flour [9]. Cooked lentil seeds can be served as a main or side dish, as well as in salads with rice or other cereals. Lentil flour is used in soups, stews, and purees [10] and can be added in quantities greater than 10% [11–13].

The main culinary trait of lentils that is associated with the easiness of preparation by consumers [14,15] is related to seed softness; it is defined as the amount of time required from the beginning of cooking to render the seeds soft. It has also been identified as the most significant commercial characteristic that reflects the cooking seed quality [16,17]. Thus, one of the most important factors in cooking quality is cooking time.

Cooking time has been shown to be a heritable characteristic, and thus, the genotype that regulates seed structure also controls water absorption by the cotyledon during cooking [18,19]. Furthermore, the cultivation conditions, such as air temperature and soil moisture [20], among others, induce variability of agronomic seed traits (size, maturity, etc.) and cooking time [17,21]. Additionally, the main factors influencing cooking time are related to storage conditions [17,22–24].

The acceptable commercial cooking time for cultivars is 30 min [25]. The reported cooking time of Greek cultivars ranges from 22.5 to 30.5 min [24], and of Turkish cultivars, between 15.2 and 23.9 min. Other reported cooking time values range between 33 and 43 min [18,26,27]. The differences in cooking time are also attributed to the variability of their determination methods used by researchers. This reflects, on the one hand, the size and shape of lentil seeds and, on the other, the absence of standard official methodology. To achieve cooking convenience and reduced energy cost requirements [28], studies include cooking time as an important trait characterizing cultivars and locations suitable for lentil cultivation apart from yield and stability.

Seed quality trait differences in lentils are considered the result of genetic and environmental factors [18,29]. When lentils were cultivated in various locations, different cooking times were observed, and this was primarily explained by variations in climatic conditions and soil fertility [17,21–24]. The interaction of cultivation locations with the cultivars has lately been explored, though not thoroughly. The stability of cultivar performance in terms of yield and seed quality, including cooking quality, was determined through trials conducted at multiple locations with a multitude of cultivars. Additionally, the phytochemical content and antioxidant activities of lentil cultivars were evaluated [24,30,31]. Commercially successful lentil cultivars are distinguished by their increased yield and stability in a range of environmental conditions, encompassing cooking quality. This has been achieved by trials conducted at multiple locations yearly. The interactions of lentil cultivars with varying environmental conditions (when tested at multiple locations) [32] may rank cultivars for the target seed characteristics, including cooking time, and provide a pattern of cultivar responses across environments.

Among commercial local cultivars in Greece, the most popular in terms of high yield potential and their good adaptability in Greek conditions are Thessalia, Samos, Dimitra, and Elpida which are deposited at the ELGO-'Demeter', Institute of Industrial and Forage Crops (IIFC), Larissa, Greece. Cv. 03-24L originates from ICARDA and was improved by IIFC, which is also considered promising for cultivation. The following cultivars are characterized by different seed sizes, colors, and cooking time requirements: Dimitra, by small seed with light green color and short cooking time [24,25,33]; Thessalia, a medium flat seed of light green color with a medium cooking time [17,24,33]; Samos by small lens-shaped seed with light green color and short-medium cooking time [17,24,25,33]; Elpida by large and flat seeds with light yellow color and medium-long cooking time [24,33]; 03-24L by medium seed of red cotyledon and medium cooking time [24,33].

Greece's climate is regarded as typical Mediterranean, with long, sunny days for the majority of the year, hot, dry summers, and mild, rainy winters. However, due to diverse local relief, it is divided into many regions with different climatic and microclimatic zones. Vlachostergios et al. [24] reported that 4 different zones could be classified according to

the Köppen–Geiger [34], which are considered proper for rain-fed lentil cultivation environments. Additionally, they discussed how the environment affected the lentil cultivars' protein content, cooking times, agronomic qualities, and seed yield in various locations in Greece where lentils are cultivated [24].

The purpose of this study was to examine the practical implications of understanding how cultivars and locations interact to influence cooking time. The impact of five different cultivars of lentils on cooking time as influenced by the cultivation environment in four different zones or nine different locations was investigated. These results were then linked to the properties of both raw and cooked seeds in an effort to identify the potential benefits of using seeds for a variety of applications, including consumption, processing, and plant propagation.

2. Materials and Methods

2.1. Plant Materials

Five lentil cultivars (*Lens culinaris* M.) were examined in seeds grown in nine different locations throughout Greece. The four most widely used commercial green seed cultivars were Dimitra, Elpida, Samos, and Thessalia, along with the promising red seed 03-24L.

The production sites were chosen in typical Greek lentil cultivation areas categorized using the Köppen–Geiger classification [34]: An arid, steppe, cold zone (BSk) which include cultivation locations at Domokos (central Greece), Komotini and Thessaloniki (northern Greece), a temperate (dry/hot summer), which include Ipato (central Greece) and Orestiada (Northern Greece) (Csa), or an intermediate which include Larissa and Agioi Anargyroi (central Greece) (BSk/Csa) as well as a temperate, without dry season, hot summer zone which include Patriki and Petrana (Northern Greece) (Cfa). Table 1 shows additional soil and environmental characteristics of cultivation locations. Cv. Elpida and Samos were missing from Thessaloniki and Komotini, respectively. Cv. Elpida and Samos were missing from the locations of Thessaloniki and Komotini, respectively.

Table 1. Soil and environmental characteristics of production locations.

Cultivation Locations	Climate Type *	Altitude	Soil pH	Soil Organic Matter (%)	Average Temp.** (°C)	Precipitation *** (mm)
Ag. Anargiri	BSk/Csa	121	7.4	1.4	13.7	85.8
Domokos	BSk	500	7.1	1.7	11.3	81.8
Ipato	Csa	118	7.9	1.4	14.1	78.8
Komotini	BSk	32	8.1	1.2	13.5	105
Larissa	BSk/Csa	77	7.7	1.1	13.9	72.0
Orestiada	Csa	26	7.8	1.7	12.6	118.3
Petrana	Cfa	476	7.9	2.1	10.1	133.6
Patriki	Cfa	50	7.9	1.2	13.4	68.6
Thessaloniki	BSk	5	8.1	1.0	14.0	107.8

* Categorized according to the Köppen–Geiger classification [34]; ** average temperature from November to July; *** precipitation: April–May (beginning of flowering to pod filling).

2018–2019 was the growing season for the samples of lentil crops. In all locations, pre-sowing basal fertilization with 160 kg ha^{-1} (0N-46P_2O_5-0K_2O) was applied. The cultivars were grouped in a randomized complete block design with four replications at each location. Sowing took place in the final week of November 2018. Hand labor was used for phytosanitary tasks like weeding, and local recommendations were followed for disease and pest control.

Seeds were harvested in 2019 and stored in linen-clothed sacks at room conditions (21 °C and 50% relative humidity) for 5 months [18] before the cooking quality study was started. A total of 200 g lentil seed samples (13% moisture) were used, with seeds from each cultivar per plot and location. The raw and cooked characteristics of the lentils were examined.

