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Deliverable 3.1

Report of the nutritional profile of the almonds and intercrops varieties

VALMEDALM: Valorization of **Med**iterranean **Alm**ond orchards through the use of intercropping integrated strategies

Índice

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1. Executive Summary

This report presents the results of the characterisation of the physical properties and nutritional composition of almonds and the intercrop species assessed in the five countries participating in the VALMEDALM project, including Italy, Morocco, Portugal, Israel and Croatia. Various legume-based intercrop systems were evaluated, based on the agronomic conditions of each country, including *Medicago spp*. and *Sulla coronaria* in Italy, fava beans and lentils in Morocco, and chickpeas and clover in Portugal. Experimental sites in Israel and Croatia focused on comparing systems with and without cover crops, and on the variability between different almond cultivars, respectively.

The analyses included colour assessment (CIELAB), texture profile analysis (TPA) and approximate composition (moisture, crude fat, protein, ash, carbohydrates and energy content) of the almonds, as well as the nutritional characterisation of the intercropped species. The report compiles the results obtained during the control year, where applicable, and in subsequent intercropping seasons, providing a comprehensive overview of the influence of different intercropping systems on almond quality and the nutritional value of the associated crops in contrasting Mediterranean environments.

Deviation: With regard to the work plan initially proposed, it was not possible to characterize the almond samples corresponding to the second production year at the Croatian trial site, nor the chickpea samples corresponding to the third production year at the Portuguese trial site, as no agricultural production was obtained at these sites during the respective years. This situation resulted from agronomic and environmental conditions inherent to field trials and beyond the control of the project team, which prevented the collection of the planned samples. Consequently, the characterization of these crops was based solely on the production years for which representative samples were available.

2. Italy

Control Year Results

Prior to the establishment of the intercropping trial, a control year was conducted to characterise baseline almond quality at the trial site in Licata, Agrigento (C. da Volpara, 92027; 37°12'31.2"N, 13°50'38.2"E). Three groups of control samples were collected from the plots subsequently assigned to the experimental blocks: AIC1 (block 1), AIC5 (block 5), and AIC7 (block 7). These samples reflect the inherent variability of the orchard prior to intercropping and serve as a reference for interpreting results from subsequent production years.

Colour Analysis

Colour parameters were determined using the CIELAB colour space and are presented in Table 1. $L*$ values ranged from 51±1 (AIC1) to 54±4 (AIC7), indicating moderate lightness with some variability across blocks, particularly in AIC7 where the wider standard deviation reflects greater within-plot heterogeneity. The $a*$ parameter was consistent across all three blocks, with no meaningful differences in redness among the control plots. The $b*$ parameter ranged from 36±1 (AIC1) to 38±3 (AIC7), with AIC7 showing the highest yellowness value and the greatest variability. Overall, the colour profiles of the three control blocks were broadly similar, confirming a homogeneous baseline for the orchard prior to intercropping establishment.

Table 1. Colour parameters (L*, a* and b*) for the control almond samples collected in the baseline year (mean ± SD).

	AIC1	AIC5	AIC7
*L**	51±1	52±2	54±4
*a**	15±1	15±1	15±1
*b**	36±1	36±2	38±3
Conversion into RGB value			

*L**:luminosity; *a**: chromatic axis from green (-) to red (+); *b**: chromatic axis from blue (-) to yellow (+). **AIC1:** control almonds collected from block 1; **AIC5**: control almonds collected from block 5; **AIC7**: control almonds collected from block 7.

Texture Profile Analysis

Texture Profile Analysis (TPA) results for the control samples are presented in Table 2**.** Hardness ranged from 36935±3334 g (AIC5) to 42558±4316 g (AIC7), with AIC7 being the most resistant to compression and AIC5 the least. Fracturability showed an inverse trend, with AIC1 presenting the highest value (30040±5560 g) and AIC7 the lowest (26491±3713 g), suggesting that the harder kernels in AIC7 were less prone to fracture. Adhesiveness values were low and negative across all three blocks (-2.3±0.3 to -2±1 g/sec), as expected for dry almond kernels. Springiness was identical across all blocks (1±0.1 to 1±0.02 sec), indicating uniform elastic recovery. Cohesiveness was slightly higher in AIC7 (0.5±0.1 g/sec) compared to AIC1 and AIC5 (both 0.4 g/sec), reflecting marginally stronger internal bonding in that block. Gumminess and chewiness followed the hardness pattern, with AIC7 recording the highest values (19592±4439 g and 13160±4181 g/sec, respectively) and AIC5 the lowest (14421±1834 g and 8890±1102 g/sec, respectively). Resilience was comparable across all blocks (0.2-0.3 g/sec). Overall, the texture parameters of the control year reflect natural between-block variability in the orchard, with AIC7 consistently showing a denser and more structurally resistant kernel profile.

Table 2. Texture evaluation for the almonds harvested in Italy.

	AIC1	AIC5	AIC7
Hardness (g)	39799±5065	36935±3334	42558±4316
Fracturability (g)	30040±5560	29586±6797	26491±3713
Adhesiveness (g/sec)	-2.3±0.3	-2.0±0.5	-2±1
Springiness (sec)	0.6±0.1	0.62±0.02	0.7±0.1
Cohesiveness (g/sec)	0.4±0.1	0.39±0.03	0.5±0.1
Gumminess (g)	16561±5072	14421±1834	19592±4439
Chewiness (g/sec)	10542 ±4148	8890±1102	13160±4181
Resilience (g/sec)	0.2±0.1	0.22±0.02	0.27±0.05

AIC1: control almonds from block 1; **AIC5**: control almonds from block 5; **AIC7**: control almonds from block 7.

Proximate Composition

The proximate composition and energy content of the control samples are presented in Table 3. Moisture content was consistent across all three blocks (5.8±0.1 to 6.0±0.4 g/100 g *fw*), confirming uniform drying conditions. Crude fat content ranged from 42±0.1 g/100 g *fw* (AIC5 and AIC7) to 43.8±0.1 g/100 g *fw* (AIC1), with AIC1 showing the highest lipid content. Protein content was highest in AIC1 and AIC7 (both 21 g/100 g *fw*) and slightly lower in AIC5 (19.5±0.2 g/100 g *fw*). Ash content was similar across all blocks, indicating comparable mineral content in the baseline year. Carbohydrate content varied more markedly, ranging from 25.5±0.4 g/100 g *fw* (AIC1) to 33.2±0.5 g/100 g *fw* (AIC5), inversely reflecting the fat content differences between blocks. Energy values followed the fat content trend, with AIC1 recording the highest caloric value (580±1 kcal/100 g; 2427±4 kJ/100 g) and AIC5 the lowest (549±12 kcal/100 g; 2297±52 kJ/100 g). These baseline values are consistent with typical nutritional profiles reported for Mediterranean almond cultivars and confirm the suitability of the trial site for the subsequent intercropping experiment.

Table 3. Nutritional profile of control almond samples collected in the baseline year (mean ± SD; expressed per 100 g fw).

	Moisture (g/100 g fw)	Crude Fat (g/100 g fw)	Proteins (g/100 g fw)	Ash (g/100 g fw)	Carbohydrates (g/100 g fw)	Energy (Kcal/100g)	Energy (Kj/100g)
AIC1	6.0±0.4	43.8±0.2	20.8±0.2	3.8±0.2	25.8±0.4	580±1	2427±4
AIC5	5.8±0.3	42±5	19.5±0.2	4±1	33.2±0.5	549±12	2297±52
AIC7	5.9±0.1	42.0±0.1	21.03±0.05	3.756±0.002	27.3±0.2	571.9±0.4	2395±2

Year 1 Intercropping Results

Experimental Design and Sample Identification

Nine almond samples were collected from a trial comprising three blocks, each containing three plots assigned to one of the following treatments: control (no intercropping), intercropping with *Medicago* spp., and intercropping with *Sulla coronaria*. Samples were identified as follows: **AP1C** (control, block 1, plot 1; 37°12'36.34″N, 13°50'37.11″E), AP2M (*Medicago* spp., block 1, plot 2), **AP3S** (*Sulla coronaria*, block 1, plot 3), **AP4M** (*Medicago* spp., block 2, plot 4), AP5C (control, block 2, plot 5), **AP6S** (*Sulla coronaria*, block 2, plot 6), **AP7C** (control, block 3, plot 7), **AP8S** (*Sulla coronaria*, block 3, plot 8), and **AP9M** (*Medicago* spp., block 3, plot 9).

Colour Analysis

Colour parameters were evaluated using the CIELAB colour space (*L*, a*, b**) and are presented in Table 4.

Table 4. Colour parameters (L*, a* and b*) for analyzed almonds samples (mean ± SD).

	AP1C	APM2	AP3S	AP4M	AP5C	AP6S	AP7C	AP8S	AP9M
*L**	45±2	47±2	47±1	48±2	45±2	47±1	48±2	48±2	48±2
*a**	15.4±0.5	15±1	14.9±0.5	15±1	15.2±0.4	15.0±0.4	15±1	15.0±0.3	14.9±0.4
*b**	30±2	31±2	31±1	31±2	30±1	30±1	30±2	31±1	32±2
Conversion into RGB value									

*L**luminosity; *a** chromatic axis from green (-) to red (+); *b**. chromatic axis from blue (-) to yellow (+). **AP1C:** control almond from block 1, plot 1; **AP2M**: almond intercropped with *Medicago* spp. from block 1, plot 2; **AP3S:** almond intercropped with *Sulla coronaria* from block 1, plot 3; **AP4M:** almond intercropped with *Medicago* spp. from block 2, plot 4; **AP5C:** Control almond from block 2, plot 5; **AP6S:** almond intercropped with *Sulla coronaria* from block 2, plot 6; **AP7C:** Control almond from block 3, plot 7; **AP8S:** almond intercropped with *Sulla coronaria* from block 3, plot 8; **AP9M:** almond intercropped with *Medicago* spp. from block 3, plot 9.

*L** values, indicating lightness on a scale from 0 (black) to 100 (white), ranged narrowly from 45±2 to 48±2. Intercropped samples, particularly those from *Medicago* spp. plots (AP2M, AP4M, AP9M) and Sulla coronaria plots (AP3S, AP6S, AP8S), tended to show slightly higher lightness values compared to the control plots (AP1C: 45±2; AP5C: 45±2; AP7C: 48±2). The *a** parameter, which reflects redness, was the most consistent across treatments, ranging from 14.9±0.4 to 15.4±0.5, with the control AP1C recording the highest value. For the *b** parameter, values ranged from 30±1 to 32±2; AP9M (*Medicago* spp., block 3) showed the highest yellowness (32±2), while control samples AP1C, AP5C, and AP7C remained at 30±1 to 30±2. Overall, colour differences across treatments were small and within the range of natural within-orchard variability, suggesting that intercropping with *Medicago* spp. or *Sulla coronaria* did not substantially alter almond skin colour in the first year of the trial. The slight numerical tendency towards higher *L** in intercropped plots may reflect differences in canopy microclimate or soil water dynamics associated with the cover crops.

Texture Profile Analysis

Texture Profile Analysis (TPA) was conducted using Exponent software, assessing hardness, fracturability, adhesiveness, springiness, cohesiveness, gumminess, chewiness, and resilience. Results are presented in Table 5.

Table 5. Texture evaluation for the almonds harvested in the first year of intercropping in Italy (mean±SD).

	AP1C	AP2M	AP3S	AP4M	AP5C	AP6S	AP7C	AP8S	AP9M
Hardness (g)	39838±7212	37734±4225	42686±6569	40173±5096	40468±3951	41686±6084	42863±3803	40934±4892	42602±2844
Fracturability (g)	27789±6958	27495±5399	26292±8675	26571±9132	27667±6298	28514±4275	30961±6898	25397±6802	32428±4323
Adhesiveness (g/sec)	-4±3	-2±1	-2±1	-2±1	-1.9±0.4	-3±1	-2±1	-2.5±0.5	-2.6±0.4
Springiness (sec)	0.6±0.1	0.56±0.03	0.6±0.1	0.6±0.1	0.7±0.1	0.6±0.1	0.62±0.05	0.62±0.05	0.6±0.1
Cohesiveness (g/sec)	0.4±0.1	0.42±0.04	0.5±0.1	0.4±0.1	0.5±0.1	0.4±0.1	0.46±0.04	0.46±0.04	0.44±0.05
Gumminess (g)	17842±6004	16113±3133	20335±7337	17269±4336	20001±4215	17928±5225	19854±2780	19149±3542	18973±3128
Chewiness (g/sec)	10691±4623	9135±2172	13144±5766	10189±3076	13586±3704	10630±4394	12410±2351	11890±2788	11401±2793
Resilience (g/sec)	0.3±0.1	0.25±0.03	0.3±0.1	0.26±0.04	0.30±0.05	0.3±0.1	0.28±0.03	0.28±0.03	0.27±0.04

Hardness values ranged from 37734±4225 g (AP2M, *Medicago* spp.) to 42863±3803 g (AP7C, control), indicating that the control sample from block 3 was the most resistant to compression. *Sulla coronaria* intercropped samples (AP3S, AP6S, AP8S) showed intermediate hardness values close to or slightly above the overall mean, while *Medicago* spp. samples (AP2M, AP4M, AP9M) were generally comparable to or slightly below the control.

