OPTIONS méditerranéennes

Final results of the MEDIET project, sustainability assessment and nutritional evaluation of legumes produced in the Mediterranean basin

MEDIET
BUILD SUSTAINABLE AND RESILIENT FOOD SYSTEMS IN THE MEDITERRANEAN AREA

Edited by:
Gianluigi Cardone, Antonio Trani,
Annalisa Carignani, Biagio Di Terlizzi

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Centre International de Hautes Etudes Agronomiques Méditerranéennes

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Foreword

Biagio Di Terlizzi

Director of CIHEAM Bari

The Mediterranean Diet is more than a list of foods: it is a lived knowledge that links nutrition to culture, community, and place. Recognized by UNESCO as an Intangible Cultural Heritage, this model celebrates conviviality, seasonality, and local knowledge. Those qualities, respect for biodiversity, moderation, and an ethic that ties human health to environmental stewardship, are not merely nostalgic traits of a regional cuisine; they are practical guideposts for rethinking food systems in an era of climate instability, resource constraints, and widening social inequalities. The Food and Agriculture Organization has identified the Mediterranean Diet as a leading example of a sustainable diet, and for good reason (FAO, 2023).

Today's food systems sit at the intersection of multiple crises. Rural livelihoods are fragile, many countries depend on volatile global markets, and agricultural practices often intensify environmental pressures rather than relieve them. Addressing these challenges requires integrated strategies that reconcile ecological sustainability, nutritional adequacy, economic resilience, and social justice. Fragmented, single-sector responses will not suffice; what we need are cross-disciplinary partnerships, policy coherence, and community-rooted innovation.

Legumes occupy a central place in this transition. Beans, lentils, chickpeas, and peas are nutritional powerhouses: they supply protein, fiber and a range of bioactive compounds that support cardiovascular and metabolic health. Their amino-acid profiles complement cereals, making them essential in balanced diets and particularly valuable in plant-based dietary patterns (Lisciani *et al.*, 2024). Beyond their direct nutritional contribution, legumes are agroecological allies. Through biological nitrogen fixation they reduce dependence on synthetic fertilizers, enhance soil structure, and support biodiversity. In Mediterranean agroecosystems, traditional practices such as intercropping legumes with cereals have long sustained soil fertility and diversified farm incomes, practices that recent research now validates and seeks to scale (Martinelli *et al*., 2023; Carlini *et al*. 2024; Hwalla *et al*., 2025).

The environmental and economic benefits of legumes are tangible. By lowering the carbon and water footprints of diets and reducing input costs for farmers, legumes contribute to climate mitigation and to more resilient rural economies. Yet realizing these benefits at scale requires more than isolated studies: it demands coordinated research, knowledge exchange, and inclusive partnerships that connect scientists, policymakers, producers, and consumers across borders. International organizations and research networks increasingly recognize legumes as a scalable, evidence-based solution for sustainable diets and climate-smart agriculture.

Public policy and education are pivotal levers. Several Mediterranean and neighboring countries have begun to integrate legumes into dietary guidance and agricultural strategies. Spain's national guidance now emphasizes plant-based foods and recommends increased legume consumption. Italy promotes legumes through dietary guidance and public campaigns that revive traditional legume-rich dishes. France includes pulses in its national nutrition program and sustainability communications. In North Africa and the Eastern Mediterranean, Morocco supports legume production and climate-resilient farming for faba bean, chickpea, and lentil; Tunisia integrates legumes into resilience programs that combine sustainable practices with market access; Egypt embeds pulses and crop diversification in climate-smart agriculture strategies; and Lebanon is working to revitalize chickpea production and strengthen local legume value chains with international support. These examples show that policy, when coherent and culturally attuned, can shift both production and consumption patterns toward sustainability.

The MEDIET initiative as highlighted by the BEANS Network illustrates how coordinated action can amplify impact. By combining traditional knowledge with scientific innovation, MEDIET promotes legumes as a vehicle for biodiversity-based agriculture and climate resilience, while the BEANS Network fosters collaboration across research institutions, civil society, and policy actors (BEANS Network, 2025).

There is also an ethical dimension to this work. Promoting legumes is not only a technical intervention to reduce emissions or improve soil health; it is an invitation to reframe consumption as a moral choice that connects personal well-being with collective stewardship. Research from CIHEAM Bari and partner institutions underscores that increasing legume intake can simultaneously lower the environmental footprint of diets and improve nutritional outcomes, an outcome that is both scientifically robust and ethically compelling.

Education plays a decisive role in embedding these changes for the long term. Integrating knowledge about legumes into school curricula, culinary training, and public health campaigns can cultivate appreciation for seasonal, local foods among younger generations. Practical measures such as supporting farmer cooperatives, improving seed systems, investing in value-chain infrastructure, and aligning subsidies with sustainability goals, will help ensure that legumes are not only recommended but accessible and economically viable for producers and consumers alike.

As director of CIHEAM-Bari, I see in legumes a rare convergence of benefits: nutritional, environmental, economic, and cultural. They offer a pragmatic pathway to make the Mediterranean Diet a living model for global food sustainability. But the path forward requires sustained commitment: research that is transdisciplinary and participatory, policies that are coherent and equitable, and communities that are empowered to steward their food heritage.

This special issue of *Options Meditérranéennes* reflects the vision and achievements of MEDIET, and invites researchers, policymakers, and communities to sustain its momentum toward a more resilient, inclusive, and sustainable Mediterranean future.

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References

BEANS Network, 2025. *MEDIET Initiative: Revitalizing the Mediterranean Diet through legume-based systems. BEANS Network Report*. Rome: BEANS Network.

Carlini B., Lucini C. and Velázquez J., 2024. The role of legumes in the sustainable Mediterranean Diet: Analysis of the consumption of legumes in the Mediterranean population over the last ten years a PRISMA Statement Methodology. *Sustainability*, 16(7), 3081. https://doi.org/10.3390/su16073081.

FAO, 2023. *Sustainable diets and biodiversity: Directions and solutions for policy, research and action.* Rome: FAO. https://www.fao.org/3/i3004e/i3004e.pdf.

Hwalla N., Al Bakain R., Trani A., Mondelli D., Di Terlizzi B. and Hamzé M., 2025. Exploring the nutritional and nutraceutical significance of legumes: A comparative analysis across Mashreq Countries. *New Medit*, 24(2): 73–88. https://doi.org/10.30682/nm2502e.

Lisciani F., D'Addezio M. and Rossi, 2024. Legumes and sustainable diets: Nutritional and environmental perspectives in the Mediterranean context. *Journal of Sustainable Nutrition*, 12 (1): 45–62.

Martinelli F., Vollheyde A.L., Maria A. Cebrián-Piqueras M.A., von Haaren C., Lorenzetti E., Barberi P., Loreto F., Piergiovanni A.R., Totev V.V. and Bedini A., 2023. LEGU-MED: Developing biodiversity-based agriculture with legume cropping systems in the Mediterranean Basin. *Agronomy*, 12(132). https://doi.org/10.3390/agronomy12010132.

Cultivating Mediterranean innovation for sustainable food systems

Introduction to the MEDIET Project

Biagio Di Terlizzi

Director of CIHEAM Bari

The MEDIET project was conceived in response to the profound transformations affecting Mediterranean food systems. While the Mediterranean Diet is globally celebrated for its health benefits, the region faces increasing pressures: climate variability, biodiversity loss, shifting consumption patterns, and the challenge of balancing agricultural productivity with environmental sustainability. These pressures have been further intensified by conflicts, trade disruptions, and limited access to essential resources, making traditional diets progressively less sustainable. Against this backdrop, MEDIET was designed as a multidisciplinary, transnational initiative to reassess legumes, key components of Mediterranean agriculture and diets, through integrated scientific, environmental, and socio-economic perspectives.

I – Framework and objectives

Implemented by CIHEAM-Bari between 2022 and 2025 with the support of the Italian Directorate General for Development Cooperation (DGCS/MAECI), MEDIET engaged partners from 17 countries across the Mashreq (Lebanon, Syria, Jordan, Palestine, Iraq, Egypt), the Maghreb (Morocco, Tunisia, Algeria, Libya, Mauritania), and the Balkans (Albania, North Macedonia, Montenegro, Bosnia & Herzegovina, Serbia). Capturing this diversity was essential to generate knowledge that is both scientifically robust and contextually relevant.

The project combined rigorous scientific investigation with practical application, seeking not only to generate data but also to promote dialogue, capacity building, and policy engagement. Its ambition was to encourage the adoption of alternative agronomic practices, foster innovation throughout production and processing value chains, inform dietary guidance, and support the development of sustainability strategies across the Mediterranean basin.

MEDIET pursued four interrelated objectives:

1. **Development of the FEED Platform**
   A digital knowledge hub designed to strengthen evidence-based decision-making and promote cross-border knowledge sharing.
2. **Advancing scientific understanding of nutritional and nutraceutical properties**
   Systematic characterization of lentils, chickpeas, fava beans, and Phaseolus beans highlighted their nutritional value and roles in soil fertility, biodiversity, and climate resilience. Analyses covered protein content, amino acid profiles, dietary fiber, micronutrients, and bioactive compounds.
3. **Assessing environmental and socio-economic impacts**
   Legumes' contributions to soil health, reduced inputs, and resilient cropping systems were quantified using updated sustainability indicators. Socio-economic assessments complemented thés work by examining value chains, markets, and livelihood butomes.

4. **Strengthening dialogue and cooperation**
   Capacity-building activities and international conferences ensured scientific evidence informed policy, markets, and practices, underscoring inclusivity and regional integration.

II – Approach and results

MEDIET adopted a participatory, interdisciplinary approach, with coordinated efforts among national research institutions, project partners and field experts. This coherence ensured results to be regionally interpretable while respecting local specificities.

Key outcomes include:

- **Nutritional and nutraceutical profiling**
  More than 150 cultivars of lentils, chickpeas, fava beans, and Phaseolus beans were analyzed using standardized protocols at CIHEAM-Bari's Laboratory of Environmental and Agricultural Chemistry. The resulting dataset offers unprecedented insights into compositional variability, functional properties, and resilience traits, supporting breeding, cultivation strategies, and dietary recommendations.

- **Creation of the FEED Platform**
  A digital hub consolidating over 4,000 references on food security and sustainability, serving as connective infrastructure for researchers and practitioners (feedcommunity.net).

- **Environmental assessments**
  Harmonized indicators captured resource use, emissions, and ecosystem interactions across cultivars, providing a comprehensive sustainability evaluation.

- **Scientific dissemination**
  Collaborative publications and thematic analyses expanded MEDIET's reach. A notable example is the paper *"Exploring the nutritional and nutraceutical significance of legumes: A comparative analysis across Mashreq countries"* (NEW MEDIT, 2025), which examined 50 cultivars across four Levant countries and Egypt.

In parallel, CIHEAM-Bari researchers prepared two contributions for *Options Meditérranéennes*:

- *Nutritional and nutraceutical features of Mediterranean pulses – Final Results of the MEDIET Project* mapping legume properties across North Africa, the Balkans, and the Levant.
- *Technical-scientific report for the environmental and socio-economic sustainability assessment of the legumes selected in Project MEDIET* analyzing environmental impacts with updated sustainability indicators.

The project's conclusion marked a transition rather than an endpoint. In 2025, partners established the **International Meta-Network BEANS**, building on MEDIET's foundations to expand research, promote innovation, and support policy engagement related to legumes and sustainable food systems (beans.ciheam.org).

III – Legacy and perspectives

MEDIET's legacy lies in both knowledge and orientation. The identification of nutritionally and environmentally promising cultivars opens pathways for "Champion Cultivars," linking scientific characterization with agricultural adoption and market development. The integration of environmental indicators strengthens the case for legumes within climate and sustainability strategies.

Equally important, the collaborative frameworks established through MEDIET illustrate the potential of Mediterranean cooperation as a driver of innovation.

In summary, MEDIET demonstrates how multidisciplinary research, participatory methodologies, and regional partnerships can generate actionable insights. By reconnecting biodiversity, nutrition, and sustainability, the project contributes to a renewed understanding of legumes as strategic assets within Mediterranean and global food systems.

Technical-scientific report for the environmental and socio-economic sustainability assessment of the legumes selected in Project MEDIET

Gianluigi Cardone, Annalisa Carignani

Centre International d'Hautes Etudes Agronomiques Méditerranéennes Bari (CIHEAM Bari), Italy

Abstract. The main objective of the study is to conduct an initial and comprehensive assessment and quantification of the environmental and socio-economic impacts associated with the cultivation of five food legumes-chickpea (*Cicer arietinum*), lentil (*Lens culinaris*), bean (*Phaseolus vulgaris*), fava (*Vicia faba*) and black-eyed pea (*Vigna unguiculata*)-on a large scale across target countries in the Mediterranean region, with a particular focus on local and indigenous varieties. Specific objectives include quantifying the environmental and socio-economic impact for each species and variety per country, identifying the key drives of these impacts, formulating recommendations to reduce environmental footprint and improve profitability in the cultivation of the target legumes. Regarding environmental sustainability, results highlight that most of the analysed legume systems have a lower environmental impact than the benchmarks found in existing literature, confirming the value of traditional farming systems. In term of socio-economic sustainability, the results show that profitability is overall positive for the selected crops, and agricultural labour costs exceed the guaranteed minimum threshold of agricultural wages, except in Albania and Jordan.

Keywords. Legumes, Local varieties, Sustainability, Environmental impact, Socio-economic analysis, Traditional system.

Title: Rapport technico-scientifique pour l'évaluation de la durabilité environnementale et socio-économique des légumineuses sélectionnées dans le cadre du projet MEDIET

Résumé. *L'objectif principal de cette étude est de mener une évaluation et une quantification initiales et exhaustives des impacts environnementaux et socio-économiques associés à la culture à grande échelle de cinq légumineuses alimentaires — le pois chiche (Cicer arietinum), la lentille (Lens culinaris), le haricot commun (Phaseolus vulgaris), la fève (Vicia faba) et le niébé (Vigna unguiculata) — dans les pays cibles de la région méditerranéenne, avec un accent particulier sur les variétés locales et autochtones. Les objectifs spécifiques comprennent la quantification de l'impact environnemental et socio-économique pour chaque espèce et variété par pays, l'identification des principaux facteurs de ces impacts, ainsi que la formulation de recommandations visant à réduire l'empreinte environnementale et à améliorer la rentabilité de la culture des légumineuses cibles. En ce qui concerne la durabilité environnementale, les résultats soulignent que la plupart des systèmes de légumineuses analysés présentent un impact environnemental inférieur aux valeurs de référence trouvées dans la littérature existante, confirmant ainsi la valeur des systèmes agricoles traditionnels. En termes de durabilité socio-économique, les résultats montrent que la rentabilité est globalement positive pour les cultures sélectionnées et que les coûts de la main-d'œuvre agricole dépassent le seuil minimum garanti des salaires agricoles, à l'exception de l'Albanie et de la Jordanie.*

Mots-clés: *Légumineuses, Variétés locales, Durabilité, Impact environnemental, Analyse socio-économique, Système traditionnel.*

I – Introduction

This report builds upon the work undertaken during the second and the third year of MEDIET project with an expanded analytical scope integrating both environmental and socio-economic dimensions. The study focuses on the principal food legumes cultivated across the Mediterranean region, namely chickpea (Cicer arietinum), lentil (Lens culinaris), common bean (Phaseolus vulgaris), faba bean (Vicia faba), and black-eyed pea (Vigna unguiculata). These crops are of particular relevance due to their agronomic adaptability, nutritional value, and recognized role in sustainable food systems.

The analysis forms part of OUTPUT 3 "Environmental and Socio-Economic Impact Analysis of Legumes" of the Project, for Activity A.3.1 "Collect and process data on environmental impact" and for Activity A.3.2 "Collect and process data on environmental impact", which address the collection and processing of environmental and socio-economic data. The assessment period extended from June 2024 to May 2025, ensuring temporal continuity with previous project phases while enabling the refinement of methodological approaches.

While the second-year evaluation was based on a broad dataset comprising 108 questionnaires, the third-year assessment adopted a more targeted strategy. The sustainability analysis was conducted using a subset of 20 detailed questionnaires designed to capture agronomic practices, input use, yield performance, and economic variables. This focused sampling approach allowed for deeper exploration of variability among selected legume varieties while maintaining analytical robustness. Data collection concentrated on 20 legume varieties previously identified during earlier project stages and cultivated across experimental or production fields in eight Mediterranean basin countries: Albania, Algeria, Jordan, Mauritania, Morocco, Serbia, Syria, Tunisia. The selection of these sites ensured geographical diversity and reflected contrasting agro-ecological conditions representative of Mediterranean farming systems. Moreover, the decision to resample from the same fields enabled longitudinal comparison and supported Activity A.2.2""To deepen the nutritional characterization of selected varietal accessions".

Overall, this integrated assessment framework strengthens the evidence base for understanding the environmental performance, economic viability, and social relevance of Mediterranean legumes within sustainable agri-food systems.

II –Environmental impact assessment

The environmental sustainability assessment was carried out following the Life Cycle Assessment (LCA) methodology approach, using the SimaPro software in line with EPD method (2018), and in compliance with the guidelines of the ISO 14040 and 14044 standards.

LCA is recognized worldwide as the primary tool for assessing the environmental performance of a product or service; it provides an in-depth analysis of a product's life cycle environmental impact. Conducting an LCA assessment requires the collection of comprehensive data covering each stage of the product's life cycle. For this study, data were specifically collected on the cultivation of chickpeas, lentils, beans, and faba beans for Albania, Algeria, Jordan, Morocco, Serbia, Syria, and Tunisia, as well as cowpeas for Mauritania.

The SimaPro software was used to calculate the main environmental impact categories. The SimaPro software allows for the collection, analysis, and monitoring of data relating to emissions and environmental damage caused by the production process.

The specific objectives of this goal were as follows:

- Quantify the environmental impact for each species and variety in each country: Measure and evaluate the environmental effects of growing food legumes, taking into account key impact categories such as greenhouse gas emissions, acidification, eutrophication, and land use.
- Identify key environmental impact factors: Key factors include fertilizer and pesticide use, fuel and irrigation water consumption, as well as yield for each legume type
- Produce recommendations to reduce environmental impact: Provide recommendations or information on sustainable practices or interventions that can help limit the environmental impact associated with growing legumes in the target area.

1. Functional Unit

The functional unit (FU) in life cycle assessment (LCA) is the object of the study; therefore, in the inventory phase of the LCA, all inputs used to produce it are taken into account; the FU serves as a reference point against which the inputs and outputs of the stock are measured (ISO, 2006). For this study, the functional unit chosen is one kilogram (kg) of legumes harvested per hectare (ha).

In this assessment, all inputs were calculated per kilogram. This includes the quantification of chemical inputs, such as pesticides and their active ingredients, as well as fertilizers used, based on fertilizer titters and units, the energy consumption associated with the cultivation process, and the amount of water used.

It should be noted that, in many cases, the assessment did not explicitly include electricity and water consumption for irrigation, as the areas were predominantly rainfed, where irrigation requirements were generally minimal or non-existent, or in areas where there were no available and/or usable water sources for irrigation.

2. System limitations

The system boundaries were set as "cradle to farm," taking into account, as inputs, the energy and products used in the system for field activities such as cultivation operations, type of fertilizer application and nutrient fate in the environment, land use and transformation, and the underlying system that includes the production processes of chemicals, fuels, materials, and infrastructure.

3. Work plan, life cycle inventory analysis

Life Cycle Inventory (LCI) analysis is an inventory of all input data related to UF production in the studied systems.

Conducting a life cycle assessment (LCA) requires the collection of comprehensive data covering each stage of the crop's life cycle. For this study, specific data were collected on the cultivation of chickpeas, lentils, faba beans, and kidney beans.

Finally, to collect the data necessary for the survey, traditional tools such as questionnaires and Excel spreadsheets were used, which allowed us to obtain relevant information for the life cycle analysis (Annex 1).

A questionnaire was developed to collect farm and crop information (inventory) from farmers. The questionnaire included a general description of the farm (location, georeferenced location, altitude, area, species and varieties being evaluated, soil quality, irrigation water, etc.), the data collection field (cultivation method, rotation or intercropping, etc.), information on the inputs used in growing the species and varieties being analysed for cultivation operations (tillage, sowing, fertility management, insect and pathogen control, irrigation, harvesting), production yields, and an inventory of the capital employed in cultivation (machinery, inputs, and equipment), as well as producers' opinions on productivity and market issues.

Primary data were collected directly in the field, in close collaboration with local farmers in the same fields where grain samples of the legume were taken for the laboratory evaluation of the organoleptic and nutritional characteristics of the target legumes (Activity 2.2).

After being collected by local technicians and sent by Project focal points, the questionnaires were reviewed by CIHEAM Bari experts. If they were deemed unacceptable, they returned them to the focal point and local compiler for appropriate revisions and updates.

4. Selected indicators and specific activities carried out

The SimaPro computer program was used as a tool for calculating the main environmental impact categories based on the life cycle analysis (LCA).

SimaPro allows you to collect, analyse, and monitor data on the environmental performance of products and services. The software enables various applications, such as calculating carbon and water footprints, biodiversity, and provides the basis for product eco-design and environmental product declarations (EPDs).

The impact assessment was conducted using the Middle-Point EPD (Environmental Product Declaration) method in accordance with ISO 14040 to assess the environmental impacts of legumes throughout their life cycle. In addition to the EPD method (2018), the environmental assessment was also integrated using Eco-Indicator 99, an End-Point method.

The EPD method (2018), closely linked to the EPD certification (Environmental Product Declaration), divides the overall impact of the production process into fixed impact categories:

- *Global warming* (GWP100) - measured in kilograms of carbon dioxide equivalent (kg CO_2 eq): this category assesses the potential impact of inputs (in agriculture, particularly fertilizers and fuels) on greenhouse gas emissions and their contribution to global warming. The higher the indicator, the greater the impact on global warming generated by the analysed production process (life cycle);
- *Ozone depletion* (ODP) - measured in kilograms of trichlorofluoromethane equivalent (kg CFC-11 eq): This category assesses the potential impact of substances used in production to deplete the ozone layer. The higher the indicator, the greater the potential of the inputs used to deplete the ozone layer;
- *Photochemical oxidation* - measured in kilograms of ethylene equivalent (kg C_2H_4 eq): this category assesses the potential of substances used in production to contribute to the formation of photochemical smog. The higher the indicator, the greater the potential impact of substances used throughout the life cycle on the photochemical smog formation process;
- *Acidification* - measured in kilograms of sulphur dioxide equivalent (kg eq SO_2): this category assesses the potential of substances used (in agriculture, particularly fertilizers rich in nitrogen and sulphur, as well as fuels) to cause acid rain. The higher the indicator, the greater the contribution of the substances used to the acid rain formation process;
- *Eutrophication* - measured in kilograms of phosphate equivalent (kg PO_4 eq): this category assesses the potential impact of substances used (in agriculture, particularly fertilizers rich in nitrogen, phosphorus, and sulphur, as well as fuels) throughout the product's life cycle, causing nutrient enrichment and eutrophication of water bodies. The higher the indicator, the greater the negative impact the substances used have on the eutrophication process of water bodies;
- *Abiotic depletion, fossil fuels / components* - measured in megajoule equivalent (MJ eq) for fossil fuels (oil, gas, etc.), and in kilograms of antimony (kg Sb eq) for components (sand, solar energy, wind, etc.): this category evaluates the consumption of non-renewable fossil resources as well as naturally occurring and non-natural elements. The higher the indicator, the greater the negative contribution the substances used have to the abiotic depletion process;
- *Water scarcity* - measured in cubic meters equivalent (m^3 eq): this category, based on the AWARE Method, represents the amount of available water remaining per area in a

river basin after human and aquatic ecosystem demand has been met. The higher the indicator, the greater the amount of water removed from the available river basin.

The inclusion of Eco-Indicator 99 during the environmental assessment allows the grouping of the different indicators, coming from the impact categories, within 3 damage categories (end-points):

- *Damage to human health* - in which the various disabilities caused by diseases are weighted; these harms are expressed in terms of years of life lost and years of life lived with disability. These data are summarized in disability-adjusted life years (DALYs), a measure also used by organizations such as the World Bank and the WHO. This category includes aspects such as carcinogens, respiratory organic substances, respiratory inorganic substances, the impacts of climate change, radiation, and ozone depletion that impact human health;
- *Damage to ecosystem quality* - This is the loss of species in a given area over a given period of time (PDF*m2yr = Potentially Disappeared Fraction of plant species). This category includes factors such as ecotoxicity, acidification/eutrophication, and land-use impacts that impact the ecosystem;
- *Damage to resources* - this is the excess energy required for the future extraction of minerals and fossil fuels (MJ surplus energy requirement to compensate for lower future ore grade). This category includes impacts related to the depletion of minerals and fossil fuels (Cardone et al., 2018).

With the inclusion of Eco-Indicator 99, it was deemed useful to measure land use, an indicator that falls within the above-mentioned damage category “Damage to ecosystem quality”.

This indicator, measured in terms of damage, is simply a measurement of land conversion or land occupation and expressed as a fraction potentially lost (PDF)* m2*year/m2 or m2a. Land use (in human systems) impacts species diversity. Species diversity depends on the type of land use and the size of the area.

After being validated by CIHEAM Bari experts (Table 3), the 20 questionnaires were entered into the SimaPro software, which allowed the relevant information to be processed for the life cycle analysis of the legumes. This interpretation allowed the environmental impact of each cultivar to be determined based on the main indicators.

Table 1 below identifies the 20 questionnaires deemed valid by CIHEAM Bari experts. The validated data were entered into the SimaPro software, which allowed the environmental impact of individual cultivars to be determined based on the key indicators identified.

Table 1. Report of receipt and processing of questionnaires

Macro area	Country	Bean	Chickpea	Black-eyed pea	Broad bean	Lentil	TOTAL
BALKANS	*Albania*	2	-	-	-	-	**2**
	Serbia	2	-	-	-	-	**2**
TOTAL BALKANS		**4**	**-**	**-**	**-**	**-**	**4**
MASHREQ	*Jordan*	-	1	-	-	-	**1**
	Syria	-	-	-	1	1	**2**
TOTAL MASHREQ		**-**	**1**	**-**	**1**	**1**	**3**
MAGHREB	*Algeria*	2	-	-	1	1	**4**
	Mauritania	-	-	3	-	-	**3**
	Morocco	2		1		1	**4**
	Tunisia	-	1	-	1	-	**2**
TOTAL MAGHREB		**4**	**1**	**4**	**2**	**2**	**13**
TOTAL		**8**	**2**	**4**	**3**	**3**	**20**

5. Results

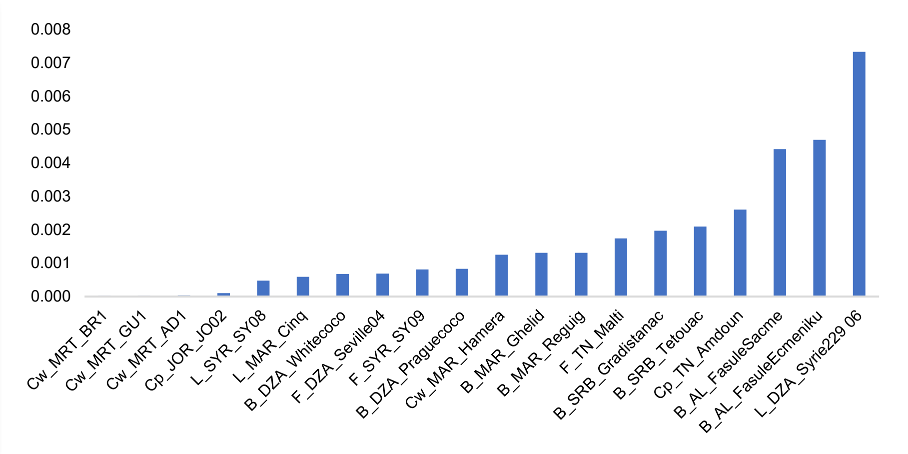
For each of the 3 macro-areas (Maghreb, Mashreq and Balkans), grain samples of the 4 species of legumes (chickpea, bean, broad bean, lentil) were collected, as well as the black-eyed pea, specifically of typically local or native varieties, according to their presence and diffusion in the individual countries. Each sample was accompanied by a questionnaire for the evaluation of environmental sustainability.

By interpreting and then entering the information into the SimaPro software, it was possible to define the environmental impact of each cultivar as defined by the main indicators.

A. By impact category per questionnaire

Starting from Figure 1, the results of the impact categories for legume production are shown in the following countries: Albania, Algeria, Jordan, Mauritania, Morocco, Serbia, Syria, and Tunisia. Regarding the first impact category, acidification, the highest levels are found in Algeria, for lentil production, with code L_DZA_Syrie229 06, equal to 0.0073 kg SO2 eq, and in bean production in Albania, with codes B_AL_FasuleEcmeniku and B_AL_FasuleSacme, 0.0047 kg SO2 eq and 0.0044 kg SO2 eq, respectively.

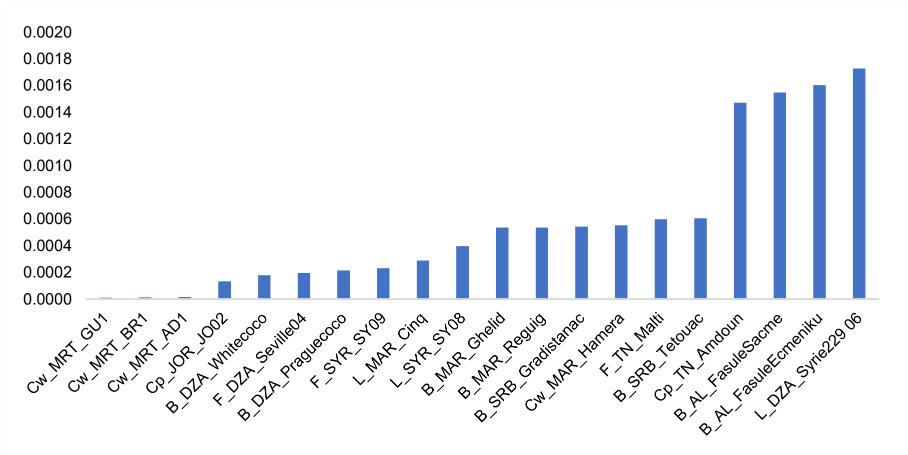
Figure 1. Acidification (kg SO2 eq)



Source: CIHEAM Bari elaboration on data from the SimaPro software

The second impact category is eutrophication, the highest levels of which, as shown in Figure 2, are found in Algeria, for lentil production, with code L_DZA_Syrie229 06, equal to 0.0017 kg PO4 eq, and in bean production in Albania with codes B_AL_FasuleEcmeniku and B_AL_FasuleSacme, 0.0016 kg PO4 eq and 0.0015 kg PO4 eq respectively.

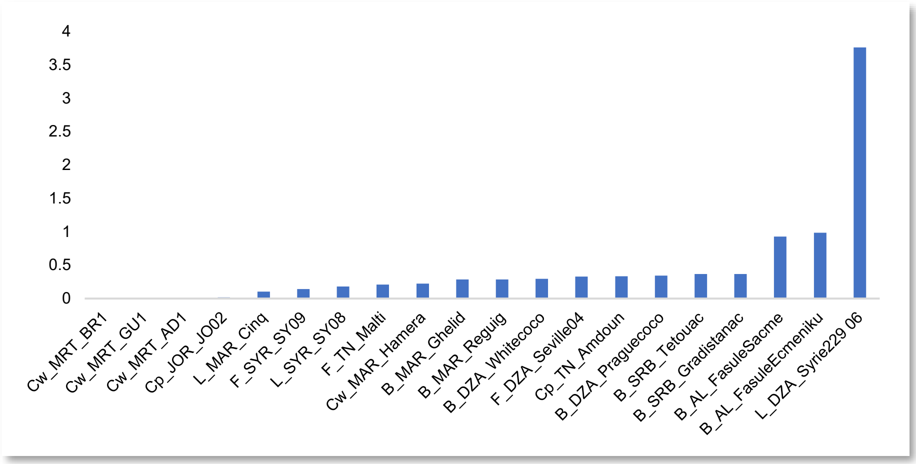
Figure 2. Eutrophication (kg PO4 eq)



Source: CIHEAM Bari elaboration on data from the SimaPro software

The third impact category is Global Warming, the highest levels of which, as shown in Figure 3, are found in Algeria, for the production of lentils, with code L_DZA_Syrie229 06, equal to 3.7622 kg CO2 eq, and in the production of beans in Albania with codes B_AL_FasuleEcmeniku and B_AL_FasuleSacme, respectively 0 0.9856 kg CO2 eq and 0.9273 kg CO2 eq.