2.2. Determination of Raw Seed Characteristics

The 1000-seed mass (MTS) was determined by counting 5 × 200 intact lentil seeds using α Kern EG420-3NM scale (0.001 g accuracy; Kern & Sohn GmbH, Ballingen, Germany). The percentage of green (or brown)-colored seed samples was measured visually based on epidermal coloration (PGS).

A Minolta CR-410 chroma meter (Minolta, Osaka, Japan) was used to measure the color of intact lentil seeds. The instrument was equipped with an 8-mm measuring head and a C illuminant (6774 K). Calibration was performed using the manufacturer's standard white plate. Data on quantifiable color changes were gathered for the color spaces L*, a*, and b*. L* refer to lightness; 0 is black, and 100 is white. a* is redness or greenness, and b* is yellowness or blueness. For every sample, the color data were derived from the mean of six separate measurements.

2.3. Assessment of Cooking Quality

2.3.1. Characteristics of Cooked Seeds

For each seed sample, 10 g-subsamples were used, and the number of seeds was counted. After that, 150 mL of boiling distilled water was added to the 250 mL glass Pyrex bottle with a screw cap containing the seeds after they had been rinsed in deionized water. The bottle was not closed; it was simply capped. The bottle was heated on a hot plate, submerged in a covered boiling water bath (100 °C), and cooked for 30 min [17]. Three sample replications per cultivar and location of cultivation were used. After cooking, the lentil seeds were separated from the broth, which was collected in a beaker until further used for organoleptic analysis. After that, the seeds were placed on a paper towel to cool to room temperature while undergoing an organoleptic test, which evaluated aroma. In addition, a measurement of the seed mass was taken, and the percentage of mass increase (water absorbed) during cooking was calculated (PMI). A sample of intact cooked seeds was used for hardness testing by tactile and chewing organoleptic evaluation as well as texture analysis. Overcooked seeds were defined as seeds with a torn seed coat and split or mashed cotyledon. These seeds were counted beforehand and expressed as the percentage of overcooked seeds (POS). Further, they were excluded from the texture analysis since they were regarded as fully cooked.

The collected broth, when its temperature was cooled to near room temperature, was subjected to an organoleptic test (evaluation of aroma) and used for color measurement using a CR-400 Konica Minolta chroma meter as described above.

2.3.2. Determination of Optimum Cooking Time

Optimum cooking time (OCT) refers to the amount of cooking time needed to render most of the seeds soft for consumption. To determine OCT, additional seed samples, 10 g-subsamples, were subjected to cooking following the procedure described above (Section 2.3.1) for 20, 40, and 60 min [21]. Following cooking, both intact and overcooked seeds were counted, and the hardness of intact seeds, 24 seeds (12 brown and 12 green), per cultivar and cultivation location was measured by penetration test.

Optimum cooking time (OCT) was then calculated as follows: A 90 g model threshold value was adopted for the maximum penetration force that determines when the seeds are defined as cooked to softness [21]. The percentage of cooked seeds with maximum penetration force values less than the threshold value for maximum penetration force (90 g) was then calculated for each subsample. OCT was determined for each sample by applying a sigmoid model to these data.

The definition of 90% cooked seed served as the basis for determining the optimal cooking time (OCT) in this study.

2.3.3. Organoleptic Broth and Seed Aroma Evaluation

Immediately after cooking, but when still the broth and the seeds reached room temperature, an evaluation for aroma took place using a scale from 1 to 5, where 1 corresponds

to less intense and 5 to very intense (1 = nearly none, 2 = faint, 3 = apparent, 4 = more apparent, 5 = pungent). The organoleptic tests were conducted by a panel of three trained staff members (two men and one woman).

2.3.4. Seed Hardness Testing

A 20-min standing period was selected to standardize the procedure and prevent an increase in seed hardness, as seeds typically become harder after cooling down, though the difference in hardness is less noticeable between 2 and 30 min. Twenty to thirty individual typical seeds were used for each sample, 50% of which were brown or green in color. For texture analysis, individual seeds were chosen at random and set on the bottom of a single chip rig (TA.XT plus C, Stable Micro Systems Ltd., Surrey, UK). A 2 mm diameter cylindrical needle probe was used to penetrate each seed, with a crosshead speed of 0.8 mm s^{-1}. Five to ten seeds were measured individually for overcooked seeds. The absolute force needed to penetrate the seed was the texture analysis parameter used, expressed in g (PFT).

To evaluate the organoleptic tactile texture (OTT), seeds were pressed, one at a time, between the thumb and forefinger. The panelists evaluated 10 intact seeds per replication—5 brown and 5 green in color [24].

Additionally, organoleptic chewiness (OCH) was evaluated in 10 intact seed samples per replication by using the molars to chew seeds by breaking them down into tiny particles as they were masticated.

The organoleptic tests were conducted by a panel of three trained staff members (two men and one woman). The seeds were graded using the following 1–5 scale: 1 = uncooked: the seed is extremely hard to the touch and difficult to break, or it feels extremely hard in the mouth; 2 = undercooked: the seed has a hard, difficult-to-smash texture or feels extremely hard in the mouth; 3 = moderately cooked: there are particles present during mastication, but the seed is reasonably soft and smashes easily; 4 = cooked: there are barely any particles left in the seed, or it is soft and easy to smash; 5 = overcooked: the seed is extremely soft and mushy, or it is mushy and masticates into no particles.

2.4. Statistical Analyses

Three to five replicates of each treatment were used in a complete randomized factorial design (5 × 9) for this investigation. The primary determinants were the seed cultivar and the cultivation location. Data were modeled and subjected to analysis of variance (two-way ANOVA) using Microsoft Excel and the statistical software SPSS v.25. Duncan's new multiple range test was used to separate the means ($p < 0.05$). Each factor's effect size was assessed using partial η^2 (eta squared), which was computed as η^2 = SS factor/(SS factor + SS total), where SS stands for the sum of squares. Missing values were substituted by the average of factors with higher and significant ($p < 0.05$) η^2. Pearson's correlation coefficient (r) and principal component analysis (PCA) were performed using the statistical software SPSS v.25 to determine correlations.

3. Results and Discussion

The present study seeks to analyze some of the most important factors affecting raw and cooked lentil seed characteristics in view of their final cooking quality. These factors include cultivar and location of cultivation and their interaction. Attention is given to the relation between raw and cooked seed attributes and to their significance in cooking quality.

3.1. Raw Seed Characteristics

The analysis of variance for the raw lentil seed characteristics used in this study, including the mass of 1000 seeds (MTS), percentage of green seeds (PGS), and seed color parameters L*, a*, and b* values, are displayed in Table 2. The significance of the two factors under investigation, as well as their interaction, were revealed by eta square. The cultivar factor had a greater impact than either the cultivation location factor or their interaction.

Table 2. Analysis of variance of raw lentil seed characteristics of 5 cultivars evaluated at 9 locations.