Fracturability, which indicates the ease with which the kernel breaks, was highest in AP9M (*Medicago* spp., 32428±4323 g) and lowest in AP8S (*Sulla coronaria*, 25397±6802 g). Adhesiveness was low and negative across all samples, as expected for dry nut kernels, with no meaningful differences between treatments. Springiness values were similar across the experiment, with AP5C (control, 0.7±0.1 sec) showing the highest recovery after deformation. Cohesiveness was marginally higher in AP3S and AP5C (both 0.5±0.1 g/sec), reflecting stronger internal structural bonding. Gumminess and chewiness followed similar trends, with AP3S (*Sulla coronaria*) and AP5C (control) exhibiting the highest values, suggesting denser, more structurally resistant kernels. Resilience was comparable across all samples (0.25–0.30 g/sec), with no clear differentiation between treatments.

In summary, texture parameters were broadly comparable across the three treatments. The variability observed among blocks within each treatment was of similar magnitude to the differences between treatments, and no consistent effect of intercropping on kernel texture was apparent in Year 1.

Proximate Composition

The proximate composition (including moisture, crude fat, protein, ash, and carbohydrates) and energy content of the nine samples were evaluated and are presented in Table 6. All values are expressed per 100 g of fresh weight (fw).

Table 6. Nutritional profile of almonds produced under different conditions by intercropping systems.

	Moisture (g/100 g fw)	Crude Fat (g/100 g fw)	Proteins (g/100 g fw)	Ash (g/100 g fw)	Carbohydrates (g/100 g fw)	Energy (Kcal/100g	Energy (Kj/100g)
AP1C	5.6±0.1	42±1	17±1	3±1	32.680±0.002	577±3	2414±12
AP2M	5.6±0.1	42±1	18±1	2.866±0.003	31.820±0.003	576±4	2412±18
AP3S	5.2±0.1	43±1	16.3±0.1	2.9±0.1	32.757±0.001	582±10	2435±40
AP4M	5.7±0.1	46±3	17±1	2.862±0.003	28±2	597±14	2498±60
AP5C	5.9±0.1	37±2	16.9±0.1	2.858±0.003	38±2	548±11	2294±46
AP6S	5.7±0.2	47±2	16.1±0.1	2.865±0.004	28±2	601±8	2518±33
AP7C	6.0±0.6	40±1	17±1	3.0±0.1	34±1	567±7	2372±28
AP8S	5.4±0.3	40±2	17±1	3.0±0.2	34±3	569±8	2381±33
AP9M	5.7±0.1	43±3	15.3±0.2	2.862±0.002	33±3	582±14	2435±57

AP1C: control almond from block 1, plot 1; **AP2M**: almond intercropped with *Medicago* spp. from block 1, plot 2; **AP3S:** almond intercropped with *Sulla coronaria* from block 1, plot **AP4M:** almond intercropped with *Medicago* spp. from block 2, plot 4; **AP5C:** Control almond from block 2, plot 5; **AP6S:** almond intercropped with *Sulla coronaria* from block 2, plot 6; **AP7C:** Control almond from block 3, plot 7; **AP8S:** almond intercropped with *Sulla coronaria* from block 3, plot 8; **AP9M:** almond intercropped with *Medicago* spp. from block 3, plot 9.

Moisture content was low across all samples (5.2–6.0 g/100 g fw), consistent with properly dried almond kernels. No systematic difference was observed between intercropped and control plots. Crude fat content showed the greatest variability, ranging from 37±2 g/100 g fw (AP5C, control) to 47±2 g/100 g fw (AP6S, *Sulla coronaria*). Sulla coronaria intercropped plots (AP3S: 43±1; AP6S: 47±2) tended to show numerically higher fat content than the corresponding controls, while *Medicago* spp. plots showed more variable results (AP2M: 42±1; AP4M: 46±3; AP9M: 43±3). However, the high within-treatment variability across blocks precludes any firm conclusions at this stage.

Protein content was relatively consistent across treatments, ranging from 15.3±0.2 g/100 g fw (AP9M) to 18±1 g/100 g fw (AP2M), values in line with published nutritional profiles for Mediterranean almonds. Ash content, reflecting total mineral content, was similar across all plots (2.86–3.0 g/100 g fw), with no evident effect of intercropping. Carbohydrate content varied inversely with fat content, as expected from compositional constraints: AP5C showed the highest carbohydrate value (38±2 g/100 g fw) coinciding with its lowest fat content, while AP4M and AP6S, both with elevated fat, showed the lowest carbohydrate values (28±2 g/100 g fw).

Energy content mirrored fat content, ranging from 548±11 kcal/100 g (AP5C) to 601±8 kcal/100 g (AP6S). Overall, the nutritional composition of all samples falls within the typical range reported for almond cultivars grown under Mediterranean conditions. The numerical trends suggesting higher fat and consequently higher energy, in *Sulla coronaria* intercropped plots are of interest, consistent with the potential role of legume-mediated improvements in soil nitrogen availability on almond lipid accumulation.

Year 2 Intercropping Results

Experimental Design and Sample Identification

Nine almond samples were collected in the second year of intercropping from the same trial site in Licata, Agrigento (37°12'36.34″N, 13°50'37.11″E), comprising a six-year-old irrigated orchard of the Tuono cultivar. The experimental design maintained three blocks, each containing three plots assigned to one of the following treatments: control (soil tillage, no intercropping), intercropping with *Medicago* spp., and intercropping with *Sulla coronaria*. Sample codes followed the same convention as Year 1: **AP1C2** (control, block 1), **AP2M2** (*Medicago* spp., block 1), **AP3S2** (*Sulla coronaria*, block 1), **AP4M2** (*Medicago* spp., block 2), **AP5C2** (control, block 2), **AP6S2** (*Sulla coronaria*, block 2), **AP7C2** (control, block 3), **AP8S2** (*Sulla coronaria*, block 3), and **AP9M2** (*Medicago* spp., block 3).

Colour Analysis

Colour parameters were determined using the CIELAB colour space (*L*, a*, b**) and are presented in Table 7.

Table 7. Colour parameters (L*, a* and b*) for analyzed almonds samples.

	AP1C2	AP2M2	AP3S2	AP4M2	AP5C2	AP6S2	AP7C2	AP8S2	AP9M2
*L**	41±1	41±2	42±2	42±2	41±1	42±2	40±2	41±1	40±1
*a**	12±1	12±1	12.3±0.4	12±1	12±1	12±1	11±1	13±1	11.9±0.2
*b**	18±1	18±1	19±1	19±1	18±1	19±1	18±1	19±1	18.1±0.5
Conversion into RGB value									

*L**luminosity; *a** chromatic axis from green (-) to red (+); *b**. chromatic axis from blue (-) to yellow (+). **AP1C2:** control almond from block 1, plot 1; **AP2M2**: almond intercropped with *Medicago* spp. from block 1, plot 2; **AP3S2:** almond intercropped with *Sulla coronaria* from block 1, plot 3; **AP4M2:** almond intercropped with *Medicago* spp. from block 2, plot 4; **AP5C2:** Control almond from block 2, plot 5; **AP6S2:** almond intercropped with *Sulla coronaria* from block 2, plot 6; **AP7C2:** Control almond from block 3, plot 7; **AP8S2:** almond intercropped with *Sulla coronaria* from block 3, plot 8; **AP9M2:** almond intercropped with *Medicago* spp. from block 3, plot 9.

*L** values ranged from 40±2 (AP7C2, control) to 42±2 (AP6S2, *Sulla coronaria*), indicating low lightness variability across treatments. Intercropped samples showed no systematic trend in lightness relative to control plots. The *a** parameter ranged from 11±1 (AP7C2) to 13±1 (AP8S2, *Sulla coronaria*), with values reflecting moderate redness across all treatments. Yellowness (*b**) ranged from 18±1 (AP7C2) to 19±1 (AP4M2, *Medicago* spp.), with *Medicago* spp. plots in block 2 showing the highest yellowness values.

Compared to Year 1, colour parameters in Year 2 were generally lower in $L*$ and $a*$, consistent with natural annual variation in almond skin pigmentation related to climatic conditions during fruit development. No treatment-related pattern was observed, suggesting that intercropping with either *Medicago* spp. or *Sulla coronaria* did not influence almond skin colour in the second year of the trial.

Texture Profile Analysis

Texture Profile Analysis (TPA) was conducted using Exponent software, assessing hardness, fracturability, adhesiveness, springiness, cohesiveness, gumminess, chewiness, and resilience. Results are presented in Table 8.

Table 8. Texture evaluation for the almonds harvested in the second year of intercropping in Italy.

	AP1C2	AP2M2	AP3S2	AP4M2	AP5C2	AP6S2	AP7C2	AP8S2	AP9M2
Hardness (g)	27318±4288	27573±3896	28685±4562	26164±3543	28030±3130	26087±5571	28767±2228	26083±4852	29409±4228
Fracturability (g)	24573±3659	23707±6257	22951±3320	21374±4950	24322±3843	22653±5790	22395±6703	22810±4055	25055±6088
Springiness (sec)	1±2	0.8±0.1	1±2	0.76±0.04	0.79±0.05	0.8±0.1	0.8±0.1	0.77±0.04	0.81±0.03
Cohesiveness (g/sec)	0.5±0.1	0.5±0.1	0.5±0.1	0.4±0.2	0.3±0.1	0.3±0.1	0.32±0.03	0.4±0.1	0.35±0.02
Gumminess (g)	11903±4494	14501±8067	13724±3420	11439±4871	9703±1676	9749±5165	9352±1425	9754±3187	10604±1887
Chewiness (g/sec)	10981±2889	11748±7878	10192±2773	8837±4116	7645±1353	7469±4235	7541±1162	7575±2689	8571±1752
Resilience (g/sec)	0.3±0.1	0.3±0.1	0.4±0.1	0.3±0.1	0.3±0.1	0.3±0.1	0.3±0.1	0.3±0.1	0.4±0.1

Hardness ranged from 26083±4852 g (AP8S2, Sulla coronaria) to 29409±4228 g (AP9M2, *Medicago* spp.). Control plots showed intermediate and consistent hardness values (AP1C2: 27318±4288 g; AP5C2: 28030±3130 g; AP7C2: 28767±2228 g), while values in intercropped plots were more variable across blocks. Fracturability ranged from 21374±4950 g (AP4M2, Medicago spp.) to 25055±6088 g (AP9M2, *Medicago* spp.), with no clear differentiation between treatments.

Springiness values were broadly similar across all samples (0.76–0.81 sec), with the exception of AP1C2 and AP3S2, which presented higher mean values (1±2 sec) with considerable within-plot variability. Cohesiveness was highest in the *Medicago* spp. and *Sulla coronaria* samples from block 1 (AP1C2, AP2M2, AP3S2: 0.5±0.1 g/sec) and tended to decrease towards block 3, where control and intercropped plots showed values of 0.3–0.4 g/sec. Resilience was comparable across all samples (0.3–0.4 g/sec), with AP3S2 and AP9M2 showing the highest values (0.4±0.1 g/sec).

Gumminess and chewiness were notably higher in the intercropped plots from block 1, AP2M2 (14501±8067 g; 11748±7878 g/sec) and AP3S2 (13724±3420 g; 10192±2773 g/sec), and in the control AP1C2 (11903±4494 g; 10981±2889 g/sec), compared to blocks 2 and 3, where all treatments showed lower and more uniform values. This block-level pattern suggests that soil or microsite conditions in block 1 may have had a greater influence on kernel texture than the intercropping treatment itself.

Overall, texture parameters in Year 2 were lower than those observed in Year 1, which may reflect differences in fruit maturation conditions between years. No consistent treatment effect was apparent across blocks.

Proximate Composition

The proximate composition and energy content of the nine samples are presented in Table 9. All values are expressed per 100 g of fresh weight (fw).

Table 9. Nutritional profile of almonds produced under different conditions by intercropping systems.

	Moisture (g/100 g fw)	Crude Fat (g/100 g fw)	Proteins (g/100 g fw)	Ash (g/100 g fw)	Carbohydrates (g/100 g fw)	Energy (Kcal/100g	Energy (Kj/100g)
AP1C2	5.6±0.5	50±2	14.1±0.4	3.23±0.03	27±2	614±12	2572±49
AP2M	5.5±0.2	44±1	15±1	3±1	32±1	586±2	2452±9
AP3S2	5.3±0.2	45±2	15.06±0.04	3.0±0.3	31±2	593±8	2482±35
AP4M2	4±1	45±3	16±1	3.5±0.3	31±1	593±16	2482±67
AP5C2	5.2±0.1	45±1	16±1	3.0±0.1	30±1	594±7	2487±30
AP6S2	4.9±0.1	44±1	14.8±0.5	3.2±0.2	33±1	590±3	2470±14
AP7C2	5.5±0.3	44±1	15.3±0.2	3.3±0.2	32±1	586±7	2454±31
AP8S2	5.0±0.4	46±3	16±1	3.2±0.2	30±3	597±14	2499±59
AP9M2	5.2±0.1	45±3	17±1	3.1±0.1	30±2	590±13	2470±53

AP1C2: control almond from block 1, plot 1; **AP2M2**: almond intercropped with *Medicago* spp. from block 1, plot 2; **AP3S2:** almond intercropped with *Sulla coronaria* from block 1, plot **AP4M2:** almond intercropped with *Medicago* spp. from block 2, plot 4; **AP5C2:** Control almond from block 2, plot 5; **AP6S2:** almond intercropped with *Sulla coronaria* from block 2, plot 6; **AP7C2:** Control almond from block 3, plot 7; **AP8S2:** almond intercropped with *Sulla coronaria* from block 3, plot 8; **AP9M2:** almond intercropped with *Medicago* spp. from block 3, plot 9.