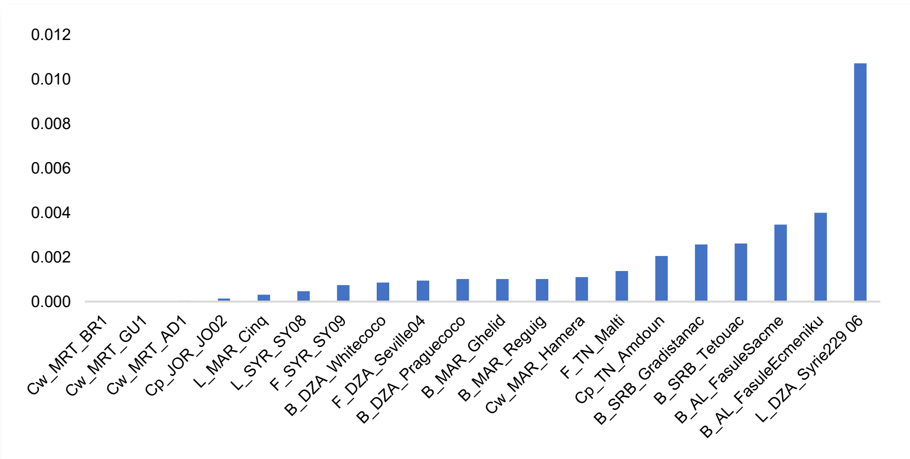
Figure 3. Global Warming (kg CO2 eq)



Source: CIHEAM Bari elaboration on data from the SimaPro software

The fourth impact category is Photochemical oxidation, the highest levels of which, as shown in Figure 4, are found in Algeria, for the production of lentils, with code L_DZA_Syrie229 06, equal to 0.0107 kg NMVOC, and in the production of beans in Albania with codes B_AL_FasuleEcmeniku and B_AL_FasuleSacme, respectively 0.0040 kg NMVOC and 0.0035 kg NMVOC.

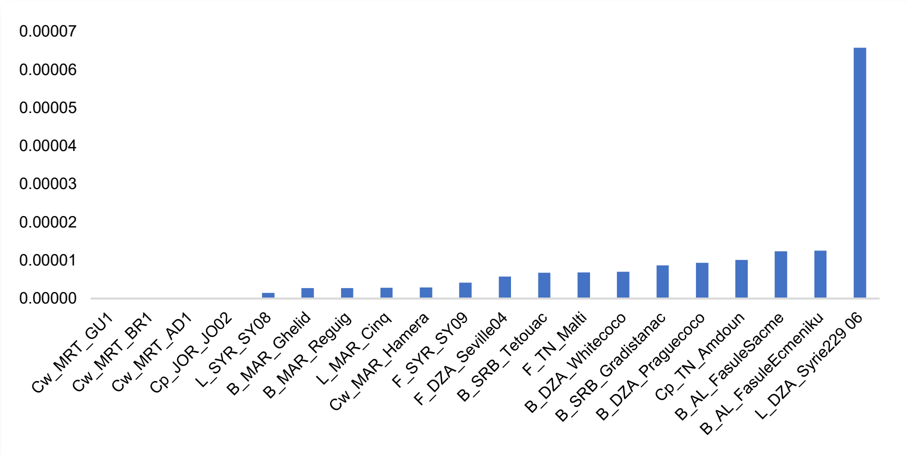
Figure 4. Photochemical oxidation (kg NMVOC)



Source: CIHEAM Bari elaboration on data from the SimaPro software

The fifth impact category is Abiotic depletion - elements, the highest levels of which, as shown in Figure 5, are found in Algeria, for the production of lentils, with code L_DZA_Syrie229 06, equal to 0.000066 kg Sb eq, and in the production of beans in Albania with codes B_AL_FasuleEcmeniku and B_AL_FasuleSacme, respectively 0.000013 kg Sb eq and 0.000012 kg Sb eq.

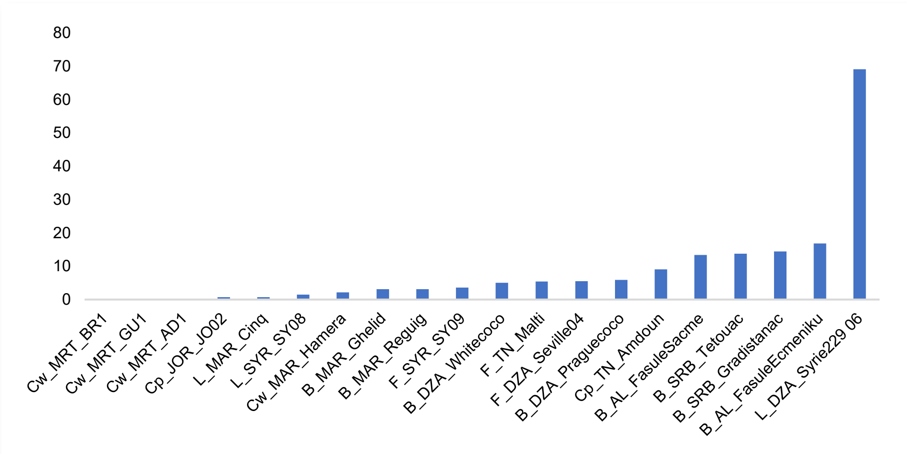
Figure 5. Abiotic depletion, elements (kg Sb eq)



Source: CIHEAM Bari elaboration on data from the SimaPro software

The sixth impact category is Abiotic depletion – fossil fuels, the highest levels of which, as shown in Figure 6, are found in Algeria, for the production of lentils, with code L_DZA_Syrie229 06, equal to 69 MJ, and in the production of beans in Albania with code B_AL_FasuleEcmeniku, and in Serbia with code B_SRB_Gradistanac, respectively 17 MJ and 14 MJ.

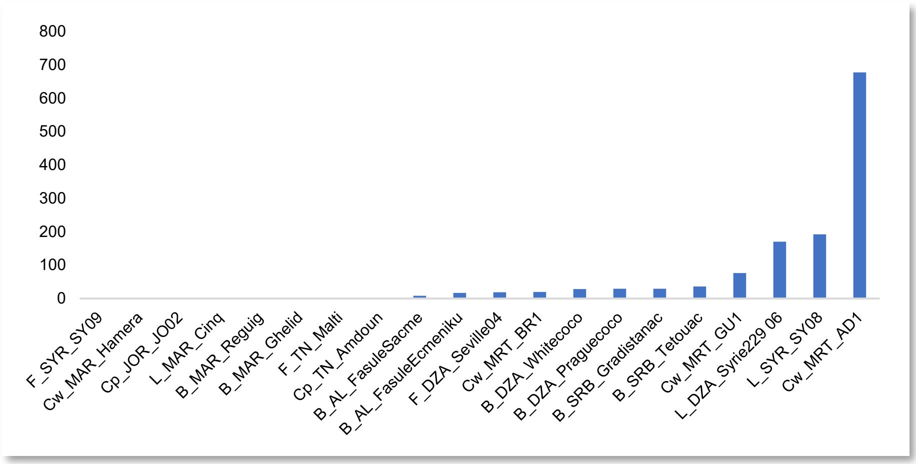
Figure 6. Abiotic depletion, fossil fuels (MJ)



Source: CIHEAM Bari elaboration on data from the SimaPro software

The seventh impact category is Water Scarcity, the highest levels of which, as shown in Figure 7, are found in Mauritania, for cowpea production, with code Cw_MRT_AD1, equal to 678 m3 eq, and in lentil production in Syria with code L_SYR_SY08, and in lentil production in Algeria with code L_DZA_Syrie229 06, respectively 193 m3 eq and 170 m3 eq.

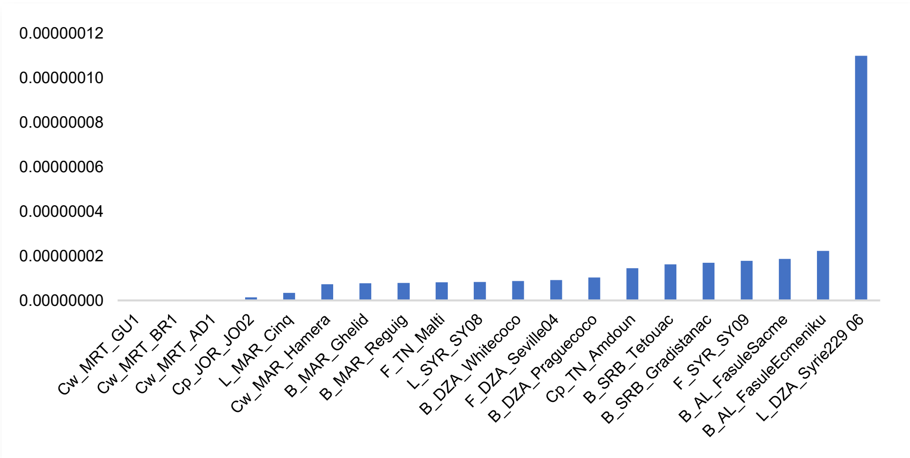
Figure 7. Water Scarcity (m3 eq



Source: CIHEAM Bari elaboration on data from the SimaPro software

The eighth and final impact category is Ozone layer depletion, the highest levels of which, as shown in Figure 8, are found in Algeria for lentil production, with code L_DZA_Syrie229 06, equal to 0.00000011 kg CFC-11 eq, and in bean production in Albania with codes B_AL_FasuleEcmeniku and B_AL_FasuleSacme, respectively 0.0000000223 kg CFC-11 eq and 0.0000000186 kg CFC-11 eq.

Figure 8. Ozone layer depletion (kg CFC-11 eq)

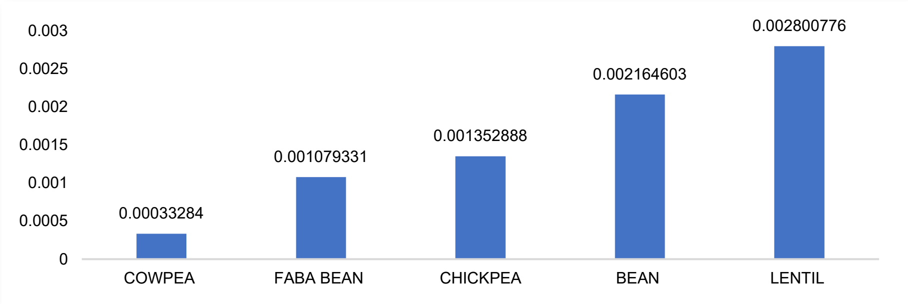


Source: CIHEAM Bari elaboration on data from the SimaPro software

B. By impact category for legume

Starting from Figure 9, the same impact categories were analyzed among the selected cultivated legumes, with the aim of identifying, for each, which legume has the greatest environmental impact. In Figure 9, regarding the level of acidification, lentils have the highest level of acidification, equal to 0.0028 kg SO2 eq.

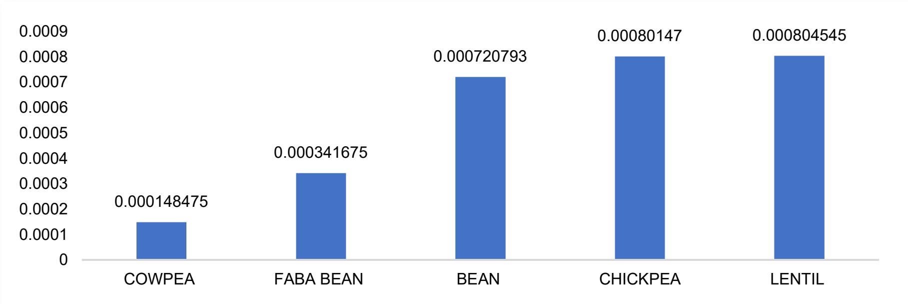
Figure 9. Acidification (kg SO2 eq)



Source: CIHEAM Bari elaboration on data from the SimaPro software

In Figure 10, as regards the level of eutrophication, lentils are the ones with the highest level of eutrophication, equal to 0.000805 kg PO4 eq, slightly higher than chickpeas, equal to 0.000801 kg PO4 eq.

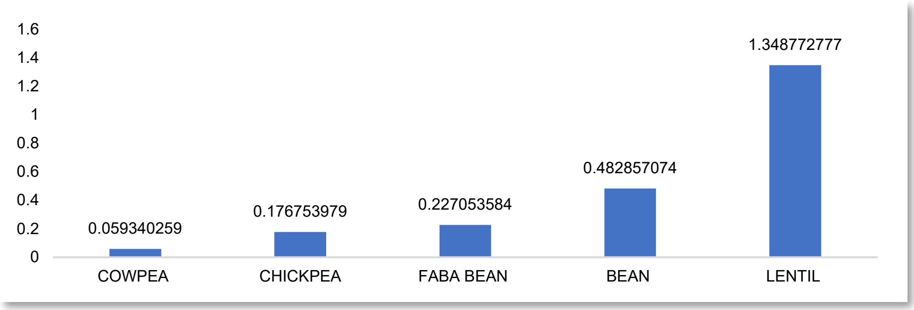
Figure 10. Eutrophication (kg PO4 eq)



Source: CIHEAM Bari elaboration on data from the SimaPro software

In Figure 11, as regards Global Warming, lentils have the greatest impact, equal to 1.35 kg CO2 eq.

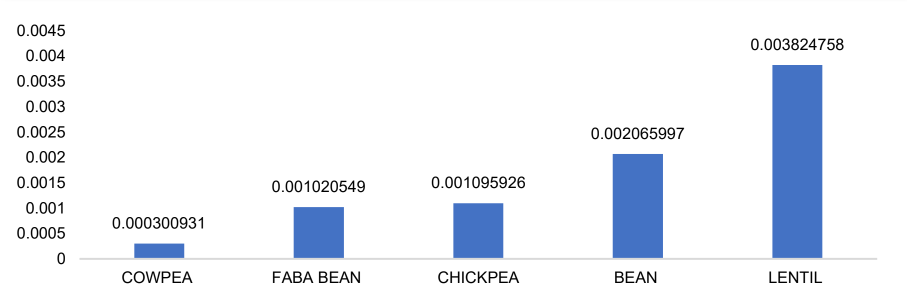
Figure 11. Global warming (kg CO2 eq)



Source: CIHEAM Bari elaboration on data from the SimaPro software

In Figure 12, as regards Photochemical oxidation, lentil is the one with the highest impact, equal to 0.0038 kg NMVOC.

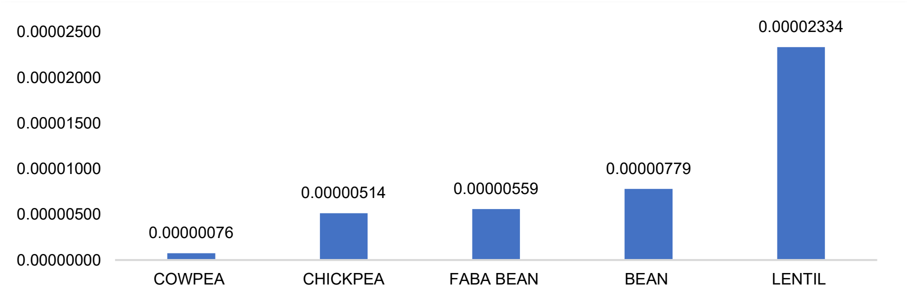
Figure 12. Photochemical oxidation (kg NMVOC)



Source: CIHEAM Bari elaboration on data from the SimaPro software

In Figure 13, as regards Abiotic depletion - elements, lentil is the one with the highest impact, equal to 0.000023 kg Sb eq.

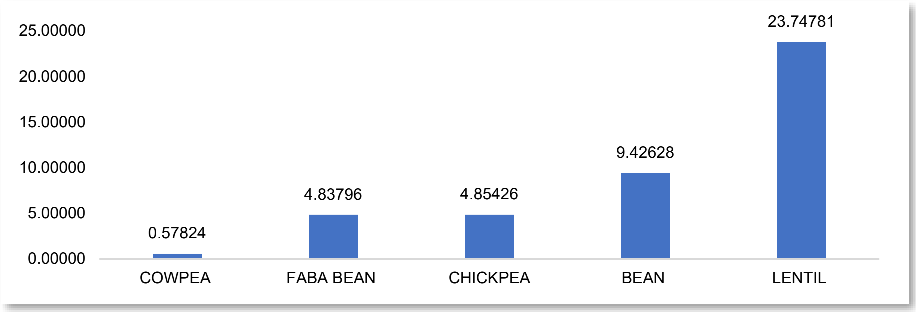
Figure 13. Abiotic depletion, elements (kg Sb eq)



Source: CIHEAM Bari elaboration on data from the SimaPro software

In Figure 14, as regards Abiotic depletion – fossil fuels, lentils have the greatest impact, equal to 23.75 MJ.

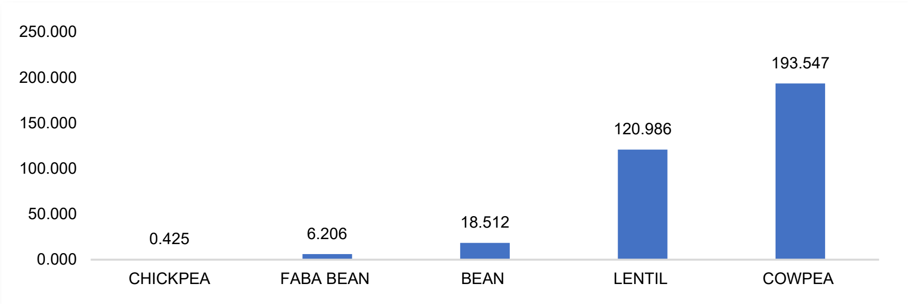
Figure 14. Abiotic depletion, fossil fuels (MJ)



Source: CIHEAM Bari elaboration on data from the SimaPro software

In Figure 15, as regards Water Scarcity, cowpea has the greatest impact, equal to 193.5 m3 eq.

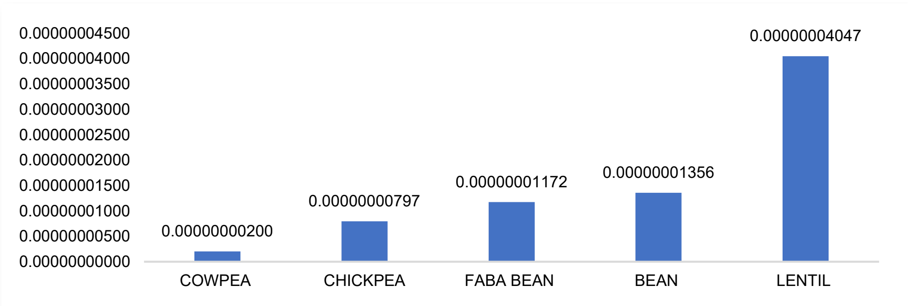
Figure 15. Water scarcity (m3 eq)



Source: CIHEAM Bari elaboration on data from the SimaPro software

In Figure 16, as regards Ozone layer depletion, the lentil is the one with the greatest impact, equal to 0.00000004047 kg CFC-11 eq.

Figure 16. Ozone layer depletion (kg CFC-11 eq)



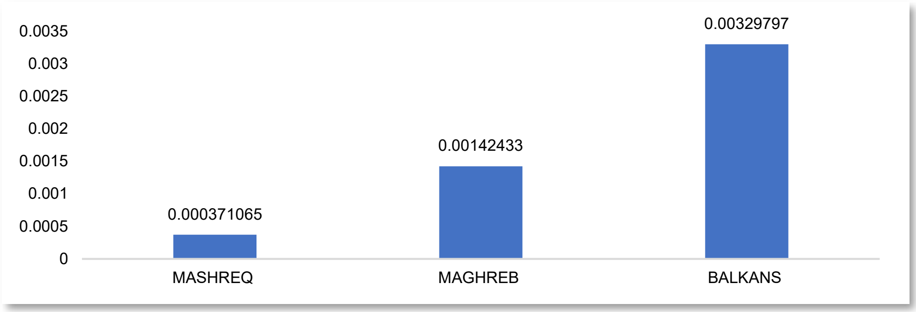
Source: CIHEAM Bari elaboration on data from the SimaPro software

C. By impact category for macro-area

Starting from Figure 17, the same impact categories were analyzed by macro-area, with the aim of identifying, for each category, the area that has the greatest environmental impact.

In Figure 17, as regards the level of acidification, the Balkans are the area with the highest level of acidification, equal to an average value of 0.0033 kg SO2 eq.

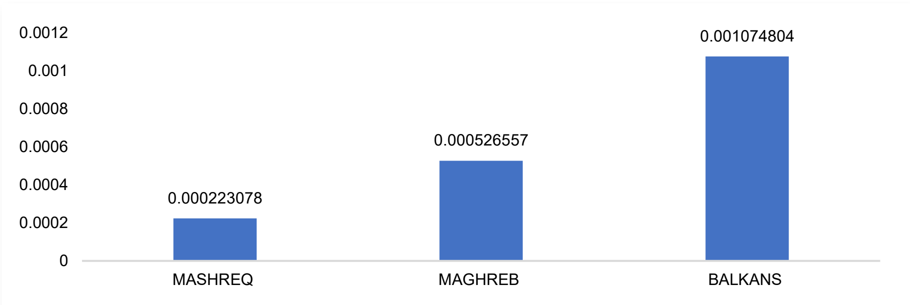
Figure 17. Acidification (kg SO2 eq)



Source: CIHEAM Bari elaboration on data from the SimaPro software

In Figure 18, as regards the level of eutrophication, the Balkans are the area with the greatest impact, equal to an average value of 0.0011 kg PO4 eq.

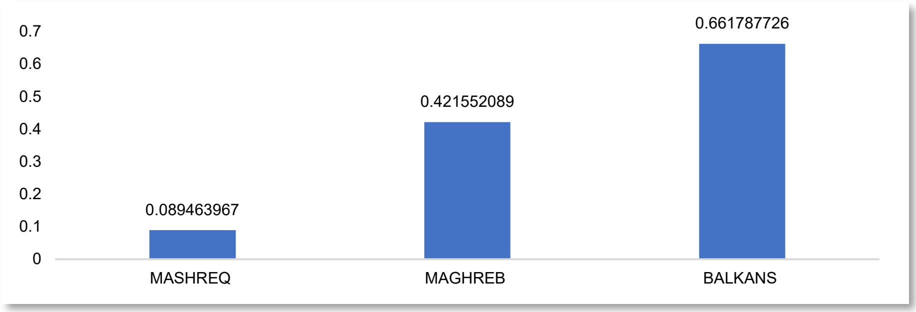
Figure 18. Eutrophication (kg PO4 eq)



Source: CIHEAM Bari elaboration on data from the SimaPro software

In Figure 19, as regards Global Warming, the Balkans are the area with the greatest impact, equal to an average value of 0.66 kg CO2 eq.

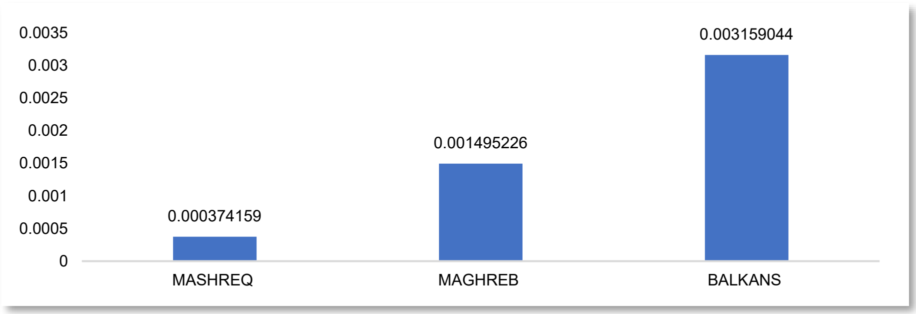
Figure 19. Global warming (kg CO2 eq)



Source: CIHEAM Bari elaboration on data from the SimaPro software

In Figure 20, as regards Photochemical oxidation, the Balkans are the area with the highest impact, equal to an average value of 0.0032 kg NMVOC.

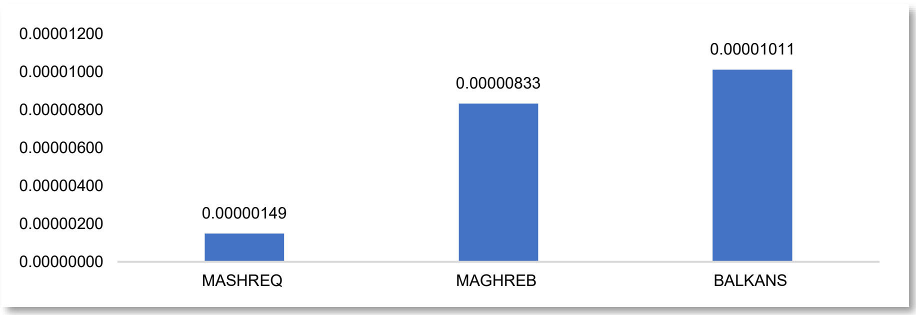
Figure 20. Photochemical oxidation (kg NMVOC)



Source: CIHEAM Bari elaboration on data from the SimaPro software

In Figure 21, as regards Abiotic depletion - elements, the Balkans are the area with the highest impact, equal to an average value of 0.000012 kg Sb eq.

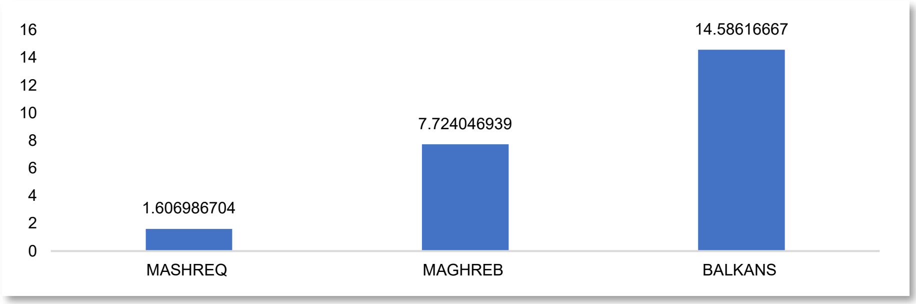
Figure 21. Abiotic depletion, elements (kg Sb eq)



Source: CIHEAM Bari elaboration on data from the SimaPro software

In Figure 22, as regards Abiotic depletion - fossil fuels, the Balkans are the area with the greatest impact, equal to an average value of 14.59 MJ.

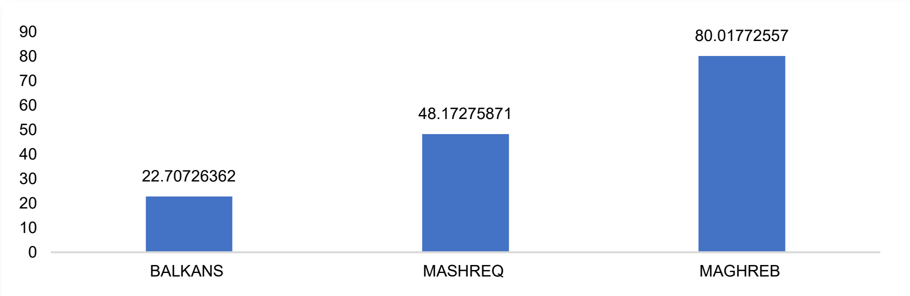
Figure 22. Abiotic depletion, fossil fuels (MJ)



Source: CIHEAM Bari elaboration on data from the SimaPro software

In Figure 23, as regards Water scarcity, the MAGHREB is the area with the greatest impact, equal to an average value of 80 m3 eq.

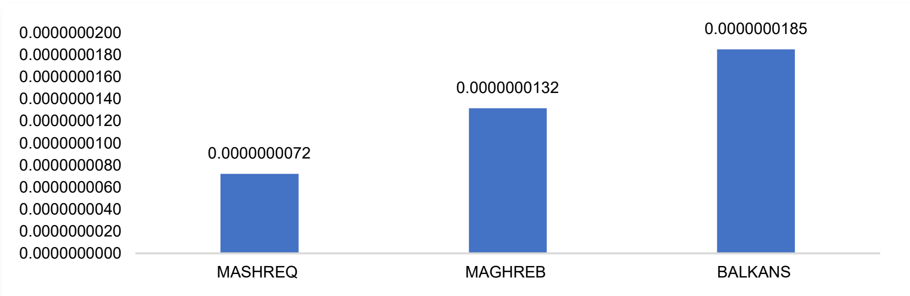
Figure 23. Water scarcity (m3 eq)



Source: CIHEAM Bari elaboration on data from the SimaPro software

In Figure 24, as regards Ozone layer depletion, the Balkans are the area with the greatest impact, equal to an average value of 0.0000000185 m3 eq.

Figure 24. Ozone layer depletion (kg CFC-11 eq)



Source: CIHEAM Bari elaboration on data from the SimaPro software

D. By impact category for cultivation

To complete the environmental analysis, thus also including a so-called endpoint method, Eco-Indicator 99 was used, which, starting from Table 2, shows the different results obtained by damage category, crop and macro-area.

Table 2 shows that, for the category of damage related to Human Health, measured by DALY, lentil production in Algeria L_DZA_Syrie229 06 is the one that generates the greatest damage on human health, equal to 0.000002180 DALY.

Table 2. Human Health (DALYs)

SAMPLES	Human Health
	DALY
Cw_MRT_BR1	0.000000005
Cw_MRT_GU1	0.000000005
Cw_MRT_AD1	0.000000008
Cp_JOR_JO02	0.000000077
F_SYR_SY09	0.000000184
B_DZA_Whitecoco	0.000000191
F_DZA_Seville04	0.000000202
B_DZA_Praguecoco	0.000000230
L_MAR_Cinq	0.000000242
L_SYR_SY08	0.000000315
Cw_MAR_Hamera	0.000000333
B_MAR_Ghelid	0.000000368
B_MAR_Reguig	0.000000368
F_TN_Malti	0.000000458
B_SRB_Gradistanac	0.000000509
B_SRB_Tetouac	0.000000612
Cp_TN_Amdoun	0.000001059
B_AL_FasuleEcmeniku	0.000001290
B_AL_FasuleSacme	0.000001345
L_DZA_Syrie229 06	0.000002180

Source: CIHEAM Bari elaboration on data from the SimaPro software

Table 3 shows that, for the damage category related to Ecosystem Quality, measured by PDF*m2yr, lentil production in Syria L_SYR_SY08 is the one that generates the greatest damage on ecosystem quality, equal to 8.027529 PDF*m2yr.

Table 3. Ecosystem quality (PDF*m2yr)

SAMPLES	Ecosystem quality
	PDF*m2yr
Cw_MAR_Hamera	-0.102902
B_MAR_Ghelid	-0.039414
B_MAR_Reguig	-0.039389
F_SYR_SY09	-0.037873
B_AL_FasuleSacme	-0.006572
B_SRB_Tetouac	-0.006399
B_SRB_Gradistanac	-0.005017
Cw_MRT_AD1	-0.004720
Cw_MRT_BR1	-0.004433
F_DZA_Seville04	-0.004386
Cw_MRT_GU1	-0.003724
B_AL_FasuleEcmeniku	-0.002383
F_TN_Malti	-0.000690
B_DZA_Whitecoco	0.001684
Cp_JOR_JO02	0.001956
B_DZA_Praguecoco	0.002528
Cp_TN_Amdoun	0.104233
L_DZA_Syrie229 06	1.556672
L_MAR_Cinq	3.031932
L_SYR_SY08	8.027529

Source: CIHEAM Bari elaboration on data from the SimaPro software

Table 4 shows that, for the damage category related to Resources, measured by MJ surplus, lentil production in Algeria L_DZA_Syrie229 06, is the one that generates the greatest damage on resource availability, equal to 6.06360957 MJ surplus.

Table 4. Resources (MJ surplus)

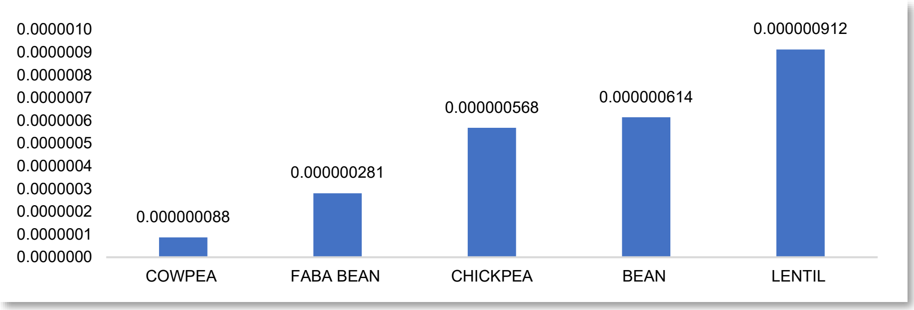
SAMPLES	Resources
	MJ surplus
Cw_MRT_BR1	0.002648841
Cw_MRT_GU1	0.003299723
Cw_MRT_AD1	0.004815249
Cp_JOR_JO02	0.056445479
L_MAR_Cinq	0.06815662
L_SYR_SY08	0.123998789
Cw_MAR_Hamera	0.19097279
B_MAR_Ghelid	0.264993949
B_MAR_Reguig	0.26695918
F_SYR_SY09	0.320359695
B_DZA_Whitecoco	0.44410321
F_TN_Malti	0.47512374
F_DZA_Seville04	0.484253717
B_DZA_Praguecoco	0.520655778
Cp_TN_Amdoun	0.787968448
B_AL_FasuleEcmeniku	1.167059692
B_SRB_Tetouac	1.172080854
B_SRB_Gradistanac	1.220074871
B_AL_FasuleSacme	1.454539845
L_DZA_Syrie229 06	6.06360957

Source: CIHEAM Bari elaboration on data from the SimaPro software

E. By damage categories for legumes

Starting from Figure 25, the same damage categories were analyzed among legumes, with the aim of identifying, for each, which of the five cultivars causes the greatest damage.
In Figure 25, as regards the Human Health damage category, lentils are the ones that cause the greatest damage, equal to 0.000000912 DALYs.