	DF	MTS (g)		PGS (%)		Seed L*		Seed a*		Seed b*	
		PARTIAL ETA SQR (η^2)									
Cultivar	7	0.98	***	0.69	***	0.10	***	0.69	***	0.35	***
Location	1	0.84	***	0.49	***	0.03	***	0.37	***	0.28	***
Cultivar × Location	28	0.79	***	0.61	***	0.29	***	0.34	***	0.31	***
MAIN EFFECTS		MEANS									
Cultivar	03-24L	44.78	c	44.77	c	54.98	c	6.85	a	24.10	c
	Dimitra	33.13	e	60.12	a	57.34	a	2.73	bc	25.83	a
	Elpida	62.89	a	58.48	a	55.56	bc	2.40	c	25.09	b
	Samos	41.30	d	41.77	d	55.39	bc	2.88	b	25.51	a
	Thessalia	48.80	b	53.71	b	56.36	b	2.92	b	25.76	a
Location	Ag. Anargyroi	39.11	g	53.57	c	56.60	b	3.75	bc	24.91	de
	Domokos	45.43	d	54.43	bc	56.91	b	3.34	c	24.89	de
	Ipato	47.99	c	53.02	c	54.90	d	3.99	b	25.27	cd
	Komotini	49.40	b	59.96	a	56.76	b	3.92	bc	24.43	e
	Larissa	42.14	e	43.49	d	54.95	cd	3.80	bc	25.81	b
	Orestiada	46.09	d	46.48	d	53.43	e	5.01	a	25.59	bc
	Patriki	50.47	a	51.16	c	58.61	a	3.73	bc	24.52	e
	Petrana	41.34	f	45.95	d	57.59	ab	2.13	d	26.48	a
	Thessaloniki	42.25	e	57.28	ab	56.32	bc	2.50	d	25.10	cd

DF: degrees of freedom; MTS: mass of 1000 seeds; PGS: percentage of green seeds; ***: significant effect at level $p < 0.001$. Values within each factor following different letters differ significantly at $p > 0.05$, according to Duncan's multiple range test.

The MTS parameter showed significant differences across all cultivars; Elpida displayed the highest value (62.89 g), Dimitra the lowest (33.13), and Thessalia, Samos, and 03-24L were in the middle. Elpida had the highest MTS, indicating that its seeds were the largest, whereas Dimitra's seeds were the smallest [24]. The mean MTS of the five cultivars varied by location, ranging from high (50.47 g) in Patriki to low (39.11 g) in Ag. Anargyroi, with the remaining locations falling in between (Table 2). There was no difference in MTS between seeds from Larissa and Thessaloniki or Domokos and Orestiada [24].

The color of the seeds was found to be greenish or brown, signifying their respective stages of maturation—immature and mature seeds, respectively [21]. The location cultivar, as well as their interaction, had an increasingly significant impact on the PGS's eta value. Dimitra and Elpida had the highest PGS among the cultivars, at 60.12 and 58.48%, respectively. According to Table 2, Komotini and Thessaloniki produced seeds with the highest PGS (59.96 and 57.28%, respectively), followed by Ag. Anargyroi, Domokos Ipato, and Patriki.

The eta values of a* were high, as in PGS, but those of L* were extremely low. Index a* denotes redness/greenness, and index L* denotes lightness/darkness. The index b* values were of moderate significance. Comparing 03-24L seeds to all other cultivars with similar L* values, Dimitra's showed decreased light/brownish tones and increased dark tones. Additionally, the seeds from 03-24L had the lowest b* values and the highest a* values. The highest L* and lowest b* values were found in seeds produced at Patriki, whereas Petrana and Thessaloniki had the lowest a* values.

3.2. Analysis of Cooked Seed Characteristics

Table 3 presents the results of the analysis of variance for cooked lentil seeds and the features of the cooking broth used in this investigation after the lentil seeds were cooked for 30 min.

Table 3. Analysis of variance of cooked lentil seeds characteristics of 5 cultivars cultivated at 9 locations, following cooking at 100 °C for 30 min.

	DF	PMI (%)	POS (%)	PFT (g)	OCH	OTT	OSA	OBA	Broth L*	Broth a*	Broth b*
						PARTIAL ETA SQR (η^2)					
Cultivar	4	0.10 *	0.20 ***	0.02 ***	0.02 ns	0.04 ns	0.04 ns	0.22 ***	0.12 *	0.25 ***	0.04 ns
Location	8	0.21 **	0.45 ***	0.03 ***	0.06 ns	0.20 *	0.12 *	0.36 ***	0.36 ***	0.33 ***	0.14 *
Cult. × Loc.	30	0.09 ns	0.15 ns	0.04 ***	0.05 ns	0.37 *	0.15 *	0.22 ns	0.24 ns	0.60 ns	0.16 ns
MAIN EFFECTS						MEANS					
Cultivar	03-24L	109.88 ab	19.84 a	119.8 ab	2.81 a	2.96 a	3.08 a	2.78 b	51.02 b	1.69 a	14.35 a
	Dimitra	114.18 a	14.92 b	102.4 c	2.94 a	2.61 a	3.14 a	3.14 a	53.64 a	1.07 c	12.97 a
	Elpida	113.55 a	21.37 a	114.3 b	2.63 a	2.79 a	2.88 a	2.46 c	51.21 b	1.87 a	14.12 a
	Samos	105.69 b	12.04 b	126.7 a	2.78 a	2.85 a	3.13 a	2.59 bc	53.66 a	1.29 b	13.14 a
	Thessalia	105.84 b	11.45 b	121.9 ab	2.68 a	2.70 a	2.94 a	2.57 bc	52.62 ab	1.46 b	13.04 a
Location	Ag. Anargyroi	108.27 bc	12.12 d	111.6 cd	3.00 a	2.87 a	3.29 a	2.50 cd	53.27 cd	1.18 ef	13.21 bc
	Domokos	115.14 ab	21.44 b	115.8 bc	2.97 a	2.67 a	3.08 abc	2.80 bc	53.96 b	1.24 ed	14.35 abc
	Ipato	106.42 c	10.89 d	125.5 ab	2.85 ab	2.13 b	3.33 a	3.27 a	55.22 ab	1.50 bcd	12.28 bc
	Komotini	120.38 a	30.23 a	101.7 d	2.81 ab	2.80 a	3.00 abc	2.50 cd	50.62 d	1.39 bcde	12.50 bc
	Larissa	102.86 c	3.21 e	135.0 a	2.70 ab	3.00 a	2.77 c	3.23 a	51.38 cd	1.63 b	13.85 abc
	Orestiada	109.23 bc	18.80 bc	112.2 cd	2.75 ab	3.08 a	2.88 bc	2.28 d	50.84 dc	2.13 a	15.83 a
	Patriki	102.19 c	13.97 cd	125.8 ab	2.33 b	2.80 a	3.20 abc	2.93 ab	56.74 a	0.95 f	11.90 c
	Petrana	104.60 c	9.46 de	136.7 a	2.56 ab	3.07 a	3.13 abc	2.47 cd	51.51 cd	1.46 bcd	13.46 abc
	Thessaloniki	116.46 ab	21.55 b	106.8 cd	2.91 ab	2.83 a	2.95 abc	2.59 bcd	50.01 d	1.30 ecd	12.30 bc

DF: degrees of freedom; PMI: % mass increase; POS: % overcooked seeds; PFT: penetration test; OCH: chew test; OTT: tactile test; OBA: organoleptic broth aroma; OSA: organoleptic seed aroma; η^2: partial eta squared; *p*: probability: *, ** and ***: significant at 0.05, 0.01 and 0.001 levels, and ns: non-significant, respectively. Different letters following values within each factor and column indicate significantly different values at 0.05 level according to Duncan's multiple range test.