Moisture content was low and consistent across all samples, ranging from 4±1 g/100 g fw (AP4M2, Medicago spp.) to 5.6±0.5 g/100 g fw (AP1C2, control), in line with values expected for properly dried almond kernels. Crude fat content was highest in AP1C2 (control, 50±2 g/100 g fw) and lowest in AP2M2 and AP7C2 (both 44±1 g/100 g fw), with intercropped samples generally showing lower or similar fat values compared to the control plots. AP8S2 (*Sulla coronaria*) was the exception, presenting a slightly elevated fat content (46±3 g/100 g fw).

Protein content ranged from 14.1±0.4 g/100 g fw (AP1C2, control) to 17±1 g/100 g fw (AP9M2, *Medicago* spp.). Intercropped plots tended to show higher protein values than controls, particularly Medicago spp. plots (AP2M2: 15±1; AP4M2: 16±1; AP9M2: 17±1 g/100 g fw), which may reflect enhanced nitrogen availability in the soil promoted by legume root activity. Ash content was similar across all treatments, ranging from 3±1 g/100 g fw (AP2M2) to 3.5±0.3 g/100 g fw (AP4M2), indicating no meaningful effect of intercropping on total mineral content.

Carbohydrate content varied inversely with fat content: AP1C2, with the highest fat, showed the lowest carbohydrate value (27±2 g/100 g fw), while AP6S2 (*Sulla coronaria*) presented the highest carbohydrate content (33±1 g/100 g fw) alongside one of the lowest fat values. Energy content followed fat content closely, ranging from 586±2 kcal/100 g (AP2M2 and AP7C2) to 614±12 kcal/100 g (AP1C2). The elevated energy value of AP1C2 is directly attributable to its higher fat content. Overall, the nutritional composition of all samples falls within the typical range for Mediterranean almonds, and the trend of higher protein in *Medicago* spp. intercropped plots observed in Year 1 was maintained in Year 2.

3. Morocco

Year 1 Intercropping Results

Experimental Design and Sample Identification

Twenty-seven samples were received from Morocco, including 9 samples of almonds, 6 of lentils and 12 samples of fava beans. The almonds were identified as a) Azilal Control Almond Block 1 (**BCA1**) (31°56'42 N, 6°35'50 W), b) Azilal Control Almond Block 2 (**BCA2**), c) Azilal Control Almond Block 3 (**BCA3**), d) Azilal Intercrop Almond with Fava Bean Block 1 (**BIAF1**), e) Azilal Intercrop Almond with Fava Bean Block 2 (**BIAF2**), f) Azilal Intercrop Almond with Fava Bean Block 3 (**BIAF3**), g) Azilal Intercrop Almond with Lentil Block 1 (**BIAL1**), h) Azilal Intercrop Almond with Lentil Block 2 (**BIAL2**) and i) Azilal Intercrop Almond with Lentil Block 3 (**BIAL3**). Regarding the lentils, they were identified as a) Taoujdate Intercrop Lentil Block 1 (**TIL1**) (33°56'11 N, 5°09'32W), b) Taoujdate Intercrop Lentil Block 2 (**TIL2**), c) Taoujdate Intercrop Lentil Block 3 (**TIL3**), d) Taoujdate Control Lentil Block 1 (**TCL1**), e) Taoujdate Control Lentil Block 2 (**TCL2**) and f) Taoujdate Control Lentil Block 3 (**TCL3**). As for the fava beans, they were named as a) Taoujdate Intercrop Fava bean Block 1 (**TIF1**), b) Taoujdate Intercrop Fava bean Block 2 (**TIF2**), c) Taoujdate Intercrop Fava bean Block 3 (**TIF3**), d) Taoujdate Control Fava bean Block 1 (**TCF1**), e) Taoujdate Control Fava bean Block 2 (**TCF2**), f) Taoujdate Control Fava bean Block 3 (**TCF3**), g) Azilal Intercrop Fava bean Block 1 (**BIF1**), h) Azilal Intercrop Fava bean Block 2 (**BIF2**), i) Azilal Intercrop Fava bean Block 3 (**BIF3**), j) Azilal Control Fava bean Block 1 (**BCF1**), k) Azilal Control Fava bean Block 2 (**BCF2**) and l) Azilal Control Fava bean Block 3 (**BCF3**).

Colour Analysis

The colour of the almonds was measured in triplicate for each group of samples, and the results of the colour parameters (L^*, a^* and b^*) in the almonds cultivated in intercropping with lentils and fava beans are shown in Table 10. The data indicated that intercropping did not result in significant changes in the colour parameters of the almonds. However, it was observed that the almonds in the control group were slightly darker in colour compared to the others (Figure 1-3).

Table 10. Colour parameters (L*, a* and b*) for analyzed almonds samples.

	BCA1	BCA2	BCA3	BIAF1	BIAF2	BIAF3	BIAL1	BIAL2	BIAL3
L^*	44±1	41±2	42±2	45±4	45±4	45±3	46±5	49±4	49±2
a^*	14±1	14±1	15±1	16±1	15±1	15±1	14±1	14±1	15±1
b^*	23±1	22±1	24±1	27±2	26±3	26±3	26±3	28±3	28±3
Conversion into RGB value									

L^*luminosity; a^* chromatic axis from green (-) to red (+); b^*, chromatic axis from blue (-) to yellow (+).

Figure 1. Azilal control almonds from blocks 1, 2 and 3.

Figure 2. Azilal intercrop almond with fava bean from blocks 1, 2 and 3.

Figure 3. Azilal intercrop almond with lentil from blocks 1, 2 and 3.

The results showed that the lentils intercropped with almonds had more light-coloured grains compared to the control (Table 11) (Figure 4 and 5).

Table 11. Colour parameters (L*, a* and b*) for analyzed lentils samples

	TCL1	TCL2	TCL3	TIL1	TIL2	TIL3
*L**	53±4	54±3	55±3	60±3	61±3	61±2
*a**	5±2	6±2	6±2	2±1	1±1	2±1
*b**	23±1	24±1	23±1	24±1	25±1	24±1
Conversion into RGB value						

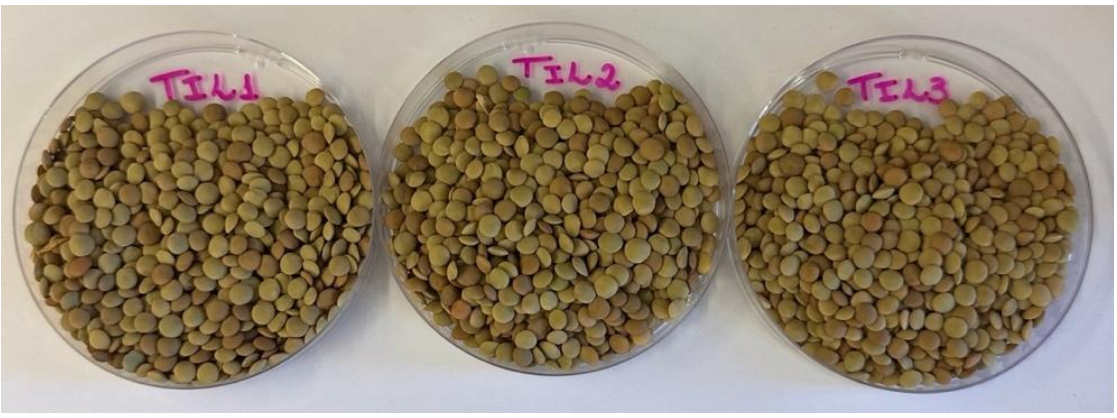

Figure 4. Taoujdate Intercrop lentil from blocks 1, 2 and 3.

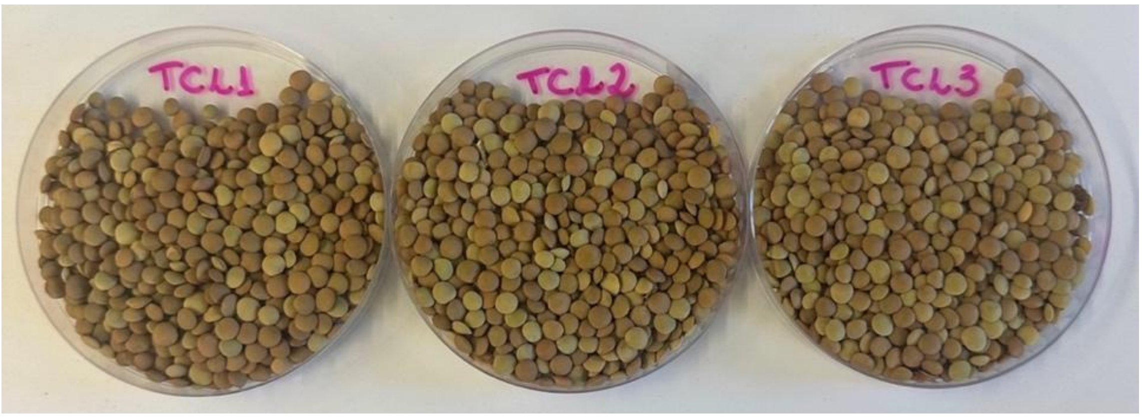

Figure 5. Taoujdate control lentil from blocks 1, 2 and 3.

Regarding favas, the results showed that the favas intercropped with almonds located in Taoujdate had lighter grains than the others (Table 12 and 13) (Figure 6 to 9).

Table 12. Colour parameters (L*, a* and b*) for control and intercropped fava beans in the Azilal region evaluated in different blocks.

	BIF1	BIF2	BIF3	BCF1	BCF2	BCF3
*L**	46±3	54±4	45±6	45±4	52±6	51±6
*a**	9±2	4±3	5±4	9±3	-0.3±6.8	2±3
*b**	26±3	26±2	27±3	26±2	42±4	26±10
Conversion into RGB value						

Table 13. Colour parameters (L*, a* and b*) for control and intercropped fava beans in the Taoujdate region evaluated in different blocks.

	TCF1	TCF2	TCF3	TIF1	TIF2	TIF3
*L**	58±3	55±4	58±6	56±6	55±4	54±3
*a**	4±4	5±4	4±7	3±3	4±4	6±7
*b**	28±1	27±1	27±2	25±2	27±1	28±2
Conversion into RGB value						

Figure 6. Azilal Intercrop fava bean from blocks 1, 2 and 3.

Figure 7. Azilal control fava bean from blocks 1, 2 and 3.

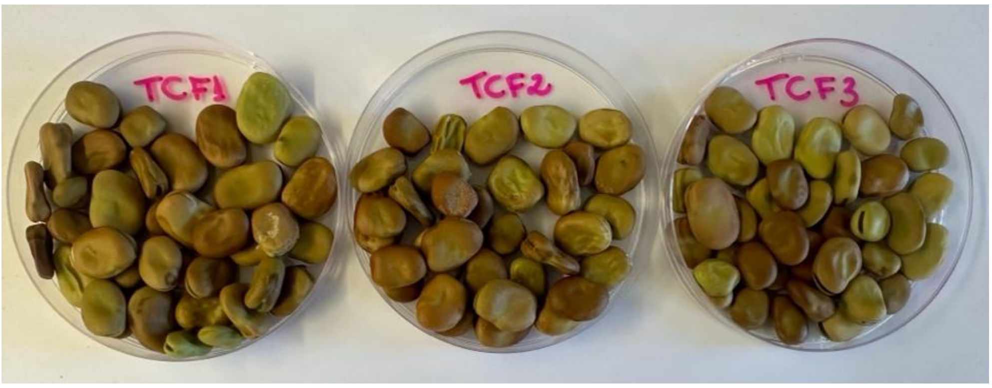

Figure 8. Taoujdate control fava bean from blocks 1, 2 and 3.

Figure 9. Taoujdate Intercrop Fava bean from blocks 1, 2 and 3.

Texture Profile Analysis

Regarding to the texture profile, the Hardness values ranged from 14.769 g to 26.030 g. The highest value was observed for BIAF2, indicating this samples had the greatest resistance to deformation. Conversely, BIAL3 showed the lowest hardness, indicating a softer texture. Samples BCA1–BCA3 and BIAF1 presented intermediate values. Fracturability followed a similar trend. BIAF3 required the greatest force to fracture, while BIAF1 was the most fragile. BCA and BIAL samples showed moderate fracturability. All samples exhibited low adhesiveness values (approximately -2 g/sec), suggesting minimal stickiness. Notably, BIAF3 was slightly less adhesive (-1 g/sec), which may contribute to improved mouthfeel. In terms of springiness, BCA2 and BCA3 showed the highest values (0.6 sec), indicating better ability to return to original shape after deformation. The lowest springiness was recorded for BIAL1 (0.4 sec).