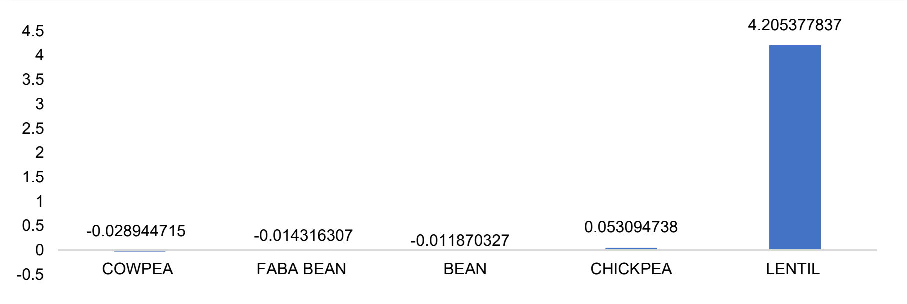
Figure 25. Human Health (DALY)



Source: CIHEAM Bari elaboration on data from the SimaPro software

In Figure 26, as regards the Ecosystem Quality damage category, lentil is the one that causes the greatest damage, equal to 4.21 PDF*m2yr.

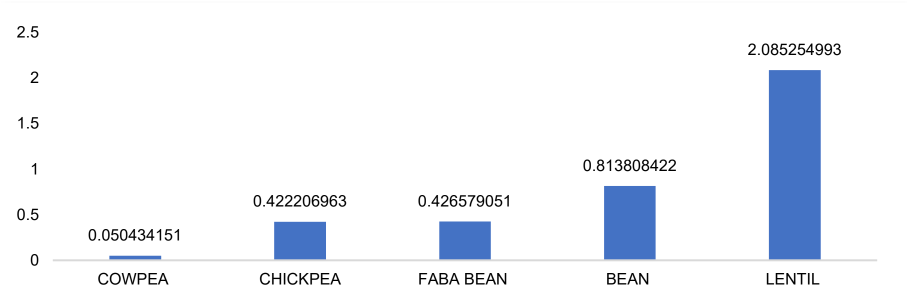
Figure 26. Ecosystem Quality (PDF*m2yr)



Source: CIHEAM Bari elaboration on data from the SimaPro software

In Figure 27, for the Resources damage category, lentil is the one that causes the greatest damage, equal to 2.09 MJ Surplus.

Figure 27. Resources (MJ Surplus)



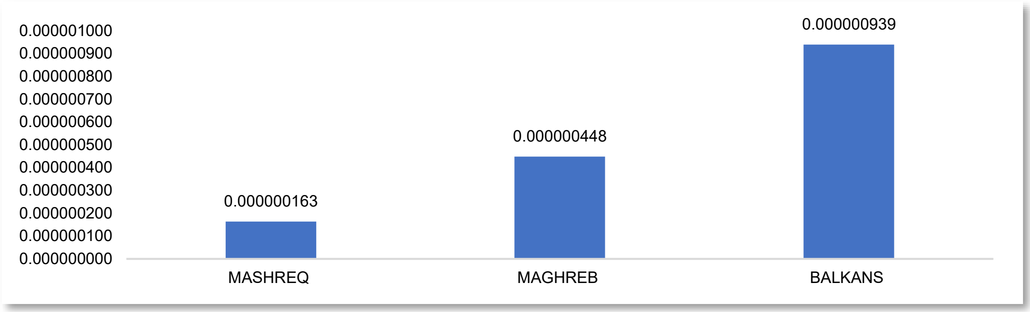
Source: CIHEAM Bari elaboration on data from the SimaPro software

F. By damage categories for macro-area

Starting from Figure 28, the same damage categories were analyzed by macro-area, with the aim of identifying, for each category, the area that causes the greatest damage in terms of human health, ecosystem quality, and resource availability.

Figure 32 shows that in the Balkans, on average, production causes greater damage to the Human Health category, equal to 0.000000939 DALYs.

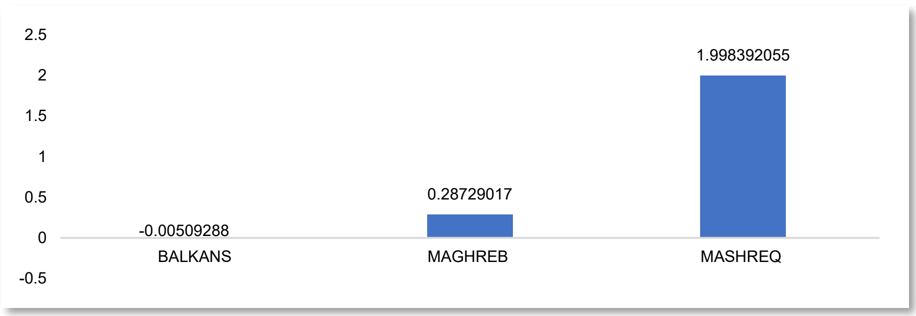
Figure 28. Human Health (DALY)



Source: CIHEAM Bari elaboration on data from the SimaPro software

Figure 29 shows that in MASHREQ, production, on average, causes greater damage to the Ecosystem Quality category, equal to 1,998 PDF*m2yr.

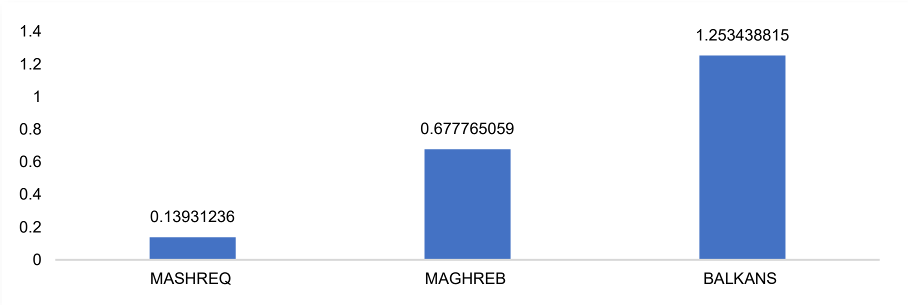
Figure 29. Ecosystem Quality (PDF*m2yr)



Source: CIHEAM Bari elaboration on data from the SimaPro software

Figure 30 shows that in the Balkans, on average, production causes greater damage to the Resources category, equal to 1.25 MJ Surplus.

Figure 30. Resources (MJ Surplus)



Source: CIHEAM Bari elaboration on data from the SimaPro software

G. Normalization and single score

By automatically normalizing the results, performed by the software, it was possible to standardize the damage categories and obtain a final result of the damage generated by each sample, which indirectly identifies a different field production system used based on the cultivar and country. Table 5 shows that the field production system that causes the most damage is that relating to lentils in Syria with code L_SYR_SY08, equal to 580.

Table 5. Single score

SAMPLES	Single score
Cw_MRT_BR1	-0.38137175
Cp_JOR_JO02	5.648094517
Cw_MAR_Hamera	14.73010893
F_SYR_SY09	17.12048831
B_MAR_Ghelid	23.37041451
B_MAR_Reguig	23.45713098
B_DZA_Whitecoco	24.65064706
F_DZA_Seville04	26.14992078
B_DZA_Praguecoco	29.22539038
F_TN_Malti	37.69228988
B_SRB_Gradistanac	66.33658789
B_SRB_Tetouac	69.17033971
Cp_TN_Amdoun	83.41811243
B_AL_FasuleEcmeniku	99.97852249
Cw_MRT_GU1	100.240349
B_AL_FasuleSacme	112.4546074
Cw_MRT_AD1	186.3586516
L_MAR_Cinq	225.3820075

L_DZA_Syrie229 06	424.3745911
L_SYR_SY08	580.0025987

Source: CIHEAM Bari elaboration on data from the SimaPro software

6. Comparison with the results obtained with the first phase of the Project

Results obtained with the 20 questionnaires relating to legumes from the 2024 harvest were compared with the same ones collected in 2023, and reported below for each impact category, each variety, and each Country (see Table 6).

Table 6. Comparison of impact categories by Country and legume in 2024 and 2023 crop years

Year	24	23	24	23	24	23	24	23	24	23	24	23	24	23	24	23
I.C.[1]	Acidification		Eutrophication		Global warming		Photochemical oxidation		Abiotic depletion, elements		Abiotic depletion, fossil fuels		Water scarcity		Ozone layer depletion	
U.M.	kg SO2eq		kg PO4-eq		kg CO2eq		kg NMVOC		kg Sbeq		MJ		m3eq		kg CFC-11eq	
ALBANIA																
Bean	4.56E-03	2.59E-03	1.58E-03	5.78E-04	9.60E-01	1.80E-01	3.73E-03	1.45E-03	1.25E-05	1.45E-03	1.51E+01	5.49E+00	1.26E+01	2.00E-02	2.04E-08	1.08E-08
SERBIA																
Bean	2.04E-03	4.87E-03	5.74E-04	5.32E-04	3.70E-01	2.60E-01	2.59E-03	1.56E-03	7.70E-06	1.92E-05	1.41E+01	1.71E+00	3.28E+01	1.10E-01	1.66E-08	2.41E-08
JORDAN																
Chickpea	9.90E-05	1.14E-04	1.32E-04	1.53E-04	2.00E-02	2.00E-02	1.44E-04	1.66E-04	2.00E-07	2.00E-07	6.70E-01	7.80E-01	7.00E-02	8.00E-02	1.40E-09	1.60E-09
SYRIA																
Faba bean	8.09E-04	5.26E-04	2.31E-04	2.65E-04	1.40E-01	5.00E-02	7.46E-04	3.87E-04	4.20E-06	2.10E-06	3.62E+00	9.50E-01	3.00E-02	3.60E+01	1.78E-08	2.40E-09
Lentil	4.77E-04	4.35E-04	3.97E-04	3.50E-04	1.80E-01	1.60E-01	4.63E-04	4.40E-04	1.50E-06	1.30E-06	1.46E+00	1.52E+00	1.93E+02	1.00E-02	8.20E-09	7.40E-09
ALGERIA																
Bean	1.51E-03	5.01E-04	3.94E-04	6.70E-05	6.40E-01	4.00E-02	1.86E-03	2.46E-04	1.64E-05	9.00E-07	1.09E+01	1.28E+00	5.71E+01	1.00E-02	1.89E-08	3.00E-09
Faba bean	6.90E-04	1.84E-04	1.96E-04	5.10E-05	3.30E-01	3.00E-02	9.43E-04	1.85E-04	5.70E-06	6.00E-07	5.47E+00	9.60E-01	1.84E+01	1.00E-02	9.20E-09	2.20E-09
Lentil	7.33E-03	1.96E-03	1.73E-03	3.80E-04	3.76E+00	3.50E-01	1.07E-02	2.23E-03	6.58E-05	3.00E-06	6.91E+01	1.48E+01	1.70E+02	6.00E-02	1.10E-07	5.60E-08
MAURITANIA																
Black-eyed pea	2.60E-05	4.81E-04	1.30E-05	3.40E-05	0.00E+00	1.00E-02	3.19E-05	7.02E-05	1.00E-07	2.00E-07	4.00E-02	8.00E-02	2.58E+02	7.36E+01	2.00E-10	6.00E-10
MOROCCO																
Bean	2.62E-03	8.69E-04	1.07E-03	3.78E-04	5.70E-01	1.70E-01	2.03E-03	7.79E-04	5.50E-06	1.90E-06	6.14E+00	2.11E+00	2.00E-01	5.00E-02	1.56E-08	5.80E-09
Black-eyed pea	1.25E-03	9.43E-04	5.54E-04	4.05E-04	2.30E-01	1.70E-01	1.11E-03	8.07E-04	2.90E-06	2.10E-06	2.19E+00	1.68E+00	7.00E-02	5.00E-02	7.30E-09	5.10E-09
Lentil	5.93E-04	3.75E-04	2.90E-04	1.80E-04	1.00E-01	8.00E-02	3.07E-04	2.18E-04	2.80E-06	2.60E-06	7.10E-01	5.40E-01	8.00E-02	2.00E-02	3.40E-09	5.00E-09
TUNISIA																
Chickpea	2.61E-03	9.06E-04	1.47E-03	1.07E-03	3.30E-01	2.10E-01	2.05E-03	8.27E-04	1.01E-05	1.90E-06	9.04E+00	2.80E+00	7.80E-01	5.60E-01	1.45E-08	8.20E-09

Source: CIHEAM Bari elaboration on data from the SimaPro software

[1] I.C.= Impact categories.

As highlighted in Table 6, the values for the impact categories are generally higher in 2024 than in the first year. The exceptions are chickpea cultivation in Jordan and cowpea in Mauritania, for which values for all environmental impact categories are reduced in 2024 compared to 2023.

Table 7. Comparison of impact categories for legumes in the 2024 and 2023 vintages

Impact categories	Year	Bean	Chickpea	Black-eyed pea	Faba bean	Lentil
Acidification	**2024**	2.68E-03	1.35E-03	6.40E-04	1.08E-03	2.80E-03
	2023	2.21E-03	5.10E-04	7.12E-04	6.15E-04	9.22E-04
Eutrophication	**2024**	9.04E-04	8.01E-04	2.84E-04	3.42E-04	8.05E-04
	2023	3.89E-04	6.11E-04	2.19E-04	3.01E-04	3.03E-04
Global warming	**2024**	6.35E-01	1.77E-01	1.15E-01	2.27E-01	1.35E+00
	2023	1.61E-01	1.14E-01	9.12E-02	1.01E-01	1.97E-01
Photochemical oxidation	**2024**	2.55E-03	1.10E-03	5.70E-04	1.02E-03	3.83E-03
	2023	1.01E-03	4.97E-04	4.38E-04	5.12E-04	9.64E-04
Abiotic depletion, elements	**2024**	1.10E-05	5.10E-06	1.50E-06	5.60E-06	2.33E-05
	2023	3.67E-04	1.10E-06	1.10E-06	1.80E-06	2.30E-06
Abiotic depletion, fossil fuels	**2024**	1.16E+01	4.85E+00	1.11E+00	4.84E+00	2.37E+01
	2023	2.65E+00	1.79E+00	8.83E-01	1.78E+00	5.61E+00
Water scarcity	**2024**	2.57E+01	4.25E-01	1.29E+02	6.21E+00	1.21E+02
	2023	4.85E-02	3.23E-01	3.68E+01	2.16E+01	2.98E-02
Ozone layer depletion	**2024**	1.79E-08	8.00E-09	3.80E-09	1.17E-08	4.05E-08
	2023	1.09E-08	4.90E-09	2.90E-09	3.10E-09	2.28E-08

Source: CIHEAM Bari elaboration on data from the SimaPro software

Looking at the data from a more general perspective (Table 7), considering the averages for each legume without geographical distinction, some interesting trends emerge:

- Cowpea shows a lower value in 2024 than in 2023 for the Acidification category;
- Beans show a lower value in 2024 than in the previous year in the Abiotic Depletion – Elements category.

By applying the Eco-Indicator Method, it was also possible to analyze the three macro-categories of damage: Human Health, Ecosystem Quality, and Resources. As highlighted in Table 8, the results of the second year show an overall improvement, both in terms of environmental impact and damage to human health, compared to the first year.

In particular, progress is observed in the following cases:

- Bean production in Serbia: improvements in the Human Health and Ecosystem Quality categories;
- Chickpea production in Jordan: improvements in all three damage categories;
- Faba bean production in Syria: improvement in the Ecosystem Quality category;
- Lentil production in Syria: improvement in the Resources category;
- Cowpea Production in Mauritania: Improvements in Human Health and Resources Categories;
- Cowpea production in Morocco: improvement in the Ecosystem Quality category;
- Faba bean production in Tunisia: improvement in the Human Health category.

Table 8. Comparison of damage categories by country and legume in 2024 and 2023

Year	2024	2023	2024	2023	2024	2023
Damage categories	Human Health		Ecosystem Quality		Resources	
U.of M.	DALY		PDF*m2yr		MJ surplus	
			ABANIA			
Bean	1.32E-06	3.50E-07	-4.48E-03	-7.38E-02	1.31E+00	4.80E-01
			SERBIA			
Bean	5.60E-07	1.00E-06	-5.71E-03	-4.89E-03	1.20E+00	5.00E-01
			JORDAN			
Chickpea	7.70E-08	9.00E-08	1.96E-03	2.26E-03	5.64E-02	7.00E-02
			SYRIA			
Faba bean	1.84E-07	1.40E-07	-3.79E-02	-1.64E-02	3.20E-01	9.00E-02
Lentil	3.15E-07	2.80E-07	8.03E+00	7.02E+00	1.24E-01	1.30E-01
			ALGERIA			
Bean	2.11E-07	4.70E-08	2.11E-03	-7.66E-03	4.82E-01	1.10E-01
Faba bean	2.02E-07	3.40E-08	-4.39E-03	-6.06E-03	4.84E-01	8.00E-02
Lentil	2.18E-06	4.00E-07	1.56E+00	1.38E+00	6.06E+00	1.25E+00
			MAURITANIA			
Black-eyed pea	5.90E-09	1.30E-08	-4.29E-03	-1.20E-02	3.59E-03	1.00E-02
			MOROCCO			
Bean	3.68E-07	2.40E-07	3.68E-07	-6.23E-02	2.66E-01	1.60E-01
Black-eyed pea	3.33E-07	2.60E-07	-1.03E-01	-6.60E-02	1.91E-01	1.50E-01
Lentil	2.42E-07	1.70E-07	3.03E+00	3.02E+00	6.82E-02	5.00E-02
			TUNISIA			
Chickpea	1.06E-06	6.30E-07	1.04E-01	1.95E-02	7.88E-01	2.40E-01
Faba bean	4.58E-07	5.60E-07	-6.90E-04	-4.92E-03	4.75E-01	2.80E-01

Source: CIHEAM Bari elaboration on data from the SimaPro software

7. Comments and recommendations

As specified in the analysis for legume crops in 2023, it is also important to note that for 2024, legume samples and the related questionnaires for different species and/or native varieties were collected, based on availability, primarily from fields belonging to different farms, and therefore under different soil, climate, and pedoclimatic conditions. The variability of exogenous conditions, such as environmental ones, and the variability of endogenous conditions, such as the cultivation techniques adopted, at the local and national level, significantly impacted the results between the same species and by country.

In fact, the multiplicity of these variables across countries and selected fields has not allowed to draw definitive conclusions and to state with certainty that one cultivated variety is more environmentally sustainable than another based solely on its genetic characteristics. However, we have been able to obtain some general indications or evidence that can be further explored and confirmed in future studies.

In conclusion, the current study shows with good reliability that it is possible to correlate the greater or lesser environmental impacts of the legumes harvested and analyzed with different cultivation techniques. Indeed, growers in some countries and on some farms are using more inputs such as fertilizers for fertility management, more fuels for mechanized cultivation, more pesticides for plant protection, and more water for irrigation, even though legumes generally do not require much water or nutrients. These substantial differences in cultivation methods across countries, and even within the same countries, in the fields where the samples were collected, are the basis for the different environmental impacts (emissions and damage) in the study. This is likely not strictly attributable to the variety (local variety or landrace), but rather to the production techniques and the soil and climate conditions of the cultivation field.

Table 9 and Table 10 show the complete picture of what emerged, with some differences from the previous year, with reference to the environmental indicators developed for each country and species.

From the analysis in the Mediterranean area by indicator, calculated according to the EDP method (2018), and by species of the legume samples analysed, the following average results are highlighted:

- *Global Warming*: Lentils have higher GW indicator values than beans, broad beans, chickpeas and cowpeas, this is essentially due to the greater use of inorganic fertilizers, machinery (fuel) and pesticides.
- *Acidification*: lentils have higher indicator values than beans, broad beans, chickpeas and cowpeas, this is mainly due to a greater use of inorganic N-based fertilizers and machinery (fuel).
- *Eutrophication*: lentils and chickpeas have, almost equally, higher impacts than the others, due to a substantially greater application of nitrogen and phosphoric fertilizers, and to greater use of machinery (fuel).
- *Ozone depletion*: the highest values are for lentils.
- *Photochemical oxidation*: the highest values are for lentils.
- *Abiotic depletion from fossil fuels*: the highest values are for lentils.
- *Abiotic depletion, components*: the highest values are for lentils.
- *Water scarcity*: the highest value is for black-eyed peas, due to the greater quantities of water used, followed at a distance by lentils and beans.

With reference to the Eco-Indicator 99 method, depending on the indicators, the main findings, as reported in Table 10, are:

- *Damage to human health*: lentils have the highest values, having a particularly strong impact on the respiratory system, carcinogenic, the other crops have the lowest values.
- *Damage to ecosystem quality*: lentils have the highest values, having the greatest impact on land use; others have values more or less close to zero, which indicates that they are to be considered more or less positive in land use.
- *Damage to resource availability*: lentils have the highest value, due to a greater use of fossil fuels.

However, it is worth noting that the environmental indicator values calculated for each species are often lower than the respective benchmarks, as documented in the limited literature available. This demonstrates that the harvest fields in the eight countries adopt agricultural practices that have a lower overall environmental impact. This is the normal consequence of cultivating typical local varieties, often underutilized, which are often grown only by small producers (so-called custodians), and in some cases only for family use.

In other words, the aforementioned producers of local varieties generally adopt more traditional cultivation techniques. In fact, they follow less intensive cultivation methods. In some cases, many operations are still done by hand (sowing, weed control, pesticide application, harvesting). In general, they use fewer inorganic fertilizers and synthetic chemical pesticides. This is compared to those producers who adopt more productive cultivation methods on farms that produce primarily for the market, primarily growing "international" varieties for a higher yield per hectare.

Furthermore, it is important to recognize that, in general, the deterioration in environmental sustainability in the cultivation of key crops such as cereals, tree crops, and horticultural crops is essentially the result of a trend toward increased yields, and thus the increased use of fossil fuels and inorganic fertilizers, as well as irrigation water. It is also important to recognize that, specifically among legumes, local or native varieties are grown more for their rural and local food traditions, and therefore for their uniqueness, as well as for their adaptation to unfavorable local soil and climate conditions, rather than for high yields. The confirmation of this second study on the environmental impact of legumes in eight Mediterranean countries, conducted as part of the MEDIET Project, likely confirms that growing local or native varieties using traditional and less intensive cultivation methods can contribute to mitigating climate change and reducing biodiversity loss.

In conclusion, the comparative analysis between data collected in 2023 and those for the 2024 crop year highlights a general trend of increasing environmental impacts, with some notable exceptions. Chickpea cultivation in Jordan and cowpea cultivation in Mauritania, for example, showed a significant reduction in environmental impacts across all categories analyzed.

These differences are not solely attributable to the genetics of the varieties, but are strongly influenced by external factors, in particular:

- the different origin of the samples (farms with variable soil and climate conditions, orography and cultivation techniques);
- and the intensity of use of agricultural inputs (fertilizers, fuels, pesticides, water).

The 2024 analysis therefore confirms that cultivation techniques are the primary determinant of environmental impact, more than the variety grown alone. Specifically, crops such as lentils continue to register the highest scores in the main environmental impact categories and in damage according to the Eco-Indicator 99 method, due to more intensive cultivation practices. Conversely, chickpeas, cowpeas, and other local varieties, in contexts where they are grown using traditional methods, exhibit a significantly lower environmental impact. Overall, the data collected in 2024 reinforces some strategic indications that emerged in the first year of the study. In light of this evidence, the following recommendations are proposed:

1. **Promote low environmental impact agricultural practices**: it is essential to encourage the adoption of sustainable techniques in contexts with high levels of chemical inputs and resources. Training, technology transfer, and technical assistance could guide producers toward more efficient and less impactful systems.
2. **Promote local varieties and small custodian producers**: evidence shows that native varieties, grown extensively and often manually, are more environmentally sustainable. Policies to protect and promote these crops, including commercially, are needed.
3. **Standardize data collection and strengthen multi-annual monitoring**: it is desirable to maintain continuous and harmonized monitoring of crops and production contexts, in order to more clearly isolate the effects linked to agricultural practices and improve comparability between years.
4. **Systematically integrate environmental analysis with socio-economic analysis:** starting in 2024, a complementary socioeconomic analysis has been introduced, confirming the importance of a multidimensional approach to sustainability. Only by simultaneously examining environmental impacts, producers' economic conditions, and social aspects is it possible to develop realistic, effective, and local-specific strategies.
5. **Making the results accessible and usable**: the data collected and the evidence that emerges must be translated into dissemination and communication tools for the productive world, research, institutions and consumers, in order to guide decisions towards more sustainable production and consumption models.

Table 9. Values by Country and cultivar 2024, EPD Method (2018)

Impact categories	Acidification	Eutrophication	Global warming	Photochemical oxidation	Abiotic depletion, elements	Abiotic depletion, fossil fuels	Water scarcity	Ozone layer depletion
U. of M.	***kg SO2 eq***	***kg PO4 eq***	***kg CO2 eq***	***kg NMVOC***	***kg Sb eq***	***MJ***	***m3 eq***	***kg CFC-11 eq***
ALBANIA								
B_AL_Fasule Sacme	4.42E-03	1.55E-03	9.30E-01	3.46E-03	1.24E-05	1.34E+01	8.53E+00	1.86E-08
B_AL_Fasule Ecmeniku	4.70E-03	1.60E-03	9.90E-01	4.00E-03	1.25E-05	1.68E+01	1.67E+01	2.23E-08
SERBIA								
B_SRB_Gradistanac	1.98E-03	5.44E-04	3.70E-01	2.56E-03	8.70E-06	2.38pm	2.97E+01	1.69E-08
B_SRB_Tetouac	2.10E-03	6.05E-04	3.70E-01	2.61E-03	6.80E-06	1.38E+01	3.59E+01	1.62E-08
JORDAN								
Cp_JOR_JO02	9.90E-05	1.32E-04	2.00E-02	1.44E-04	2.00E-07	6.70E-01	7.00E-02	1.40E-09
SYRIA								
L_SYR_SY08	4.77E-04	3.97E-04	1.80E-01	4.63E-04	1.50E-06	1.46E+00	1.93E+02	8.24E-09
F_SYR_SY09	8.09E-04	2.31E-04	1.40E-01	7.46E-04	4.20E-06	3.62E+00	3.00E-02	1.78E-08
ALGERIA								
F_DZA_Seville04	6.90E-04	1.96E-04	3.30E-01	9.43E-04	5.70E-06	5.47E+00	1.84E+01	9.21E-09
L_DZA_Syrie 229 06	7.33E-03	1.73E-03	3.76E+00	1.07E-02	6.58E-05	6.91E+01	1.70E+02	1.10E-07
B_DZA_Whitecoco	6.75E-04	1.79E-04	3.00E-01	8.54E-04	7.00E-06	5.03E+00	2.81E+01	8.69E-09
B_DZA_Praguecoco	8.30E-04	2.15E-04	3.40E-01	1.01E-03	9.30E-06	5.90E+00	2.89E+01	1.02E-08
MAURITANIA								
Cw_MRT_AD1	3.30E-05	1.60E-05	1.00E-02	4.10E-05	1.00E-07	6.00E-02	6.78E+02	2.70E-10
Cw_MRT_BR1	2.20E-05	1.30E-05	0.00E+00	2.60E-05	1.00E-07	3.00E-02	2.01E+01	2.20E-10
Cw_MRT_GU1	2.40E-05	1.20E-05	0.00E+00	2.90E-05	1.00E-07	4.00E-02	7.61E+01	2.00E-10
MOROCCO								
L_MAR_Cinq	5.93E-04	2.90E-04	1.00E-01	3.07E-04	2.80E-06	7.10E-01	8.00E-02	3.37E-09
B_MAR_Ghelid	1.31E-03	5.36E-04	2.90E-01	1.01E-03	2.80E-06	3.06E+00	1.10E-01	7.78E-09
B_MAR_Reguig	1.31E-03	5.37E-04	2.90E-01	1.02E-03	2.80E-06	3.08E+00	1.00E-01	7.80E-09
Cw_MAR_Hamera	1.25E-03	5.54E-04	2.30E-01	1.11E-03	2.90E-06	2.19E+00	7.00E-02	7.32E-09
TUNISIA								
F_TN_Malti	1.74E-03	5.98E-04	2.10E-01	1.37E-03	6.80E-06	5.42E+00	2.10E-01	8.12E-09
Cp_TN_Amdoun	2.61E-03	1.47E-03	3.30E-01	2.05E-03	1.01E-05	9.04E+00	7.80E-01	1.45E-08
AVERAGE DATA FOR MACRO-AREA								
BALKANS	3.30E-03	1.08E-03	6.60E-01	3.16E-03	1.01E-05	2.59pm	2.27E+01	1.85E-08
MASHREQ	3.71E-04	2.23E-04	9.00E-02	3.74E-04	1.50E-06	1.61E+00	4.82E+01	7.21E-09
MAGHREB	1.42E-03	5.27E-04	4.20E-01	1.50E-03	8.30E-06	7.72E+00	8.00E+01	1.32E-08
AVERAGE DATA PER SPECIES								
BEAN	2.17E-03	7.21E-04	4.80E-01	2.07E-03	7.80E-06	9.43E+00	1.85E+01	1.36E-08
CHICKPEA	1.35E-03	8.01E-04	1.80E-01	1.10E-03	5.10E-06	4.85E+00	4.30E-01	7.97E-09
BLACK-EYED BEAN	3.33E-04	1.48E-04	6.00E-02	3.01E-04	8.00E-07	5.80E-01	1.94E+02	2.00E-09
BEAN	1.08E-03	3.42E-04	2.30E-01	1.02E-03	5.60E-06	4.84E+00	6.21E+00	1.17E-08
LENTIL	2.80E-03	8.05E-04	1.35E+00	3.83E-03	2.33E-05	2.38E+01	1.21E+02	4.05E-08

Source: CIHEAM Bari elaboration on data from the SimaPro software

Table 10. Values by country and cultivar 2024, Eco-Indicator Method

DAMAGE CATEGORIES	Human Health	Ecosystem Quality	Resources	SINGLE SCORE
U. of M.	DALY	PDF*m2yr	MJ surplus	Mpt
		ALBANIA		
B_AL_FasuleSacme	1.30E-06	-6.57E-03	1.45E+00	1.13E+02
B_AL_FasuleEcmeniku	1.30E-06	-2.38E-03	1.17E+00	1.00E+02
		SERBIA		
B_SRB_Gradistanac	5.10E-07	-5.02E-03	1.22E+00	6.63E+01
B_SRB_Tetouac	6.10E-07	-6.40E-03	1.17E+00	6.92E+01
		JORDAN		
Cp_JOR_JO02	7.70E-08	1.96E-03	5.64E-02	5.60E+00
		SYRIA		
L_SYR_SY08	3.15E-07	8.03E+00	1.24E-01	5.80E+02
F_SYR_SY09	1.84E-07	-3.79E-02	3.20E-01	1.71E+01
		ALGERIA		
F_DZA_Seville04	2.02E-07	-4.39E-03	4.84E-01	2.61E+01
L_DZA_Syrie229 06	2.18E-06	1.56E+00	6.06E+00	4.24E+02
B_DZA_Whitecoco	1.91E-07	1.68E-03	4.44E-01	2.47E+01
B_DZA_Praguecoco	2.30E-07	2.53E-03	5.21E-01	2.92E+01
		MAURITANIA		
Cw_MRT_AD1	8.00E-09	-4.72E-03	4.82E-03	1.86E+02
Cw_MRT_BR1	5.00E-09	-4.43E-03	2.65E-03	-4.00E-01
Cw_MRT_GU1	5.00E-09	-3.72E-03	3.30E-03	1.00E+02
		MOROCCO		
L_MAR_Cinq	2.42E-07	3.03E+00	6.82E-02	2.25E+02
B_MAR_Ghelid	3.68E-07	-3.94E-02	2.65E-01	2.34E+01
B_MAR_Reguig	3.68E-07	-3.94E-02	2.67E-01	2.35E+01
Cw_MAR_Hamera	3.33E-07	-1.03E-01	1.91E-01	1.47E+01
		TUNISIA		
F_TN_Malti	4.58E-07	-6.90E-04	4.75E-01	3.77E+01
Cp_TN_Amdoun	1.06E-06	1.04E-01	7.88E-01	8.34E+01
		AVERAGE DATA FOR MACRO-AREA		
BALKANS	9.39E-07	-5.09E-03	1.25E+00	8.70E+01
MASHREQ	1.63E-07	2.00E+00	1.39E-01	1.52E+02
MAGHREB	4.48E-07	2.87E-01	6.78E-01	8.84E+01
		AVERAGE DATA PER SPECIES		
BEAN	6.14E-07	-1.19E-02	8.14E-01	5.61E+01
CHICKPEA	5.68E-07	5.31E-02	4.22E-01	4.45E+01
BLACK-EYED BEAN	8.78E-08	-2.89E-02	5.04E-02	7.52E+01
BEAN	2.81E-07	-1.43E-02	4.27E-01	2.70E+01
LENTIL	9.12E-07	4.21E+00	2.09E+00	4.10E+02

Source: CIHEAM Bari elaboration on data from the SimaPro software

III – Socio-economic impact assessment

The economic sustainability assessment was carried out using the cost-benefit analysis (CBA) methodology, through the identification of economic indicators reported per unit of surface area, which was indicated as the hectare.