For the percentage of mass increase (PMI), the eta square (η^2) value was as low as 0.1 but significant; for the penetration test (PFT), it was even lower, and for the percentage of overcooked seeds (POS), it was intermediate (0.2). Samos and Thessalia absorbed water slower than other cultivars, with a PMI of ~105.7% and low POS (11.5–12%) after cooking for 30 min. Also, cultivars Samos, Thessalia, and 03-24L had the highest levels of PFT (>120 g), while Dimitra and Elpida had the lowest (102.4 and 114.3 g, respectively). According to these data, in regard to the ease of cooking, Dimitra and Elpida were easier to cook than Samos Thessalia, while 03-24L was intermediate.

No differences were observed between cultivars in the organoleptic seed aroma (OSA) or in the tactile (OTT) and chewing (OCH) tests. Regarding the aroma of the broth (OBA) and the chromatometric values a* (green/red tones), significant η^2 was found for the factor of cultivar. The broth aroma was higher in cultivar Dimitra, but the broth (a*) values were lowest.

In relation to the cultivation locations under investigation, the partial eta square (η^2) of PMI was intermediate (0.21), but of POS was as high as 0.45, and PFT-hardness was minimal. Moreover, the tactile test's η^2 value was intermediate, while the seed aromas were low. The PMI of lentil seeds produced in Domokos, Komotini, and Thessaloniki was the highest (115.1–120.4%) when compared to the other locations: Thessaloniki, Domokos, and Komotini, followed by Orestiada, all had increased POS, which was also linked to the higher PMI than other cultivars. The PFT-hardness of intact seeds of Komotini, Ipato, Larissa, and Patriki was the highest among cultivars, ranging from 125.8 to 136.7 g. Lentil seeds from the location of Patriki had relatively increased PFT-hardness, though it was associated with low tactile and mastication test or decreased broth aroma maximum chromatometric L* and minimum a*.

3.3. Determination of Optimum Cooking Time

The definition of 90% cooked seeds was used in this study to determine the optimal cooking time (OCT); seeds were considered cooked when their hardness, as determined

by the penetration test, was less than 90 g. The hardness of cooked seeds is usually measured using penetration or organoleptic tests to assess cooking quality [22,35]. The 90 g penetration threshold was within the reported range of 80 to 90 g for cooked seeds [21]. In order to account for variations in samples from different cultivars and cultivation locations, a higher value (90 g) was chosen.

Different pulses and cultivars, or even the same cultivar of a given pulse, define cooked seeds differently. Organoleptic hardness tests (tactile and chewing) or comparisons of organoleptic with penetration tests are used to determine the definition of cooked seed. According to Wood [28], definitions of 50–100% for cooked pulses have been adopted for penetration tests using the Mattson cooker. Scanlon et al. [36] defined cooked lentil seeds as 80%, Svarna et al. [21] as 95%, and Erskine et al. [18] as 90%.

Although it may seem ideal, using 100% definition is practically impossible because it requires softening the very last hard seed of PFT > 90 g, which could, on the one hand, require an extensive amount of cooking time and energy. On the other hand, early-softening seeds run the risk of being overcooked and become mushy. Therefore, it would seem that the definition of OCT generally changes based on the type of seed. The current study defined cooked seeds as those that have softened to 90% to account for variations in samples from various cultivars and cultivation locations.

Plotting all values against cooking time, a sigmoid curve model was fitted, wherein 0% represented hard or uncooked seeds at the start of the cooking process (0 min) and 100% represented fully cooked seeds [21]. Furthermore, this model includes total seed penetration readings (green and brown), and the percentage of cooked seeds is calculated using the PGS.

As a representative of the nine locations, Figure 1 illustrates the evolution of the percentage of cooked lentil seeds from five cultivars that were cultivated at Larissa after cooking them for 20–60 min at 100 °C.

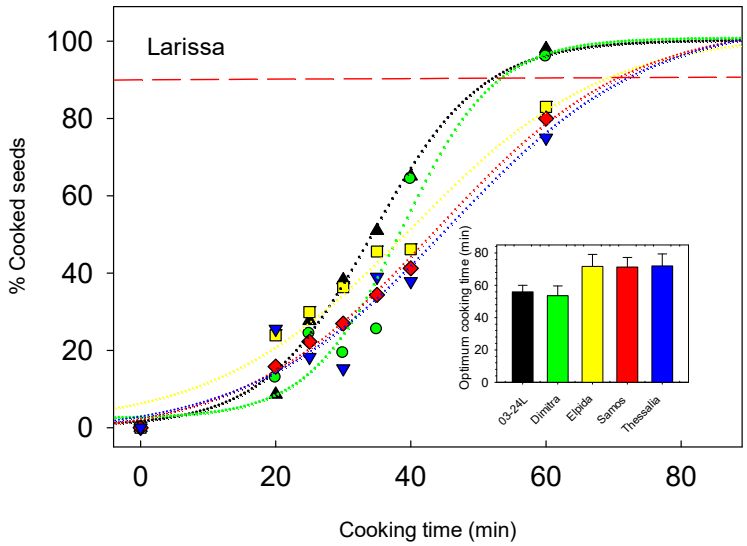


Figure 1. The evolution of the percentage of cooked seeds (calculated on the basis of penetration test values of lentil seeds below 90 g) of lentil seeds of 5 cultivars cultivated at the location of Larissa, following cooking at 100 °C for 0–60 min. Dotted lines represent curve fitting according to the sigmoid model. The dashed line indicates the definition of 90% of cooked seeds for optimum cooking time (OCT). The enclosed figure shows the values ± standard deviation of OCT (min) of lentil seed cultivars obtained from the particular location of cultivation (Larissa).