Cohesiveness was highest in BIAF1 and BIAF2 (0.4 g/sec), reflecting stronger internal bonding. BIAL3 had the lowest cohesiveness (0.26 g/sec), suggesting a more crumbly or less uniform structure. Gumminess was most pronounced in BIAF2 (10.221 g), implying a denser and more compact texture. On the other hand, BIAL3 was the least gummy (3.825 g), aligning with its lower hardness and cohesiveness. Chewiness values indicated that BIAF2 required the most chewing effort (6.431 g/sec), while BIAL3 was easiest to chew (1.998 g/sec). Intermediate chewiness was observed in BCA3 and BIAF1. Finally, resilience, which reflects the sample's ability to recover after compression, was highest in BIAF2 (0.21 g/sec) and lowest in BIAL3 (0.15 g/sec). In summary, BIAF2 demonstrated the most desirable texture characteristics in terms of firmness, cohesion, and chewability, making it potentially more acceptable from a sensory standpoint. In contrast, BIAL3 exhibited the lowest values in most parameters, indicating a significantly softer and less cohesive texture. The BCA samples generally showed intermediate behaviour, depending on the parameter considered. The results were analysed by Exponent software and presented in Table 14.

Table 14. Texture evaluation for the almonds harvested in the first year of intercropping in Morocco.

	BCA1	BCA2	BCA3	BIAF1	BIAF2	BIAF3	BIAL1	BIAL2	BIAL3
Hardness (g)	20734±2732	20406±3168	22128±4587	21976±3326	26030±6846	25328±4190	18439±4387	21882±2392	14769±2030
Fracturability (g)	15567±4824	14311±2753	15549±5115	11918±2142	16739±6675	18571±4986	14564±3992	15818±4392	12609±3138
Adhesiveness (g/sec)	-2±1	-2±1	-2±2	-2±1	-2±1	-1±1	-2±1	-2±1	-2±2
Springiness (sec)	0.51±0.04	0.6±0.1	0.6±0.2	0.6±0.1	0.6±0.1	0.6±0.1	0.4±0.1	0.5±0.1	0.51±0.14
Cohesiveness (g/sec)	0.31±0.04	0.30±0.05	0.3±0.1	0.34±0.05	0.4±0.1	0.4±0.1	0.3±0.1	0.33±0.03	0.26±0.02
Gumminess (g)	6534±1573	6254±1957	7325±2296	7630±2139	10221±5162	9160±2566	5179±2068	7348±1373	3825±807
Chewiness (g/sec)	3362±881	3681±1049	4305±1519	4271±1518	6431±4325	5310±1413	2398±1112	3924±955	1998±771
Resilience (g/sec)	0.18±0.03	0.16±0.03	0.18±0.04	0.19±0.03	0.21±0.05	0.20±0.04	0.16±0.04	0.19±0.02	0.15±0.02

Proximate Composition

Concerning the nutritional composition of the almond harvest from the first year of intercropping, the moisture content ranged from 4.0±0.1 g/100 g fw (BIAL2) to 4.8±0.2 g/100 g fw (BIAF3), indicating low water activity and high preservation stability (**Table 15**). Crude fat was the most abundant component, varying between 42±2 g/100 g fw (BIAL2) and 47.58±0.01 g/100 g fw (BCA3), confirming almonds' richness in lipids.

Protein content remained relatively stable across samples, with values ranging from 12.5±0.2 g/100 g fw (BIAL3) to 14.0±0.1 g/100 g fw (BCA1 and BCA3). Ash content ranged from 3.0±0.1 g/100 g fw in most samples to 3.4±0.2 g/100 g fw (BCA2), reflecting consistent mineral content. Carbohydrate content varied more substantially, from 30.91±0.02 g/100 g fw (BCA3) to 38±2 g/100 g fw (BIAL2), likely influenced by natural compositional variability. As a result, energy values ranged between 582±11 Kcal/100 g (BIAL2) and 608±1 Kcal/100 g (BCA3).

These data confirm that the almond samples analyzed are nutritionally dense, with high lipid and protein content and relatively low moisture, making them suitable for long-term storage and energetic intake.

Table 15. Nutritional profile of almonds produced under different conditions by intercropping systems.

	Moisture (g/100 g fw)	Crude Fat (g/100 g fw)	Proteins (g/100 g fw)	Ash (g/100 g fw)	Carbohydrates (g/100 g fw)	Energy (Kcal/100g	Energy (Kj/100g)
BCA1	4.7±0.3	44±2	14.0±0.1	3.1±0.1	34.1±0.1	589±7	2465±31
BCA2	4.7±0.1	45.4±0.3	13.8±0.3	3.4±0.2	32.8±0.2	595±3	2489±11
BCA3	4.4±0.2	47.58±0.01	14.0±0.1	3.0±0.1	30.91±0.02	608±1	2545±3
BIAL1	4.2±0.1	44±1	13.4±0.3	3.0±0.1	35±1	593±6	2483±27
BIAL2	4.0±0.1	42±2	13.14±0.02	3.08±0.02	38±2	582±11	2439±45
BIAL3	4.1±0.1	45±1	12.5±0.2	3.1±0.1	35±1	597±5	2501±20
BIAF1	4.2±0.2	45±1	13.4±0.3	3.0±0.1	34±1	598±5	2503±21
BIAF2	4.7±0.3	43±1	13.0±0.3	3.0±0.1	36±1	586±1	2453±3
BIAF3	4.8±0.2	47±2	13.3±0.1	3.0±0.1	32±2	603±9	2525±39

BCA1: Azilal Control Almond Block 1; **BCA2:** Azilal Control Almond Block 2; **BCA3:** Azilal Control Almond Block 3; **BIAL1:** Azilal Intercrop Almond with Lentil Block 1; **BIAL2:** Azilal Intercrop Almond with Lentil Block 2, **BIAL3:** Azilal Intercrop Almond with Lentil Block 3; **BIAF1:** Azilal Intercrop Almond with Fava Bean Block 1; **BIAF2:** Azilal Intercrop Almond with Fava Bean Block 2; **BIAF3:** Azilal Intercrop Almond with Fava Bean Block 3.

The proximate composition of the lentil samples, both control (TCL) and those intercropped with almond trees (TIL), showed some variations. Moisture ranged from 10.3 to 10.7g/100 g fw, slightly higher than expected for dry pulses, which may affect shelf stability. Fat content was low (0.79 to 0.99g/100 g fw), below typical values for lentils (**Table 16**). Protein levels ranged from 16.0 to 18.6g/100 g fw, with a tendency to be lower in the intercropped samples, suggesting a possible effect of intercropping on this parameter.

Ash content (2.1 to 3.1g/100 g fw) was slightly elevated in some samples, indicating higher mineral concentration. Carbohydrates were the main component (67.1 to 70.6g/100 g fw), contributing to a high energy value (350 to 354Kcal/100 g). Overall, the data suggest that intercropping with almond trees may slightly influence the nutritional profile of lentils, particularly in terms of protein and mineral content.

Table 16. Nutritional profile of control lentils and lentils cultivated with almonds produced in the first year of intercropping.

	Moisture (g/100 g fw)	Crude Fat (g/100 g fw)	Proteins (g/100 g fw)	Ash (g/100 g fw)	Carbohydrates (g/100 g fw)	Energy (Kcal/100g	Energy (Kj/100g)
TCL1	10.4±0.2	0.98±0.01	18.6±0.3	2.3±0.1	67.8±0.2	354.4±0.3	1484±1
TCL2	10.7±0.3	0.91±0.05	18.0±0.2	2.64±0.04	67.8±0.3	351±1	1470±4
TCL3	10.4±0.4	0.787 ±0.002	18.6±0.5	3.1±0.1	67.1±0.3	350±2	1465±8
TIL1	10.3±0.3	0.86±0.04	16.2±0.4	2.3±0.1	70±1	354±2	1482±6
TIL2	10.4±0.2	0.99±0.04	16±1	2.31±0.05	70.6±0.4	354±1	1483±4
TIL3	10.4±0.3	0.84±0.01	16.12±0.02	2.1±0.1	70.5±0.3	354±1	1482±6

TCL1: Taoujdate Control Lentil Block 1; **TCL2**: Taoujdate Control Lentil Block 2; **TCL3:** Taoujdate Control Lentil Block 3; **TIL1:** Taoujdate Intercrop Lentil Block 1; **TIL2:** Taoujdate Intercrop Lentil Block 2; **TIL3:** Taoujdate Intercrop Lentil Block 3.

The proximate composition of faba bean samples, including both control groups (BCF and TCF) and those intercropped with almond trees (BIF and TIF), exhibited comparable nutritional characteristics. Moisture content ranged from 9.6 to 11.0g/100 g fresh weight, indicating a typical low water activity for dry legumes (**Table 17**). Crude fat content was low across all samples (0.94 to 1.2 g/100 g fw), as expected for faba beans.

Protein content was relatively high, varying between 17.6 and 21.0g/100 g fw. Control samples (especially TCF1 and TCF2) showed slightly higher protein values compared to some intercropped samples. TIF1 presented the highest protein content among all intercropped samples. Ash content ranged from 2.69 to 3.45 g/100 g fw, with no significant differences between treatments. Carbohydrates were the predominant component, ranging from 64 to 67.9 g/100 g fw, contributing to similar energy values across all samples (349-354 Kcal/100 g). In summary, intercropping with almond trees did not lead to major changes in the proximate composition of faba beans, although minor variations in protein and ash content were observed.

Table 17. Nutritional profile of control favas and favas cultivated with almonds produced in the first year of intercropping.

	Moisture (g/100 g fw)	Crude Fat (g/100 g fw)	Proteins (g/100 g fw)	Ash (g/100 g fw)	Carbohydrates (g/100 g fw)	Energy (Kcal/100g	Energy (Kj/100g)
BCF1	9.6±0.4	1.10±0.04	19.0±0.1	3.3±0.1	67±1	354±2	1482±8
BCF2	11±1	1.08±0.04	19.3±0.4	3.1±0.1	65±1	349±2	1459±10
BCF3	10±1	1.13±0.05	18.0±0.1	3.45±0.01	67±1	351±2	1471±10
BIF1	10.1±0.3	1.1±0.1	17.6±04	3.35±0.02	67.9±0.2	352±1	1472±4
BIF2	10.4±0.4	1.2±0.1	17.6±0.3	3.3±0.1	67.5±0.3	351±1	1468±4
BIF3	9.6±0.4	1.1±0.1	18.0±0.1	3.40±0.01	67.9±0.5	354±1	1481±6
TCF1	10.8±0.3	0.95±0.02	21.0±0.2	3.13±0.02	64±1	349±1	1462±5
TCF2	10.7±0.3	1.00±0.02	20.0±0.1	3.12±0.01	65.2±0.2	350±1	1465±6
TCF3	10.7±0.2	0.94±0.03	19.7±0.4	3.1±0.1	65.5±0.5	349±1	1462±3
TIF1	10.2±0.2	0.99±0.05	20.2±0.5	3.1±0.2	65±1	352±1	1472±2
TIF2	10.4±0.3	1.02±0.01	18.5±0.4	2.69±0.02	67±1	353±1	1477±4
TIF3	10.2±0.2	0.97±0.03	19.6±0.5	2.7±0.1	67±1	353±1	1479±5

BCF1: Azilal Control Fava bean Block 1; **BCF2:** Azilal Control Fava bean Block 2; **BCF3:** Azilal Control Fava bean Block 3; **BIF1:** Azilal Intercrop Fava bean Block 1; **BIF2:** Azilal Intercrop Fava bean Block 2 **BIF3:** Azilal Intercrop Fava bean Block 3; **TCF1:** Control Fava bean Block 1; **TCF2:** Taoujdate Control Fava bean Block 2; **TCF3:** Taoujdate Control Fava bean Block 3; **TIF1:** Taoujdate Intercrop Fava bean Block 1; **TIF2:** Taoujdate Intercrop Fava bean Block 2; **TIF3:** Taoujdate Intercrop Fava bean Block 3; Taoujdate.

Year 2 Intercropping Results

Experimental Design and Sample Identification

For the second year of intercropping, twenty-seven samples were received from Morocco, including 11 samples of almonds, 6 of lentils and 10 samples of fava beans. The almonds were identified as a) Azilal Control Almond (**BCA**) (31°56'42 N, 6°35'50 W), b) Taoujdate Intercrop Almond with Fava Bean Block 1 (**AIAF1**), c) Taoujdate Intercrop Almond with Fava Bean Block 2 (**AIAF2**), d) Taoujdate Intercrop Almond with Fava Bean Block 3 (**AIAF3**), e) Taoujdate Intercrop Almond with Lentil Block 1 (**AIAL1**), f) Taoujdate Intercrop Almond with Lentil Block 2 (**AIAL2**) , g) Azilal Intercrop Almond with Lentil Block 3 (**AIAL3**) and h) Azilal Intercrop Almond with Fava Bean (**BIAF**). Regarding the lentils, they were identified as a) Taoujdate Intercrop Lentil Block 1 (**TIL1**) (33°56'11 N, 5°09'32W), b) Taoujdate Intercrop Lentil Block 2 (**TIL2**), c) Taoujdate Intercrop Lentil Block 3 (**TIL3**), d) Taoujdate Control Lentil Block 1 (**TCL1**), e) Taoujdate Control Lentil Block 2 (**TCL2**) and f) Taoujdate Control Lentil Block 3 (**TCL3**).