8. Methodology, selected indicators and tools

Using a specially constructed questionnaire (Annex 1), technical-economic data were collected from the producer on the quantities of production inputs and their unit prices, based on the chosen indicators (Table 11), to process them in a specially constructed spreadsheet; therefore, production costs, called variable or direct costs, were calculated for seeds, agrochemicals, fertilizers, fuels, irrigation water, labor, as well as interests; then, data on production yields and the selling price were collected to calculate the revenues from the final products (Kay *et al.,* 2011; Torquati, 2015).

Specifically, the cost of labor was calculated based on the hours of work spent in the field and the cost per working hour.

Finally, gross income was calculated from the difference between revenues and variable costs, with the aim of evaluating the profitability of growing these legume species.

For the social assessment, based on the FAO's Sustainability Assessment of Food and Agriculture Systems (SAFA) methodology, agricultural labour income per hectare, per hour, and per day was calculated to assess whether it was equitable compared to the average cost of agricultural labour in the country, understood as the opportunity cost, known as the shadow price. Labor efficiency was also calculated by dividing revenue by labour hours and labour costs. Labor efficiency was also calculated as the ratio of gross income divided by the labour hours required to cultivate the crop, or as the ratio of gross income divided by labour costs. Therefore, if in the first case the value obtained is higher than the hourly cost, and if in the second case the value is positive, social sustainability is considered positive.

Due to the limited availability and difficulty of economic data in scientific literature and in official databases by country and crop, it was only possible to gather information from unofficial databases, alternative sources, such as Chat GPT and Google AI Studio, and interviews with some national experts.

Table 11. Selected socio-economic indicators

Socio-economic indicators	Values
Revenue/ha	- €
Variable Costs/ha	- €
Gross Income/ha	- €
Labor Cost/Hour	- €
Labor Cost/Day	- €
Total Labor Cost/ha	- €
Revenue/Work Hours	- €
Revenue/Labor Cost	- €
Gross Income/Hour Worked	- €
Gross Income/Labor Cost	- €
Minimum Labor Cost/Hour (Country)	- €
Company/Country Delta Labor Cost	- €

Table 12 has been produced, which collects indicative and general information on some economic indicators, considering that there is a high variability depending on the varieties grown, the cultivation techniques, the climate, the use of manpower and the level of mechanization.

Table 12. Indicative economic data in the Mediterranean area

Crop	Variable costs (€)	Yield (t/ha)	Price (€/kg)	Revenue (€)	Gross Margin (€)
Chickpea	800 – 1,200	1.5 – 2.0	1.8 – 2.2	2,700 – 4,400	**1,500– 3,000**
Faba Bean	700 – 1,100	1.8 – 2.5	1.6 – 2.0	2,880 – 5,000	**1,500– 3,800**
Lentil	850 – 1,300	1.0 – 1.5	2.0 – 2.4	2,000 – 3,600	**800 – 2,300**
Common Bean	1,200 – 1,800	2.0 – 3.0	2.0 – 2.5	4,000 – 7,500	**2,200–5,700**

Source: CIHEAM Bari elaboration on data from interviews with experts

9. Results

The comparison of the economic values obtained from the selected indicators is highlighted in graph 31.

It can be noted that the highest revenues per hectare are obtained on average from broad beans at 5,833 euros and from beans at 4,845 euros, particularly higher in Algeria with 15,050 euros per broad bean and 18,750 euros per bean.

While the highest average production costs per hectare, also known as variable or direct costs, are found in the cultivation of beans at 1,361 euros, particularly in Serbia at 2,430 euros, the lowest for broad beans at 765 euros.

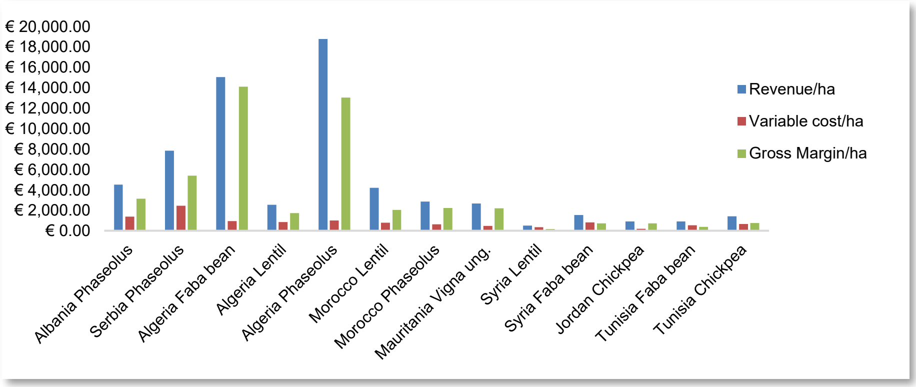
The profitability indicator as gross margin, calculated as the difference between revenues and variable costs, highlights (Table 13 and Figure 31) the highest average values among the species for beans at 5,944 euros with a maximum of 14,103 euros in Algeria, followed by broad beans at 5,068 euros, thanks to good yields and excellent selling prices, with a highest value of 13,017 euros in Algeria; while the average profitability is lower at 1,302 euros for lentils and 729 euros for chickpeas.

Table 13. Mean values processed by species in the fields of selected countries in the Mediterranean area

Socio-economic indicators	Bean	Faba bean	Lentil	Chickpea	Black-eyed pea
Revenue/ha	€8,485.42	€5,833.33	€2,419.50	€1,150.00	€2,650.95
Variable costs/ha	€1,361.11	€765.34	€659.34	€421.32	€468.99
Gross Income/ha	€5,944.31	€5,068.00	€1,301.93	€728.68	€ 2,181.96

Source: CIHEAM Bari elaboration on data from interviews with experts

Figure 31. Economic indicators by legume and by country



Source: CIHEAM Bari processing of data from interviews with producers

From what has been said above, it can be noted that, in general terms, the comparison with the general socio-economic data in the Mediterranean area (Table 12) confirms the higher revenues deriving from beans and broad beans, and the higher production costs for beans, in addition to a higher gross profitability for beans and broad beans.

Inputs must take into account the diversity of the species examined, local farming methods, and therefore the degree of mechanization, as well as the use of irrigation, which is very useful for increasing production yields and varies depending on seasonality and availability. In some fields, cultivation is done by hand, increasing the labor burden on inputs.

Generally speaking, for chickpeas the greatest impact on input costs depends on the purchase of seeds and irrigation, if used.

For lentils, which generally require fewer inputs than chickpeas, the higher costs are due to seeds, fertilizers and mechanization, where present.

The cost of beans is mainly due to seeds and irrigation, often used to ensure good yields, as well as fertilizers (Algeria) and agrochemicals (Morocco).

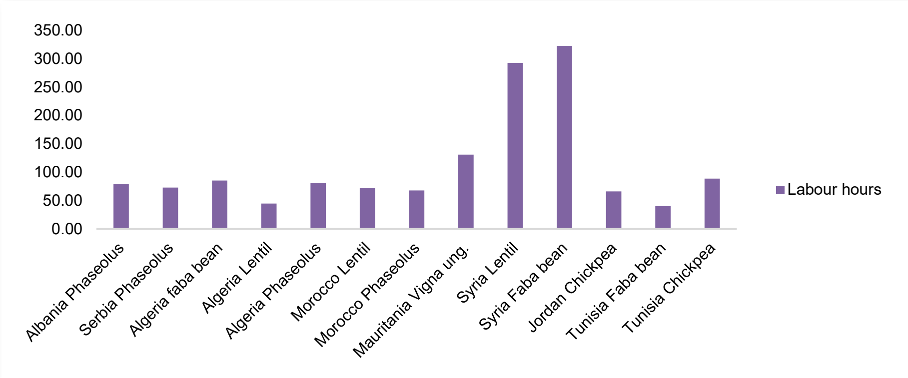
For broad beans, input costs are fairly distributed, with a prevalence for seeds.

For cowpeas, the white one shows higher irrigation costs, while for the grey and brown ones, labour costs are the most expensive item.

The analysis of labour requirements and their cost in relation to surface area, revenues, and income allows us to draw conclusions, as can be seen in the following graphs.

Labor requirements (Figure 32) vary from crop to crop and based on cultivation techniques and the degree of mechanization in the fields of the selected countries and farms. Generally, the highest labour hours were required for growing faba beans and lentils in Syria, at 322 hours and 292 hours per hectare, respectively, followed by cowpea cultivation in Mauritania, at 131 hours per hectare.

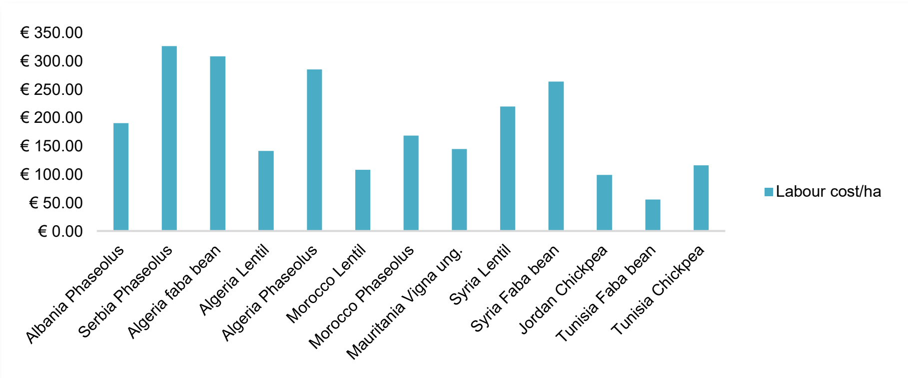
Figure 32. Labour requirements by legume and by country



Source: CIHEAM Bari elaboration on data from interviews with producers.

In terms of labor costs or income from work for agricultural workers (Figure 33), the highest values were recorded for bean cultivation in Serbia but also in Algeria, while the value for broad beans was quite high in Algeria and Syria.

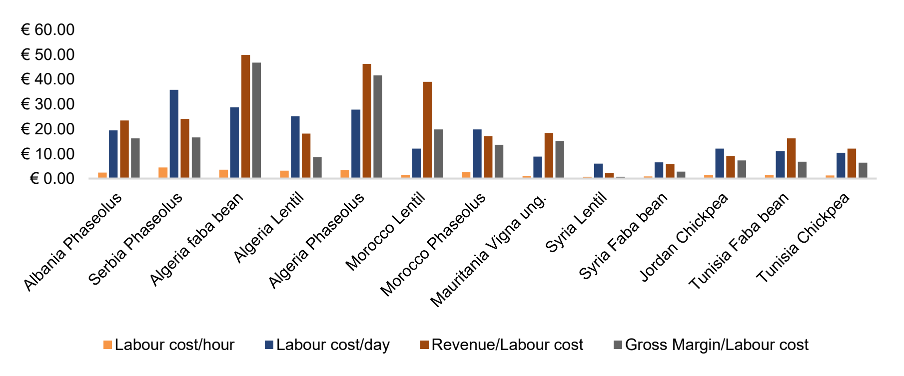
Figure 33. Labor costs by legume and country



Source: CIHEAM Bari processing of data from interviews with producers

Figure 34 shows that labour costs per hour and per hectare are higher in Serbia, while the return on labour costs (revenue), which expresses labour productivity, is higher in Algeria for faba beans and beans, but also in Morocco for lentils. The return on labour costs (revenue), which expresses labour profitability, is also higher in Algeria for faba beans and beans, as is the aforementioned productivity.

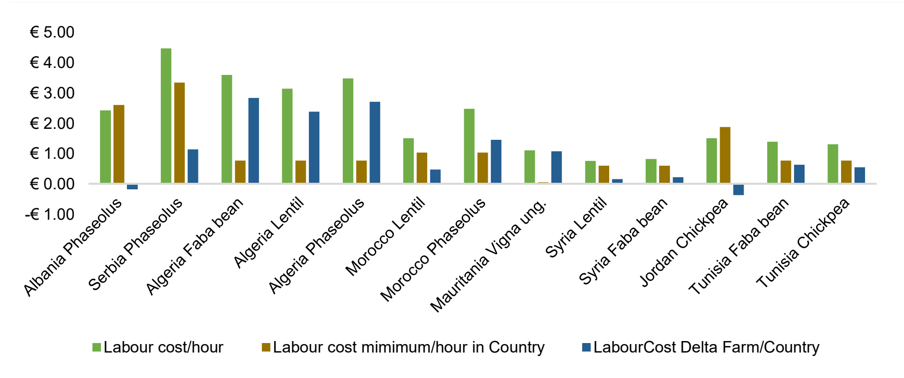
Figure 34. Labour efficiency by legume and by country



Source: CIHEAM Bari processing of data from interviews with producers

The hourly labour cost (Figure 35), and therefore the labour income for workers employed in the selected fields, shows that it is higher than the minimum guaranteed income in the countries considered, particularly in Algeria, which leads to the conclusion that social sustainability is positive in the selected countries, while only in Albania and Jordan is the labour cost in the fields under analysis slightly lower than the minimum guaranteed income in the country.

Figure 35. Social indicator by legume and by country



Source: CIHEAM Bari processing of data from interviews with producers

10. Comments and recommendations

The socioeconomic analysis carried out in 2024 was based on 20 case studies in 8 Mediterranean countries. The selection was made based on their relevance to the nutritional and environmental analyses conducted in 2023.

In a context where farm-level socioeconomic sustainability studies on native legumes are lacking or of limited relevance, the study provided an initial overview of the socioeconomic sustainability of growing native varieties of the most important legumes in the selected countries. However, it does not claim to provide comprehensive and representative results on the socioeconomic sustainability of the selected legumes. In any case, a methodology and tools were developed to interview, collect, and process technical and economic data, even in diverse regional contexts, without having comprehensive and representative regional statistical data that could be used as benchmarks.

In any case, the study results show that profitability is positive for all crops. Interestingly, beans and broad beans have the highest yields per hectare, despite higher production costs, but they still yield higher gross profitability than lentils and chickpeas. The labour analysis highlights higher costs for growing beans and broad beans, despite their greater potential for increased productivity and profitability.

From a social sustainability perspective, the study highlighted that hourly labour costs are slightly below the minimum guaranteed threshold in agriculture only in Albania and Jordan, leading to the conclusion that in these case studies, agricultural workers should be given greater protection in terms of wages.

In any case, producers of native legumes are encouraged to inform and promote, when selling their legumes at local markets, that these typical, locally sourced products offer the intrinsic added value of economic sustainability, providing a fair return to the producers themselves. They also offer environmental and social sustainability, with a positive impact on the local area and community, which will be able to purchase sustainable, typical, and traditional, locally sourced legumes.

In conclusion, the following recommendations are made to ensure the sustainability of native legume cultivars in Mediterranean countries:

1. Promote low-impact agricultural practices through training, technology transfer, and support in high-input areas, involving extension services and vocational training (AKIS).
2. Improve genotype and phenotype analysis on local varieties and landraces.
3. Standardize and monitor environmental and socioeconomic data collection over time and across countries for comparability and better understanding.
4. Support native varieties and small farmers (custodians) through targeted policies (such as targeted interventions for cover crops), market development (such as the agricultural market for traditional zero-mile products) and valorization strategies (such as public procurement for canteens).
5. Translating results into concrete actions by creating accessible tools for farmers, researchers, policy makers and consumers, promoted by BEANS META NETWORK.
6. Cooperation between local farmers of traditional products for a transition towards a sustainable local agri-food system.

References

FAO, 2014. *SAFA – Sustainability Assessment of Food and Agriculture Systems: Guidelines*. Version 3.0. Rome, FAO.

Kay R.D., Edwards W.M., Duffy P.A., 2011. *Farm Management*. 7th edition. McGraw-Hill International Edition.

PRé Sustainability, 2023. *SimaPro Database Manual – Methods Library*. PRé Sustainability, Amersfoort.

Torquati B., 2015. *Economics and Management of Agricultural Business*. Bologna, Edagricole.

Annex

Annex 1

A - GENERAL INFORMATION ABOUT THE FARM AND THE COLLECTION FIELD	
FARM PROFILE	
Information referring to the whole farm area	
	Value
FARM NAME	
FOUNDATION (year)	
BUSINESS SIZE (micro - small - medium)	
SITE LOCATION	
TOTAL FARM SURFARCE (ha or m2)	
Utilized Agricultural Area UAA (ha or m2)	
Farm ownership (private/institutional property/cooperative/other)	
Rainfall (average mm/year and average of harvest year)	
Information referring exclusively to the experimental area or collection field	
Geographical coordinates (N …) (E …)	
Legume (Species)	
Legume (Cultivar/Landrace)	
Year of harvesting and season	
Average altitude (m)	
Average distance from farm centre (km)	
Organic agriculture method (Y/N)	
Soil type (estimation)	
Sandy	
Loam	
Silt/Clay	
Other	
Soil fertility (estimation poor, fairly, good)	
Poor	
Fair	
Good	
	IF AVAILABLE
Organic matter	
N	

P	
K	
Morphological configuration	
Terrace	
Valley	
Plane	
Average inclination (%)	
Irrigation system (drip, sprinkler, border, etc.)	
Irrigation planning (seasonable, emergency)	
Quality of irrigation water (good or poor)	
	IF AVAILABLE
pH	
Salinity	
Hardness	
Sodium Absorption Ratio – SAR	
Type of rotation applied (crops of yearly or seasonable rotation)	

B - INFORMATION RELATED TO FIXED CAPITAL OR FIXED ASSETS USED IN LEGUME CULTIVATION*		
Machinery Owned		
Type (tractor, tiller, ripper, pesticide sprayer, motocoltivator, carriage, eletricity generator, etc.)	Description (HP, Brand and model, type of fuel, weight, etc.)	Age (years)
		0
		0
		0
		0
		0
Systems (investments) Owned		
Type (irrigation system, water well, drenage, terrace, etc.)	Description (m2, m, etc.)	Age (years)
		0
		0

		0
Buildings (investments) Owned		
Type (family house, worker house, storage, garage, etc.)	Description (m2, m3, floors, etc.)	Age (years)
		0
		0
Other info		
Type	Description	Age (years)
		0

C - FIELD PRACTICES (INPUTS AND OUTPUT)										
Legume:			**Area (ha or m2):**				**Sample code****			
Cultivar/Landrace:										
Date (month)	**Activity***	**Item description (details on seeds, fertilizer, pesticide, trap, erbicide, fuel, eletricity, rent or owned machine, water, yield, etc.)**	**Inputs**				**Output**			
			Units (kg, l, m³, n., KWh, etc.)	**Unite Price (€)**	**Quantity**	**Cost*****	**Units (kg, l, m³, n.. etc.)**	**Unit Price (€)**	**Quantity**	**Value*****
				0.00	0.00	0.00		0.00	0.00	0.00
				0.00	0.00	0.00		0.00	0.00	0.00
				0.00	0.00	0.00		0.00	0.00	0.00
				0.00	0.00	0.00		0.00	0.00	0.00
				0.00	0.00	0.00		0.00	0.00	0.00
				0.00	0.00	0.00		0.00	0.00	0.00
				0.00	0.00	0.00		0.00	0.00	0.00

				0.00	0.00	0.00		0.00	0.00	0.00
				0.00	0.00	0.00		0.00	0.00	0.00
				0.00	0.00	0.00		0.00	0.00	0.00
				0.00	0.00	0.00		0.00	0.00	0.00
				0.00	0.00	0.00		0.00	0.00	0.00
				0.00	0.00	0.00		0.00	0.00	0.00
				0.00	0.00	0.00		0.00	0.00	0.00
				0.00	0.00	0.00		0.00	0.00	0.00
				0.00	0.00	0.00		0.00	0.00	0.00
				0.00	0.00	0.00		0.00	0.00	0.00
				0.00	0.00	0.00		0.00	0.00	0.00
				0.00	0.00	0.00		0.00	0.00	0.00
				0.00	0.00	0.00		0.00	0.00	0.00
				0.00	0.00	0.00		0.00	0.00	0.00
				0.00	0.00	0.00		0.00	0.00	0.00

Nutritional and nutraceutical features of Mediterranean pulses
The MEDIET project – Final report

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Abstract. The present manuscript reports the results of the MEDIET project focused on the nutritional characterization of local pulse varieties collected across Mediterranean countries. During the first phase of the project, more than 140 legume seed samples were collected from 15 countries throughout the Mediterranean basin and subsequently analyzed. Samples were obtained directly from farmers and belonged to the species *Phaseolus vulgaris*, *Cicer arietinum*, *Vicia faba*, *Lens culinaris*, and *Vigna unguiculata*. Nutritional composition, including macro- and micronutrients, as well as nutraceutical and antinutritional compounds, was determined. A subset of selected accessions was then re-collected and re-analysed during the second phase of the project. The results highlight the high nutritional value of pulses as sources of proteins and dietary fibre; moreover, they represent important sources of B vitamins and antioxidants. The findings also reveal substantial variability among cultivated varieties, as well as differences related to year and area of production within the same legume species.

Keywords. Legumes; Pulses; Nutritional composition; Nutraceutical properties; Mediterranean region.

Title. Caractéristiques nutritionnelles et nutraceutiques des légumineuses méditerranéennes

Résumé. *Ce manuscrit présente les résultats finaux du projet MEDIET, consacré à l'évaluation nutritionnelle de variétés locales de légumineuses collectées dans les pays méditerranéens. Au cours de la première phase du projet, plus de 140 échantillons de graines ont été collectés et analysés dans 15 pays du bassin méditerranéen. Les échantillons, obtenus directement auprès des agriculteurs, appartenaient aux espèces Phaseolus vulgaris, Cicer arietinum, Vicia faba, Lens culinaris et Vigna unguiculata. Les analyses ont porté sur la composition nutritionnelle, incluant les teneurs en macro- et micronutriments essentiels, ainsi que sur les composés nutraceutiques et les facteurs antinutritionnels. Lors de la seconde phase, un sous-ensemble d'accessions sélectionnées a fait l'objet d'une nouvelle collecte et d'analyses complémentaires. Les résultats confirment la haute valeur nutritionnelle des légumineuses étudiées, caractérisées notamment par des teneurs élevées en protéines et en fibres, et identifiées comme des sources importantes de vitamines du groupe B et de composés antioxydants. Les analyses révèlent également une variabilité significative entre les cultivars étudiés, ainsi que des effets notables liés à l'année et à la zone géographique de production au sein d'une même espèce. Ces observations soulignent l'importance des ressources génétiques locales et des conditions de production dans la détermination de la qualité nutritionnelle des légumineuses méditerranéennes.*

Mots-clés. Légumineuses, nutrition, nutraceutique, méditerranéens.

I – Introduction

The food system is a holistic concept that includes farming, transportation, food processing, consumption, and waste management (FAO, 2018). A sustainable food system must be more productive, inclusive of poor and marginalized populations, environmentally sustainable, and resilient, while also being able to deliver healthy and nutritious diets. Considering these aspects,

pulse production and consumption appear to be among the most promising strategies for enabling the global population to achieve the Sustainable Development Goals (SDGs) in the near future. This perspective is also supported by the planetary health diet guidelines proposed by the EAT-Lancet Commission on Food, Planet, and Health (2019). According to these guidelines, global dietary patterns should shift toward reduced consumption of animal-derived foods and a twofold increase in the intake of vegetables, nuts, and pulses.
One of the main objectives of the MEDIET project was to promote and valorise neglected and underutilized local legume varieties in the participating countries. This objective is closely linked to several Sustainable Development Goals, particularly:

- SDG 1 – Zero Hunger, through the selection of resilient legume varieties capable of adapting to climate change;
- SDG 3 – Good Health and Well-Being, by promoting the consumption of legumes, which are rich in dietary fiber and nutraceutical compounds and characterized by a balanced protein-to-carbohydrate ratio and a low glycemic index;
- SDG 12 – Responsible Consumption and Production, due to the low energy input required for legume cultivation and the positive effects of these crops on food system sustainability;
- SDG 15 – Life on Land, through the positive impact of legume cultivation on soil fertility and the conservation of agrobiodiversity via the preservation of neglected varieties.

The project was structured into two main phases. During the first phase, legume samples were collected across different countries of the Mediterranean basin and analyzed for their nutritional characteristics. Based on the results obtained, selected samples were re-collected during a second phase to assess the variability of their nutritional profiles across different production years and to evaluate the effects of cooking on their nutritional properties. Preliminary and partial results of the MEDIET project have already been published, highlighting significant nutritional and nutraceutical differences among samples collected in the Mashrek region (Hwalla et al., 2025). The present manuscript provides a comprehensive analysis of the nutritional characteristics of all samples collected throughout the MEDIET project.

II – Material and methods

1. Gross composition and total dietary fibers

Dry legume seeds were ground using an electrical grinder to obtain a homogeneous powder capable of passing through a 35-mesh stainless steel sieve (0.5 mm opening). Dry matter content was determined by oven-drying the powdered samples at 105 °C until constant weight, according to AACC Method 44-17.01. Ash content was measured following AACC Method 08-16.01 by incinerating the dried samples in a muffle furnace at 550 °C for 6 h.

Total protein content was determined according to AOAC Method 2001.11 using the Kjeldahl method, with a UDK6 heating block and a UDK129 steam distillation unit (Velp Scientifica, Monza, Italy). Nitrogen content was converted to protein using a conversion factor of 5.71. Total fat content was measured using a Soxtec™ System model 2050 (Foss, Denmark) with petroleum ether (40–60 °C boiling range) as the extraction solvent, in accordance with ISO 11085:2008.

Total dietary fiber was quantified using an enzymatic assay kit (Megazyme, Bray, Ireland) following AOAC Method 991.43. Total starch content was calculated by difference as the complement to 100% of the sum of total protein, total fat, total dietary fiber, and ash contents.

2. Fatty acids methyl esters (FAME) quantitative determination by gas chromatography

Total lipids extracted using the Soxtec apparatus were trans-methylated by a cold method using 2 N KOH in methanolic solution. Fatty acid methyl esters (FAMEs) were then analyzed by gas chromatography using the system described above, equipped with a DB-Fast FAME capillary column (Agilent; 20 m × 0.18 mm i.d., 0.20 μm film thickness). Chromatographic conditions were as follows: hydrogen was used as the carrier gas at a constant linear velocity of 35 cm s^{-1}; injector temperature was set at 230 °C with a split ratio of 1:50. The oven temperature program started at 80 °C, increased to 175 °C at 65 °C min^{-1}, then to 185 °C at 10 °C min^{-1}, followed by an increase to 230 °C at 7 °C min^{-1}, and finally held isothermal for 3 min. Quantification was performed using an external calibration method with a FAME 37 standard mixture analyzed at five concentration levels under the same chromatographic conditions as the samples. Results were expressed as mg per 100 g of dry seed.

3. Minerals elements by acid mineralization and ICP-OES

Mineral elements quantification was obtained according to the AOAC-2011.14 by digestion using nitric acid and hydrogen peroxide, in microwave digester model Ethos (FKV, Italy) followed by Inductively Coupled Plasma - Optical Emission spectrometry (ICP-OES) detection using an instrument model iCAP 6000 (Thermo Fisher Scientific, US). The following spectral lines were considered: 422.673 (Ca), 766.49 and 769.896 (K), 280.27 and 285.213 (Mg), 224.7 (Cu), 206.2(Zn), 259.94(Fe), 257.61(Mn).

4. Quantitative determination of amino acids

The quantitative determination of proteinogenic amino acids was performed by the application of three different types of hydrolysis: HCl 6N after oxidation with performic acid for the determination of sulfur containing amino acids (i.e. cysteine and methionine); NaOH 4N for tryptophan determination and HCl 6N for all remaining amino acids. All hydrolysis processes were performed in amber borosilicate vials, under N_2, in presence of pyrogallol as an antioxidant, at 110°C per 24h using a block heater with temperature control. After hydrolysis, 100nmol of nor-leucine was added as internal standard, then samples were neutralized, diluted with ultrapure water and analyzed by ions chromatography and post column derivatization with ninhydrin using the amino analyzer Biochrom 30+ (Harvard Bioscience, MA, USA). The concentration of each amino acid was calculated using an internal calibration method. The calibration curves were obtained by the injection of 5 levels of calibration from 5 to 500 nmol/mL of a standard mix (Protein hydrolysate standard mix, Biochrom) in triplicate.

5. Total polyphenols, Tannins and antioxidants capacity

Polyphenols were extracted from powdered dry seeds (Section 2.1) using acetone–water–acetic acid (70:29.5:0.5, v/v/v). Two grams of powder were mixed with 20 mL of solvent, sonicated for 15 min, shaken for 2 h, and centrifuged at 4000 RCF for 10 min at 10 °C. The pellet was re-extracted, and the combined extracts were filtered (0.45 μm) and stored at 4 °C.

Total polyphenols were measured using the Folin–Ciocalteu micro-assay (Wrolstad et al., 2005) with gallic acid standards (10–400 mg L^{-1}) and expressed as mg GAE per 100 g dry seeds. Antioxidant activity was determined by the ABTS assay calibrated with Trolox. ABTS radical solution was prepared by reacting 7 mM ABTS with 4.95 mM potassium persulfate for 12 h, diluted to an absorbance of ~0.7 at 730 nm, and reacted with 20 μL of extract for 25 min. Results were expressed as μmol Trolox equivalents (TEAC) per 100 g dry seeds.

Total tannins were quantified by protein precipitation using bovine casein. One gram of casein was mixed with 12 mL of extract and 8 mL water, shaken for 3 h, and centrifuged at 4000 × g for 15 min at 10 °C. Residual polyphenols in the supernatant were measured by the Folin–Ciocalteu assay, and total tannins were calculated as the difference, expressed as tannic acid equivalents.

6. Total phytates

The total amount of phytate was obtained using a colorimetric method and the "Phytic Acid Assay Kit" from Megazyme. An aliquot of 1 g of powdered sample was extracted with 20 mL of HCl 0.66M, for 3h at room temperature. Then the extract was neutralized with NaOH and centrifuged at 7000 RCF for 15 min. The clear upper phase was then used for the colorimetric assay before and after the in-sequence action of phytase and alkaline phosphatase. The difference between free P and bonded P was used to obtain the amount of phytates in the initial sample.

7. Trypsin inhibitory assay

One gram of powdered sample was extracted with 50 ml of 10 mM NaOH for 3 h at room temperature with orbital mixer. The extract was diluted with water so that 1 ml caused 30%–70% trypsin inhibition. The assay was conducted in a water bath at 37C° and initiated by mixing 1 mL of a dilute extract with 2.5 mL DL-BAPA working solution (0.4 mg/mL). This was followed by adding 1 mL trypsin working solution (20 µg/mL) to initiate the colorimetric reaction at 410 nm. After 10 min , 0.5 mL 30% (v/v) acetic acid was added to stop the reaction. For a reference reading, 1.0 mL water was used instead of the dilute extract. The tests for sample reading and reference reading were duplicated. A sample blank and a reagent (reference) blank were also prepared and measured. Results were expressed as Trypsin Units Inhibited (TUI) per g of sample.