The OCT found for each seed sample is displayed in Table 4. The factor cultivar accounted for relatively high and significant η^2 values (0.31, $p < 0.001$) for the OCT trait (Table 4). Reported significance was placed mainly on the cultivar factor rather than on the location [23]. The mean OCTs of Cv. Dimitra and 03-24L were 49.02 and 51.24 min,

respectively; Samos and Thessalia had higher mean OCTs (~65 min), while Elpida had an intermediate one (Table 4). OCT values that have been reported are as low as 23.05 min for cv. Dimitra, approximately 26.5 min for Samos and Elpida and as high as 27.9 and 28.5 min for Thessalia and 03-04L, respectively [17,23,25]. In these investigations, the tactile test was used to estimate the OCT. However, when it comes to determining whether seeds are cooked or not, the tactile test does not agree with the penetration test; instead, it shows the seeds as softer than the penetration test [21]. Even though the reported OCTs were estimated using the tactile test, its differential trend within cultivars was comparable to the penetration test used in the current study. In addition, the tactile test may have produced a different relative significance for each factor or their interaction when used to estimate the OCT. This could explain why the cultivar factor is reported to be more significant, whereas the location has a greater effect in the current study.

Table 4. Analysis of variance of lentil seed cooking time (CT) of 5 cultivars cultivated at 9 locations, defined as the number of mins required during cooking at 100 °C to result in 90% of cooked seeds.

Cultivar: / Location:	03-24L	Dimitra	Elpida	Samos	Thessalia	MEANS (Location)
Ag. Anargyroi	54.3 ± 5.1	38.9 ± 3.2	52.1 ± 6.8	49.6 ± 7	57.4 ± 4	50.5 C
Domokos	47.4 ± 5.1	44.7 ± 3.2	53.7 ± 6.8	57.4 ± 11	56.1 ± 9	51.9 C
Ipato	50.2 ± 3.4	45.3 ± 4.6	57.2 ± 6.1	49.9 ± 9.9	54.7 ± 4.5	51.5 C
Komotini	51.6 ± 4.8	48.5 ± 1.9	42.6 ± 3.6	48.4 ± 8.2	50.9 ± 3.5	48.4 C
Larisa	56.0 ± 4	53.6 ± 6	71.7 ± 7.4	71.3 ± 5.9	72.0 ± 7.4	64.9 A
Orestiada	47.0 ± 3.4	50.1 ± 3.7	54.3 ± 1.3	54.2 ± 4	54.1 ± 3.2	51.9 C
Patriki	52.4 ± 6.9	54.5 ± 2.4	56.6 ± 2.4	63.6 ± 9.6	66.5 ± 11	58.7 B
Petrana	62.9 ± 11	59.8 ± 13	71.7 ± 10	71.9 ± 11	58.7 ± 16	65.0 A
Thessaloniki	69.6 ± 5.7	45.7 ± 5.6	58.4 ± 9.2	56.5 ± 6.6	61.7 ± 8.4	58.4 B
			MEANS (Cultivar)			
	54.6 B	49.0 C	57.6 AB	58.1 AB	59.1 A	
			PARTIAL ETA SQR (η^2)			
Cultivar			0.31 ***			
Location			0.91 ***			
Cultivar × Location			0.37 ***			

The mean ± SD is used to represent the data. Duncan's test at $p < 0.05$ indicates that the various letters denote the significance within the mean column (Location) or row (Cultivar). *** Highly significant difference at $p < 0.001$.

For lentils, a correlation between a higher PMI capacity and a shorter OCT has been demonstrated [13]. It is also well-known that consumers prefer short OCTs. Using a similar hardness measurement method to the one used in this study (penetration test), Theologidou et al. [17] and Abdel-Aal et al. [37] reported that the OCT for lentils was as low as 25 min. The OCT values in the current study ranged from 25 to 75 min, with a mean cooking time of 53.21 min. Similar results for lentil seeds (54.04 and 52.05 min) were reported by Palacios et al. [38] and by Akdeniz et al. [39] (40.5 and 46.0 min).

The OCT presented by cultivars in various cultivation locations is also displayed in Table 4; the location factor had very high and significant η^2 values (0.91, $p < 0.001$), indicating a greater impact on OCT than the factor cultivar or the interaction cultivar × location.

The five cultivars' mean OCT varied from 48.4 to 65 min between locations. Patriki and Thessaloniki locations had maximum mean OCTs of 58.71 and 58.4 min, respectively, after the seeds were produced at Larissa (Figure 1) and Petrana (Table 4). The locations of Komotini displayed a minimum OCT of 48.4 min, while Ag. Anargyroi, Domokos, Ipato, and Orestiada displayed intermediate OCT of produced seeds with a range of 50.46–51.94 min (Table 4). Again, the correlation between a higher PMI capacity and a shorter cooking time [13] was confirmed to be valid.

It is well known that the primary influencing factors [17,20–24] on seed size and maturity, among other factors that induce variability of OCT, are soil (pH, soil organic

matter) and weather conditions (temperature, precipitation during the period between the start of flowering to pod filling).

By taking into account additional factors such as yield and protein content, Vlachostergios et al. [24] estimated OCT using the tactile test and reported that Orestiada and Ipato had been identified as the ideal locations for low-seed OCT. Komotini and Ag. Anargyroi were the two locations in this study that also showed relatively low OCT; the seeds produced at these locations might be better suited for human consumption, while the remaining locations may yield material for seed propagation or processing. Once more, the differential trend of OCT within locations was similar to the current study despite the difference in the methods used for the estimation of OCT (tactile vs. penetration test).

A noteworthy cultivar × location effect was also shown by OCT (Table 4), with a η^2 value of 0.36, roughly comparable to the effects of the cultivar factor. According to Iliadis [25], to reliably produce seed with a short or long OCT, the cultivar factor predominates over soil and weather (location) factors to a large extent.

In order to select the superior cultivars and locations based on the traits under examination, additional cultivar discrimination among locations was attempted using Pearson correlation and PCA analysis.

3.4. Pearson Correlation and PCA Analysis

The relationships between the studied traits were examined using Pearson correlation analysis at $p < 0.01$ (Table 5). All correlations observed were weak to medium strong, indicating the multiplicity of influence of several factors on cooking quality.

Table 5. Pearson correlation matrix between raw and cooked seed characteristics.

	MTS	PGS	Seed L*	Seed a*	Seed b*	PMI	POS	PFT	OTT	OCH	OBA	OSA	Broth L*	Broth a*	Broth b*
PGS	0.039														
Seed L*	−0.071	0.129													
Seed a*	0.065	−0.351 *	−0.505 ***												
Seed b*	−0.244	0.063	0.042	−0.416 **											
PMI	−0.083	0.487 ***	0.018	−0.099	−0.086										
POS	0.19	0.324 *	−0.121	0.221	−0.316	0.797									
PFT	0.22	−0.52 ***	0.01	0.519 ***	−0.505 ***	−0.453 **	−0.133								
OTT	−0.299	0.168	−0.274	0.186	0.065	0.414 **	0.277	−0.302							
OCH	−0.341 *	0.16	−0.387 *	0.209	0.071	0.382 *	0.218	−0.327 *	0.95						
OBA	−0.246	0.143	−0.138	0.105	−0.087	0.073	−0.153	0.094	0.023	0.129					
OSA	−0.155	0.09	0.143	−0.157	0.143	0.225	−0.045	−0.198	0.077	0.057	0.33 *				
Broth L*	0.004	−0.093	0.21	−0.209	0.021	−0.281	−0.382 *	0.148	−0.266	−0.248	0.148	0.131			
Broth a*	0.421 **	−0.113	−0.162	0.295	0.045	−0.057	0.037	0.059	−0.007	0.01	−0.186	−0.06	−0.403 **		
Broth b*	0.035	−0.201	0.05	0.262	−0.203	0.279	0.251	0.192	0.158	0.163	−0.016	0.24	0.082	0.136	
OCT	0.403 **	−0.351 *	0.025	0.02	0.036	−0.391 *	−0.199	0.224	−0.167	−0.192	−0.304	−0.401 **	0.076	0.094	−0.155