As for the fava beans, they were named as a) Taoujdate Intercrop Fava bean Block 1 (**TIF1**), b) Taoujdate Intercrop Fava bean Block 2 (**TIF2**), c) Taoujdate Intercrop Fava bean Block 3 (**TIF3**), d) Taoujdate Control Fava bean Block 1 (**TCF1**), e) Taoujdate Control Fava bean Block 2 (**TCF2**), f) Taoujdate Control Fava bean Block 3 (**TCF3**), g) Azilal Intercrop Fava bean Block 1 (**BIF1**), h) Azilal Intercrop Fava bean Block 2 (**BIF2**), i) Azilal Intercrop Fava bean Block 3 (**BIF3**) and j) Azilal Control Fava bean (**BCF**).

Colour Analysis

The colour of the almonds was measured in triplicate for each group of samples, and the results of the colour parameters (*L**, *a** and *b**) in the almonds cultivated in intercropping with lentils and fava beans are shown in **Table 18.** The data indicated that intercropping did not result in significant changes in the colour parameters of the almonds.

Table 18. Colour parameters (L*, a* and b*) for analyzed almonds samples.

	ACA1	ACA2	ACA3	AIAL1	AIAL2	AIAL3	AIAF1	AIAF2	AIAF3	BCA	BIAF
*L**	40±2	38±1	39±2	41±1	37±1	38±2	39±2	41±2	39±2	40±1	38±2
*a**	13±1	12±1	13±1	13±1	13±1	12±1	12±1	13.5±0.4	12±1	10.9±0.4	10±1
*b**	17±1	16±1	18±1	18±1	16±1.0	16±1	17±1	18±1	17±1	16±1	15±1
Conversion into RGB value											

*L**luminosity; *a** chromatic axis from green (-) to red (+); *b**, chromatic axis from blue (-) to yellow (+).

Texture Profile Analysis

The control group, consisting of samples BCA, ACA1, ACA2, and ACA3, showed significant variation among themselves (**Table 19**). The BCA sample (Azilal Control Almond) stood out with the highest values for hardness (36856 g), fracturability (27186 g), and adhesiveness (-4 g/s), indicating a firmer, more cohesive, and adhesive texture. The ACA samples showed a progressive reduction in these parameters, with ACA3 presenting the lowest hardness (13777 g) and chewiness (1940 g/s), suggesting a softer and less cohesive texture. The samples intercropped with lentils (AIAL1, AIAL2, and AIAL3) exhibited a softer texture compared to the control group. Among them, AIAL2 was the softest, with reduced values for hardness, gumminess, and cohesiveness. AIAL3, while still softer than the control, displayed characteristics closer to BCA, with intermediate values of hardness and elasticity.

The samples intercropped with fava beans (AIAF1, AIAF2, AIAF3, and BIAF) were generally firmer and more chewable. The BIAF sample (Azilal Intercrop Almond with Fava Bean) stood out from all samples, presenting the highest values for hardness (37639 g), cohesiveness (0.43), gumminess (16167 g), and chewiness (10854 g/sec), as well as high springiness (0,7 sec). These results indicate a dense, cohesive, and elastic texture. The AIAF samples (Taoujdate with fava) showed intermediate performance, with good elasticity and cohesiveness, but slightly lower than BIAF.

In summary, the control samples exhibited greater variability, with BCA serving as the reference for firmness and adhesiveness. Almonds intercropped with lentils showed softer and less cohesive textures, whereas those intercropped with fava beans, particularly BIAF, demonstrated the most intense and consistent textural properties, indicating greater mechanical resistance and chewability.

Table 19. Texture evaluation for the almonds harvested on the second year of intercropping in Morocco.

Samples	Hardness (g)	Fracturability (g)	Adhesiveness (g/sec)	Springiness (sec)	Cohesiveness (g/sec)	Gumminess (g)	Chewiness (g/sec)	Resilience (g/sec)
BCA	36856±2687	27186±7254	-4±4	0.66±0.03	0.41±0.03	15134±2145	9964±1629	0.25±0.03
ACA1	30878±9109	24214±9455	-1±1	0.66±0.03	0.3±0.1	11566±5178	7636±3397	0.2±0.1
ACA2	21211±7071	17972±4537	-1.4±0.3	0.6±0.1	0.2±0.1	5637±3764	3455±2560	0.1±0.1
ACA3	13777±12092	19679±5715	-2±1	0.6±0.1	0.26±0.05	3573±3390	1940±1847	0.14±0.03
AIAL1	26823±4046	20579±5282	-1±1	0.55±0.05	0.31±0.03	8335±1846	4641±1394	0.17±0.02
AIAL2	19423±6648	17616±6861	-1±1	0.6±0.1	0.2±0.1	5058±3112	2878±1851	0.12±0.05
AIAL3	31458±4323	24473±4529	-1.7±0.3	0.6±0.1	0.34±0.05	10988±2817	6866±2035	0.20±0.03
AIAF1	33336±8748	24757±6513	-1.8±0.4	0.6±0.1	0.37±0.01	13615±6596	9277±5648	0.2±0.1
AIAF2	32076±5629	25582±6431	-1.6±0.4	0.57±0.04	0.3±0.1	11137±3476	6409±2331	0.19±0.04
AIAF3	30367±9433	22804±7846	-2±1	0.6±0.1	0.3±0.1	10812±5015	6778±3433	0.20±0.04
BIAF	37639±3112	28043±7550	-2±1	0.7±0.1	0.43±0.04	16167±2370	10854±2169	0.25±0.03

BCA: Azilal Control Almond; **AIAF1:** Taoujdate Intercrop Almond with Fava Bean Block 1; **AIAF2:** Taoujdate Intercrop Almond with Fava Bean Block 2; **AIAF3:** Taoujdate Intercrop Almond with Fava Bean Block 3; **AIAL1:** Taoujdate Intercrop Almond with Lentil Block 1; **AIAL2:** Taoujdate Intercrop Almond with Lentil Block 2; **AIAL3:** Azilal Intercrop Almond with Lentil Block 3; **BIAF:** Azilal Intercrop Almond with Fava Bean.

In terms of nutritional composition, the moisture content ranged from 4.2% to 4.7%, showing consistency in the drying and preservation processes (**Table 20**). Sample ACA3 had the lowest moisture level (4.21 ± 0.03%), while AIAF1, ACA1, and AIAF3 recorded the highest values (4.7%). Regarding crude fat, the samples intercropped with lentils, especially AIAL3 (46.8 g/100 g), and some with fava beans (AIAF1 and AIAF3 with 46 g/100 g) showed the highest fat contents, reflecting high energy potential. On the other hand, AIAF2 and BIAF exhibited the lowest fat levels (38 g/100 g), suggesting a possible influence of intercropping on lipid composition. Protein content varied from 15.8 g/100 g (ACA3) to 17.9 g/100 g (ACA2), with overall high levels across all samples, highlighting almonds as a rich protein source. Differences between groups were not substantial. Ash content ranged from 2.7 g to 3.7 g/100 g. Samples intercropped with fava beans (AIAF1 and AIAF3) showed the highest values (3.7 g), which may indicate a higher concentration of minerals. Carbohydrate levels showed more notable variation, with AIAF2 and BIAF presenting the highest amounts (38 g/100 g), while AIAL1 had the lowest (28.5 g/100 g). This parameter strongly influences the overall energy value. The caloric value ranged from 561 to 604 Kcal/100 g. Sample AIAL3 had the highest energy value (604 Kcal), supported by its high fat and carbohydrate content. In contrast, BIAF showed the lowest energy value (561 Kcal), corresponding with its lower fat content.

Table 20. Nutritional profile of control almonds and almonds intercropped with fava beans and lentils produced on the second year of intercropping.

	Moisture (g/100 g fw)	Crude Fat (g/100 g fw)	Proteins (g/100 g fw)	Ash (g/100 g fw)	Carbohydrates (g/100 g fw)	Energy (Kcal/100g	Energy (Kj/100g)
BCA	4.5±0.1	46±2	16.2±0.2	2.7±0.2	30.75±0.03	600±10	2512±42
ACA1	4.7±0.1	45.5±0.2	16.48±0.02	3.5±0.1	29.9±0.1	595±2	2490±7
ACA2	4.6±0.1	39.2±0.3	17.90±0.03	3.11±0.03	35.3±0.1	565±2	2367±9
ACA3	4.21±0.03	44.4±0.1	15.8±0.3	2.8±0.1	32.8±0.3	594±1	2486±4
AIAL1	4.6±0.1	46.4±0.2	17.4±0.1	3.1±0.1	28.5±0.5	601±1	2517±2
AIAL2	4.2±0.1	44.9±0.4	17±1	3.0±0.1	31.2±0.1	596±2	2495±7
AIAL3	4.42±0.04	46.8±0.4	17±1	3.1±0.1	28.8±0.2	604±2	2529±7
AIAF1	4.7±0.3	46±3	17±1	3.7±0.4	29±4	593±1	2483±6
AIAF2	4.5±0.1	38±2	17.1±0.3	2.84±0.03	38±2	573±1	2398±3
AIAF3	4.7±0.1	46±2	16.98±0.04	3.7±0.1	29±2	594±7	2486±29
BIAF	4.5±0.1	38±2	17.1±0.3	2.84±0.03	38±2	561±8	2348±35

BCA: Azilal Control Almond; **AIAF1:** Taoujdate Intercrop Almond with Fava Bean Block 1; **AIAF2:** Taoujdate Intercrop Almond with Fava Bean Block 2; **AIAF3:** Taoujdate Intercrop Almond with Fava Bean Block 3; **AIAL1:** Taoujdate Intercrop Almond with Lentil Block 1; **AIAL2:** Taoujdate Intercrop Almond with Lentil Block 2; **AIAL3:** Azilal Intercrop Almond with Lentil Block 3; **BIAF:** Azilal Intercrop Almond with Fava Bean.

With regard to the nutritional composition of the lentils in the second year of production, the moisture content varied slightly among samples, ranging from 10.7% to 11.6% (Table 21). Intercropped samples (TIL) generally had slightly higher moisture levels compared to control samples (TCL), with TIL1 showing the highest moisture content (11.6%). Crude fat content remained low in all samples, with values between 0.63 g and 0.85 g/100 g, with intercropped lentils (TIL) exhibiting slightly higher fat levels than control samples, which may be due to interspecific interactions affecting lipid accumulation. Protein content ranged from 15.1 g to 18.1 g/100 g. Control sample TCL3 recorded the highest protein concentration (18.1 g), while TIL1 had the lowest (15.1 g), suggesting that intercropping may influence protein synthesis. Ash content showed some variability, with control samples presenting higher values (up to 3.09 g in TCL1), while TIL2 exhibited the lowest ash content (1.96 g), indicating a possible reduction in mineral concentration under intercropping. Carbohydrate content was relatively stable across all samples, ranging from 67.3 g to 69.8 g/100 g, with energy values consistently ranging from 346.6 to 350.4 kcal/100 g (1451 to 1467 kJ/100 g).

Table 21. Nutritional profile of control lentils and lentils cultivated with almonds produced on the second year of intercropping.

	Moisture (g/100 g fw)	Crude Fat (g/100 g fw)	Proteins (g/100 g fw)	Ash (g/100 g fw)	Carbohydrates (g/100 g fw)	Energy (Kcal/100g)	Energy (Kj/100g)
TCL1	10.8±0.2	0.63±0.02	17.5±0.3	3.09±0.03	68.0±0.3	347±1	1455±4
TCL2	10.7±0.4	0.69±0.04	17.8±0.3	2.78±0.01	68±1	350±2	1464±7
TCL3	11.2±0.1	0.66±0.03	18.1±0.3	2.742±0.002	67.3±0.2	347.6±0.4	1455±2
TIL1	11.6±0.1	0.8±0.1	15.1±0.2	2.7±0.1	69.8±0.2	346.6±0.4	1451±2
TIL2	11.50±0.03	0.85±0.04	16.2±0.2	1.96±0.05	69.5±0.1	350.4±0.3	1467±1
TIL3	11.5±0.2	0.8±0.1	16.7±0.2	2.4±0.1	68.6±1	348±1	1458±3

TCL1: Taoujdate Control Lentil Block 1; **TCL2**: Taoujdate Control Lentil Block 2; **TCL3:** Taoujdate Control Lentil Block 3; **TIL1:** Taoujdate Intercrop Lentil Block 1; **TIL2:** Taoujdate Intercrop Lentil Block 2; **TIL3:** Taoujdate Intercrop Lentil Block 3.

The proximate composition of fava bean samples from Taoujdate and Azilal, under intercropping and control conditions, was evaluated to assess the impact of location and cultivation practices. Azilal samples showed lower moisture content (8.8-9.4%) compared to Taoujdate samples (11.2-12%). Fat content was consistently low across all samples (0.83-0.94 g/100g) (Table 22). Protein levels were highest in Azilal intercrop samples (up to 24.07 g/100g), while Taoujdate samples had lower protein content (18.24-21 g/100g). Ash content was higher in Taoujdate samples (3.49-3.57 g/100g), suggesting differences in mineral content. Carbohydrates were the major component in all samples (62.7-66%), resulting in similar energy values ranging from 344 to 357 Kcal/100g. Overall, location and cropping system influenced protein and mineral content, while fat and carbohydrate levels remained stable.