8. Vitamins

Thiamin (B1), niacin (B3), biotin (B7) and folate (B9) were quantified using microbial kit Vitafast (R-Biopharm, Germany). Vitamin E, as total tocopherols, was determined according to the method ISO 9936, by alkaline hydrolysis in presence of pyrogallol as antioxidant under nitrogen, followed by liquid – liquid extraction with petroleum ether at 40-60°C. The obtained extract was concentrated under vacuum and re-suspended in 1.0 mL of isooctane containing 0.2% of butylhydroxytoluene. Twenty microliters of this solution were injected into a High-Performance Liquid Chromatography (HPLC) system. The HPLC system comprised a normal-phase isocratic pump (LC-40D) coupled with a fluorescence detector (RF-20A XS; Shimadzu, Kyoto, Japan). The mobile phase was hexane containing 1% dioxane, delivered isocratically at a flow rate of 1.0 mL/min. Separation was achieved on a Zorbax RX-Sil column (100 mm × 3.0 mm i.d., 1.8 µm particle size). Quantification was performed using a calibration curve prepared from five concentrations of α-tocopherol standard (0.1–10 µg/mL). Results were expressed as mg α-tocopherol equivalents per 100 g of dry seeds.

9. The soaking and boiling process

Aliquots of 25 g of seeds per sample were exactly weighed in beakers and 100 mL of distillated water were added. After 12 h of soaking the excess of water was drained and the hydrated seeds were dried at room temperature for 1 h on bibulous paper. The seeds were then weighed for calculating the percentage of hydration according to the following formula:

$$Hydration\ (\%) = \frac{Weight\ of\ hydrate\ sample - Weight\ of\ raw\ sample}{Weight\ of\ raw\ sample} * 100$$

Then, samples were added of clean distilled water in a ratio of 1:3 by volume and heated on electric hot plate. The cooking time measurement started when the boiling process started and stopped when almost all seeds in the beaker reached a buttery texture. Moreover, during the cooking procedure hot distillated water was added at convenience leaving all seed covered by 1cm layer of hot water during the process. At the end of the cooking phase, samples were left to cool down for about 30 minutes, the residual water was not taken away, and the samples were then homogenized using a common blender, obtaining a homogeneous paste. The prepared samples were frozen at -20 C° overnight and freeze dried for about 72h. After freeze-drying, the samples were pulverized using a manual ceramic mortar and collected in plastic bags for the chemical analysis.

10. Statistical analysis and data élaboration

All results were processed using IBM SPSS Statistics to calculate mean values, standard deviations, and to perform principal component analysis (PCA). Tables report averages from at least two analytical replicates per parameter. A three-color scale (red, yellow, green) was applied to compare each value with the reference, indicating below, equal, or above levels; this scale was reversed for antinutritional factors.

III – Results of the first phase project

1. Samples information

During the year 2023, thanks to the support of local experts involved in the project, one hundred and forty-six samples of legume seeds were collected belonging to 15 countries of the Mediterranean basin. These samples, together with information regarding the legume type and origin are listed in Table 1.

Table 1. List of samples collected during the first year of MEDIET project.

Legume	Type	AREA	Country	Location	Variety
Bean	Borlotti	Balkans	Albania	Hardhi/Belsh	Kallmet
Bean	White kidney	Balkans	Albania	Kryekuo/Lushnje	Shijaku
Bean	Borlotti	Balkans	Albania	Jube, Durres	Laroshja kalmeet
Bean	Borlotti	Balkans	Albania	Ishem, Durres	Laroshja Kallmet
Bean	Borlotti	Balkans	Albania	Kallmet i Madh, Lezhe	Kallmet
Bean	Borlotti	Balkans	Albania	Sukth, Durres	Sukthi
Bean	White kidney	Balkans	Albania	Jube, Durres	Shijaku
Bean	Navy	Balkans	Albania	Gollomboc, Pustec Korca	Fasule Sacme
Bean	Baby Lima	Balkans	Albania	Pojan, Korca	Fasule Trenare
Bean	White kidney	Balkans	Albania	Pojan, Korca	Fasule Ecmeniku
Bean	Large white kidney	Balkans	Albania	Pojan, Korca	Fasule kokerrmadhe or Pllage or Hocishti
Bean	Cannellini	Maghreb	Algeria	Tipaza	White Coco
Bean	Borlotti	Maghreb	Algeria	Mascara	Prague Coco
Bean	Borlotti	Maghreb	Algeria	Biskra	Prague Coco
Bean	Light brown kidney	Balkans	Bosnia and Herz.		ssp. nanus

Legume	Type	AREA	Country	Location	Variety
Bean	Pink	Balkans	Bosnia and Herz.	Saničani, Prijedor	ssp. nanus
Bean	Borlotti	Balkans	Bosnia and Herz.	Osredak, Republika Srpska	ssp. nanus
Bean	Pink	Balkans	Bosnia and Herz.	Balatun, Bijeljina	ssp. nanus
Bean	Borlotti	Balkans	Bosnia and Herz.	Ribnik	ssp. nanus
Bean	White kidney	Balkans	Bosnia and Herz.	Balatun, Bijeljina	ssp. nanus
Bean	Navy	Balkans	Bosnia and Herz.	Konopljišta, Petrovo	ssp. nanus
Bean	Cannellini	Mashreq	Jordan	Al-Balawneh	Sibarius
Bean	Large white kidney	Balkans	Kosovo	Kuk, Dragash municipality	Traditional var
Bean	Cannellini	Balkans	Kosovo	podujeva	Traditional var
Bean	Large white kidney	Balkans	Kosovo	Prishten	Traditional var
Bean	Large white kidney	Balkans	Kosovo	Sllavi-lipjan	Traditional var
Bean	Borlotti dryed	Balkans	Kosovo	Gmic, Kamenice	Traditional var
Bean	Borlotti dryed	Balkans	Kosovo	Gmic, Kamenice	Traditional var
Bean	Borlotti	Mashreq	Lebanon	Kemed El Loze	Bean Red Oval
Bean	Christmas Lima Beans	Mashreq	Lebanon	Kemed El Loze	Baladi Large Red
Bean	Baby Lima	Mashreq	Lebanon	Jeb Jennine	Baladi White large
Bean	Borlotti	Balkans	Montenegro	Bijelo Polje	
Bean	Borlotti	Balkans	Montenegro	Ulcininj	
Bean	Navy	Balkans	Montenegro	Plav	
Bean	Navy	Maghreb	Morocco	Moulay Abdelkader	Ghelid
Bean	Cannellini	Maghreb	Morocco	Moulay Abdelkader	Reguig
Bean	White kidney	Balkans	N. Macedonia	Mustafino, Sveti Nikole	Cacar
Bean	Cannellini	Balkans	Serbia	Central Banat District	Gradistanac
Bean	White kidney	Balkans	Serbia	Srem District	Tetovac
Bean	Kidney red	Balkans	Serbia	South Backa District	Zlatko
Bean	Kidney red	Balkans	Serbia	Central Banat District	Zlatko
Bean	Pink	Balkans	Serbia	Srem District	Sumporas
Bean	White kidney	Balkans	Serbia	South Backa District	Gradistanac
Bean	Cannellini	Balkans	Serbia	Srem District	Gradistanac
Bean	White kidney	Balkans	Serbia	South Backa District	Tetovac

Legume	Type	AREA	Country	Location	Variety
Bean	White kidney	Balkans	Serbia	Belica	Gradistanac
Bean	Borlotti	Balkans	Serbia	South Backa District	Tresnjevac
Bean	Borlotti	Balkans	Serbia	Srem District	Tresnjevac
Bean	Pink	Balkans	Serbia	Central Banat District	Sumporas
Bean	Borlotti	Maghreb	Tunisia	Mornag (Ben Arous)	Coco nain
Chickpea	Desy	Maghreb	Algeria	Tizi-ouzou	Desi
Chickpea	Desy	Maghreb	Algeria	Chlef	Desi
Chickpea	Kabuli	Maghreb	Algeria	Mascara	Desi
Chickpea	Desy	Maghreb	Algeria	Tlemcen	Desi
Chickpea	Kabuli	Mashreq	Jordan	Al-Koora-Irbid	Baladi
Chickpea	Kabuli	Mashreq	Jordan	Eira-Al-Salt	Baladi small
Chickpea	Kabuli	Mashreq	Lebanon	Ser'eene	CP Baladi Jumbo
Chickpea	Kabuli	Mashreq	Lebanon	Hezzine	Baladi Red Small
Chickpea	Kabuli	Mashreq	Lebanon	Ebba Nabatieh	Baladi medium
Chickpea	Kabuli	Maghreb	Morocco	Bouadel Taounate	Beldia
Chickpea	Desy	Maghreb	Morocco	Mokrisset	Maizou
Chickpea	Kabuli	Maghreb	Morocco	Moulay Abdelkader	Kerfasa
Chickpea	Kabuli	Maghreb	Morocco	Moulay Abdelkader	Meksik
Chickpea	Kabuli	Maghreb	Morocco	Mokrisset	Ghelid
Chickpea	Desy	Balkans	N. Macedonia	Mustafino, Sveti Nikole	Traditional var
Chickpea	Desy	Balkans	N. Macedonia	village Vrsakovo	Traditional var
Chickpea	Desy	Mashreq	Palestina	Sanour- Jenin	Baladi
Chickpea	Desy	Mashreq	Syria	ElGhab	ElGhab#3 ICARDA
Chickpea	Desy	Mashreq	Syria	ElGhab	Ghab#4 ICARDA
Chickpea	Desy	Mashreq	Syria	ICARDA Tal Hadya	GHAB#3 ICARDA
Chickpea	Desy	Mashreq	Syria	ICARDA Tal Hadya	GHAB#4 ICARDA
Chickpea	Desy	Mashreq	Syria	ICARDA Tal Hadya	Ghab#5 ICARDA
Chickpea	Desy	Mashreq	Syria	Tal Hadya	Ghab#3 ICARDA
Chickpea	Desy	Mashreq	Syria	Tal Hadya	Ghab#4 ICARDA
Chickpea	Desy	Mashreq	Syria	Tal Hadya	Ghab#5 ICARDA
Chickpea	Desy	Maghreb	Tunisia	Amdoun (Beja)	Amdoun
Chickpea	Kabuli	Maghreb	Tunisia	Mateur - Bizerte	Chetoui
Cowpea	Cowpea white	Maghreb	Algeria	Boumerdes	Niébé

Legume	Type	AREA	Country	Location	Variety
Cowpea	Cowpea white	Maghreb	Mauritania	Mhairith/Adrar	Cowpeas/Vigna unguiculata (white color)
Cowpea	Cowpea violet	Maghreb	Mauritania	Rosso/Trarza	Cowpeas/Vigna unguiculata (brown-gray color)
Cowpea	Cowpea green speckled	Maghreb	Mauritania	Mhairith/Adrar	Cowpeas/Vigna unguiculata (spotted gray color)
Cowpea	Cowpea green speckled	Maghreb	Mauritania	Maghtaa Lahjar/Brakna	Cowpeas/Vigna unguiculata (spotted gray color)
Cowpea	Cowpea white	Maghreb	Mauritania	Gourdiouma/Gorgol	Cowpeas/Vigna unguiculata (white color)
Cowpea	Cowpea white	Maghreb	Mauritania	Coumba Ndao/Guidimakha	Cowpeas/Vigna unguiculata (white color)
Cowpea	Cowpea violet	Maghreb	Mauritania	Mbekhere/Guidimakha	Cowpeas/Vigna unguiculata (brown-gray color)
Cowpea	Cowpea violet	Maghreb	Mauritania	Maghtaa Lahjar/Brakna	Cowpeas/Vigna unguiculata (brown-gray color)
Cowpea	Cowpea violet	Maghreb	Mauritania	Aghoratt/Assaba	Cowpeas/Vigna unguiculata (brown-gray color)
Cowpea	Cowpea violet	Maghreb	Mauritania	Mhairith/Adrar	Cowpeas/Vigna unguiculata (brown-gray color)
Cowpea	Cowpea white	Maghreb	Mauritania	Maghtaa Lahjar/Brakna	Cowpeas/Vigna unguiculata (white color)
Cowpea	Cowpea white	Maghreb	Mauritania	Rosso/Trarza	Cowpeas/Vigna unguiculata (white color)
Cowpea	Cowpea violet	Maghreb	Mauritania	Gourdiouma/Gorgol	Cowpeas/Vigna unguiculata (brown-gray color)
Cowpea	Cowpea white	Maghreb	Mauritania	Aghoratt/Assaba	Cowpeas/Vigna unguiculata (white color)
Cowpea	Cowpea brown	Maghreb	Morocco	Aghebalou	Hamera
Faba	Large	Maghreb	Algeria	Tizi-ouzou	Seville

Legume	Type	AREA	Country	Location	Variety
Faba	Large	Maghreb	Algeria	Biskra	Seville
Faba	Large	Maghreb	Algeria	Ouargla	Seville
Faba	Large	Maghreb	Algeria	Ain defla	Muchanie
Faba	Medium	Balkans	Bosnia and Herz.	Todorići, Trebinje	Vicia faba
Faba	Small	Mashreq	Egypt	Deir el-Bahari	Breeding, resistance to rust & brown spot disease, Very early production
Faba	Small	Mashreq	Egypt	New valley Governorate & Delta	Breeding Very early (Flower +40d) resistant Brown Spot & rust
Faba	Small	Mashreq	Egypt	Sharkiah	Breeding, mild resistant to rust & brown spot disease, Very early production
Faba	Small	Mashreq	Egypt	Al Wajh El Bahri	Breeding Adaptable all climates Very early Resistant to weeds & Fungi
Faba	Small	Mashreq	Egypt	New valley Governorate & Alwajh ElKobly	Breeding Variety, Very early production
Faba	Large	Mashreq	Jordan	DeirAlla	Baladi
Faba	Small	Mashreq	Lebanon	Ebba Nabatieh	Baladi small Red
Faba	Small black	Maghreb	Morocco	Mokrisset	Genaoui
Faba	Large	Maghreb	Morocco	Mokrisset	Tamer
Faba	Smal	Maghreb	Morocco	Aghebal Zaer	Foulet (féveroles)
Faba	Medium	Maghreb	Morocco	Bouadel Taounate	Beldia
Faba	Medium	Maghreb	Morocco	Moulay Abdelkader	Malqi
Faba	Small	Maghreb	Morocco	Moulay Abdelkader	Foulet (féveroles)
Faba	Small	Mashreq	Palestina	Aljadeada- Jenin	Baladi
Faba	Large	Balkans	Serbia	Ribare	Traditional var
Faba	Large	Balkans	Serbia	Belica	Traditional var
Faba	Medium	Mashreq	Syria	Aleppo	Baladi Local large dry
Faba	Large	Maghreb	Tunisia	Utique	Malti
Faba	Large	Maghreb	Tunisia	Ben Bechir (Jendouba)	Malti
Faba	Large	Maghreb	Tunisia	Oued Ellil - Manouba	Malti
Faba	Medium	Maghreb	Tunisia	Mateur - Bizerte	Aquadulce

Legume	Type	AREA	Country	Location	Variety
Faba	Small	Maghreb	Tunisia	Ain Soltan, Ghdor, Beja	Arbi
Faba	Medium	Mashreq	Syria	Al-Madekh	Traditional var
Faba	Medium	Mashreq	Syria	Al-Hader	Traditional var
Faba	Small	Mashreq	Syria	ICARDA Tal Hadya	Fouad malouf
Lentil	Small	Maghreb	Algeria	Chlef	Surie 229
Lentil	Small	Maghreb	Algeria	Relizane	Syrie 229
Lentil	Small	Maghreb	Algeria	Mascara	Syrie 230
Lentil	Small	Mashreq	Lebanon	Talia	Baladi brown mixt
Lentil	Large	Mashreq	Lebanon	Hezzine	Baladi medium mixt
Lentil	Small	Mashreq	Lebanon	Ebba Nabatieh	Baladi small
Lentil	Large green	Maghreb	Morocco	Mokrisset	Finou
Lentil	Large brown	Maghreb	Morocco	Bouadel Taounate	Beldia
Lentil	Large brown	Maghreb	Morocco	Aghebal Zaer	Cinq
Lentil	Large	Mashreq	Palestina	Aqabaa -Tubas	Baladi
Lentil	Small	Mashreq	Syria	Idleb	Idleb#2 ICARDA
Lentil	Large	Mashreq	Syria	Ebla	Ebla#1 ICARDA
Lentil	Small	Mashreq	Syria	Idleb	Idleb#3 ICARDA
Lentil	Small	Mashreq	Syria	Aleppo	Baladi Local
Lentil	Small	Mashreq	Syria	Al-Hus	Traditional var
Lentil	Small	Mashreq	Syria	Al-Safireh	Traditional var
Lentil	Large	Mashreq	Syria	ICARDA Tal Hadya	IDLEB#2 ICARDA
Lentil	Small	Mashreq	Syria	ICARDA Tal Hadya	IDLEB#3 ICARDA
Lentil	Large	Mashreq	Syria	ICARDA Tal Hadya	IDLEB#4 ICARDA
Lentil	Large	Mashreq	Syria	Banous	IDLEB#1 ICARDA
Lentil	Large	Mashreq	Syria	Banous	IDLEB#2 ICARDA
Lentil	Small	Mashreq	Syria	Banous	IDLEB#3 ICARDA
Lentil	Large	Mashreq	Syria	Banous	IDLEB#4 ICARDA

2. Dataset elaboration and Principal Component Analysis application

Overall more than 65 analytical parameters were determined in these samples and used to build a dataset of results then analyzed using SPSS and data reduction by the application of Principal Component Analysis, after the verification of all needed assumptions (normal distribution, homogeneity of variance, and sphericity of data). Two factors were extracted without rotation and the loadings plot was reported in Figure 1.

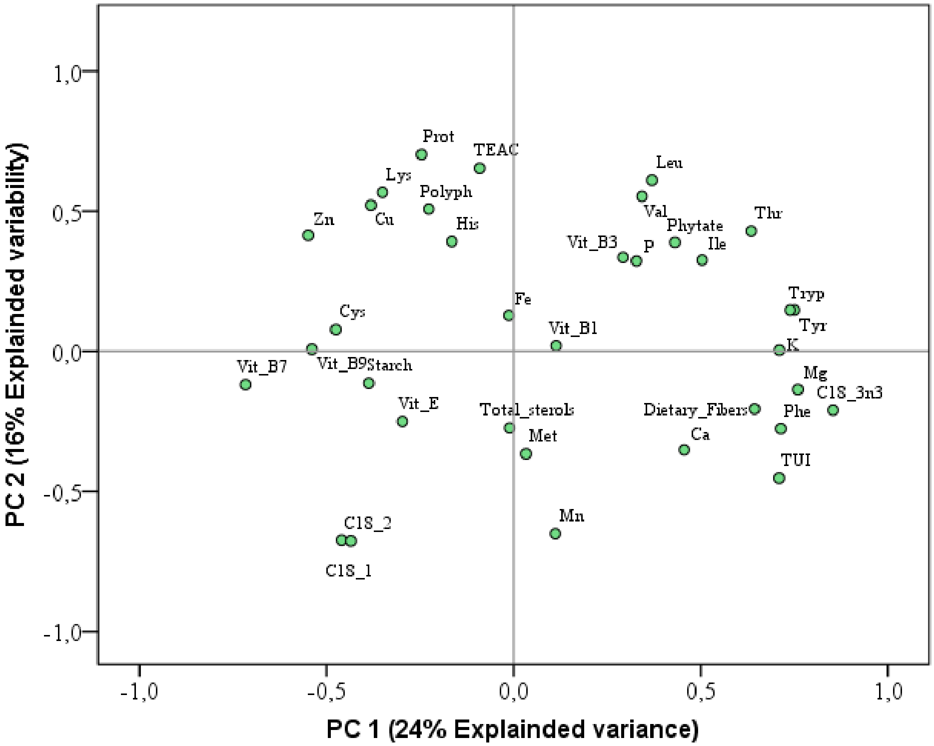

Figure 1. Loading plot of the first two principal component extracted using the full dataset of first year

As can be seen in this loading plot, a part the low level of total variance explained ((40%), important and expected correlations were found among the analysed parameters. Noteworthy is the high correlation between the antioxidant capacity, total proteins and total polyphenols, or that among dietary fibres, Ca, Mg, phenylalanine and trypsin inhibitor activity. Using the upper mentioned PCs and calculating the factor scores for each samples, a clear groups distribution was obtained among the considered species (Figure 2).

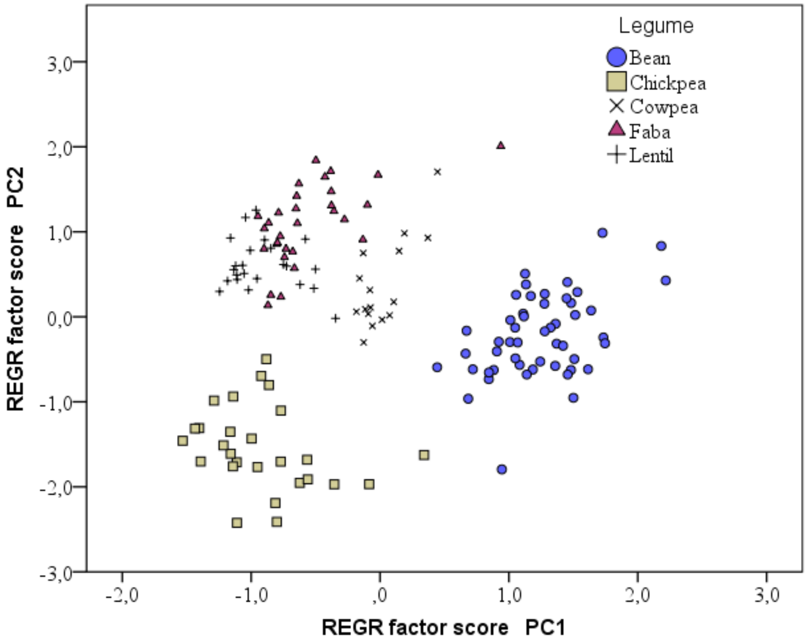

Figure 2. Score plots of legume samples collected during the first year according to the PCs reported in figure 1.

By comparing the results showed in Figure 1 and Figure 2, it is possible to reach the following statements:

- Among the considered legume species faba beans and lentils accessions were characterized by the highest value in total proteins, antioxidants, Cu and Zn.
- Beans are richest legume in dietary fibres, phenylalanine, tyrosine, tryptophane, linolenic acid, but they are also the legume type with the highest value of trypsin inhibitory compounds and phytates
- Chickpeas distinctive features are the high content in vitamin E, oleic and linoleic fatty acids, Vitamin B_7 and B_9.
- Cowpeas were characterized by a balanced composition between proteins, essential amino acids, dietary fibres, and antinutritional factors.

3. Selection of the most important compositional parameters determined

A pool of nutritional parameters, including essential nutrients and nutraceutical ones are listed in Table 2 together with the mean value per 100g of raw product obtained on the collected samples during the season 2023. The percentage coverages of the Recommended Daily Allowance (RDA) were also calculated and reported for each considered parameter. This value was calculated considering the consumption of 100g raw portion, according to the World Health Organization (WHO) indication, and referred to a man of 75kg average weight. The mean values were calculated for each legume species.

Table 2. Mean value and coverage percentage of the RDA obtained by the consumption of 100g of raw product, by adult man of 75kg. Yellow cells underline values below the threshold of 30 % of RDA contribution.

	Beans		Chickpea		Cowpea		Faba bean		Lentill		Mean %RDA
	Average	%RDA	Average	%RDA	Average	%RDA	Average	%RDA	Average	%RDA	
Prot	25	44	24.3	43	26.4	47	30.3	54	28.0	50	48
Dietary Fibers	25	98	19.1	76	15.0	60	18.4	73	19.6	78	77
C18:2	0.21	2	1.73	12	0.26	2	0.33	2	0.18	1	4
C18:3n3	0.34	21	0.08	5	0.21	13	0.03	2	0.06	4	9
K	1698	50	1133	33	1586	47	1424	42	911	27	40
Ca	177	18	154	15	128	13	128	13	114	11	14
Mg	191	46	149	36	199	47	151	36	114	27	38
P	461	66	364	52	456	65	507	72	351	50	61
Fe	6.95	87	6	75	7	86	6	72	9	118	88
Zn	3.59	33	4	40	5	41	5	48	5	44	41
Mn	1.60	70	2	87	2	66	1	52	1	55	66
Cu	0.93	104	1	111	1	109	2	183	1	125	126
Vit_E	4.45	30	11.71	78	16.18	108	6.43	43	4.20	28	57
Vit_B1	0.70	58	0.73	61	0.99	83	0.64	54	0.59	49	61
Vit_B3	3.60	23	2.72	17	4.12	26	3.69	23	2.78	17	21
Vit_B8	12	39	23.57	79	12.39	41	19.42	65	20.89	70	59
Vit_B9	75	19	244	61	309	77	213	53	112	28	48
His	0.60	86	0.7	95	1.2	166	0.7	106	0.83	118	114
Ile	0.49	35	0.4	29	0.5	36	0.5	33	0.41	29	32

	Beans		Chickpea		Cowpea		Faba bean		Lentill		Mean %RDA
	Average	%RDA	Average	%RDA	Average	%RDA	Average	%RDA	Average	%RDA	
Leu	1.34	49	1.2	43	1.3	49	1.4	52	1.26	46	48
Lys	1.48	71	1.6	76	2.1	100	1.9	89	1.80	86	84
Met_Cys	0.41	39	0.5	50	0.4	41	0.5	48	0.39	37	43
Phe_Tyr	2.51	144	1.8	105	1.8	101	1.7	99	1.75	100	110
Thr	0.89	84	0.7	62	0.9	86	0.8	76	0.72	68	75
Tryp	0.21	77	0.1	53	0.2	66	0.2	62	0.14	50	62
Val	0.74	41	0.6	34	0.8	43	0.7	41	0.69	38	39
Total Polyph.	452	45	162	16	317	32	757	76	1089	109	56
Total sterols	64	4	73	5	50	3	64	4	58	4	4
Prot	25	44	24.3	43	26.4	47	30.3	54	28.0	50	48
Dietary Fibers	25	98	19.1	76	15.0	60	18.4	73	19.6	78	77

A limit higher than 30% of RDA was fixed to select the most important parameters to be considered in the following phases of data elaboration. With this approach, twenty-three parameters were selected and used in a statistical model based on Principal Component Analysis (PCA) to summarize the total observed variance. The first results of the PCA analysis are illustrated in Figure 3 and represent the loading plot related to the first two extracted components.

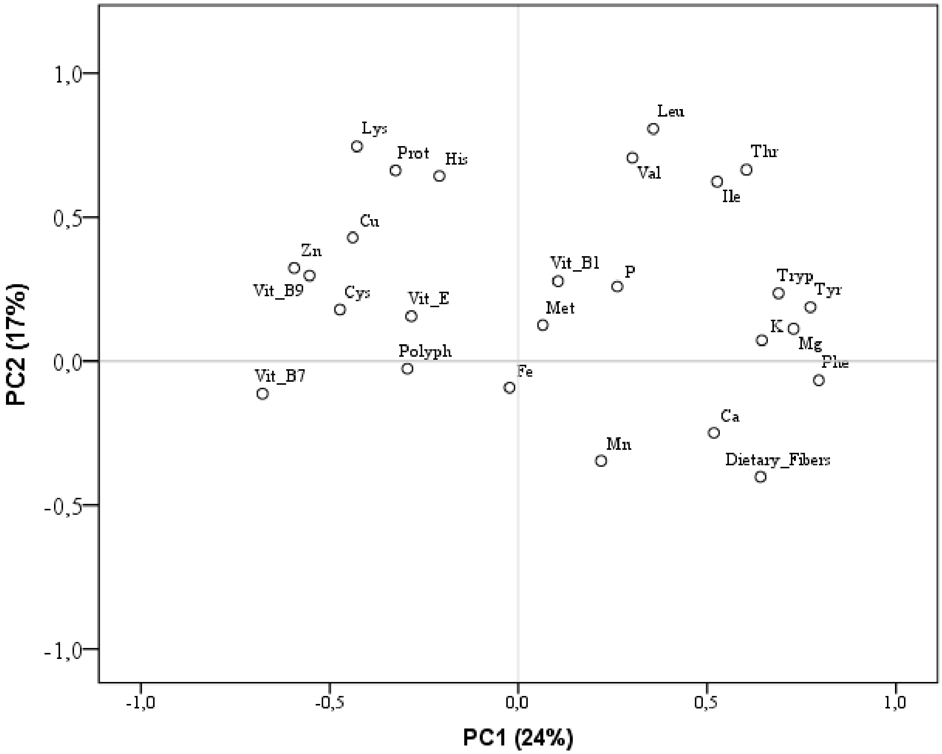

Figure 3. Loading plot of the selected nutritional and nutraceutical parameters on the first two principal components extracted.

As can be seen by the loading plot represented in Figure 3, the following parameters are characterized by a low loading (<0.4): Fe, P, Vit. B1, TEAC (Trolox Equivalent Antioxidant Capacity), Vit. E, Total polyphenols. Therefore, the PCA analysis was then recalculated excluding these parameters. The second elaboration of PCA led to the calculation of two new components, namely PC1 (x axis) and PC2 (y axis) explaining 30 and 23% of the total variance respectively. The PC1 showed a high positive correlation with the concentration of the two aromatic amino acids phenylalanine and tyrosine, total dietary fibers and with the two mineral elements Mg and K. At the same time, PC1 has got a high negative correlation with Vit. B8, Vit. B9, cysteine, Zn, Cu and lysine. The second component PC2 showed positive correlation with almost all considered parameters, and only a weak negative correlation with total dietary fibers, Mn and vitamin B8.

The factors score for both PC1 and PC2 were calculated for each legume sample and used for the following phase of sample selection. In Figure 4, the score plot of beans and chickpeas samples are reported for convenience. The score representations were characterized by an area where most of the samples analyzed falls which represent the more frequently observed values. The samples more externally placed in respect to the above-mentioned area were characterized by the highest score for the two extracted components, as well as the highest content in nutritional constituents.

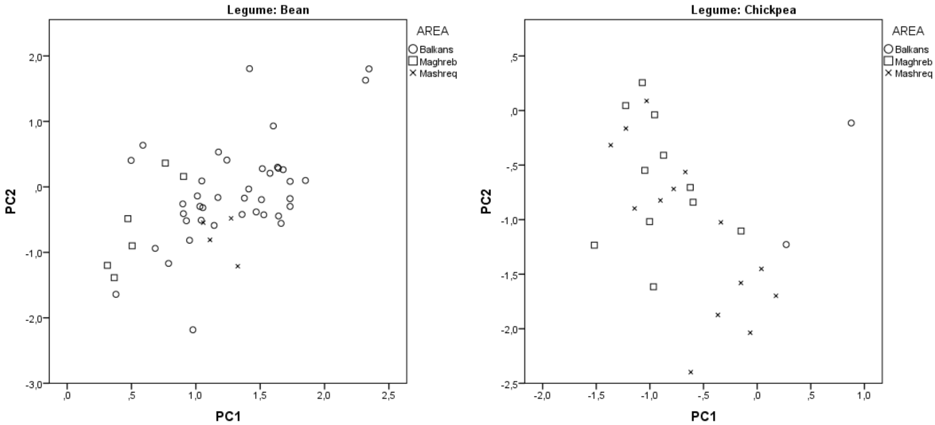

Figure 4. Score plots of beans and chickpeas samples calculated on the principal components PC1 and PC2.

4. Selection of samples for the following phase of the project

Considering the before score distribution, an initial pool of samples was selected for their nutritional and nutraceutical characteristics and listed in Table 3.

Table 3. List of the selected samples to be considered in the 3rd year of Mediet project, according to the nutritional and nutraceutical characteristics solely.