MTS: mass of 1000 seeds; PGS: percentage of green seeds; Seed L*: raw seed L* color index; Seed a*: raw seed a*color index; Seed b*: raw seed b* color index; PMI: percentage of mass increase; POS: percentage of overcooked seeds; OTT: tactile test (organoleptic); OCH: chewing test (organoleptic); OBA: broth aroma (organoleptic); OSA: seed aroma (organoleptic); Broth L*: L*color index; Broth a*: a* color index; Broth b*, b*color index; OCT: optimum cooking time; *, ** and ***: significant at 0.05, 0.01 and 0.001 levels, respectively.

Table 5 displays a noteworthy positive correlation between MTS and OCT or color index a* of broth and a negative correlation with OCH values. It has been reported that the cultivar factor influences raw seed quality traits such as seed size, which is a measure of MTS; larger or heavier seeds are indicated by higher MTS. Bhatty [5] reported that cultivars with extra-large seed sizes required twice as long to cook as cultivars with small seed sizes, confirming the effects of size on cooking times [16,18,21,23]. He also concluded that the seed size effect is dominant over other traits in terms of cooking time. However, when evaluating local cultivars, Ninou et al. [3] found no relationship between cooking time and MTS. Thus, of all the cultivars under study, Dimitra, which had a low MTS, and Elpida, which had a high MTS (Table 2), demonstrated the lowest and the highest OCT, respectively (Table 4).

Table 5 demonstrated a positive significant correlation of PGS with PMI and POS and a negative and significant correlation between PGS and seed color index a*, PFT-hardness, and OCT; PGS's negative correlation between index a* is evident since smaller a* values are indicative of more greenish tones (increase in PGS).

However, despite the significant correlation between PGS and PFT-hardness, OCT, PMI, or POS, this correlation appears to be inverse. The trait PGS (or seed color index a*) is

a measure of the ratio of immature (green-colored) to mature (brown-colored) seeds in a seed sample of a cultivar. Svarna et al. [21] reported that immature seeds take longer to cook than mature ones or seeds with high PGS present increased OCT. Accordingly, they also reported that, compared to the cultivar that needed a shorter cooking time (low OCT), the cultivar that required a longer cooking time (high OCT) had a higher MTS and a lower PGS [21] in the current study cv. Dimitra had a low MTS (33.13 g—Table 2) and a low OCT (49.0 min—Table 4). Also, had high PMI (114.18%—Table 2), although it was also high PGS (60.12%—Table 2). Conversely, cv. Elpida also displayed high PGS (62.89%—Table 2) or PMI (113.55%—Table 2) but showed a high MTS (62.89 g—Table 2) and a high OCT (57.5 min—Table 4). These findings suggest that PGS is subordinate to MTS and that the direct correlations observed between PGS and other traits (PFT-hardness and OCT or PMI and POS) are rather inverse. Furthermore, they suggest that future research should focus on the definition and effects of seed maturation.

The correlation between OCT and PMI has been addressed by the findings of Bhatty [40], who stated that cultivars with low cooking time requirements absorb more water than those with high requirements. Svarna et al. [21] also provided confirmation of this.

Ultimately, significant correlations between PMI and hardness, as well as between the tactile or chewing test and OCT, were found, indicating that the water absorbed during cooking influences these characteristics in cooked lentil seeds [21,40]. For lentils, it has been demonstrated that a higher PMI capacity translates into a shorter OCT [13].

To better understand the relationships between the lentil cultivars examined in this research, a principal component analysis (Figure 2A) of the primary seed attributes of raw or cooked seed traits found to have a significant correlation (Table 5) was performed. In addition, a second principal component analysis (Figure 2B) for location discrimination was performed using additional soil and climate characteristics (Table 1) to those used in Figure 2A.

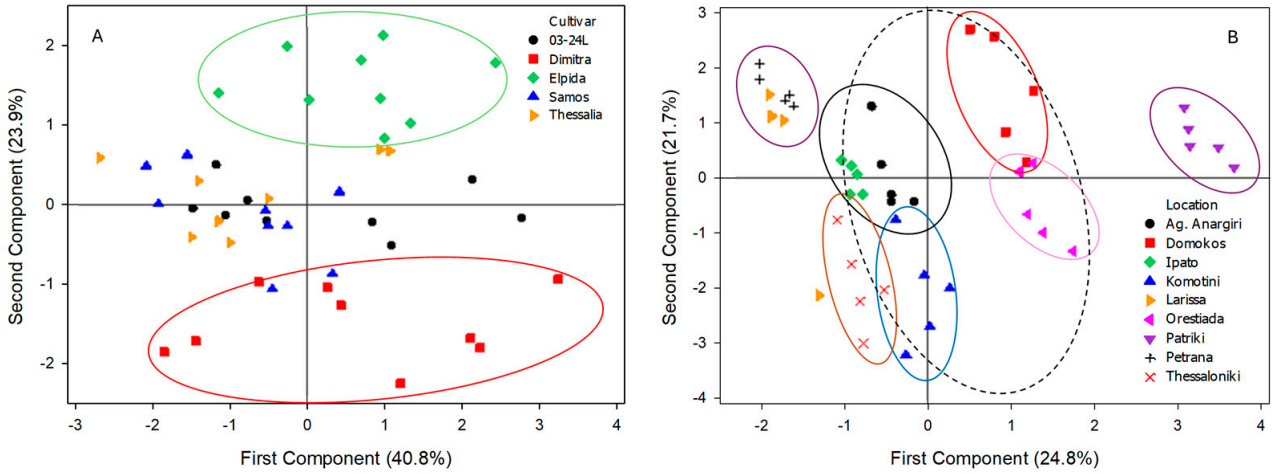


Figure 2. Principal component analysis is used to distinguish between cultivars (**A**) and locations (**B**). (**A**,**B**) use the main seed attributes that were found to have a significant correlation (mass of 1000 seeds (MTS), percentage of green seeds (PGS), percentage of mass increase (PMI), and percentage of overcooked seeds (POS). (**B**) also shows the pedoclimatic data from Table 1. Embedded circles in (**A**) indicate individual cultivars, while circles in (**B**) represent individual or grouped cultivation locations.