Table 22. Nutritional profile of control favas and favas cultivated with almonds produced on the second year of intercropping.

	Moisture (g/100 g fw)	Crude Fat (g/100 g fw)	Proteins (g/100 g fw)	Ash (g/100 g fw)	Carbohydrates (g/100 g fw)	Energy (Kcal/100g	Energy (Kj/100g)
BCF	8.8±0.3	0.83±0.01	21.8±0.1	3.1313±0.0001	65.5±0.3	357±1	1493±5
BIF1	9.2±0.1	0.85±0.01	22.0±0.4	3.16±0.02	64.8±0.3	355±1	1486±2
BIF2	9.3±0.3	0.94±0.01	24.07±0.01	2.97±0.01	62.7±0.3	356±1	1488±4
BIF3	9.4±0.2	0.85±0.01	22.8±0.4	3.3±0.1	64±1	353±1	1479±3
TCF1	11.4±0.3	0.84±0.02	19.7±0.2	3.49±0.03	64.6±0.3	345±1	1443±4
TCF2	11.6±0.3	0.91±0.05	18.24±0.01	3.5±0.1	65.8±0.3	344±1	1442±5
TCF3	11.5±0.2	0.86±0.04	20±1	3.57±0.04	64±1	344±1	1440±4
TIF1	12.0±0.5	0.83±0.04	19.1±0.2	2.7±0.1	65±1	345±3	1446±11
TIF2	11.2±0.3	0.93±0.03	21±1	2.68±0.04	64.2±0.5	349±1	1461±4
TIF3	11.6±0.4	0.85±0.03	19±1	2.94±0.03	66±1	346±1	1450±6

TIF1: Taoujdate Intercrop Fava bean Block 1; **TIF2:** Taoujdate Intercrop Fava bean Block 2; TIF**3:** Taoujdate Intercrop Fava bean Block 3; **TCF1:** Taoujdate Control Fava bean Block 1; **TCF2:** Taoujdate Control Fava bean Block 2; **TCF3:** Taoujdate Control Fava bean Block 3; **BIF1:** Azilal Intercrop Fava bean Block 1; **BIF2:** Azilal Intercrop Fava bean Block 2; **BIF3:** Azilal Intercrop Fava bean Block 3; Azilal **BCF**: Control Fava bean.

4. Portugal

Experimental Design and Sample Identification

The Portuguese trial was conducted at three demonstration sites in the Trás-os-Montes region (northeast Portugal), established by the Centro Nacional de Competências dos Frutos Secos (CNCFS). Two sites, located in Macedo de Cavaleiros and Vinhais, comprised rainfed orchards under full production, while a third irrigated orchard was established in Argozelo. Three intercropping treatments were applied in the inter-row area:

chickpea (*Cicer arietinum* L.), short-cycle clover (*Trifolium* spp.), and a control with no cover crop. Almond kernel quality was assessed over three consecutive production years (2023–2025).

Colour Analysis

The results obtained for the different colour parameters (L^*, a^* and b^*) in the almonds of the dry and irrigated almond grove are presented in Table 23. The results showed that the type of almond grove does not seem to cause changes in the different colour parameters.

Table 23. Colour parameters (L*, a* and b*) for both analyzed almond samples.

	Almonds collected from the dry almond grove	**Almonds collected from the irrigated almond grove**
*L**	56±2	55±1
*a**	15±1	15,1±0,2
*b**	41±4	40±2
Conversion into RGB value		

Texture Profile Analysis

Texture attributes were evaluated by Texture Profile Analysis (TPA). In the evaluation of the texture of both types of almond samples, the parameters related to hardness, fractureability, adhesiveness and springiness did not present significant changes, showing that the matrix rigidity was not affected by the different types of cultivation (**Table 24**). However, when measuring the ability of the matrix to withstand a second deformation and to return to its initial state (cohesiveness, gumminess, chewiness, resilience) there were significant changes, highlighting the almonds sample collected from the dry almond grove with greater speed and strength to recover the initial form.

Table 24. Texture evaluation for both analyzed almond samples.

	Almonds collected from the dry almond grove	**Almonds collected from the irrigated almond grove**
Hardness (g)	29827±1300	28162±1479
Fracturability (g)	26980±1332	24330±1198
Adhesiveness (g/sec)	-1.3±0.3	-1.1±0.1
Springiness (sec)	0.59±0.03	0.54±0.01
Cohesiveness (g/sec)	0.42±0.02	0.37±0.02
Gumminess (g)	14382±708	9827±521
Chewiness (g/sec)	7026±279	5030±270
Resilience (g/sec)	0.25±0.01	0.19±0.01

Proximate Composition

The results showed that, for almonds grown in irrigated soil, they presented a slightly higher carbohydrate and energy content when compared to almonds from non-irrigated soil (Table 25). However, for the samples collected from the dry almond grove, they showed a higher content of proteins. For the ash, moisture and fat did not present significant changes, showing that some nutritional aspects were not affected by the different types of cultivation.

Table 25. Nutritional profile of control almond samples collected in the baseline year (mean ± SD; expressed per 100 g fw).

	Moisture (g/100 g fw)	Crude Fat (g/100 g fw)	Proteins (g/100 g fw)	Ash (g/100 g fw)	Carbohydrates (g/100 g fw)	Energy (Kcal/100g	Energy (Kj/100g)
AES	3.01±0.01	51±1	16.2±0.2	3.096±0.004	26.9±0.3	629±3	2635±11
ADR	2.89±0.01	51±1	15.1±0.2	3.097±0.001	28±1	632±6	2644±25

AES: Almonds collected from the dry almond grove; **ADR:** Almonds collected from the irrigated almond grove;

Year 2 Intercropping Results

Colour Analysis

Almond kernel colour was evaluated using the CIELAB colour space (*L*, a*, b**) and is presented in **Table 26**. *L** values, reflecting kernel lightness, ranged from 47±1 to 54±1 across all treatments and years, with no consistent pattern attributable to either irrigation regime or intercropping system. Under irrigated conditions, *L** values tended to be slightly higher in chickpea-intercropped plots (up to 54±1 in Year 2) (**Figure 10**), while rainfed plots showed greater variability across years. The *b** parameter (yellowness) was broadly stable across treatments, ranging from 32±6 to 39±2, with no significant differentiation related to irrigation or intercropping, indicating that the yellow colour component of almond kernels is relatively insensitive to the agronomic management strategies evaluated.

The *a** parameter, which reflects redness, showed the most pronounced variation across treatments and years. Higher *a** values were consistently associated with rainfed conditions, with this trend becoming more pronounced in later production years: rainfed control almonds reached 17±1 in Year 2 and 18±1 in Year 3, compared to 13.1±0.4 and 12.5±0.3 in irrigated control plots, respectively. This pattern is consistent with stress-induced physiological responses under water deficit, which are known to stimulate pigment synthesis and alter secondary metabolite accumulation during fruit development. Intercropping with chickpea or clover did not substantially modify this response, suggesting that irrigation regime is the primary driver of redness variation in Portuguese production conditions.

Table 26. Colour parameters (L*, a*, b*) of almond kernels under different irrigation regimes and intercropping systems over three production years.

*CIEL*a*b** coordinates	Crop	1 Irrigated	1 Rainfed	2 Irrigated	2 Rainfed	3 Irrigated	3 Rainfed
L*	Control	50±1	50±3	52±1	47±1	51±1	51±2
L*	Chickpea	52±1	49±2	54±1	50±2	51±1	49±1
L*	Clover	48±3	51±1	54±1	52±1	50±2	51±2
a*	Control	14±2	15.8±0.4	13.1±0.4	17±1	12.5±0.3	18±1
a*	Chickpea	13±1	15±1	13.4±0.2	16.9±0.4	13±1	17±2
a*	Clover	14±2	16±1	14±1	17.6±0.4	14.0±0.2	17±2
b*	Control	35±6	37±2	36±2	33±1	33±1	39±2
b*	Chickpea	38±3 [a]	37±4	39±1	37±1	33±1	37.0±0.5
b*	Clover	32±6	37±1	38±1	39±1	33±2	38±2

*L**luminosity; *a** chromatic axis from green (-) to red (+); *b**, chromatic axis from blue (-) to yellow (+).

Figure 10. Control almonds and almonds from intercropping systems with clover and chickpeas during the first and second years of intercropping in Portugal. AIC: irrigated control; AIGB: irrigated + chickpea; AIT: irrigated + clover; ANIC: rainfed control; ANIGB: rainfed + chickpea; ANIT: rainfed + clover.

Texture Profile Analysis

Texture attributes were evaluated by Texture Profile Analysis (TPA). Hardness was the parameter most strongly influenced by the interaction between year, irrigation regime, and cropping system (Table 27). In Year 1, hardness did not differ significantly among treatments, reflecting comparable mechanical properties under both irrigated and rainfed conditions during the first year of intercropping establishment. In Year 2, however, a marked reduction in hardness was observed under rainfed conditions, particularly in the control treatment, indicating that water deficit significantly reduced kernel mechanical resistance when seasonal drought stress was most intense. In Year 3, partial recovery of hardness values was observed, consistent with the interannual variability in climatic conditions recorded across the trial period.

Gumminess and chewiness followed a similar pattern to hardness, with lower values under rainfed conditions in Year 2. Cohesiveness and springiness were comparatively stable across treatments and years, suggesting that these structural properties are less sensitive to irrigation regime and cropping system. The limited and inconsistent effect of intercropping on texture parameters across years indicates that the mechanical quality of almond kernels in the Portuguese trial was primarily driven by water availability rather than by the intercropping species employed.

Table 27. Texture evaluation of almonds grown in intercropping systems over two years of production in Portugal.

Year	Irrigation	Crop	Gumminess	Chewiness	Cohesiveness	Springiness	Adhesiveness
1	Irrigated	Control	19264±3712	13660±3435	0.46±0.05	0.70±0.04	-1.8±0.2
1	Irrigated	Chickpea	15546±686	11742±1616	0.43±0.01	0.8±0.1	-1.5±0.4
1	Irrigated	Clover	17041±1738	12630±663	0.45±0.01	0.7±0.1	-1.5±0.4
1	Rainfed	Control	15011±450	9550±742	0.41±0.01	0.64±0.03	-2±1
1	Rainfed	Chickpea	17285±985	11500±868	0.44±0.03	0.7±0.1	-2±1
1	Rainfed	Clover	15547±1498	10062±735	0.41±0.03	0.65±0.02	-2±1
2	Irrigated	Control	19960±5497	11928±3981	0.5±0.1	0.59±0.04	-6±2
2	Irrigated	Chickpea	16159±4475	7934±3208	0.4±0.1	0.5±0.1	-17±6
2	Irrigated	Clover	12571±1468	5666±878	0.39±0.02	0.45±0.02	-22±7
2	Rainfed	Control	6268±2845	2400±950	0.3±0.1	0.4±0.1	-22±14
2	Rainfed	Chickpea	15320±2419	6431±1635	0.42±0.04	0.42±0.04	-21±3
2	Rainfed	Clover	12695±7569	6152±3211	0.4±0.1	0.5±0.1	-27±12
3	Irrigated	Control	18139±4857	11944±3631	0.5±0.1	0.65±0.03	-2.0±0.1
3	Irrigated	Chickpea	12074±7447	6779±4463	0.4±0.1	0.56±0.05	-2.2±0.3
3	Irrigated	Clover	16723±3745	10346±2509	0.5±0.1	0.6±0.1	-2±1
3	Rainfed	Control	13605±1832	7373±1345	0.42±0.05	0.54±0.04	-2.2±0.3
3	Rainfed	Chickpea	10284 ±2293	4985±766	0.4±0.1	0.5±0.1	-1.9±1
3	Rainfed	Clover	13067±691	6755±895	0.40±0.05	0.52±0.04	-2.0±0.40

Proximate Composition

The proximate composition of almond kernels varied across treatments and production years. Fat content was the dominant macronutrient, ranging from 40.46 to 53.64 g/100 g fresh weight, and was generally higher under irrigated conditions, particularly in the irrigated control during Year 1, suggesting that adequate water supply favours lipid accumulation during kernel development (Table 28). Fat content showed some year-to-year variability across all treatments, reflecting the sensitivity of lipid biosynthesis to interannual climatic conditions.

Protein content ranged from 12.39 to 21.20 g/100 g fresh weight and tended to increase progressively across production years. Legume intercropping, particularly clover, was associated with higher protein content compared to the control in several year-treatment combinations, consistent with the role of legume cover crops in enhancing soil nitrogen availability through biological nitrogen fixation, which can promote nitrogen assimilation and protein accumulation in almond kernels. Carbohydrate content showed an inverse relationship with fat content and tended to be higher under rainfed conditions, particularly in the clover intercropping system during Year 1. Ash content was broadly stable across treatments (approximately 2.5-3.5 g/100 g fw), indicating that mineral composition is comparatively less sensitive to irrigation regime or cropping system. Energy values closely followed fat content trends, with higher caloric values associated with irrigated conditions.

Table 28. Proximate composition of almond kernels as affected by irrigation regime and intercropping system over three production years.