COD LAB	Legume	AREA	Country	Variety
B05	Bean	Balkans	Albania	Kallmet
B07	Bean	Balkans	Albania	Shijaku
B08	Bean	Balkans	North Macedonia	Cacar
B13	Bean	Balkans	Albania	Fasule Sacme
B14	Bean	Balkans	Albania	Fasule Trenare
B15	Bean	Balkans	Albania	Fasule Ecmeniku
B26	Bean	Balkans	Serbia	Gradistanac
B27	Bean	Balkans	Serbia	Tetovac
B31	Bean	Balkans	Serbia	Sumporas
B34	Bean	Balkans	Kosovo	Traditional var
B39	Bean	Balkans	Bosnia and Herzegovina	ssp. nanus
B44	Bean	Balkans	Bosnia and Herzegovina	ssp. nanus
M05	Bean	Mshreq	Lebanon	Baladi Large Red

COD LAB	Legume	AREA	Country	Variety
N21	Bean	Maghreb	Tunisia	Coco nain
N34	Bean	Maghreb	Algeria	White Coco
N35	Bean	Maghreb	Algeria	Prague Coco
N36	Bean	Maghreb	Algeria	Prague Coco
N52	Bean	Maghreb	Morocco	Ghelid
N53	Bean	Maghreb	Morocco	Reguig
B09	Chickpea	Balkans	North Macedonia	Traditional var
B10	Chickpea	Balkans	North Macedonia	Traditional var
M02	Chickpea	Mshreq	Lebanon	CP Baladi Jumbo
M03	Chickpea	Mshreq	Lebanon	Baladi Red Small
M08	Chickpea	Mshreq	Lebanon	Baladi medium
M12	Chickpea	Mshreq	Jordan	Baladi small
M30	Chickpea	Mshreq	Syria	GHAB#3 ICARDA
M31	Chickpea	Mshreq	Syria	GHAB#4 ICARDA
M32	Chickpea	Mshreq	Syria	Ghab#5 ICARDA
M45	Chickpea	Mshreq	Palestina	Baladi
N16	Chickpea	Maghreb	Tunisia	Amdoun
N22	Chickpea	Maghreb	Algeria	Desi
N47	Chickpea	Maghreb	Morocco	Maizou
N48	Chickpea	Maghreb	Morocco	Kerfasa
N49	Chickpea	Maghreb	Morocco	Meksik
N01	Cowpea	Maghreb	Mauritania	Cowpeas (white color)
N04	Cowpea	Maghreb	Mauritania	Cowpeas (spotted gray color)
N05	Cowpea	Maghreb	Mauritania	Cowpeas (white color)
N06	Cowpea	Maghreb	Mauritania	Cowpeas (white color)
N07	Cowpea	Maghreb	Mauritania	Cowpeas (brown-gray color)
N12	Cowpea	Maghreb	Mauritania	Cowpeas (white color)
N33	Cowpea	Maghreb	Algeria	Niébé
B18	Faba	Balkans	Serbia	Traditional var
B19	Faba	Balkans	Serbia	Traditional var
M10	Faba	Mshreq	Lebanon	Baladi small Red
M14	Faba	Mshreq	Jordan	Baladi
M21	Faba	Mshreq	Syria	Baladi Local large dry
M41	Faba	Mshreq	Egypt	Breeding resistant Brown Spot & rust

COD LAB	Legume	AREA	Country	Variety
M42	Faba	Mshreq	Egypt	Breeding mild resistent to rust & brown
M43	Faba	Mshreq	Egypt	Breed. Resist. weeds & Fungi and resilient
M44	Faba	Mshreq	Egypt	Breeding Very early
N15	Faba	Maghreb	Tunisia	Malti
N17	Faba	Maghreb	Tunisia	Malti
N26	Faba	Maghreb	Algeria	Seville
N29	Faba	Maghreb	Algeria	Muchaniel
N37	Faba	Maghreb	Morocco	Genaoui
N38	Faba	Maghreb	Morocco	Tamer
M23	Faba	Mshreq	Syria	Traditional var
M25	Faba	Mshreq	Syria	Traditional var
M07	Lentil	Mshreq	Lebanon	Baladi medium mixt
M09	Lentil	Mshreq	Lebanon	Baladi small
M19	Lentil	Mshreq	Syria	Baladi Local
M22	Lentil	Mshreq	Syria	Traditional var
M33	Lentil	Mshreq	Syria	IDLEB#1 ICARDA
M34	Lentil	Mshreq	Syria	IDLEB#2 ICARDA
M35	Lentil	Mshreq	Syria	IDLEB#3 ICARDA
M36	Lentil	Mshreq	Syria	IDLEB#4 ICARDA
N30	Lentil	Maghreb	Algeria	Syrie 229
N31	Lentil	Maghreb	Algeria	Syrie 229
N45	Lentil	Maghreb	Morocco	Cinq
N51	Cowpea	Maghreb	Morocco	Hamera

As can be seen from the list reported in Table 3, a total of 70 samples of legumes samples were initially selected according to their nutritional and nutraceutical characteristics. These samples were then further selected considering the availability of data referred to their production environmental impact obtained by the Life Cycle Assessment (LCA) analysis. At the end, a group of 20 legumes varieties were selected as results of the combined nutritional and environmental analysis. The final list of the selected samples is reported in Table 4.

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Table 4. Final list of the selected legume varieties considered for the 3rd year of Mediet project.

Internal cod.	Original cod.	Species	Area	Country	Variety
B13	AL07	Bean	Balkans	Albania	Fasule Sacme
B15	AL09	Bean	Balkans	Albania	Fasule Ecmeniku
B26	SRB03_06_09	Bean	Balkans	Serbia	Gradistanac
B27	SRB04_11	Bean	Balkans	Serbia	Tetovac
N21	TN07	Bean	Maghreb	Tunisia	Coco nain
N34	DZ13	Bean	Maghreb	Algeria	White Coco
N36	DZ14_15	Bean	Maghreb	Algeria	Prague Coco
N52	MA15	Bean	Maghreb	Morocco	Ghelid
N53	MA16	Bean	Maghreb	Morocco	Reguig
M08	LB08	Chickpea	Mshreq	Lebanon	Baladi medium
M12	JO02	Chickpea	Mshreq	Jordan	Baladi small
N16	TN02	Chickpea	Maghreb	Tunisia	Amdoun
N01	MR01	Cowpea	Maghreb	Mauritania	Cowpeas (white color)
N04	MR04	Cowpea	Maghreb	Mauritania	Cowpeas (spotted gray color)
N07	MR07	Cowpea	Maghreb	Mauritania	Cowpeas (brown-gray color)
M10	LB10	Faba	Mshreq	Lebanon	Baladi small Red
N15	TN01	Faba	Maghreb	Tunisia	Malti
N26	DZ05	Faba	Maghreb	Algeria	Seville
M23	SY009	Faba	Mshreq	Syria	Traditional var
M09	LB09	Lentil	Mshreq	Lebanon	Baladi small
M22	SY008	Lentil	Mshreq	Syria	Traditional var
N30	DZ09	Lentil	Maghreb	Algeria	Syrie 229
N45	MA12	Lentil	Maghreb	Morocco	Cinq
N51	MA17	Cowpea	Maghreb	Morocco	Hamera

IV – Results of the third year

1. Analysis of nutritional data of beans samples

Nine beans' samples were collected belonging to 8 local varieties. Considering the shape, color, and dimension, the samples can be classified in four types namely: white kidney, navy, cranberry and cannellini beans. The weight of 100 seeds for each sample in the two sampling years are listed in Table 5.

Table 5. Beans type classification and mean value of 100 seed weight in the sampling seasons.

Sample	Type	100 seeds g '24	100 seeds g '23
FasuleEcmeniku	White kidney	44	33
FasuleSacme	Navy	33	20
Praguecoco01	Borlotti	70	43
Praguecoco02	Borlotti	68	43
Whitecoco	Cannellini	52	38
B_MAR_Ghelid	Navy	69	56
Reguig	Cannellini	45	40
Gradistanac	Cannellini	56	57
Tetovac	White kidney	84	56

As can be seen by comparing the weight of 100 seeds in the two sampling years, there was a great variability ranging from 9 to 30% of the average and, specifically, seeds are always bigger in 2024 than in 2023, with the unique exception of Gradistanac which reported quite the same weight.

A. Gross composition percentage of beans samples

The mean values of the gross composition percentage in dry matter, ash, total proteins, total fat, total dietary fibers and total starch were reported in Table 6.

Table 6. Gross composition of beans variety, value are mean value in grams on 100g of dry matter basis. The data reported in the last rows are the mean value of beans samples found in the relative database FAO or USDA.

Variety	Type	Year	DM	Ash	Prot	Fat	TDF	Starch
Ecmeniku	White kidney	2023	88.71	4.45	24.73	1.51	26.39	42.91
Ecmeniku	White kidney	2024	89.57	4.42	29.57	1.42	26.17	38.43
Ghelid	Navy	2023	88.68	4.48	24.42	1.14	21.77	48.19
Ghelid	Navy	2024	87.58	4.33	23.37	1.44	24.65	46.21
Gradistanac	Cannellini	2023	90.05	4.53	25.39	1.15	23.68	46.37
Gradistanac	Cannellini	2024	88.97	4.48	23.27	1.28	22.49	47.37
Praguecoco	Borlotti	2023	89.43	4.31	22.53	1.38	23.78	48.01
Praguecoco	Borlotti	2024	87.12	3.96	25.90	1.49	22.85	45.80
Reguig	Cannellini	2023	88.13	4.09	25.06	1.40	22.76	46.69
Reguig	Cannellini	2024	86.86	4.18	23.99	1.15	21.37	49.31
Sacme	Navy	2023	89.38	4.32	27.84	1.42	26.03	40.40

Variety	Type	Year	DM	Ash	Prot	Fat	TDF	Starch
Sacme	Navy	2024	89.92	4.65	30.03	1.48	23.46	40.37
Tetovac	White kidney	2023	89.10	4.36	25.50	1.44	24.67	44.04
Tetovac	White kidney	2024	89.84	4.88	21.20	2.07	25.97	45.88
Whitecoco	Cannellini	2023	89.70	4.82	24.65	1.38	23.32	45.82
Whitecoco	Cannellini	2024	89.95	4.82	24.14	1.26	21.73	48.06
			Standard deviation among areas and producers					
Borlotti			0.6	0.4	2.0	0.1	1.1	2.6
Cannellini			0.6	0.2	1.4	0.1	1.7	1.1
Navy			1.0	0.3	2.9	0.1	2.4	2.7
White kidney			1.4	0.2	2.5	0.3	1.3	2.3
			Standard deviation between the years of production					
Borlotti			1.6	0.2	2.4	0.1	0.7	1.6
Cannellini			0.6	0.0	0.9	0.1	1.0	1.4
Navy			0.6	0.2	1.1	0.1	1.9	0.7
White kidney			0.6	0.2	3.2	0.3	0.5	2.2
	FAO		88	4.4	24.3	1.8	23.1	45.8
	USDA		89	3.8	25	1.29	22.35	47

When comparing values for the same variety across the two years, ash and total fat contents were very similar, with average standard deviations of 0.18 and 0.10, respectively. Greater variability was observed for total protein and total dietary fiber, with standard deviations of 2.0 and 1.3%, respectively. Notably, protein content increased by 5% in 2024 for Ekmenicu, while Tetovac showed a 3% decrease.

Some variability in starch content is expected, as this parameter is calculated from the other proximate components; therefore, its variation reflects the combined variability of the constituents involved in its estimation.

In 2023, fifty-two bean samples were collected. On a dry weight basis, protein content ranged from 19.2% (Mashreq) to 22.9% (Balkans), while total dietary fiber ranged from 23.5% (Maghreb) to 24.8% (Balkans). As shown in Table 6, most samples collected in 2024 reported higher values than the corresponding 2023 averages from the same production areas, supporting the selection based on nutritional quality.

The bottom rows of Table 6 present standard deviation values estimating the variability attributable either to different agricultural practices and geographical areas or to the same legume sampled in two different years. The magnitude of these two sources of variation is comparable and provides an overall estimate of the potential variability for each parameter.

Considering the observed variability and the obtained values, it should be noted that the Albanese varieties Ecmeniku and Sacme reported high values of proteins and TDF higher than the mean values registered for beans in the FAO and USDA database. Furthermore, the Serbian Tetovac showed high TDF in both years but the level of proteins which was good in the 2023 showed a drastic decrease in 2024.

B. Minerals elements in beans samples

In Table 7 the mean values for the minerals contents of beans samples were reported. Comparing the same variety in the two sampled years, the contents of P, K, Mg and Mn reported the lowest percentages of variability with 16, 13, 8 and 9 % respectively, calculated in respect to the general mean of both years. Higher percentage of variability were observed for the other elements with value close to 25%. Particularly high was the variability observed for Na, even if the concentration found for this element is low and of little significances from a nutritional point of view. As in the case of gross composition the last part of the Table 7 reports the standard deviation values referred to the type of beans in function of the different area of production and the two years. Apart P and K, whose contents surely is importantly affected by fertilization practices, as well as the soil availability, all other elements showed the same variability for both geographical area and year of production effects.

It is relevant to highlight the high content of Fe in Sacme and Tetovac varieties for two years in a row, and the outstanding Fe content of Ecmenicu and White coco, even if these values were reached only in one of the two sampled years. The Sacme beans reported also the highest values for P and Mg. Finally, the Gradistanic beans reported a good content of P, Ca, K, and Cu. Comparing the results with the mean values of FAO, it is noteworthy that almost all samples reported higher content in P, Ca and K.

Table 7. Mineral elements content of beans samples as mg/100g of dry matter.

Variety	Year	P	Ca	K	Mg	Na	Cu	Fe	Mn	Zn
Ecmeniku	2023	426	178	1789	196	19	1.18	5.99	1.40	3.71
Ecmeniku	2024	515	254	1518	207	9	1.07	8.93	1.48	2.57
Ghelid	2023	443	154	1745	168	15	0.78	5.39	1.25	2.96
Ghelid	2024	505	228	1553	168	8	0.81	6.29	1.23	2.43
Gradistanac	2023	546	196	1685	182	30	1.11	7.34	1.45	3.62
Gradistanac	2024	509	189	1670	180	9	0.87	6.29	1.39	2.53
Praguecoco	2023	497	128	1862	196	12	0.86	6.68	1.34	4.21
Praguecoco	2024	436	114	1461	176	15	0.82	5.41	1.14	2.39
Reguig	2023	505	186	1507	176	5	0.99	6.46	1.31	3.52
Reguig	2024	533	135	1584	159	8	0.60	5.06	1.26	2.20
Sacme	2023	606	150	1619	193	9	0.86	7.69	1.38	4.33
Sacme	2024	576	188	1786	201	13	1.16	7.16	1.29	3.63
Tetovac	2023	288	234	1619	180	28	1.06	7.60	2.40	2.81
Tetovac	2024	434	160	1887	214	2	0.53	6.17	2.00	2.64
Whitecoco	2023	458	159	2117	213	23	0.74	9.91	1.45	4.17
Whitecoco	2024	611	170	1738	190	11	0.85	5.95	1.25	3.58
		Standard deviation among areas and producers								
Borlotti		84	20	180	13	6	0.1	1.3	0.2	0.4

Cannellini	39	33	170	16	13	0.1	1.5	0.1	0.4
Navy	62	39	103	8	2	0.2	0.5	0.3	1.0
White kidney	120	33	163	19	10	0.2	1.2	0.4	0.5
	Standard deviation between the years of production								
Borlotti	43	10	283	14	2	0.0	1	0.1	1.3
Cannellini	51	17	111	10	8	0.2	2	0.1	0.7
Navy	32	40	127	3	4	0.1	1	0.0	0.4
White kidney	84	53	191	16	13	0.2	2	0.2	0.5
FAO	456	136	1479	187	11	0.9	7	1.7	3.2
USDA	454	149	1583	210	12	0.9	7	1.5	3.5

C. Fatty acids content of beans samples

The fatty acids contents of the bean samples are reported in Table 8. In the majority of cases the values are very close by comparing the same variety in the two years, and this statement is particularly true considering the values of fatty acids present in low quantities such as heptadecanoic (C17:0), stearic (C18:0), eicosanoic (C20:0), eicosenoic (C20:1), behenic (C22:0), tricosanoic (C23:0) and lignoceric (C24:0). As well known, the most representative fatty acids of beans fat were the two essential fatty acids, namely linolenic (C18:3) and linoleic (C18:2), which showed a high variability between the two sampled years ranging from 7 to 50%.

Table 8. Fatty acids content of beans samples

Variety	Year	C16	C16_1	C17	C18	C18_1	C18_2	C18_3	C20	C20_1	C22	C23	C24
Ecmeniku	2023	69	1.3	0.9	11	64	218	321	2.8	0.8	3.9	1.1	3.8
Ecmeniku	2024	82	5.0	1.2	17	109	325	481	4.7	1.5	6.9	2.2	5.7
Ghelid	2023	42	1,2	0.6	9	48	139	284	2.6	0.9	3.1	0.9	2.9
Ghelid	2024	100	3.7	1.4	17	86	323	462	4.1	1.4	6.0	1.4	6.0
Gradistanac	2023	57	1.5	0.7	10	70	188	347	2.6	1.0	3.8	1.1	3.4
Gradistanac	2024	65	4.0	0.9	11	90	218	453	3.5	1.4	5.8	1.4	4.8
Praguecoco	2023	76	2.0	1.0	11	123	271	353	4.0	1.9	5.8	1.5	4.8
Praguecoco	2024	88	3.9	1.1	11	109	291	487	3.3	1.5	6.2	1.3	5.0
Reguig	2023	65	1.9	1.0	14	65	186	374	3.3	0.9	4.8	1.2	4.2
Reguig	2024	70	2.7	0.8	11	75	222	350	3.1	1.1	4.4	1.3	4.1
Sacme	2023	49	1.9	0.9	12	73	190	348	3.3	1.0	5.1	1.5	3.5
Sacme	2024	97	4.7	1.6	20	135	356	579	5.1	1.9	7.7	2.0	5.4
Tetovac	2023	68	1.4	0.9	12	81	217	391	3.3	1.2	5.1	1.4	4.3
Tetovac	2024	134	6.3	1.6	33	177	794	555	7.8	2.5	6.7	1.5	5.3
Whitecoco	2023	51	1.0	0.6	7	74	186	335	2.5	1.6	3.4	1.4	3.3
Whitecoco	2024	52	2.5	0.7	11	83	230	487	2.9	1.2	4.6	1.1	4.0
Standard deviation among areas and producers													
Borlotti		20	0.5	0.2	2.9	29	76	73	0.9	0.5	1.5	0.5	1.4
Cannellini		9	0.3	0.1	1.6	10	22	31	0.1	0.2	0.7	0.2	0.5
Navy		20	0.4	0.2	1.9	6	51	71	0.4	0.1	0.9	0.3	1.0
White kidney		24	0.6	0.3	6.0	34	159	72	1.1	0.6	0.9	0.3	1.2
Standard deviation between the years of production													

Variety	Year	C16	C16_1	C17	C18	C18_1	C18_2	C18_3	C20	C20_1	C22	C23	C24
Borlotti		8	1	0.1	0.1	10	14	95	0.5	0.3	0.2	0.1	0.1
Cannellini		3	1	0.1	1.8	9	26	66	0.3	0.2	0.9	0.2	0.5
Navy		37	2	0.5	5.7	35	124	144	1.2	0.5	1.9	0.4	1.8
White kidney		28	3	0.4	9.3	50	242	115	2.3	0.7	1.6	0.4	1.0
USDA						90	300	311					

Due to year-to-year variability, it was not possible to identify samples consistently characterized by particularly high and repeatable levels of essential fatty acids. However, noteworthy concentrations of linoleic and linolenic acids were observed in Tetovac and Sacme beans, while most selected varieties showed appreciable levels of linolenic acid. These findings are supported by comparison with the USDA database values (reported in the last row of the table) and are visually emphasized through the applied chromatic scale.

To provide a comprehensive and synthetic overview of fatty acid composition, the data were further analyzed using principal component analysis (PCA). The loading plot of the first two principal components is shown in Figure 5. PC1 and PC2 explained 63% and 22% of the total variance, respectively, accounting for a cumulative 85%. PC1 was positively correlated with all fatty acids except linolenic acid, whereas PC2 showed positive correlations with most saturated fatty acids and negative correlations with unsaturated ones.

The score plot (right panel of Figure 5) illustrates the distribution of samples in the Euclidean space defined by the two principal components. Samples of the same variety collected in two consecutive years are positioned very close to each other, indicating good consistency and repeatability of fatty acid composition. This pattern is particularly evident for the varieties Praga coco, White coco, and Reguig.

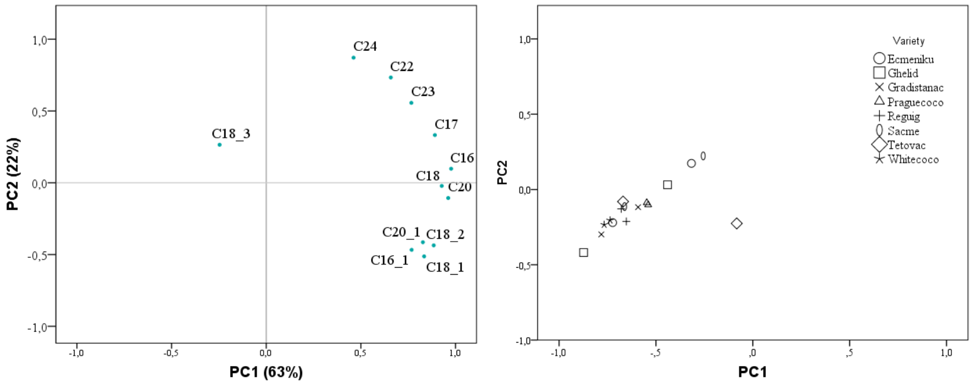

Figure 5. Loading plot related to the PCA applied to the fatty acids content of beans samples on the top, and the score plot of samples, calculated for the two extracted components on the bottom.

D. Amino acids content of bean samples

The results of amino acids content were reported in Table 9, as the mean values expressed in g/100g of dry matter. The comparison between the two sampling years for the same variety shows low standard deviation for the content in threonine, glycine, cysteine, methionine, and tryptophane (<0.1g/100g). The content in proline, isoleucine, and histidine has a variability close to 0.1 g/100g. If we compare the standard deviation values for the year and the area of production, we can observe a higher value for the area of production. There were only two amino acids whose content violated this assumption leucine and isoleucine. Serine content shows a good repeatability in the samples Ecmeniku, Ghelid, Gradistanac, Praga coco and White coco, but higher variability in the remaining varieties, higher also than the values calculated considering the same legume produced in different area. Similar observations can be made considering the values of arginine, lysine, aspartic, tyrosine, phenylalanine, glutamic and leucine, that are also the amino acids present with higher concentrations.

The above-mentioned variability can be graphically observed in the score plot reported in Figure 6. In fact, differently from the results of fatty acids, in the score plot of amino acids, the two samples belonging to the same variety but collected in the two years do not perfectly matched. This mismatch seems to be caused by a different score of PC2. In fact, if we look to the graph, we can note that the sample repetitions are quite close considering the *x* axis (PC1), but they move away from one to each other because of PC2 score which is particularly affected by the concentration of cysteine, proline, methionine and glycine.

Considering only the essential amino acids content it is relevant to highlight the good profile of Ecmenicu and Sacme samples, which showed the highest values for almost all essential amino acids.

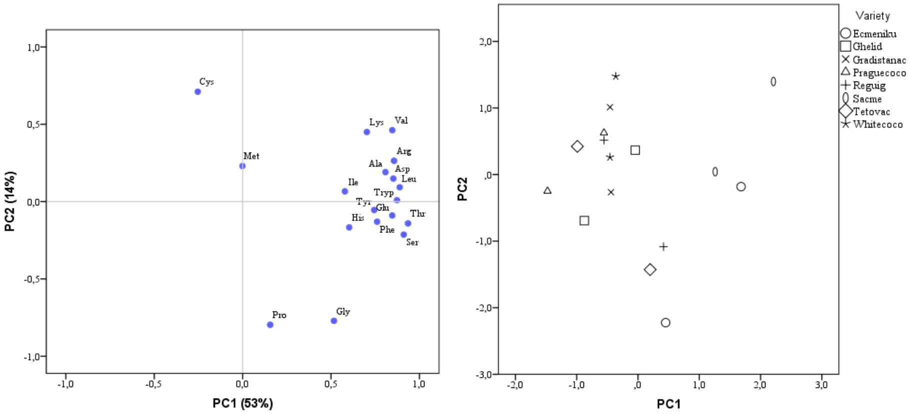

Figure 6 Loading plot and scores plot obtained by the application of PCA analysis to the results of the amino acids composition.

Comparing the amino acids content of the selected varieties with the reference values in FAO and USDA database, it is relevant to note that the values of cysteine and tyrosine we found were higher than the reference ones. The same observation is valid for the histidine and lysine content, but except for the Serbian beans. Another important difference was highlighted by the content in leucine an isoleucine whose content is about 50% lower than the references, probably as the effect of varieties. The content of valine and methionine seemed to be more consistent with the value present in the FAO dataset other than that presented by the USDA food database.

Table 9 Amino acids composition of bean samples expressed in g/100g dry matter, essential amino acids were codified with colors gradients representing the comparison with the reference values of FAO.

Variety	Year	Asp	Thr	Ser	Glu	Pro	Gly	Ala	Cys	Val	Met	Ile	Leu	Tyr	Phe	His	Lys	Tryp	Arg
Ecmeniku	2023	2.54	1.00	1.42	2.99	1.18	0.96	0.87	0.25	0.77	0.16	0.58	1.34	1.17	1.23	0.96	1.57	0.21	1.63
Ecmeniku	2024	2.79	1.04	1.49	3.36	1.02	0.88	0.97	0.27	1.05	0.15	0.72	1.77	1.30	1.37	0.90	2.33	0.25	2.33
Ghelid	2023	2.26	0.74	1.26	2.78	1.00	0.77	0.82	0.28	0.65	0.08	0.33	1.14	0.95	0.99	0.68	1.63	0.19	1.52
Ghelid	2024	2.26	0.86	1.22	2.75	0.87	0.75	0.81	0.29	0.88	0.07	0.58	1.43	1.13	1.15	0.72	1.88	0.22	1.72
Gradistanac	2023	2.35	0.82	1.30	2.80	0.84	0.80	0.84	0.28	0.70	0.14	0.43	1.26	1.09	1.28	0.60	1.41	0.23	1.38
Gradistanac	2024	2.28	0.83	1.19	2.78	0.77	0.71	0.79	0.29	0.85	0.18	0.55	1.36	1.04	1.11	0.70	1.85	0.18	1.56
Praguecoco	2023	2.18	0.69	1.10	2.56	1.04	0.67	0.73	0.28	0.61	0.14	0.34	1.05	0.79	0.83	0.59	1.51	0.19	1.28
Praguecoco	2024	2.11	0.76	1.15	2.77	0.98	0.69	0.76	0.30	0.84	0.21	0.54	1.36	1.10	1.09	0.69	1.80	0.19	1.44
Reguig	2023	2.62	0.92	1.44	3.10	1.08	0.89	0.96	0.27	0.76	0.12	0.47	1.42	1.02	1.18	0.81	1.91	0.22	1.86
Reguig	2024	2.20	0.76	1.13	2.71	0.85	0.68	0.75	0.29	0.82	0.08	0.56	1.35	1.04	1.11	0.71	1.79	0.20	1.47
Sacme	2023	4.23	1.10	1.71	3.47	0.84	0.72	1.54	0.28	1.27	0.16	0.47	1.57	1.25	1.69	0.81	2.18	0.26	2.67
Sacme	2024	2.78	1.02	1.42	3.18	0.98	0.86	0.94	0.29	1.00	0.10	0.68	1.70	1.28	1.31	0.82	2.21	0.24	2.28
Tetovac	2023	2.40	0.96	1.40	2.98	0.95	0.86	0.83	0.25	0.74	0.14	0.53	1.41	1.26	1.75	0.56	1.37	0.22	1.25
Tetovac	2024	1.94	0.83	1.03	2.29	0.81	0.67	0.76	0.26	0.78	0.15	0.48	1.19	1.02	0.95	0.61	1.73	0.20	1.39
Whitecoco	2023	2.31	0.74	1.14	3.25	0.95	0.79	0.89	0.31	0.67	0.16	0.41	1.19	0.73	0.91	0.90	1.79	0.22	2.04
Whitecoco	2024	2.23	0.85	1.20	2.71	0.79	0.70	0.77	0.32	0.86	0.18	0.56	1.34	1.13	1.11	0.69	1.84	0.21	1.63
Standard deviation among different producers and geographical area																			
Borlotti		0.25	0.09	0.12	0.25	0.18	0.06	0.13	0.03	0.10	0.02	0.09	0.14	0.28	0.29	0.10	0.15	0.03	0.15
Cannellini		0.20	0.09	0.11	0.31	0.11	0.08	0.09	0.02	0.06	0.03	0.07	0.12	0.23	0.21	0.18	0.26	0.02	0.40
Navy		0.88	0.10	0.20	0.32	0.11	0.41	0.31	0.02	0.25	0.02	0.07	0.11	0.10	0.27	0.05	0.33	0.06	0.56
White kidney		0.32	0.11	0.15	0.34	0.12	0.09	0.10	0.03	0.08	0.02	0.13	0.19	0.31	0.31	0.19	0.20	0.04	0.33

Variety	Year	Asp	Thr	Ser	Glu	Pro	Gly	Ala	Cys	Val	Met	Ile	Leu	Tyr	Phe	His	Lys	Tryp	Arg
Standard deviation between the years of production																			
Borlotti		0.05	0.05	0.03	0.14	0.04	0.02	0.02	0.01	0.16	0.05	0.14	0.23	0.22	0.19	0.07	0.21	0.00	0.12
Cannellini		0.14	0.06	0.11	0.22	0.11	0.09	0.09	0.01	0.09	0.02	0.09	0.08	0.11	0.10	0.10	0.14	0.02	0.23
Navy		0.51	0.07	0.11	0.11	0.10	0.06	0.21	0.01	0.18	0.02	0.16	0.15	0.07	0.19	0.02	0.10	0.02	0.21
White kidney		0.25	0.06	0.16	0.37	0.10	0.10	0.06	0.01	0.11	0.00	0.07	0.23	0.13	0.33	0.04	0.40	0.03	0.29
FAO		2.95	1.05	1.41	3.91	1.1	1.05	1.1	0.19	0.89	0.19	1.02	1.9	0.65	1.27	0.7	1.5	0.25	1.47
USDA		3.04	0.99	1.42	3.66	1.13	0.98	1.1	0.26	1.37	0.34	1.15	2.02	0.71	1.36	0.68	1.64	0.29	1.44

E. *Antinutritional factors content of beans samples*

The average amount of trypsin units inhibited (TUI), total tannins and phytates are reported in Table 10, together with the standard deviation values related to different areas and years of production. Overall, the TUI showed three units' lower values in 2024 than the results obtained in 2023 in the same variety. The standard deviation observed for both year and area of production for this parameter, are in the same order of magnitude but slightly higher for the effect of area of production.

Table 10. Antinutritional factors average amount of beans samples. TUI=Trypsin units inhibited per g of dry matter, Tannins in mg/100g of tannic acid equivalent on dry matter, Phytates in g/100g of dry matter. Reference values for phytates were calculated using the phytates database of FAO, whereas the reference values for TUI were obtained by (Guillamón et al., 2008)

Variety	Type	Year	TUI	Tannins	Phytate
Ecmeniku	Bean white kidney	2023	19.3	4	1.03
Ecmeniku	Bean white kidney	2024	16.6	59	0.49
Ghelid	Bean navy	2023	22.6	62	0.75
Ghelid	Bean navy	2024	19.3	35	0.29
Gradistanac	Bean Cannellini	2023	22.3	62	0.90
Gradistanac	Bean Cannellini	2024	19.2	77	0.39
Praguecoco	Bean borlotti	2023	23.9	765	0.79
Praguecoco	Bean borlotti	2024	19.9	876	0.42
Reguig	Bean Cannellini	2023	19.9	5	0.47
Reguig	Bean Cannellini	2024	23.4	29	0.56
Sacme	Bean navy	2023	13.3	11	1.43
Sacme	Bean navy	2024	8.2	65	0.60
Tetovac	Bean white kidney	2023	18.1	39	0.33
Tetovac	Bean white kidney	2024	15.3	103	0.21
Whitecoco	Bean Cannellini	2023	29.3	144	0.50
Whitecoco	Bean Cannellini	2024	25.0	52	0.72
	Standard deviation among producers and geographical areas				
	Borlotti bean		2.8	223	0.2
	Cannellini bean		3.6	33	0.3
	Navy bean		3.6	8	0.5
	White kidney bean		4.0	137	0.3
	Standard deviation between the years of production				
	Borlotti bean		2.8	79	0.3
	Cannellini bean		2.6	42	0.2
	Navy bean		3.0	28	0.3
	White kidney bean		1.9	32	0.3
	Reference		19-30		0.6

F. Vitamins and antioxidants contents of beans samples

In Table 11 the total antioxidant capacity and the polyphenols contents of beans samples were reported. As can be seen, TEAC has an important variability both for year and area of production, leading to values variability between years greater than 100%. Moreover, Praga coco borlotti and White coco cannellini resulted to be the varieties with the highest values for both TEAC and total polyphenols in the two examined years. Another important information that could be caught from Table 11 is that not always the antioxidants activity in legume samples are positively correlated with polyphenols. In fact, the great TEAC observed in White coco has almost no correlation with the total polyphenols content.

Table 11. Trolox Equivalent Antioxidant Capacity (TEAC) in µmol/100g, total polyphenols in mg/100g of gallic acid equivalent, Vitamin B1, B3 and E are in mg/100g. Vitamins B7 and B9 are expressed in µg/100g. All values are on dry matter basis. The reference values for the TEAC and Total polyphenols (TP) were obtained from (Kan et al., 2017) whereas the reference for B7 was obtained from https://nutrivore.com/foods/.