Elpida (green ellipse, Figure 2A) and Dimitra (red ellipse, Figure 2A) were discriminated from the other cultivars in all locations. Elpida displayed positive scores on PC1 or PC2, and Dimitra was negative, while the other cultivars did not present any discrimination trend among them. PCA analysis provided a visualization of the raw and cooked characteristics reflected in the grouping of the two cultivars. This confirmed the results presented previously, indicating comparative differences between Elpida and Dimitra in mainly MTS, PGS, and OCT, as well as among the other cultivars.

Patriki was the only one discriminated against from all locations, but Domokos and Orestiada, Thessaloniki and Komotini, Ipato, and Ag. Anargyroi, Larissa, and Petrana were all grouped together as couples. These groups shared soil and environmental conditions, resulting in variations in raw or cooked seed traits. The five locations in the center of Figure 2B (Ag. Anargyroi, Domokos, Ipato, Komotini, and Orestiada) with the shortest OCT were considered suitable for human consumption (dashed ellipse). Locations in the periphery of Figure 2B, such as Larissa and Petrana, which were grouped together, or Patriki and Thessaloniki (though Thessaloniki could be regarded within the dashed ellipse), which were discriminated separately, produced seeds with the highest or intermediate OCT, respectively, and could be recommended for processing or propagation.

4. Conclusions

This study confirmed that lentil seed cultivars differed in their 1000-seed mass, percentage of green seed maturity, or seed color indexes, and this was also differentiated among nine locations of cultivation. For cooked seeds, a similar differentiation was observed in terms of seed mass and overcooked seed increase, hardness, among other organoleptic traits measured at 30 min of cooking or OCT, determined after plotting the percentage of soft seeds with cooking time and fitting a sigmoid model.

This aspect might serve as the basis for a precise evaluation of the effects of cultivar, location, and cultivar x location interaction on traits related to seed quality. The interaction between cultivar and cultivation location may be crucial for future seed quality improvement, future sowing, or even for potential nutritional benefits to humans, either consumed as whole seed or processed. There is some differentiation between cultivar and location interaction as two groups of locations were identified, one producing seed with a lower OCT and one with a higher. The first group's OCT might be used for human consumption, while the second group's OCT may be used for storage, seed production for propagation purposes, or for processing food ingredients such as flour.

Pre- and post-cooking characteristics are considered crucial to describe the quality of lentil seeds more accurately across the interaction of locations and cultivars. More research is required to acknowledge this interaction and improve our understanding of seed quality. Future research addressing OCT and seed quality traits of the lentil crop should pay special attention to the use of non-destructive methods.

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References

1. Addise, N.; Asfaw, T. Evaluation of chickpea and lentil grain for protein content. In *Nile Valley Regional Program on Cool Season Food Legumes*; Annual Report 1992/93, Ethiopia ICARDA/NVRP Doc-029; ICARDA: Aleppo, Syria, 1993.
2. Nanos, G.D.; Gerasopoulos, D. Fruits, vegetables, legumes, and grains. In *The Mediterranean Diet: Constituents and Health Promotion*; Matalas, A.-L., Zampelas, A., Stavrinos, V., Eds.; CRC Press: Boca Raton, FL, USA, 2001; Volume 97, pp. 125–155. [CrossRef]
3. Ninou, E.; Papathanasiou, F.; Vlachostergios, D.N.; Mylonas, I.; Kargiotidou, A.; Pankou, C.; Papadopoulos, I.; Sinapidou, E.; Tokatlidis, I. Intense Breeding within Lentil Landraces for High-Yielding Pure Lines Sustained the Seed Quality Character-istics. *Agriculture* **2019**, *9*, 175. [CrossRef]
4. Dhull, S.B.; Kinabo, J.; Uebersax, M.A. Nutrient profile and effect of processing methods on the composition and functional properties of lentils (*Lens culinaris* Medik): A review. *Legume Sci.* **2022**, *5*, e156. [CrossRef]
5. Bhatty, R.S. Comparisons of good- and poor-cooking lentils. *J. Sci. Food Agric.* **1995**, *68*, 489–496. [CrossRef]
6. Kumar, S.; Bamboriya, S.D.; Rani, K.; Meena, R.S.; Sheoran, S.; Loyal, A.; Kumawat, A.; Jhariya, M.K. Grain legumes: A diversified diet for sustainable livelihood, food, and nutritional security. In *Elsevier eBooks*; Elsevier: Amsterdam, The Netherlands, 2022; pp. 157–178. [CrossRef]
7. Nosworthy, M.G.; Neufeld, J.; Frohlich, P.; Young, G.; Malcolmson, L.; House, J.D. Determination of the protein quality of cooked Canadian pulses. *Food Sci. Nutr.* **2017**, *5*, 896–903. [CrossRef]
8. Siva, N.; Thavarajah, D.; Johnson, C.R.; Duckett, S.; Jesch, E.D.; Thavarajah, P. Can lentil (*Lens culinaris* Medikus) reduce the risk of obesity? *J. Funct. Foods* **2017**, *38*, 706–715. [CrossRef]
9. Motte, J.; Tyler, R.; Milani, A.; Courcelles, J.; Der, T. Pea and lentil flour quality as affected by roller milling configuration. *Legume Sci.* **2021**, *3*, e97. [CrossRef]
10. Singh, K.M.; Singh, A. Lentil in India: An Overview Munich Personal REPEC Archive. (N.D.). Available online: https://mpra.ub.uni-muenchen.de/59319/ (accessed on 28 July 2024).
11. Portman, D.; Blanchard, C.; Maharjan, P.; McDonald, L.S.; Mawson, J.; Naiker, M.; Panozzo, J.F. Blending studies using wheat and lentil cotyledon flour—Effects on rheology and bread quality. *Cereal Chem.* **2018**, *95*, 849–860. [CrossRef]
12. Turfani, V.; Narducci, V.; Durazzo, A.; Galli, V.; Carcea, M. Technological, nutritional and functional properties of wheat bread enriched with lentil or carob flours. *Food Sci. Technol.* **2017**, *78*, 361–366. [CrossRef]
13. Taheri, S.; Brodie, G.; Gupta, D. Fluidisation of lentil seeds during microwave drying and disinfection could prevent detrimental impacts on their chemical and biochemical characteristics. *Food Sci. Technol.* **2020**, *129*, 109534. [CrossRef]
14. Joshi, M.; Timilsena, Y.; Adhikari, B. Global production, processing and utilization of lentil: A review. *J. Integr. Agric.* **2017**, *16*, 2898–2913. [CrossRef]
15. Ruiz, J.M.; Buatois, Q.; Chambaron, S.; Monnery-Patris, S.; Arvisenet, G. French consumers know the benefits of pulses, but do not choose them: An exploratory study combining indirect and direct approaches. *Appetite* **2019**, *141*, 104311. [CrossRef] [PubMed]
16. Bhatty, R.S.; Nielsen, M.A.; Slinkard, A.E. Comparison of the Cooking Quality of Laird and Commercial Chilean Lentils Grown in the Canadian Prairies. *Can. Inst. Food Sci. Technol. J.* **1983**, *16*, 104–110. [CrossRef]
17. Theologidou, G.S.; Lazaridou, A.; Zorić, L.; Tsialtas, I.T. Cooking Quality of Lentils Produced under Mediterranean Conditions. *Crop. Sci.* **2018**, *58*, 2121–2130. [CrossRef]
18. Erskine, W.; Williams, P.C.; Nakkoul, H. Genetic and environmental variation in the seed size, protein, yield, and cooking quality of lentils. *Field Crop. Res.* **1985**, *12*, 153–161. [CrossRef]
19. Ross, K.A.; Alejo-Lucas, D.; Malcolmson, L.; Arntfield, S.D.; Cenkowski, S. Interpretation of the force–deformation curves of cooked red lentils (*Lens culinaris*). *J. Texture Stud.* **2009**, *40*, 109–126. [CrossRef]
20. Bressani, R.; Elías, L.G. Seed quality and nutritional goals in pea, lentil, faba bean and chickpea breeding. In *World Crops: Cool Season Food Legumes*; Current Plant Science and Biotechnology in Agriculture; Summerfield, R.J., Ed.; Springer: Dordrecht, The Netherland, 1988; pp. 381–404. [CrossRef]
21. Svarna, M.; Mavromatis, A.; Vlachostergios, D.N.; Gerasopoulos, D. Modeling the effects of seed maturity on cooking time of 'Dimitra' lentils. *Foods* **2022**, *12*, 42. [CrossRef]
22. Iliadis, C. Effects of harvesting procedure, storage time and climatic conditions on cooking time of lentils (*Lens culinaris* Medikus). *J. Sci. Food Agric.* **2001**, *81*, 590–593. [CrossRef]
23. Bhatty, R.S. Composition and Quality of Lentil (*Lens culinaris* Medik): A Review. *Can. Inst. Food Sci. Technol. J.* **1988**, *21*, 144–160. [CrossRef]
24. Vlachostergios, D.N.; Noulas, C.; Kargiotidou, A.; Baxevanos, D.; Tigka, E.; Pankou, C.; Kostoula, S.; Beslemes, D.; Irakli, M.; Tziouvalekas, M.; et al. Identification of the optimum environments for the high yield and quality traits of lentil genotypes evaluated in Multi-Location trials. *Sustainability* **2021**, *13*, 8247. [CrossRef]
25. Iliadis, C. Influence of genotype and soil type on cooking time in lentil (*Lens culinaris* Medikus). *Int. J. Food Sci. Technol.* **2003**, *38*, 89–93. [CrossRef]
26. Özer, M.S.; Kaya, F. Physical, chemical and physicochemical properties of some lentil varieties grown in Turkey. *J. Food Agric. Environ.* **2010**, *8*, 610–613.
27. Jood, S.; Bishnoi, S.; Sharma, A. Chemical analysis and physico-chemical properties of chickpea and lentil cultivars. *Nahrung* **1998**, *42*, 71–74. [CrossRef]