Crop	Year × Regime	Moisture (g/100 g fw)	Protein (g/100 g fw)	Fat (g/100 g fw)	Ash (g/100 g fw)	Carbohydrates (g/100 g fw)	Energy (kcal/100 g)
Control	1 Irrigated	4.9±0.1	15.3±0.2	53.62±0.03	2.81±0.04	23.38±0.02	637.3±0.5
Control	1 Rainfed	5.0±0.1	15±1	47±1	2.7±0.1	31±1	602±6
Control	2 Irrigated	6.5±0.5	18.7±0.3	47.3±0.4	2.6±0.1	24.9±0.4	600±3
Control	2 Rainfed	7.4±0.2	18.2±0.1	44±2	2.2±0.2	30±2	577±12
Control	3 Irrigated	6.9±0.4	19.0±0.1	47±1	2.6±0.2	24±1	599±6
Control	3 Rainfed	6.9± 0.3	17.2± 0.2	46±1	2.3±0.1	28±1	590±5
Chickpea	1 Irrigated	5.4±0.2	14.6± 0.5	45±1	3.44±0.04	32±2	590± 6
Chickpea	1 Rainfed	5.0±0.1	15.8±0.2	49±1	2.71±0.02	28±1	613±2
Chickpea	2 Irrigated	7.8±0.5	16.9±0.1	49±1	2.7±1	24±1	604±1
Chickpea	2 Rainfed	6.3±0.1	17.0±0.4	44±2	2.2±0.1	31±1	588±11
Chickpea	3 Irrigated	8±1	20.9±0.2	45.2 ± 0.1	2.93±0.02	23±1	582±3
Chickpea	3 Rainfed	7±1	17.9±0.3	48.6 ± 0.3	2.16±0.01	24±1	606±2
Clover	1 Irrigated	4.7±0.1	12.41± 0.02	52.2± 0.4	3.22±0.02	27.4±0.5	629±2
Clover	1 Rainfed	5.1±0.1	18±1	42±1	2.84±0.04	33±1	577±5
Clover	2 Irrigated	6.3±0.2	17.8±0.2	50.5±0.1	2.6±0.1	22.6± 0.2	616±1
Clover	2 Rainfed	7.7±0.3	16.8±0.2	44±1	2.2±0.2	30±1	584±13
Clover	3 Irrigated	6.8±0.1	21.2±0.1	45.7±0.1	2.7±0.1	23.6±0.1	591±1
Clover	3 Rainfed	6.9±0.4	18.3±0.2	46±2	2.3±0.1	26±1	595±7

Chickpea Intercrop Results

In addition to almond kernel quality, samples of the intercropped chickpea (Cicer arietinum L.) were collected and analysed across two production years at the trial sites in the Trás-os-Montes region (northeast Portugal). Chickpea quality was assessed in terms of seed coat colour, proximate composition, and energy content, providing complementary information on the performance of the intercrop species under irrigated and rainfed conditions.

Year 1 of Intercropping - Proximate Composition

The proximate composition of chickpea seeds collected in Year 1 is presented in Table 29. Samples comprised three treatment groups: control irrigated chickpeas (A1, A2, A3), non-irrigated intercropped chickpeas (C1-1, C1-2, C1-3), and irrigated intercropped chickpeas (C2-1, C2-2, C2-3).

Moisture content differed markedly between the control and intercropped treatments: control irrigated samples (A1–A3) presented moisture values of 12±2 g/100 g fw, while all intercropped samples — both irrigated (C2) and non-irrigated (C1) — showed consistently lower moisture content (5±1 g/100 g fw). This difference likely reflects distinct post-harvest handling or drying conditions between the sample groups rather than a direct effect of the intercropping system.

Crude fat content was low across all samples, as expected for chickpea seeds, ranging from 2.77±0.03 g/100 g fw (A1) to 4.3±0.1 g/100 g fw (C1-1). Intercropped samples under both irrigated (C2) and non-irrigated (C1) conditions tended to show slightly higher fat values compared to the control, though variability was considerable within treatment groups. Protein content ranged from 15±4 g/100 g fw (C2-3) to 19.9±0.5 g/100 g fw (C1-2), with control irrigated samples (A1: 19.5±0.3; A2: 19±1 g/100 g fw) and non-irrigated intercropped samples showing the highest protein values. The higher protein content in non-irrigated intercropped chickpeas is consistent with the known effect of moderate water deficit on nitrogen metabolism, which can promote amino acid and protein accumulation in legume seeds.

Table 29. Proximate composition and energy content of chickpea seeds collected in Year 1 of intercropping in northeastern Portugal (mean ± SD; expressed per 100 g fw).

	Moisture (g/100 g fw)	Crude Fat (g/100 g fw)	Proteins (g/100 g fw)	Ash (g/100 g fw)	Carbohydrates (g/100 g fw)	Energy (Kcal/100g)	Energy (Kj/100g)
A1	12±2	2.77±0.03	19.5±0.3	3.40±0.04	62±1	351±6	1469±25
A2	12±2	3.3±0.3	19±1	2.63±0.04	63±2	357±6	1493±24
A3	12±2	3.0±0.1	15.72±0.02	2.64±0.04	66±1	355±6	1486±26
C1-1	5±1	4.3±01.	19±1	2.7±0.1	68.8±0.5	390±2	1632±10
C1-2	5±1	2.8±0.1	19.9±0.5	2.9±0.4	69±3	381±2	1595±9
C1-3	5±1	2.9±0.1	16±3	2.9±0.4	73±3	382±2	1598±9
C2-1	5±1	4±1	16±3	2.9±0.4	73±2	388±4	1623±16
C2-2	5±1	4±1	16±3	3.0±0.4	72±2	388±4	1623±15
C2-3	5±1	4±1	15±4	3.0±0.3	73±3	386±2	1614±8

A1: control irrigated chickpeas harvested in block 1; **A2:** control irrigated chickpeas harvested in block 2; **A3:** control irrigated chickpeas harvested in block 3; **C1-1**: non-irrigated intercropped chickpeas harvested in block 1; **C1-2**: non-irrigated intercropped chickpeas harvested in block 2; **C1-3**: non-irrigated intercropped chickpeas harvested in block 3; **C2-1**: irrigated intercropped chickpeas harvested in block 1; **C2-2**: irrigated intercropped chickpeas harvested in block 2; **C2-3**: irrigated intercropped chickpeas harvested in block 3.

Year 2 of Intercropping - Colour Analysis

Seed coat colour was evaluated in Year 2 using the CIELAB colour space and is presented in Table 30. GBC2 (control) and GBI2 (irrigated intercropped) presented similar lightness values ($L*$ = 74), indicating a bright seed coat colour under both conditions, while GBNI2 (non-irrigated intercropped) exhibited a markedly lower $L*$ value (62±7), corresponding to a visibly darker, brownish appearance (Figure 11). The $b*$ parameter was higher in intercropped treatments (GBI2: 17±4; GBNI2: 18±5) compared to the control (GBC2: 13±5), indicating a more pronounced yellow tone under intercropping conditions. The $a*$ values were low and comparable across all groups (2–5), with no meaningful differentiation. These differences in seed coat colour may reflect the combined influence of water availability and physiological responses associated with the intercropping system.

Table 30. Colour parameters (L*, a* and b*) for control chickpeas and chickpeas intercropped with almonds under irrigated and non-irrigated conditions (Year 2) (mean ± SD).

	GBC2	GBI2	GBNI2
*L**	74±5	74±9	62±7
*a**	4±2	2±2	5±2
*b**	13±5	17±4	18±5
Conversion into RGB value			

*L**luminosity; *a** chromatic axis from green (-) to red (+); *b**, chromatic axis from blue (-) to yellow (+).

Figure 11. Control chickpeas and chickpeas intercropped with almonds under two water regimes: irrigated and non-irrigated.

Year 2 of Intercropping - Proximate Composition

The proximate composition of chickpea seeds in Year 2 is presented in Table 31. Moisture content was consistent across all three groups (11.5-12.2 g/100 g fw), reflecting uniform post-harvest drying conditions. Crude fat content was low and similar across treatments, ranging from 4.3±0.1 g/100 g fw (GBNI2) to 4.9±0.2 g/100 g fw (GBI2), with no meaningful effect of irrigation regime or intercropping on lipid content.

Protein content showed a clear treatment-related trend, increasing from 12.1±0.2 g/100 g fw in the control (GBC2) to 13.7±0.5 g/100 g fw in the irrigated intercropped treatment (GBI2) and 14.8±0.1 g/100 g fw in the non-irrigated intercropped treatment (GBNI2). This progressive increase in protein content from control to intercropped, and from irrigated to non-irrigated intercropped, is consistent with the combined effects of competition-induced nitrogen demand and water deficit stress, both of which can stimulate nitrogen assimilation and protein accumulation in legume seeds. Ash content was slightly higher in GBNI2 (3.8±0.1 g/100 g fw) and GBC2 (3.7±0.1 g/100 g fw) compared to GBI2 (3.3±0.2 g/100 g fw), suggesting marginal differences in mineral uptake between treatments.

Carbohydrate content was highest in GBC2 (68.0±0.2 g/100 g fw) and decreased slightly in intercropped treatments (GBI2: 66±1; GBNI2: 65.2±0.4 g/100 g fw), inversely reflecting the higher protein content observed in those groups. Energy values were broadly comparable across treatments (359–362 kcal/100 g; 1502–1517 kJ/100 g), with no meaningful caloric differences attributable to intercropping or irrigation regime. Compared to Year 1, protein content in Year 2 was lower overall, while moisture and fat were more consistent across treatments, suggesting that the compositional variability observed in Year 1 may have been partly driven by differences in post-harvest handling.

Table 31. Proximate composition and energy content of chickpea seeds collected in Year 2 of intercropping in northeastern Portugal (mean ± SD; expressed per 100 g fw).

	Moisture (g/100 g fw)	Crude Fat (g/100 g fw)	Proteins (g/100 g fw)	Ash (g/100 g fw)	Carbohydrates (g/100 g fw)	Energy (Kcal/100g)	Energy (Kj/100g)
GBC2	11.5±0.4	4.6±0.1	12.1±0.2	3.7±0.1	68.0±0.2	362±2	1516±9
GBI2	12.2±0.5	4.9±0.2	13.7±0.5	3.3±0.2	66±1	362±3	1517±11
GBNI2	11.9±0.4	4.3±0.1	14.8±0.1	3.8±0.1	65.2±0.4	359±2	1502±8

GBC2: control chickpeas; **GBI2**: irrigated intercropped chickpeas; **GBNI2**: non-irrigated intercropped chickpeas.

5. Israel

Sixteen groups of almond samples were received from Israel and identified as non-cover crops and cover crops almonds (Figure 12). CCF1 and CCF2 almonds exhibited consistent colour profiles, with moderate lightness, slight reddish hues, and prominent yellow tones. The minor variations across replicates suggest high batch uniformity and minimal impact from sample handling or processing inconsistencies (Table 32 and 33). These characteristics contribute to the visual quality and consumer acceptance of chickpea-based food products.

Figure 12. Almonds from cover crops (CC) and non-cover crop (NCC) systems analyzed across multiple areas

Table 32. Colour parameters (L*, a* and b*) of almonds obtained from plots with cover crops.

	CCF1-R1	CCF1-R2	CCF1-R3	CCF1-R4	CCF1-R5	CCF2-R1	CCF2-R2	CCF2-R3	CCF2-R4
*L**	49±1	48±3	48±1	49±4	47±3	48±3	50±1	49±2	48±1
*a**	16±1	16±1	16±1	17±1	16±1	17±1	17±1	16±1	17±1
*b**	32±2	32±3	31±1	33±3	29±2	31±3	33±2	31±2	31±1
Conversion into RGB value									

*L**luminosity; *a** chromatic axis from green (-) to red (+); *b**, chromatic axis from blue (-) to yellow (+).

Table 33. Colour parameters (L*, a* and b*) of almonds obtained from plots with non-cover crops.

	NCCF1-R2	NCCF1-R3	NCCF1-R5	NCCF2-R1	NCCF2-R2	NCCF2-R4	NCCF2-R5
*L**	50±3	50±2	48±2	50±1	49±1	47±3	49±3
*a**	17±1	17±1	16±1	16,9±0,5	16±1	16,6±0,4	17±1
*b**	33±6	32±2	31±1	34±1	32±2	31±3	32±4
Conversion into RGB value							

*L**luminosity; *a** chromatic axis from green (-) to red (+); *b**, chromatic axis from blue (-) to yellow (+).

Texture parameters of samples from cover crop (CCF) and non-cover crop (NCCF) systems were evaluated through multiple areas. Hardness values ranged from approximately 31.400 to 43.100 g, with CCF samples generally showing higher average hardness compared to NCCF samples (which ranged from ~31.400 to 38.200 g) (Table 34). Fracturability followed a similar trend, with CCF samples showing higher values

(24.000 to 30.000 g) compared to NCCF (19.800 to 27.000 g), indicating that cover crop samples tend to be firmer and more brittle. Adhesiveness values were consistently slightly negative across all samples (around -2 g/sec), reflecting minimal stickiness. Springiness remained steady at approximately 0.6 sec for all samples, indicating similar elastic recovery. Cohesiveness ranged between 0.3 and 0.4 g/sec, showing little variation among samples. Gumminess and chewiness were higher in CCF samples (gumminess: ~12.500 to 19.300 g; chewiness: ~7.600 to 12.600 g/sec) compared to NCCF samples (gumminess: ~11.300 to 16.400 g; chewiness: ~6.700 to 10.600 g/sec), indicating a firmer texture in cover crop samples. Resilience was consistently low (~0.2 to 0.3 g/sec) for all samples, suggesting limited ability to recover from deformation quickly. Overall, samples from the cover crop system exhibited firmer and more cohesive textures, while non-cover crop samples showed slightly softer and less brittle characteristics.