Variety	Type	Year	TEAC	Polyph.	Vit_B1	Vit_B3	Vit_B7	Vit_B9	Vit_E
Ecmeniku	Bean white kidney	2023	538	75	0.9	3.4	14.3	70.5	4.8
Ecmeniku	Bean white kidney	2024	372	68	2.3	3.3	6.1	99.2	4.2
Ghelid	Bean navy	2023	1742	116	0.5	3.7	7.1	71.6	3.9
Ghelid	Bean navy	2024	309	70	1.0	2.6	3.8	81.3	4.1
Gradistanac	Bean Cannellini	2023	1745	106	0.5	3.6	10.9	71.8	6.2
Gradistanac	Bean Cannellini	2024	478	97	1.8	3.7	3.0	111.2	2.9
Praguecoco	Bean borlotti	2023	3137	1152	0.7	3.8	10.2	81.4	2.6
Praguecoco	Bean borlotti	2024	2628	1122	1.2	4.8	2.7	114.3	4.1
Reguig	Bean Cannellini	2023	904	138	0.7	3.5	10.1	77.0	5.1
Reguig	Bean Cannellini	2024	403	66	1.1	3.9	2.1	106.3	3.5
Sacme	Bean navy	2023	719	90	0.8	3.2	14.8	96.7	4.6
Sacme	Bean navy	2024	366	84	2.6	4.1	4.4	49.3	4.0
Tetovac	Bean white kidney	2023	2124	82	0.9	2.9	15.3	60.6	7.2
Tetovac	Bean white kidney	2024	560	121	1.6	3.3	3.5	102.9	5.6
Whitecoco	Bean Cannellini	2023	3142	165	0.8	4.8	10.7	94.2	3.8
Whitecoco	Bean Cannellini	2024	1920	115	1.9	4.4	5.0	167.1	4.3
			Standard deviation among producers and geographical areas						
	Borlotti bean		808	278	0.2	0.9	1.6	29	0.7

Variety	Type	Year	TEAC	Polyph.	Vit_B1	Vit_B3	Vit_B7	Vit_B9	Vit_E
	Cannellini bean		800	26	0.2	0.6	2.0	28	2.0
	Navy bean		493	27	0.1	1.1	2.0	8	0.6
	White kidney bean		590	142	0.2	0.9	2.3	19	1.7
			Standard deviation between the years of production						
	Borlotti bean		360	21	0.3	0.7	5	23	1.0
	Cannellini bean		705	31	0.7	0.2	5	33	1.3
	Navy bean		632	18	0.8	0.7	5	20	0.3
	White kidney bean		612	16	0.8	0.2	7	25	0.8
	FAO / *others*		100-720	25-3500	0.3	3.1	17	390	0.1
	USDA				0.8	2.0		500	0.3

The hydro soluble vitamins B1 (thiamine) and B7 (biotin) seem to be importantly affected by the year of production. Unfortunately, we cannot exclude a possible effect of the analytical method used, being the method adopted for all B group vitamins, based on microorganism growth. The vitamins B3 (niacin) and B9 (folates) showed a better repeatability between the years and similar standard deviations for year and area of production, highlighting and confirming a higher value of B3 content in White coco beans in respect to the other varieties. The vitamin E content is expressed as α-tocopherol equivalent, even if all tocopherols were determined, the content of each tocopherol was not reported in the present report because of the only information that can be obtained by these results is that in all beans varieties the γ-tocopherol is the most concentrated among all tocopherols. By comparing the vitamins content among the bean's varieties, and the reference value in food database we can highlight an overall high content of vitamins B1, B3 and E of the selected beans, whereas the mean content of folates was found three times lower than the reference in almost all samples.

2. Analysis of nutritional data of chickpeas and lentils samples

During the 3rd year of Mediet project two varieties of chickpeas and three varieties of lentils were sampled again and compared with the relative samples collected the previous year. The samples of chickpeas belonged to a local variety produced in Jordan indicated as JO02 (kabuli type) and a variety named Amdoun from Tunisia (desi type). The lentils samples belonged to the Syrie 229 from Algeria, Sy08 from Syrie (both micro sperms varieties) and the macro sperms variety Cinq from Morrocco. Apart the chickpeas from Jordan, all other samples showed a good correspondence between the seed's sizes in the two sampled years (Table 12). As expected, the cooking time of kabuli chickpeas is only half the value in respect to the Amdoun - desi. The shortest cooking time was observed on the Syrie 229 and Cinq lentils samples with a value slightly higher than 20 minutes, even if the two samples were characterized by a different size. The percentage of hydration for the two chickpeas was exactly the same, whereas the value of this parameter for lentils ranged between 112 to 89%.

Table 12. One hundreds seeds weight and type classification of chickpeas and lentils samples selected in the Mediet project.

Sample	Type	100 seeds g '24	100 seeds g '23
Cp_JOR_JO02	Kabuli chickpea	68	39
Cp_TN_Amdoun	Desi chickpea	36.5	30
L_DZA_Syrie229/06	Small lentil	3.2	3,3
L_MAR_Cinq	Medium lentil	4.9	4,3
L_SYR_SY08	Small lentil	2.5	2.8

A. Gross composition of chickpeas and lentils samples

The gross composition of chickpeas and lentils samples were reported in Table 13. For chickpeas samples should be highlighted the high variability observed in the Jordan samples with a standard deviation exceeding the value registered for the kabuli chickpeas collected from different producing and geographical areas in the previous year. Similar variability was observed in the total dietary fibers content. Differently, the Amdoun chickpeas from Tunisia showed a good repeatability for both total proteins and dietary fibers with standard deviation values below the relative value calculated the previous year considering the desi type chickpeas produced in different area.

Lentils samples showed a low variability between the years and higher values than the references, thus supporting the reasons of their selection. Of relevance is the values for TDF of lentils varieties, which resulted 30-50% higher than the values reported in the reference database.

Table 13. Gross composition on dry matter basis of chickpeas and lentils samples.

Variety	Type	Year	DM	Ash	Prot	Fat	TDF	Starch
Amdoun	Chickpea desy	2023	90.7	3.4	27.7	5.9	19.3	45.9
Amdoun	Chickpea desy	2024	90.5	3.0	25.4	5.3	18.1	46.0
JO02	Chickpea kabuli	2023	91.9	3.0	17.5	5.8	20.0	53.6
JO02	Chickpea kabuli	2024	91.8	3.1	24.0	5.3	17.6	49.9
Cinq	Lentil macro brown	2023	90.4	2.6	25.6	1.1	21.2	48.8
Cinq	Lentil macro brown	2024	88.8	2.9	27.3	1.1	21.4	49.7
SY08	Lentil micro	2023	91.2	2.7	29.8	0.9	21.7	44.4
SY08	Lentil micro	2024	92.0	2.9	27.8	1.0	19.9	52.6
Surie 229	Lentil micro	2023	89.8	2.3	27.9	0.9	20.2	47.8
Surie 229	Lentil micro	2024	88.9	2.5	29.0	1.0	21.0	49.0
		Standard deviation among producers and geographical area						
	Chickpea desy		0.9	0.2	2.6	0.5	1.8	3.2
	Chicpea kabuli		0.8	0.2	3.1	0.4	2.1	2.3
	Lentils macro		0.5	0.3	3.0	0.1	2.2	3.8
	Lentils micro		1.1	0.3	1.7	0.1	2.4	2.7
		Standard deviation between the years of production						
	Chickpea desy		0.1	0.3	1.5	0.4	0.8	2.4
	Chicpea kabuli		0.05	0.1	4.2	0.4	1.7	0.7
	Lentils macro		1.1	0.2	1.2	0.04	0.2	1.5
	Lentils micro		0.6	0.1	1.1	0.1	0.9	2.0
Chickpea	FAO Mean		90	3	21.6	5.8	19	47
	USDA Mean		92.0	3.1	22.2	6.5	13.2	55.0
Lentils	FAO Mean		91	2.8	27.7	1.3	16.3	51.3
	USDA Mean		92.0	3.0	26.8	1.2	11.7	57.0

The obtained results confirmed the high content of proteins of Amdoun chickpea, together with the high proteins content of SY08 and Syrie 229. Finally, it is also confirmed the high content of dietary fibers of lentils varietes.

B. *Minerals content of chickpeas and lentils samples*

The average mineral contents of chickpeas and lentils are reported in Table 14. A comparison of chickpea samples across the two years highlights some notable differences. In Amdoun, the Zn content was particularly high in 2023 but decreased to a more common lower value in 2024. An even more marked variation was observed for JO02, where the Fe content in the second year was three times higher than in the first. All other mineral values for chickpeas were generally confirmed and remained within the normal range of variability observed in the previous year.

Overall, the selected chickpea varieties showed good levels of P, Ca, K, Mg, Cu, and Zn. The Fe content reached a remarkably high value in the Jordan chickpea, although this was observed only in 2024.

Table 14. Minerals content of chickpeas and lentils samples in mg/100g dry matter basis.

Variety	Type	Year	P	Ca	K	Mg	Na	Cu	Fe	Mn	Zn
Amdoun	Chickpea desi	2023	161	126	1026	140	5	1.98	5.01	1.77	6.23
Amdoun	Chickpea desi	2024	347	160	1017	125	8	0.90	4.36	1.50	3.30
JO02	Chickpea kabuli	2023	301	174	1067	141	1	0.72	4.96	2.41	3.63
JO02	Chickpea kabuli	2024	325	122	1148	144	20	0.89	13.34	2.99	3.92
Cinq	Lentil macro	2023	374	87	950	109	6	1.34	11.02	0.87	3.00
Cinq	Lentil macro	2024	450	70	1025	112	3	0.93	8.23	1.00	2.65
SY08	Lentil micro	2023	236	171	958	111	6	1.29	16.71	1.43	5.54
SY08	Lentil micro	2024	288	75	892	145	8	1.12	9.29	1.17	2.55
Syrie 229	Lentil micro	2023	322	69	938	115	10	1.07	9.18	1.23	3.77
Syrie 229	Lentil micro	2024	306	70	874	105	4	0.88	9.09	1.33	2.84
			Standard deviation among areas and producers								
	Chickpea desi		101	26	127	10	7	0.3	1.6	0.6	0.9
	Chickpea kabuli		79	24	71	13	5	0.3	0.7	0.4	0.9
	Lentil macro		70	19	70	10	6	0.2	1.0	0.2	0.4
	Lentil micro		60	92	106	8	5	0.2	4.2	0.2	1.0
			Standard deviation between years of production								
	Chickpea desi		131	24	7	11	2	0.8	0.5	0.2	2.1
	Chickpea kabuli		17	36	57	2	14	0.1	5.9	0.4	0.2
	Lentil macro		53	12	53	3	2	0.3	2.0	0.1	0.2
	Lentil micro		24	34	46	16	3	0.1	2.7	0.1	1.4
	Chickpeas	FAO	313	113	968	156	14	0.6	6.8	2.7	3.4
		USDA	273	62	778	86	26	0.7	4.7	4.5	3.0
	Lentils	FAO	348	33	800	87	9	0.7	7.7	1.6	3.6
		USDA	306	38	738	51	7	0.8	7.1	1.5	3.6

Concerning the lentils samples, all results were confirmed and the variability of the data observed between the two years was almost always below the variability registered for different producers and geographical area. The SY08 variety is confirmed to be the one with the highest content in Fe and Mn, whereas the Cinq showed good level of P and K. Syrie 229 was characterized by a good level of Fe, Mn and Zn.

C. Fatty acids content of chickpeas and lentils samples

In Table 15 the average values of fatty acids content were reported for chickpeas and lentils samples. As observed for the previous parameters, chickpeas Amdoun showed a good repeatability between the two years, whereas the kabuli type JO02 collected in 2024 reported more than the double content in stearic, linoleic and behenic acids than the value obtained in 2023.

The lentils samples are characterized by a great uniformity and repeatability of fatty acids content, with a standard deviation between years below the relative values calculated for different geographical area. It should be noted that Amdoun and Cinq varieties showed the highest content in linoleic and linolenic acid among chickpeas and lentils varieties respectively.

Table 15. Fatty acids content of chickpeas and lentils samples, values in mg/100g dry matter.

Type	Variety	Year	C16	C16_1	C17	C18	C18_1	C18_2	C18_3	C20	C20_1	C22	C23	C24
Chickpea desi	Amdoun	2023	442	8.3	3.3	111	1049	2413	117	40.3	13.9	16.5	2.6	6.6
Chickpea desi	Amdoun	2024	458	18.7	3.1	116	1279	2660	139	42.9	18.8	19.0	2.9	7.5
Chickpea kabuli	JO02	2023	316	8.8	2.2	49	1212	1595	66	21.8	17.1	14.8	1.9	4.4
Chickpea kabuli	JO02	2024	416	13.7	4.1	235	1150	2750	135	68.0	13.8	23.5	3.1	7.3
Lentil macro	Cinq	2023	68	1.0	0.5	9	118	332	98	5.5	6.8	6.4	1.7	3.1
Lentil macro	Cinq	2024	83	2.1	0.6	11	159	389	127	6.4	8.2	7.2	2.0	4.2
Lentil micro	SY08	2023	96	2.1	0.5	17	186	234	83	4.3	5.9	4.2	1.6	2.9
Lentil micro	SY08	2024	82	3.5	0.5	13	150	245	87	5.1	5.7	5.0	1.8	3.2
Lentil micro	Syrie 229	2023	41	0.7	0.3	5	76	198	51	2.9	3.3	3.4	1.2	2.4
Lentil micro	Syrie 229	2024	73	2.5	0.7	9	125	298	70	5.5	6.4	4.1	1.3	1.1
	Standard deviation among areas and producers													
	Chickpea desi		61	1.3	0.5	23	504	320	21	7.1	4.6	2.8	2.2	1.6
	Chickpea kabuli		94	3.2	0.6	44	337	583	31	10.6	5.2	3.9	0.8	1.6
	Lentils macro		12	0.2	0.1	2	21	57	20	1.2	1.1	1.4	1.2	1.1
	Lentils micro		24	0.5	0.1	4	51	79	29	1.4	1.7	1.3	0.5	0.9
	Standard deviation between years of production													
	Chickpea desi		12	7	0.1	3	163	175	15	2	4	2	0.2	1
	Chickpea kabuli		70	3	1.3	131	44	817	49	33	2	6	0.8	2
	Lentil macro		11	1	0.1	1	30	40	20	1	1	1	0.2	1
	Lentil micro		16	1	0.1	3	30	39	8	1	1	1	0.1	1
USDA	Chickpeas						1500	2800	110					
	Lentils						200	450	120					

D. Amino acids content of chickpeas and lentils samples

The average amount of each proteinogenic amino acid content in chickpeas and lentils is reported in Table 16. Differently from what was observed in beans samples, chickpeas and lentils samples showed a great similarity between the samples collected in the two years. Except for few amino acids, like aspartic, glutamic, tyrosine and leucine, which showed a standard deviation in the range 0.2-0.1 g/100g, all other amino acids were characterized by a standard deviation < 0.1g/100g both considering the variability of different seasons or different areas of production.

Considering the essential amino acids (represented with colours scale in Table 16) the Amdoun variety reported the most favourable profile with good repeatability and a good content for each essential amino acid. Lentils samples resulted to be almost equivalent in terms of essential amino acids content with the exception of a slightly higher content of tryptophane in smple Syrie 229. In respect to the reference value both chickpeas and lentils samples showed high content of tyrosine, histidine, lysine and only for chickpeas cysteine. All other essential amino acids showed lower value than the relative reference.

Table 16. Amino acids content of chickpeas and lentils samples.

Variety	Type	Year	Asp	Thr	Ser	Glu	Pro	Gly	Ala	Cys	Val	Met	Ile	Leu	Tyr	Phe	His	Lys	Tryp	Arg
Amdoun	Chickpea desy	2023	2.5	0.7	1.2	3.4	1.1	0.8	0.9	0.4	0.7	0.1	0.4	1.3	0.7	1.0	0.7	1.8	0.1	2.9
Amdoun	Chickpea desy	2024	2.2	0.7	1.1	3.0	0.8	0.7	0.8	0.4	0.8	0.1	0.5	1.3	0.8	1.1	0.7	1.8	0.2	3.1
JO02	Chickpea kabuli	2023	2.1	0.6	1.0	2.7	0.8	0.7	0.7	0.3	0.6	0.1	0.4	1.1	0.6	1.1	0.4	1.2	0.1	1.6
JO02	Chickpea kabuli	2024	2.0	0.6	0.9	2.7	0.8	0.7	0.7	0.4	0.7	0.1	0.5	1.2	0.8	1.0	0.6	1.6	0.2	2.3
Cinq	Lentil macro	2023	2.2	0.6	1.1	3.0	0.9	0.8	0.8	0.3	0.7	0.1	0.4	1.1	0.7	0.8	0.9	1.8	0.2	2.0
Cinq	Lentil macro	2024	2.2	0.7	1.0	3.0	0.8	0.8	0.8	0.3	0.9	0.1	0.6	1.3	0.9	1.0	0.9	1.9	0.1	2.3
SY08	Lentil micro	2023	2.4	0.7	1.3	3.3	1.0	0.9	0.9	0.3	0.7	0.1	0.4	1.2	0.9	1.0	0.9	1.9	0.1	2.5
SY08	Lentil micro	2024	2.2	0.7	1.1	3.1	0.8	0.8	0.8	0.3	0.9	0.0	0.5	1.3	0.9	1.0	0.9	1.9	0.2	2.3
Surie 229	Lentil micro	2023	2.3	0.7	1.2	3.2	0.7	0.9	0.9	0.3	0.7	0.1	0.4	1.2	0.8	0.9	0.9	1.9	0.1	2.6
Surie 229	Lentil micro	2024	2.5	0.8	1.1	3.3	0.9	0.8	0.9	0.2	0.9	0.1	0.6	1.5	1.0	1.1	0.9	2.2	0.2	2.9
										Standard deviation among different producers and geographical area										
	Chickpea desy		0.2	0.1	0.1	0.3	0.3	0.1	0.1	0.0	0.1	0.0	0.1	0.1	0.2	0.2	0.2	0.3	0.0	0.7
	Chicpea kabuli		0.2	0.1	0.1	0.3	0.1	0.1	0.1	0.0	0.1	0.0	0.1	0.1	0.1	0.2	0.1	0.2	0.0	0.7
	Lentils macro		0.2	0.1	0.1	0.3	0.4	0.1	0.1	0.0	0.1	0.0	0.0	0.1	0.1	0.2	0.2	0.4	0.0	0.5
	Lentils micro		0.1	0.0	0.1	0.2	0.4	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.1	0.2	0.0	0.4
										Standard deviation between the year of production										
	Chickpea desy		0.2	0.0	0.1	0.2	0.2	0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.1
	Chicpea kabuli		0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.3	0.0	0.5
	Lentils macro		0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.2	0.2	0.0	0.1	0.0	0.2
	Lentils micro		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.0	0.1	0.1	0.1	0.1	0.0	0.1	0.0	0.2
Chickpeas	FAO		2.1	0.7	1.2	4.0	1.3	0.9	1.0	0.3	0.8	0.3	0.8	1.5	0.7	1.3	0.6	1.3	0.2	2.1
	USDA		2.6	0.8	1.1	3.9	0.9	0.9	1.0	0.3	0.9	0.3	1.0	1.6	0.6	1.2	0.6	1.5	0.2	2.1
Lentils	FAO		3.4	0.8	1.3	5.1	1.3	1.2	1.4	0.3	1.2	0.2	1.0	1.8	0.8	1.3	0.6	1.8	0.2	2.1
	USDA		3.0	1.0	1.2	4.2	1.1	1.1	1.1	0.4	1.3	0.2	1.2	2.0	0.7	1.3	0.8	1.9	0.2	2.1

E. Antinutritional factors of chickpeas and lentils samples

In Table 17 the average content in trypsin inhibitors, tannins and phytates of chickpeas and lentils samples were reported. Both chickpeas' varieties showed a lower value than that reported the previous year highlighting an important effect of the production season on this parameter. The opposite can be observed for tannins in chickpeas, with higher value in 2024 than in 2023, whereas the phytates content showed similar values comparing the two years and the two varieties.

Lentils samples seem to have the same behaviour as chickpeas, with variability between years for trypsin inhibitors and tannins content. Results related to phytates highlight and confirm the exceptionally low content in lentils from Syria and the higher phytate content of Cinq variety.

In comparison with the reference values the selected varieties were mainly characterized by low content of antinutritional factors except for the singular case of Amdoun in 2023 and phytates content of Cinq lentil.

Table 17. Trypsin Units Inhibited per g, total tannins in mg of tannic acid equivalent and total phytates in g/100g of chickpeas and lentils samples. Reference value for phytates were obtained from phytate database of FAO; reference value for TUI was obtained from(Guillamón et al., 2008)

Variety	Type	Year	TUI	Tannins	Phytate
Amdoun	Chickpea desi	2023	15.6	41	0.20
Amdoun	Chickpea desi	2024	9.0	116	0.32
JO02	Chickpea kabuli	2023	11.5	87	0.32
JO02	Chickpea kabuli	2024	9.0	181	0.28
Cinq	Lentil macro	2023	6.8	1011	0.61
Cinq	Lentil macro	2024	4.0	759	0.65
SY08	Lentil micro	2023	4.2	1142	0.14
SY08	Lentil micro	2024	1.7	614	0.10
Syrie 229	Lentil micro	2023	6.9	913	0.47
Syrie 229	Lentil micro	2024	3.0	844	0.22
	SD producers and geographical areas				
	Chickpea desi		2.6	160	0.23
	Chickpea kabuli		1.3	34	0.12
	Lentils macro		1.1	135	0.32
	Lentils micro		1.1	158	0.22
	SD years				
	Chickpea desi		4.7	53	0.09
	Chickpea kabuli		1.7	67	0.03
	Lentil macro		2.0	178	0.03
	Lentil micro		2.2	211	0.10
	Reference	Chickpeas	15-20		0.6
		Lentils	5-10		0.6

F. *Nutraceuticals and vitamins contents of chickpeas and lentils samples*

The antioxidant capacity, total polyphenols and vitamins contents for chickpeas and lentils samples were reported in Table 18. Results for TEAC and polyphenols of chickpeas were practically the same in the two years reporting a very low standard deviation. Effect of the year can be observed for the vitamins B1, B3, and B9 content with all values related to the 2024 higher than that of previous year. Considering the variability of data related to the vitamin E, no difference for production year was observed for the chickpea from Jordan, but a significative higher content in 2024 was registered for the variety Amdoun.

Lentils samples confirm the high values of TEAC for these legumes, with a good repeatability between the two sampling years even if the same consistency was not observed for the total polyphenols content. The local variety SY08 confirmed a relevant higher TEAC in respect to the other varieties. The three selected varieties of lentils showed a good content of vitamins B and tocopherols compared to the reference values, even if with some singular drop and the low B1 concentration found in Syrie 229. It should be noted the particular case of the total folates content (vitamin B9) found which are in good agreement with the values present in the FAO database, whereas they were importantly lower than that reported in the USDA. For the antioxidant capacity, total polyphenols and biotin (B7) the values reported as reference were taken from scientific literature and web resources.

Table 18. Trolox Equivalent Antioxidant Capacity in µmol/100g, total polyphenols in mg of gallic acid equivalent per 100g, vitamins B1 and B3 in g/100g, vitamin B7 in µg/100g, vitamin B9 and E in mg/100g. Reference values for TEAC and TP in chickpeas were that published by Y. K. Wang et al., 2016 whereas that of lentils were from (Han & Baik, 2008).The reference value for B7 vitamin was obtained from the web https://nutrivore.com/foods/.

Variety	Type	Year	TEAC	TP	Vit_B1	Vit_B3	Vit_B7	Vit_B9	Vit_E
Amdoun	Chickpea desi	2023	715	134	0.8	2.1	20.7	240.9	7.7
Amdoun	Chickpea desi	2024	732	102	2.4	5.0	24.8	308.6	13.3
JO02	Chickpea kabuli	2023	451	93	0.7	1.9	17.6	149.2	10.9
JO02	Chickpea kabuli	2024	542	85	1.1	3.8	14.6	252.0	13.6
Cinq	Lentil macro	2023	2721	1466	0.7	3.4	21.4	159.4	7.8
Cinq	Lentil macro	2024	2703	1050	0.8	3.9	11.2	151.8	4.9
SY08	Lentil micro	2023	3716	1324	0.7	2.6	23.3	128.3	5.3
SY08	Lentil micro	2024	6580	687	1.5	3.6	14.7	150.6	6.6
Syrie 229	Lentil micro	2023	2963	1032	0.3	3.6	26.0	90.8	6.1
Syrie 229	Lentil micro	2024	2672	1174	0.5	4.5	8.4	164.9	4.3
					SD producers and geographical areas				
	Chickpea desi		809	214	0.1	0.6	7	98	3
	Chickpea kabuli		92	28	0.2	0.6	4	89	5
	Lentils macro		268	160	0.2	0.3	2	70	3
	Lentils micro		422	152	0.2	0.5	6	27	3
					SD years				
	Chickpea desi		12	23	1.2	2.0	3	48	4
	Chickpea kabuli		65	6	0.3	1.3	2	73	2
	Lentil macro		13	294	0.1	0.4	7	5	2

Variety	**Type**	**Year**	**TEAC**	**TP**	**Vit_B1**	**Vit_B3**	**Vit_B7**	**Vit_B9**	**Vit_E**
	Lentil micro		322	275	0.4	0.7	9	34	1
Chickpeas	FAO / *other*		416	34	0.5	1.5	21	390	2
	USDA				0.5	1.7		600	1
Lentils	FAO / *other*		1400	1100	0.3	1.9	23	121	0.2
	USDA				1.0	2.8		520	0.5

3. Analysis of nutritional data of cowpeas and faba beans samples

The one hundred seeds weight in g, cooking time in minutes and the percentage of hydration of cowpeas and faba beans samples are listed in Table 19. Four varieties of cowpeas were collected, the brown Hamera from Morrocco, and three varieties from Mauritania distinguished for their color and pigmentation in white, green speckled and gray. Three varieties of faba beans were sampled, the large brown Seville from Algeria, a medium size local variety form Syria named SY09, and the large Malti from Tunisia. Comparing the weight of seeds of cowpeas samples collected in the two years a variability between 5 and 18% can be observed. In faba beans samples the variability in seed weight ranged between 7 to 30%. The cooking time of cowpeas was on average 30 minutes, but the gray seeds variety named GU from Mauritania, showing the lowest value (<20 min on average). The percentage of hydration ranged from 98% of Hamera to 116% of GU cowpeas, whereas for faba beans this value was included between 108 and 139%.

Table 19. Cooking time, percentage of hydration and 100 seeds weight of cowpeas and faba beans samples

Sample	Type	100 seeds g '24	100 seeds g '23
Cw_MAR_Hamera	Brown cowpea	16	13
Cw_MRT_AD	White cowpea	16	18
Cw_MRT_BR	Green speckled cowpea	21	16
Cw_MRT_GU	Gray cowpea	19	18
F_DZA_Seville	Large faba bean	204	266
F_SYR_SY09	Medium faba bean	166	106
F_TN_Malti	Large faba bean	287	267

A. Gross composition of cowpeas and faba beans samples

The gross composition of cowpeas and faba beans collected in the two years were reported in

Table 20. Regarding the proteins content of cowpeas, apart the values for the brown Hamera and the green speckled BR, which reported a certain variability between the two years, all other varieties were characterized by a low inter year variability. The protein content of all selected cowpeas ranged between 26.3 to 28.3 without relevant differences. On the other hand, the TDF content importantly differs among the cowpea's varieties, being the brow Hamera the richest variety in TDF.

Higher variability of the inter years data was observed for faba beans. The Seville and Malti varieties were characterized by a protein content of 30% on average, higher than the values found in the Syrian variety. The TDF content of faba is included between 18 and 24.5%, with the Malti confirmed to be the variety with the lower content and the SY09 the variety with the highest value. Comparing the obtained data with the reference value, it is evident a large inconsistency between the FAO and USDA regarding the TDF content, with our data more consistent with that of FAO.

Table 20. Gross composition percentage of cowpeas and faba beans samples on dry matter basis.

Variety	Type	Year	DM	Ash	Prot	Fat	TDF	Starch
Hamera	Cowpea brown	2023	89.9	3.2	26.3	1.4	20.1	47.7
Hamera	Cowpea brown	2024	86.9	3.3	28.3	1.6	17.9	53.0
Cowpea BR	Cowpea green speckled	2023	90.5	3.9	25.5	1.4	15.4	52.2
Cowpea BR	Cowpea green speckled	2024	92.8	4.1	27.5	1.3	15.8	53.0
Cowpea GU	Cowpea violet	2023	90.8	4.0	26.6	1.6	13.7	54.4
Cowpea GU	Cowpea violet	2024	93.0	3.9	26.8	1.3	14.1	55.5
Cowpea AD	Cowpea white	2023	90.8	4.0	26.6	1.4	14.2	53.1
Cowpea AD	Cowpea white	2024	92.4	3.9	26.6	1.3	14.6	55.7
Malti	Faba Large	2023	90.6	4.2	28.8	1.0	19.8	45.4
Malti	Faba Large	2024	90.3	3.5	31.8	1.2	19.7	46.5
Seville	Faba Large	2023	89.9	3.9	30.5	1.0	20.5	43.1
Seville	Faba Large	2024	90.5	3.4	29.5	1.1	18.4	50.1
SY09	Faba medium	2023	91.7	4.2	25.1	1.2	24.5	44.6
SY09	Faba medium	2024	91.8	4.3	29.0	1.0	19.0	49.2
	SD producers and geographical areas							
	Cowpea brown		0.3	0.004	0.016	0.017	1.3	1.3
	Cowpea green speckled		1.3	0.03	0.9	0.1	1.0	0.2
	Cowpea violet		1.2	0.1	0.8	0.4	0.7	0.6
	Cowpea white		1.1	0.2	1.3	0.2	3.1	4.6
	Faba Large		1.0	0.4	2.4	0.1	2.2	3.5
	Faba medium		1.4	0.3	2.3	0.1	3.0	1.7
	SD years							
	Cowpea brown		2.14	0.03	1.43	0.13	1.58	1.72
	Cowpea green speckled		1.61	0.14	1.42	0.11	0.25	1.43
	Cowpea violet		1.55	0.04	0.18	0.27	0.31	0.30
	Cowpea white		1.19	0.06	0.02	0.07	0.26	1.44
	Faba Large		0.36	0.39	1.40	0.11	0.74	2.08
	Faba medium		0.09	0.07	2.74	0.14	3.88	1.21
Cowpeas	FAO Mean		90	3.8	24.4	2.3	17.2	52.5
Cowpeas	USDA Mean		88.0	3.7	26.7	1.4	12.0	55.0
Faba beans	FAO Mean		90	3.4	27.8	1.9	22	44.8
Faba beans	USDA Mean		89.0	3.5	29.3	1.7	28.1	37.4

B. Minerals content of cowpeas and faba beans samples

All mineral contents of cowpea and faba bean samples are reported in Table 22. In cowpeas, no significant year-to-year differences were observed for P, Ca, K, Mg, Na, and Cu. However, Fe content doubled in BR green speckled in 2024 and decreased by 20% in Hamera. Mn and Zn increased in BR green speckled but significantly decreased in GU and AD in 2024. Among cowpeas, Hamera showed the lowest Ca level, while BR green speckled had the highest Fe and Zn contents.

In faba beans, high variability was observed for all macro-elements, influenced by both year and cultivation area. Significant year effects were found in Seville for P, K, and Na, and across all varieties for Cu, Mn, and Zn, while Fe remained relatively stable. Compared with reference databases, Fe values were higher than FAO data but lower than USDA values..

Table 21. Minerals content in mg/100g of dry matters of cowpeas and faba beans samples.