28. Wood, J.A. Evaluation of Cooking Time in Pulses: A Review. *Cereal Chem.* **2017**, *94*, 32–48. [CrossRef]
29. Shrestha, R.; Rizvi, A.H.; Sarker, A.; Darai, R.; Paneru, R.B.; Vandenberg, A.; Singh, M. Genotypic Variability and Genotype × Environment Interaction for Iron and Zinc Content in Lentil under Nepalese Environments. *Crop Sci.* **2018**, *58*, 2503–2510. [CrossRef]
30. Irakli, M.; Kargiotidou, A.; Tigka, E.; Beslemes, D.; Fournomiti, M.; Pankou, C.; Stavroula, K.; Tsivelika, N.; Vlachostergios, D.N. Genotypic and Environmental Effect on the Concentration of Phytochemical Contents of Lentil (*Lens culinaris* L.). *Agronomy* **2021**, *11*, 1154. [CrossRef]
31. Myrtsi, E.D.; Vlachostergios, D.N.; Petsoulas, C.; Koulocheri, S.D.; Evergetis, E.; Haroutounian, S.A. Eleven Greek legume beans: Assessment of genotypic effect on their phytochemical content and antioxidant properties. *Antioxidants* **2024**, *13*, 459. [CrossRef] [PubMed]
32. Baxevanos, D.; Kargiotidou, A.; Noulas, C.; Kouderi, A.-M.; Aggelakoudi, M.; Petsoulas, C.; Tigka, E.; Mavromatis, A.; Tokatlidis, I.; Beslemes, D.; et al. Lentil cultivar evaluation in diverse organic Mediterranean environments. *Agronomy* **2024**, *14*, 790. [CrossRef]
33. IIFC: Hellenic Agricultural Organization Demeter, Institute of Industrial and Forage Crops. 2016. Available online: https://ipsw.gr/en/services/legumes-varieties/itemlist/category/162-lentil-lens-culinaris-medik (accessed on 2 September 2024).
34. Beck, H.E.; Zimmermann, N.E.; McVicar, T.R.; Vergopolan, N.; Berg, A.; Wood, E.F. Present and future Köppen-Geiger climate classification maps at 1-km resolution. *Sci. Data* **2018**, *5*, 180214. [CrossRef]
35. Joshi, M.; Adhikari, B.; Panozzo, J.; Aldred, P. Water uptake and its impact on the texture of lentils (*Lens culinaris*). *J. Food Eng.* **2010**, *100*, 61–69. [CrossRef]
36. Scanlon, M.G.; Malcolmson, L.J.; Arntfield, S.D.; Watts, B.; Ryland, D.; Prokopowich, D.J. Micronization Pretreatments for Reducing the Cooking Time of Lentils. *J. Sci. Food Agric.* **1998**, *76*, 23–30. [CrossRef]
37. Abdel-Aal, E.-S.M.; Ragaee, S.; Rabalski, I.; Warkentin, T.; Vandenberg, A. Nutrient content and viscosity of Saskatchewan-grown pulses in relation to their cooking quality. *Can. J. Plant Sci./Can. J. Plant Sci.* **2019**, *99*, 67–77. [CrossRef]
38. Palacios, L.T.; Guindón, F.; Maglia, F.; Bermejo, C. Identification of Macrosperma and Microsperma Lentil (*Lens culinaris* Medik) Genotypes with Superior Nutritional, Industrial, and Productive Traits to Get Transgressive Segregants. *ACS Agric. Sci. Technol.* **2023**, *3*, 683–693. [CrossRef]
39. Akdeniz, H.; Koc, A.; Hosafliglu, I.; Hossain, A.; Islam, M.S.; Hafez, E.; El Sabagh, A. Evaluation of phenology, growth, yield and technological characteristics of some winter green lentil (*Lens culinaris* medik.) Genotypes grown under Mediterranean environment. *Fresenius Environ. Bull.* **2019**, *28*, 5430–5434.
40. Bhatty, R.S. Relationship between physical and chemical characters and cooking quality in lentil. *J. Agric. Food Chem.* **1984**, *32*, 1161–1164. [CrossRef]

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