Table 34. Evaluation of the texture of almonds intercropped with cover crops in Israel.

Samples	Hardness (g)	Fracturability (	Adhesiveness	Springiness	Cohesiveness	Gumminess (	Chewiness (g/	Resilience
CCF1-R1	**40102±9466**	26503±6485	-3±1	0.6±0.1	0.4±0.1	16580±7625	10182±57772	0.2±0.1
CCF1-R2	**36670±11217**	26127±8081	-2±1	0.6±0.2	0.4±0.1	14715±7212	9334±5015	0.2±0.1
CCF1-R3	**37906±6590**	30172±7065	-2.1±0.5	0.6±0.1	0.4±0.1	14986±5196	8854±3948	0.2±0.1
CCF1-R4	**39484±7686**	29267±4700	-2±0.5	0.62±0.04	0.4±0.1	16766±5874	10525±4292	0.3±0.1
CCF1-R5	**38713±7887**	27680±8543	-1.8±0.4	0.63±0.04	0.4±0.1	16272±5593	10340±3887	0.2±0.1
CCF2-R1	**33968±10211**	27382±9735	-1.8±0.5	0.6±0.1	0.3±0.1	12536±5777	7583±3754	0.2±0.1
CCF2-R2	**43069±6421**	25526±6014	-2±1	0.6±0.1	0.4±0.1	19304±4834	12599±3782	0.3±0.1
CCF2-R3	**36520±7617**	24282±7874	-2±1	0.6±0.1	0.4±0.1	14410±6235	8948±4416	0.2±0.1
CCF2-R4	**37542±6994**	29408±7298	-2±1	0.6±0.1	0.4±0.1	15853±5182	10076±4050	0.2±0.1
NCCF1-F	**33327±5857**	24680±6757	-2±1	0.6±0.1	0.3±0.1	11676±4114	6961±3138	0.2±0.1
NCCF1-F	**36531±3040**	23803±6611	-1.8±0.4	0.62±0.05	0.42±0.03	15263±2346	9443±1851	0.24±0.02
NCCF1-F	**31463±11627**	19799±9165	-2±1	0.6±0.1	0.3±0.1	11310±7364	6711±7364	0.2±0.1
NCCF2-F	**32391±7605**	25324±5704	-1.5±0.5	0.6±0.1	0.4±0.1	12519±7075	7886±5437	0.2±0.1
NCCF2-F	**31683±9915**	24723±6541	-2±1	0.6±0.1	0.3±0.1	12095±7640	7539±5360	0.2±0.1
NCCF2-F	**35069±6666**	23783±4072	-2±1	0.6±0.1	0.4±0.1	14182±5132	8794±3815	0.2±0.1
NCCF2-F	**38247±5077**	27036±7760	-2±1	0.6±0.1	0.4±0.1	16418±5805	10625±5201	0.3±0.1

The proximate composition of samples from cover crops (CC) and non-cover crop (NCC) systems was analyzed across multiple areas (R1 to R5) (Table 35). Moisture content was consistent across all samples, ranging from 4.5 to 5.4 g/100g fresh weight. Crude fat content varied, with CC samples ranging between 41.9 and 49.4 g/100g, while NCC samples showed a wider range from 39 to 56 g/100g, indicating greater fat variability in the non-cover crop system. Protein levels were generally higher in CC samples (15 to 17 g/100g) compared to NCC samples (13.6 to 16.2 g/100g). Ash content was stable across both systems, ranging from 2.8 to 3.6 g/100g, suggesting similar mineral content. Carbohydrates varied more notably in NCC samples (20 to 39 g/100g) than in CC samples (25.6 to 34 g/100g). Correspondingly, energy values ranged from 578 to 613 Kcal/100g in CC samples and from 562 to 648 Kcal/100g in NCC samples, reflecting differences in fat and carbohydrate content. In summary, the non-cover crop system exhibited greater variability in fat, carbohydrate, and energy contents, whereas the cover crop system showed more consistent nutritional profiles.

Table 35. The proximate composition of samples from cover crops (CC) and non-cover crop (NCC) systems was analyzed across multiple areas.

	Moisture (g/100 g fw)	Crude Fat (g/100 g fw)	Proteins (g/100 g fw)	Ash (g/100 g fw)	Carbohydrates (g/100 g fw)	Energy (Kcal/100g	Energy (Kj/100g)
CCF1-R1	5±1	45.5±0.1	16.3±0.1	3.1±0.1	30.1±0.1	595±2	2492±7
CCF1-R2	5.2±0.3	49.4±0.2	16.3±0.2	3.448±0.001	25.580±0.001	613±3	2565±11
CCF1-R3	5.4±0.4	48±1	16.0±0.1	3.2±0.1	27.4±0.1	606±7	2538±29
CCF1-R4	4.6±0.5	48±1	15±1	3.6±0.1	29±1	607±2	2541±9
CCF1-R5	5±1	43±2	15.9±0.1	3.52±0.05	32±2	580±13	2428±54
CCF2-R1	5.3±0.2	47.3±0.3	17±1	3.20±0.04	27.7±0.1	603±1	2523±4
CCF2-R2	5.3±0.4	46±2	15.3±0.2	3.1±0.1	31±2	594±9	2488±36
CCF2-R3	4.8±0.3	41.9±0.5	15.9±0.2	3.14±0.04	34±1	578±1	2418±5
CCF2-R4	5.2±0.2	46.0±0.4	16.1±0.3	3.2±0.2	29.6±0.4	597±3	2498±13
NCCF1-R2	5±1	39±1	13.6±0.2	3.1±0.1	39±1	562±3	2351±11
NCCF1-R3	5±1	47±2	14.5±0.5	2.8±0.1	30±2	604±7	2528±29
NCCF1-R5	5±1	56±2	16.2±0.2	3.0±0.1	20±1	648±11	2712±47
NCCF2-R1	5.0±0.5	42±1	16.0±0.4	3.08±0.04	34±1	576±5	2412±21
NCCF2-R2	4.5±0.2	42.3±0.2	14.05±0.01	3.4±0.1	35.7±0.2	580±2	2428±7
NCCF2-R4	4.8±0.2	42±1	15.3±0.3	3.0±0.1	35±1	578±5	2421±22
NCCF2-R5	5.0±0.3	41±1	16±1	3.0±0.1	35±1	576±9	2410±37

6. Croatia

Intercropping Results

Four groups of almond samples were received from Croatia, representing four cultivars grown under intercropping conditions at Selca, island of Brač (43°16'56"N, 16°48'33"E): Texas (ACT), AI (ACAI), Ferragnès (ACFG), and Ferraduel (ACFD). The inclusion of multiple cultivars in the Croatian trial allows for an assessment of genotype-related variation in almond kernel quality under intercropping management.

Colour Analysis

Colour parameters were determined using the CIELAB colour space and are presented in Table 36. $L*$ values ranged from 42±3 (ACFG, Ferragnès) to 48±2 (ACT, Texas), with ACT and ACFD presenting the highest lightness values and ACFG the lowest, indicating a visibly darker kernel appearance for the Ferragnès cultivar. The $a*$ parameter was consistent across cultivars, ranging from 14±1 (ACFG) to 16±1 (ACFD), with no meaningful differentiation between cultivars. The $b*$ parameter ranged from 30±2 (ACFG) to 36±3 (ACFD), with ACFG again presenting the lowest yellowness value. Overall, the Ferragnès cultivar was consistently the darkest across all three CIELAB parameters, reflecting cultivar-specific differences in skin pigmentation.

Table 36. Colour parameters (L*, a* and b*) for for intercropped almond samples collected in Croatia.

	ACT	ACAI	ACFG	ACFD
*L**	48±2	48±3	42±3	48±3
*a**	16±1	15±4	14±1	16±1
*b**	35±4	34±11	30±2	36±3
Conversion into RGB value				

ACT – Intercropped almond corresponding to the Texas cultivar (Selca-island Brač (43°1656 N,16°4833E); **ACAI** – Intercropped almond corresponding to the AI cultivar; **ACFG** - Intercropped almond corresponding to the Ferragnès cultivar; **ACFD** - Intercropped almond corresponding to the Ferraduel cultivar.

Texture Profile Analysis

Texture Profile Analysis (TPA) results are presented in Table 37. Hardness showed the most pronounced variation among cultivars, ranging from 24418±7350 g (ACT, Texas) to 46308±6584 g (ACFG, Ferragnès), with ACFG and ACAI (43840±5383 g) presenting the most mechanically resistant kernels and ACT the softest. Fracturability followed the same ranking, with ACFG recording the highest value (32894±9646 g) and ACT the lowest (18112±7853 g). Adhesiveness was low and negative across all cultivars, and springiness was uniform (1 sec), indicating comparable elastic recovery regardless of genotype. Gumminess and chewiness mirrored the hardness pattern, with ACFG and ACAI consistently showing the highest values and ACT the lowest. Overall, the Ferragnès and AI cultivars presented the densest and most structurally resistant kernel profiles, while the Texas cultivar was the softest across all TPA parameters.

Table 37. Texture evaluation for the almonds harvested in Croatia.

	ACAI	ACT	ACFD	ACFG
Hardness (g)	43840±5383	24418±7350	32002±5564	46308±6584
Fracturability (g)	29015±6535	18112±7853	26117±4271	32894±9646
Adhesiveness (g/sec)	-2.3±0.5	-1±1	-2±1	-2.2±0.6
Springiness (sec)	0.7±0.1	0.5±0.1	0.7±0.2	0.69±0.04
Cohesiveness (g/sec)	0.44±0.05	0.3±0.1	0.3±0.1	0.4±0.1
Gumminess (g)	19501±4272	8514±3662	10570±3558	20851±5861
Chewiness (g/sec)	13394±3790	4686±2439	7146±2993	14525±4686
Resilience (g/sec)	0.26±0.04	0.2±0.1	0.18±0.04	0.27±0.05

Proximate Composition

The proximate composition and energy content of the four Croatian cultivars are presented in Table 38. Moisture content was low across all samples (4.0–6.0 g/100 g fw). Crude fat content ranged from 47±2 g/100 g fw (ACFD) to 53.5±0.2 g/100 g fw (ACT), with the Texas cultivar presenting the highest lipid content by a considerable margin. Protein content varied substantially, from 12.26±0.02 g/100 g fw (ACFD) to 19.2±0.4 g/100 g fw (ACAI), with the AI cultivar standing out for its notably higher protein content. Ash content was broadly similar across cultivars (3.24–3.73 g/100 g fw). Carbohydrate content was highest in ACFD (30.4±0.1 g/100 g fw) and lowest in ACT (24±1 g/100 g fw), inversely reflecting fat content. Energy values ranged from 601±1 kcal/100 g (ACFD) to 637.5±0.2 kcal/100 g (ACT), with the Texas cultivar presenting the highest caloric density. Overall, genotype emerged as the primary driver of compositional variability among the Croatian cultivars evaluated.

Table 38. Nutritional profile of intercropped almond samples collected in Croatia (mean ± SD; expressed per 100 g fw).

	Moisture (g/100 g fw)	Crude Fat (g/100 g fw)	Proteins (g/100 g fw)	Ash (g/100 g fw)	Carbohydrates (g/100 g fw)	Energy (Kcal/100g)	Energy (Kj/100g)
ACFD	5.8±0.2	47±2	12.26±0.02	3.5±0.3	30.4±0.1	601±1	2514±3
ACFG	4.2±0.1	49±2	17±1	3.4±0.1	26±1	622±2	2602±9
ACT	4.0±0.2	53.5±0.2	14.7±0.2	3.2±0.1	24.5±0.2	637.5±0.2	2,0±1
ACAI	4.6±0.1	47.6±0.4	19.2±0.4	3.7±0.1	25±1	605±2	2535±8

ACT: intercropped almond, Texas cultivar; **ACAI**: intercropped almond, AI cultivar; **ACFG**: intercropped almond, Ferragnès cultivar; **ACFD**: intercropped almond, Ferraduel cultivar.

7. Conclusions

The results of this study show that the implementation of legume-based intercropping systems in Mediterranean almond orchards did not adversely affect the physical characteristics of almonds, namely their colour and texture, or their nutritional composition during the evaluation period. Most of the variability observed between samples was associated with differences between the experimental blocks and the years of production, rather than with the intercropping treatments themselves.

Although no consistent effects of the treatments were identified, some numerical trends warrant further investigation. Sulla coronaria occasionally exhibited slightly higher crude fat and energy contents, while Medicago spp. was associated with a marginally higher protein content in some experimental plots. These findings, however, were not consistent across years or between blocks and cannot yet be considered definitive treatment effects.

Overall, the findings indicate that intercropping can be adopted as a sustainable management practice without compromising almond quality, supporting its feasibility across the diverse Mediterranean conditions evaluated in this project.