Variety	Type	Year	P	Ca	K	Mg	Na	Cu	Fe	Mn	Zn
Cowpea BR	Cowpea green speckled	2023	437	105	1310	193	11	1.00	7.21	1.35	4.29
Cowpea BR	Cowpea green speckled	2024	489	111	1521	225	6	0.84	13.64	1.85	5.26
Cowpea GU	Cowpea violet	2023	448	129	1674	195	14	1.00	6.79	1.50	4.46
Cowpea GU	Cowpea violet	2024	468	117	1465	199	10	0.80	6.94	1.33	3.49
Cowpea AD	Cowpea white	2023	453	145	1630	199	22	0.95	6.93	1.62	4.47
Cowpea AD	Cowpea white	2024	429	135	1424	194	7	0.83	7.12	1.30	3.06
Hamera	Cowpea brown	2023	417	77	1246	191	15	0.93	5.81	1.41	3.71
Hamera	Cowpea brown	2024	490	59	1184	190	6	0.67	4.87	1.14	3.73
Malti	Faba Large	2023	393	157	1369	158	44	2.08	5.10	1.12	6.68
Malti	Faba Large	2024	444	132	1224	144	37	1.15	4.58	0.87	4.72
Seville	Faba Large	2023	581	123	1662	157	30	1.38	5.36	1.23	4.44
Seville	Faba Large	2024	375	99	1269	128	8	1.20	5.26	0.99	3.04
SY09	Faba medium	2023	525	120	1481	172	55	1.69	5.93	1.31	4.98
SY09	Faba medium	2024	630	93	1626	183	68	1.42	4.64	1.29	2.49
			SD producers and geographical areas								
	Cowpea brown		18	24	58	1	10	0.04	0.2	0.01	0.02
	Cowpea green speckled		29	7	5	3	5	0.1	0.5	0.2	0.1
	Cowpea violet		45	15	197	7	9	0.0	0.6	0.2	0.3
	Cowpea white		66	21	225	23	17	0.1	0.3	0.2	0.9

Variety	Type	Year	P	Ca	K	Mg	Na	Cu	Fe	Mn	Zn
	Faba Large		155	28	194	13	21	0.4	0.9	0.1	1.3
	Faba medium		124	18	232	19	28	0.3	1.1	0.1	0.7
	SD years										
	Cowpea brown		52	13	44	1	7	0.2	0.7	0.2	0.01
	Cowpea green speckled		37	4	149	23	3	0.1	4.5	0.3	0.7
	Cowpea violet		14	8	148	3	3	0.1	0.1	0.1	0.7
	Cowpea white		17	7	146	3	11	0.1	0.1	0.2	1.0
	Faba Large		91	17	190	15	10	0.4	0.2	0.2	1.2
	Faba medium		74	19	102	8	9	0.2	0.9	0.0	1.8
	Cowpeas	FAO	354	99	1279	170	18	0.7	5.7	2.0	3.0
		USDA	482	125	1261	209	18	1.0	9.4	1.7	3.5
	Faba beans	FAO	429	108	1238	147	23	0.8	4.7	1.6	3.2
		USDA	473	115	1191	215	14	0.9	7.5	1.8	3.5

C. Fatty acids content in cowpeas and faba beans samples

The mean contents of fatty acids of cowpeas and faba beans samples were reported in Table 22. Considering only the most representative fatty acids, a low variability was observed among the samples of cowpeas both belonging to different varieties and year of production. The only exception was the Hamera brown cowpeas which reported higher content in palmitic, linoleic, linolenic and eicosanoic acids in 2024.

Differently, faba beans samples showed an important effect of the year of production on the most concentrated fatty acids, namely the oleic and linoleic acids,

Table 22. Fatty acids content in mg/100g dry matter of cowpeas and faba beans samples.

Variety	Year	C16	C16_1	C17	C18	C18_1	C18_2	C18_3	C20	C20_1	C22	C23	C24
Cowpea BR	2023	247	0.7	2.3	58	65	291	241	17.7	3.7	35.5	3.2	17.9
Cowpea BR	2024	213	1.5	2.1	50	74	273	227	16.3	3.7	32.1	3.1	16.5
Cowpea GU	2023	245	2.1	2.3	56	100	261	195	14.1	3.0	23.5	2.2	12.2
Cowpea GU	2024	218	1.0	2.0	53	55	289	234	16.1	3.6	29.1	3.1	19.0
Cowpea AD	2023	207	0.9	1.9	43	67	241	203	12.0	2.8	23.0	2.4	13.2
Cowpea AD	2024	213	1.5	1.9	45	63	270	236	13.5	3.2	27.2	2.9	15.9
Hamera	2023	205	0.7	3.2	48	63	266	213	14.0	3.7	26.5	2.3	11.7
Hamera	2024	277	1.3	3.4	46	65	367	316	16.6	5.1	39.5	3.3	19.0
Malti	2023	79	0.7	0.6	13	139	344	34	7.6	3.4	4.0	1.2	2.1
Malti	2024	107	1.7	0.9	15	190	498	47	9.2	4.7	4.8	1.6	3.2
Seville	2023	67	0.5	0.5	10	103	295	32	7.1	2.9	4.0	1.3	2.2
Seville	2024	94	1.6	0.8	12	166	441	45	8.5	4.3	4.9	1.7	3.0
SY09	2023	90	1.2	0.7	15	156	310	32	8.4	3.3	4.7	1.5	2.5
SY09	2024	88	1.3	0.7	11	105	366	46	8.5	3.2	5.2	1.7	3.4
SD producers and geographical areas													
Cowpea brown		1	0.2	0.02	2	0.5	3	25	0.5	0.1	0.5	0.1	0.3
Cowpea green speckled		27	0.2	0.01	4	7	34	28	1.4	0.4	4.7	0.2	2.5
Cowpea violet		53	2.9	0.16	7	81	22	11	2.9	0.5	6.3	0.8	4.3
Cowpea white		32	0.8	0.21	8	44	31	22	1.2	0.4	3.3	0.5	1.4
Faba Large		12	0.2	0.09	2	29	52	4	1.0	0.6	0.6	0.2	0.7
Faba medium		21	0.3	0.19	3	24	86	10	1.2	0.5	1.5	0.2	0.7

Variety	Year	C16	C16_1	C17	C18	C18_1	C18_2	C18_3	C20	C20_1	C22	C23	C24
SD years													
Cowpea brown		51	0.5	0.1	1	2	72	73	1.9	1.0	9.2	0.7	5.2
Cowpea green speckled		25	0.5	0.2	6	6	12	10	1.0	0.1	2.4	0.1	0.9
Cowpea violet		20	0.8	0.2	2	32	20	28	1.4	0.4	4.0	0.6	4.8
Cowpea white		4	0.4	0.0	2	3	21	23	1.1	0.2	2.9	0.4	1.9
Faba Large		20	0.7	0.2	2	40	106	9	1.0	0.9	0.6	0.3	0.7
Faba medium		2	0.1	0.1	3	36	40	10	0.04	0.04	0.3	0.2	0.6

D. Amino acids content of cowpeas and faba beans samples

Table 23 reports the amino acid contents of cowpea and faba bean samples. Variability was influenced by both year and production area, with standard deviations depending more on the amino acid than on species. Serine, cysteine, methionine, and tryptophan showed low variability (<0.1), while glutamic acid, proline, and histidine were the most variable.

In cowpeas, BR green speckled showed significant differences across years for most amino acids, while other varieties were consistent except for methionine, which decreased in 2024. Hamera had the highest tryptophan content.

In faba beans, 2024 samples had lower methionine but higher isoleucine. Compared with USDA references, most essential amino acids were lower, except for tyrosine, histidine, and lysine.

Table 23. Amino acids content of cowpeas and faba beans samples, data are in g/100g of dry matter of raw seeds.

Variety	Type	Year	Asp	Thr	Ser	Glu	Pro	Gly	Ala	Cys	Val	Met	Ile	Leu	Tyr	Phe	His	Lys	Tryp	Arg
Cowpea BR	Cp green speckled	2023	2.7	1.2	1.0	3.0	1.7	0.7	0.5	0.3	1.0	0.2	0.6	1.4	0.6	0.8	1.4	2.4	0.2	1.8
Cowpea BR	Cp green speckled	2024	2.5	0.8	1.1	3.5	1.0	0.8	0.9	0.3	0.9	0.1	0.6	1.5	1.0	1.2	0.9	2.0	0.2	2.3
Cowpea GU	Cowpea violet	2023	2.6	0.8	1.2	3.5	1.4	0.9	1.1	0.3	0.8	0.2	0.4	1.3	0.9	1.0	1.0	2.0	0.2	2.2
Cowpea GU	Cowpea violet	2024	2.6	0.9	1.2	3.7	1.0	0.8	0.9	0.3	0.9	0.1	0.6	1.5	1.0	1.2	0.9	2.0	0.2	2.3
Cowpea AD	Cowpea white	2023	2.6	1.0	1.2	3.3	1.2	0.9	0.9	0.3	0.7	0.2	0.5	1.4	0.7	1.0	1.3	2.1	0.2	2.1
Cowpea AD	Cowpea white	2024	2.4	0.8	1.1	3.4	1.0	0.8	0.9	0.3	0.9	0.1	0.6	1.4	1.0	1.1	0.9	2.0	0.2	2.2
Hamera	Cowpea brown	2023	2.5	0.8	1.3	3.6	1.1	0.9	1.0	0.3	0.7	0.2	0.5	1.3	0.8	1.0	0.9	1.9	0.2	2.2
Hamera	Cowpea brown	2024	2.4	0.8	1.1	3.5	0.9	0.8	0.9	0.3	0.9	0.1	0.6	1.5	1.0	1.2	0.9	2.1	0.2	2.1
Malti	Faba Large	2023	2.3	0.7	1.1	3.3	1.3	0.9	1.0	0.4	0.7	0.1	0.4	1.3	0.8	0.8	0.7	1.8	0.2	3.3
Malti	Faba Large	2024	2.7	0.9	1.2	3.8	1.1	1.0	1.1	0.4	1.0	0.1	0.7	1.7	1.1	1.0	0.9	2.2	0.2	3.9
Seville	Faba Large	2023	2.5	0.8	1.2	3.6	1.1	1.0	1.0	0.4	0.8	0.1	0.4	1.4	0.8	0.8	0.8	2.0	0.2	3.6
Seville	Faba Large	2024	2.5	0.8	1.2	3.7	1.1	0.9	0.9	0.3	0.9	0.1	0.6	1.6	1.1	1.0	0.8	2.2	0.2	3.1
SY09	Faba medium	2023	1.9	0.6	0.9	2.7	0.7	0.8	0.7	0.3	0.6	0.1	0.4	1.0	0.7	0.8	0.4	1.2	0.1	1.8
SY09	Faba medium	2024	2.5	0.8	1.2	3.6	1.1	1.0	1.0	0.4	0.9	0.0	0.6	1.6	1.1	1.0	0.8	2.1	0.2	3.5
	SD producer and geographical area																			
	Cowpea brown		0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.3	0.0	0.0	0.0	0.0
	Cowpea green speckled		0.3	0.2	0.1	0.0	1.2	0.1	0.4	0.0	0.0	0.0	0.4	0.1	0.0	0.0	0.8	0.2	0.0	0.1
	Cowpea violet		0.4	0.0	0.0	0.2	0.5	0.3	0.4	0.0	0.1	0.0	0.0	0.1	0.2	0.0	0.3	0.2	0.0	0.4
	Cowpea white		0.1	0.3	0.1	0.3	0.2	0.1	0.1	0.0	0.1	0.0	0.1	0.2	0.1	0.0	0.6	0.2	0.0	0.3
	Faba Large		0.3	0.1	0.2	0.5	0.5	0.1	0.1	0.1	0.1	0.0	0.1	0.2	0.2	0.3	0.1	0.2	0.0	0.4
	Faba medium		0.3	0.1	0.2	0.5	0.2	0.1	0.1	0.0	0.1	0.0	0.1	0.2	0.1	0.1	0.1	0.4	0.1	0.5
	SD years																			
	Cowpea brown		0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.0	0.1	0.1	0.1	0.1	0.0	0.1	0.0	0.0
	Cowpea green speckled		0.1	0.3	0.1	0.3	0.5	0.1	0.3	0.0	0.1	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.0	0.4
	Cowpea violet		0.0	0.1	0.0	0.1	0.2	0.1	0.1	0.0	0.1	0.0	0.1	0.2	0.1	0.1	0.1	0.0	0.0	0.1
	Cowpea white		0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.0	0.1	0.0	0.2	0.1	0.3	0.1	0.0	0.1

Variety	Type	Year	Asp	Thr	Ser	Glu	Pro	Gly	Ala	Cys	Val	Met	Ile	Leu	Tyr	Phe	His	Lys	Tryp	Arg
	Faba Large		0.1	0.1	0.0	0.2	0.0	0.1	0.1	0.0	0.2	0.0	0.2	0.2	0.2	0.2	0.1	0.2	0.0	0.4
	Faba medium		0.5	0.2	0.2	0.6	0.2	0.1	0.2	0.1	0.3	0.0	0.2	0.4	0.3	0.1	0.3	0.7	0.0	1.2
Cowpeas	FAO		2.7	0.9	1.2	4.3	1.1	1.0	1.0	0.2	1.2	0.4	1.1	1.8	0.7	1.4	0.8	1.6	0.3	1.8
	USDA		3.2	1.0	1.2	5.1	1.2	1.1	1.2	0.3	1.3	0.4	1.1	2.0	0.9	1.6	0.8	1.8	0.3	1.9
Faba beans	FAO		3.0	1.0	1.3	4.6	1.1	1.2	1.1	0.3	1.2	0.2	1.1	2.0	0.9	1.2	0.7	1.7	0.2	2.6
	USDA		3.3	1.0	1.3	5.0	1.2	1.2	1.2	0.4	1.3	0.2	1.2	2.2	0.9	1.2	0.7	1.9	0.3	2.7

E. *The content in anti-nutritional factors in cowpeas and faba beans samples*

The average content of anti-nutritional factors for cowpeas and faba beans samples are reported in Table 24. Among cowpeas varieties it is relevant to highlight the lower value of trypsin inhibitors of the BR green speckled from Mauritania, the low content of tannins of GU violet cowpeas and the AD white of Mauritania and the highest content of tannins and phytates of brow cowpeas Hamera from Morrocco. The variability of these parameters between the years is very low if compared with the other species of legumes.

In contrast to the low variability observed for cowpeas, faba beans samples showed a great variability between the two years of production for the varieties Seville and Malti, with lower values of TUI and a higher value of tannins observed in the samples collected in 2024. The variety SY09, medium size from Syrie, showed a good repeatability between the years and confirm a high content of phytates.

Table 24. Antinutritional factors content of cowpeas and faba beans samples. TUI=trypsin units inhibited per g; total tannins in mg of tannic acid equivalent per 100g, total phytates in g/100g of dry matter. Phytates reference value was that of phytates database of FAO, that of TUI was obtained by Maia et al., 2000, that related to faba beans were obtained from (Guillamón et al., 2008)

Variety	Type	Year	TUI	Tannins	Phytate
Cowpea BR	Cp green speckled	2023	13.3	133	0.60
Cowpea BR	Cp green speckled	2024	9.8	170	0.49
Cowpea GU	Cowpea violet	2023	14.1	56	0.59
Cowpea GU	Cowpea violet	2024	13.8	79	0.54
Cowpea AD	Cowpea white	2023	13.9	42	0.54
Cowpea AD	Cowpea white	2024	14.8	91	0.33
Hamera	Cowpea brown	2023	14.0	1334	0.74
Hamera	Cowpea brown	2024	14.1	1271	0.73
Malti	Faba Large	2023	5.2	305	0.71
Malti	Faba Large	2024	1.6	516	0.58
Seville	Faba Large	2023	4.9	281	0.98
Seville	Faba Large	2024	1.8	656	0.35
SY09	Faba medium	2023	3.6	636	0.92
SY09	Faba medium	2024	2.1	750	0.86
			SD producers and geographical areas		
Cowpea brown			0.1	1	0.004
Cowpea green speckled			1.1	13	0.057
Cowpea violet			1.2	24	0.113
Cowpea white			1.4	47	0.154
Faba Large			0.5	271	0.347

Variety	Type	Year	TUI	Tannins	Phytate
Faba medium			0.9	151	0.276
			SD years		
Cowpea brown			0.1	44	0.005
Cp green speckled			2.5	26	0.084
Cowpea violet			0.2	17	0.035
Cowpea white			0.7	34	0.153
Faba Large			2.4	207	0.267
Faba medium			1.1	81	0.043
Reference	Cowpeas		12-29		0.5
	Faba beans		5-10		0.37

In comparison to the reference values the selected varieties of cowpeas resulted to have a reduced concentration of TUI and tannins (except for the Hamera).

F. *Antioxidants and vitamins content of cowpeas and faba beans samples*

The antioxidants contents and vitamins of cowpeas and faba beans were reported in Table 25. The values of TEAC and total polyphenols of cowpeas reported a good repeatability between the production years and confirmed the high value of these parameters for the brow variety Hamera. Biotin (B7) and thiamine (B1) content were characterized by an important variability in the two considered years, with value higher in 2023 for B7 and the opposite for the B1. Vitamin B3, niacin, showed constant values without significant differences a part for the high value registered in the sample of violet cowpeas GU. Finally, vitamin B9, folates, and vitamins E, tocopherols, reported low inter year variability and confirming high values for the variety Hamera of Morrocco.

Considering the reference values for both faba beans and cowpeas it must be highlighted that the selected varieties were characterised by excellent content in almost all B vitamins and vitamin E. Furthermore, the faba beans varieties reported the highest antioxidant activity among the analysed legumes.

Table 25. Trolox Equivalent Antioxidant Capacity in µmol/100g, total polyphenols (TP) in mg/100g of gallic acid equivalent, vitamins B1 and B3 in g/100g, Vitamin B7 in µg/100g, and vitamins B9 and E in mg/100g. TEAC and TP reference values for cowpeas were taken from (Singh et al., 2017), value for faba beans were referred to (Siah et al., 2014).

Variety	Type	Year	TEAC	Polyph.	Vit_B1	Vit_B3	Vit_B7	Vit_B9	Vit_E
Cowpea BR	Cowpea green speckled	2023	2197	291	0.8	4.6	10.7	269.3	15.3
Cowpea BR	Cowpea green speckled	2024	1295	296	2.6	3.9	6.9	345.4	14.0
Cowpea GU	Cowpea violet	2023	1718	195	0.9	4.1	11.9	305.1	14.9
Cowpea GU	Cowpea violet	2024	710	161	2.7	7.1	5.0	378.6	17.8
Cowpea AD	Cowpea white	2023	1354	156	0.9	4.1	11.4	304.5	15.7
Cowpea AD	Cowpea white	2024	817	168	2.7	4.5	6.7	343.2	15.1
Hamera	Cowpea brown	2023	3233	1818	1.3	3.3	14.5	397.1	26.9
Hamera	Cowpea brown	2024	2717	1735	2.9	3.7	7.4	335.3	19.0
Malti	Faba Large	2023	2728	681	0.6	4.3	18.5	217.1	3.9
Malti	Faba Large	2024	7127	644	1.0	5.1	14.8	328.4	5.4
Seville	Faba Large	2023	2873	680	0.6	4.8	24.5	241.8	6.6
Seville	Faba Large	2024	2611	1212	1.4	4.8	16.9	309.8	6.0
SY09	Faba medium	2023	3693	1387	0.4	2.7	25.2	179.4	5.4
SY09	Faba medium	2024	7885	883	1.7	5.2	27.3	268.7	6.0
SD producers and geographical areas									
Cowpea brown			18	3	0.28	0.03	2.48	5	0.11
Cowpea green speckled			58	16	0.05	0.80	1.08	76	4.32
Cowpea violet			822	89	0.06	0.24	1.88	34	2.09

Variety	Type	Year	TEAC	Polyph.	Vit_B1	Vit_B3	Vit_B7	Vit_B9	Vit_E
Cowpea white			701	157	0.62	0.41	4.49	38	1.64
Faba Large			159	248	0.08	0.64	5.55	49	1.76
Faba medium			472	282	0.12	0.91	2.44	44	1.92
					SD years				
Cowpea brown			365	58	1.07	0.33	4.96	44	5.60
Cowpea green speckled			637	3	1.27	0.49	2.71	54	0.97
Cowpea violet			713	24	1.32	2.13	4.83	52	2.03
Cowpea white			380	8	1.26	0.30	3.29	27	0.43
Faba Large			234	201	0.42	0.29	4.01	63	0.75
Faba medium			341	357	0.89	1.76	1.45	63	0.40
Reference	Cowpeas	FAO/others	1300	107	0.3	2.2	4	231	0.7
	Faba beans	USDA	4000	1000	0.6	2.1	13	250	0.1

4. About the effects of soaking and boiling on the nutritional and nutraceutical characteristics of selected pulses

A. The percentage hydration and the cooking time of the selected pulses

The analyzed legumes showed wide variation in hydration and cooking times across species and countries. Hydration ranged from 89% (Moroccan medium lentil Cinq) to 139% (Syrian medium faba bean SY09), while cooking times varied from 18 minutes (Mauritanian Gray cowpea) to 110 minutes (Tunisian Desi chickpea Amdoun).

Beans generally required 40–60 minutes, chickpeas 60–110 minutes, cowpeas cooked fastest (18–40 minutes), faba beans 78–90 minutes, and lentils 20–60 minutes. These differences reflect varietal traits and local adaptation.

The beans samples had a cooking time ranging from 40 to 105 minutes and a percentage of hydration from 92 to 109%. The shortest cooking time among beans was obtained for the cannellini beans White coco from Algeria and for the navy beans Ghelid from Morrocco. The two samples of chickpeas had a quite different cooking time with the Kabuli type from Jordan characterized by 1h of cooking in respect to almost 2h of the desi type Amdoun from Tunisia. The cowpeas samples showed the shortest cooking time in absolute ranging from 18 minutes of the gray variety from Mauritania to 40 minutes of the white variety. Consistent was the cooking time of the three faba beans samples with value in the range 80-90 minutes. Finally, the lentils Syrie 229 from Algerie and Cinq from Morrocco showed only 20 minutes of cooking time in respect to the Syrian small variety which require 1h of cooking.

B. The effect of cooking and boiling on the gross composition

To facilitate the readiness of results interpretation, highlighting only the most relevant findings, each parameter is expressed as percentage of variation of the boiled from the raw sample's dry weights, calculated as follows:

$$Variation\ (\%) = \frac{Value\ of\ boiled\ sample\ i - Value\ of\ raw\ sample\ i}{Value\ of\ raw\ sample\ i} * 100$$

The comparison within raw and boiled samples gross composition are reported in Table 26. In terms of ash content, variation below 5 % could be ascribed to the random effect of sampling plus the expected variability due to the method of analysis. As a general assumption, the ash content tends to reduce after soaking and boiling process with an average reduction of 8%. This reduction can be explained by the loss of minerals during the soaking step with the drain of the soaking water, hypothesis confirmed by the analysis of minerals elements in the following paragraphs. This assumption does not fit well with the beans samples that showed an average increase of 3% except for the Serbian samples. By assuming a 5% threshold for differences due to random effects, the sample Reguig only reveals an important ash content increase but still too weak for further dissertation. Differently, from ash, protein content increases in almost all samples with an average increase of 5%. In 9 samples out of 20 the percentage variation between raw and boiled is not significative, so the two values can be considered equivalent (no effect of processing on the proteins content). In the other samples a significative increase was observed varying between 5 and 10%. The highest increase has been recorded in Gradistanac beans, and in the medium size seeds faba bean SY08. These results can be explained by the loss of soluble components during soaking, or perhaps the degradation of other constituents during soaking and boiling, leading to the increase of proteins percentage on dry weight, even if they are not really affected by the cooking process. The scientific literature reports a general increase of proteins on dry matter basis after cooking in different type of legumes (Mananga et al., 2022; Wang et al., 2009). Considering the fat content in the major part of cases no effect or a slight reduction was observed. Important reduction caused by the boiling procedure was recorded for Ghelid and Gradistanac among beans, in all faba beans and particularly Seville, and in the lentils Syrie 229. The reduction of total fat can be considered physiological because most of the fatty acids present in pulses are unsaturated and polyunsaturated, thus more susceptible to the peroxidation by the atmospheric oxygen. Total Dietary Fiber (TDF) increased in all samples after cooking. This increase spans from 4.2 to 116.8 %, particularly high is the increase observed in cowpeas and chickpeas with a percentage close to +100%. These results are consistent with the scientific literatures(Mananga et al., 2022; Wang et al., 2009, 2010) and can be explained by different hypothesis. The first hypothesis is referred to the conversion of starch in resistant starch as the effect of the increased complexity of its tridimensional structure during boiling, consequently this fraction passes in the total dietary fibers because it resist against the amylase action and it is subtracted from the total starch, as highlighted in Table 26. The second hypothesis refers to the formation of complexes between carbohydrate and proteins because of the Maillard reaction, producing macro polymers that are quantified in the total dietary fibers. Nevertheless, an increased dietary fiber content, coupled with low fat content, supports the beneficial effects of pulses in increasing satiety, stabilizing blood sugar and insulin levels, and reducing LDL cholesterol (Abeysekara et al., 2012; Mudryj et al., 2014).

Table 26. Results of comparison of pulses samples related to the gross composition. Red bars highlight reduction after cooking, whereas blue bars increase percentage after cooking.

Country	Variety	Type	Ash	Prot.	Fat	TDF	Carb	Starch
Albania	Ecmeniku	White kidney bean	3.32	4.26	-13.12	18.64	1.97	-8.67
Albania	Sacme	Navy bean	2.27	9.16	-14.51	25.09	0.28	-13.27
Algeria	Praguecoco	Borlotti bean	4.27	-2.86	-9.67	27.10	3.72	-7.40
Algeria	Whitecoco	Cannellini bean	-1.64	6.68	-7.35	19.78	1.02	-7.11
Morrocco	Ghelid	Navy bean	5.53	3.32	-2.18	39.39	1.41	-14.89
Morrocco	Reguig	Cannellini bean	1.78	8.66	-44.57	64.06	0.99	-31.25
Serbia	Gradistanac	Cannellini bean	-4.22	10.62	-38.17	51.47	0.55	-23.87
Serbia	Tetovac	White kidney bean	-16.15	7.77	-2.03	5.62	1.07	1.65
Jordan	JO02	Kabuli chickpea	-6.81	-0.18	3.43	116.83	2.81	-35.89
Tunisia	Amdoun	Desy chickpea	-6.62	-2.09	-4.28	59.97	4.66	-16.12
Morrocco	Hamera	Brown cowpea	4.54	7.56	-6.76	29.62	0.54	-9.29
Mauritania	White	White cowpea	-9.66	6.80	-19.48	109.82	1.73	-25.66
Mauritania	Brown	Green speckled cow	-18.65	4.51	-17.09	99.35	3.13	-25.54
Mauritania	Gray	Gray cowpea	-1.77	8.25	2.97	109.69	0.44	-27.30
Algeria	Seville04	Large faba bean	-7.10	-3.65	-43.99	47.11	5.78	-9.39
Syria	SY09	Medium faba bean	-7.91	10.10	-27.80	29.44	0.67	-10.46
Tunisia	Malti	Large faba bean	-8.00	5.80	-19.99	28.10	2.25	-8.72
Algeria	Syrie229/06	Small lentil	-8.31	3.03	-11.57	4.16	2.70	2.07
Morrocco	Cinq	Medium lentil	-8.86	1.13	11.70	47.79	2.85	-16.54
Syria	SY08	Small lentil	-13.78	7.76	-8.64	37.27	-4.54	-20.40

C. The effects of soaking and boiling on the minerals content of pulses

Mineral content variation between raw and boiled samples is reported in Table 27. A general reduction of K and P can be observed independently of the pulses type. All other minerals showed an increase, particularly relevant for Ca and Zn. Indeed, besides high percentage variation the amounts in raw or boiled samples differ for micrograms thus of minor importance from a nutritional point of view. The obtained results are in good agreement with the scientific literature (Mananga et al., 2022; Wang et al., 2009, 2010)

Table 27. Minerals content percent of variation between raw and boiled samples.

Country	Variety	Type	P	Ca	K	Mg	Na	Cu	Fe	Mn	Zn
Albania	Ecmeniku	White kidney bean	-3,26	-10,03	-7,29	0,02	25,04	3,54	-15,64	8,50	34,27
Albania	Sacme	Navy bean	-4,85	8,80	-17,11	0,64	-14,61	6,89	2,59	8,43	17,63
Algeria	Praguecoco	Borlotti bean	-17,03	14,00	-5,87	-3,58	128,21	-3,40	4,05	-0,83	37,16
Algeria	Whitecoco	Cannellini bean	-5,39	26,72	-12,59	-1,79	-17,66	24,70	5,25	17,17	27,55
Morrocco	Ghelid	Navy bean	-11,30	30,46	-6,88	3,61	859,08	24,98	10,06	19,65	22,60
Morrocco	Reguig	Cannellini bean	-17,22	-18,78	-12,29	5,91	201,69	9,82	1,00	6,95	42,42
Serbia	Gradistanac	Cannellini bean	-37,78	9,02	-13,83	2,02	256,05	-6,42	-1,90	7,32	25,76
Serbia	Tetovac	White kidney bean	-13,59	25,47	-10,01	-0,94	541,68	1,19	0,59	2,70	22,92
Jordan	JO02	Kabuli chickpea	-0,43	25,09	-16,80	9,74	6,26	-4,16	-62,53	-3,03	-84,32
Tunisia	Amdoun	Desy chickpea	-13,52	32,46	-17,40	9,35	145,57	-43,64	-9,38	5,77	-4,51
Morrocco	Hamera	Brown cowpea	-5,70	64,30	-4,94	4,00	118,58	6,46	1,94	8,50	27,38
Mauritania	White	White cowpea	0,47	-3,27	-21,65	-6,48	30,92	-0,94	22,83	5,48	137,29
Mauritania	Brown	Green speck. Cowp.	-4,92	-5,31	-29,50	-9,84	474,78	-3,34	-4,19	-3,62	119,05
Mauritania	Gray	Gray cowpea	-1,70	9,43	-15,64	0,11	0,63	4,55	-11,33	-1,61	53,10
Algeria	Seville04	Large faba bean	-9,89	33,01	-17,05	8,72	86,83	9,13	2,83	10,11	34,63
Syria	SY09	Medium faba bean	-3,01	27,71	-15,66	9,90	17,08	17,82	5,36	8,08	128,96
Tunisia	Malti	Large faba bean	-2,16	38,83	-14,34	5,91	90,81	12,16	0,17	3,98	26,13
Algeria	Syrie229/06	Small lentil	1,20	9,11	-10,07	-0,55	909,82	29,47	-4,34	0,08	34,72
Morrocco	Cinq	Medium lentil	-2,74	1,90	-13,41	-4,59	311,97	6,35	-2,39	1,32	43,17
Syria	SY08	Small lentil	-26,89	-1,35	-31,65	-3,13	308,12	-20,77	-3,80	62,97	49,48

D. The effect of soaking and boiling on the amino acids content

Table 28 summarizes the effect of soaking and boiling on the essential amino acids content. Among the considered amino acids, it is evident the effect of the process in reducing the content of tyrosine, lysine and tryptophane. The highest reduction percentages were observed for chickpeas. Threonine content reported only significative reductions in chickpeas, and faba beans. Cysteine content reported a 20% reduction in most of beans with the exception of Moroccan Ghelid and Reguig. Similar behaviour can be observed for methionine. Leucine and valine reported random variability not significative, similarly trend can be observed for histidine even if this later had an important reduction in chickpeas and lentils. Surprisingly the content of isoleucine and phenylalanine increased in almost all samples with a percentage of 15 % on average. Unfortunately, there is not consistent data in scientific literature supporting or contrasting the obtained results related to the amino acids content variability after cooking.

Table 28. Essential amino acids content changes in percent between raw and cooked pulses.

Variety	Type	Thr	Cys	Val	Met	Ile	Leu	Tyr	Phe	His	Lys	Tryp
Ecmeniku	White kidney bean	-2.47	-9.82	0.40	-42.35	7.39	-3.04	-10.97	-4.59	2.82	-9.21	-15.51
Sacme	Navy bean	1.57	-23.95	2.01	-20.73	19.25	3.98	-13.71	14.21	7.09	-4.21	-29.60
Praguecoco	Borlotti bean	-5.12	-30.53	-11.46	-70.04	4.42	-9.89	-19.18	2.81	-5.64	-13.39	-8.37
Whitecoco	Cannellini bean	-3.15	-20.76	1.04	-67.57	15.95	4.28	-12.97	16.22	4.08	-5.34	-17.44
Ghelid	Navy bean	1.09	12.37	-7.18	105.43	-4.79	-5.83	-7.22	15.11	-5.89	-12.16	-0.59
Reguig	Cannellini bean	0.80	51.42	3.36	-10.57	14.13	3.64	-8.09	19.26	2.57	-5.71	0.93
Gradistanac	Cannellini bean	3.27	-8.50	3.36	-63.74	13.70	3.18	-5.21	20.94	5.69	-4.99	3.34
Tetovac	White kidney bean	-0.45	2.24	3.56	-58.49	38.99	10.09	-10.57	17.71	0.94	-5.78	-12.63
JO02	Kabuli chickpea	-11.04	5.07	-6.63	-8.17	4.35	-4.86	-12.40	8.17	-11.32	-12.86	-59.19
Amdoun	Desy chickpea	-9.08	-32.71	-4.63	-23.80	6.64	-5.92	-16.33	9.72	-11.93	-14.01	-34.49
Hamera	Brown cowpea	1.18	6.92	-0.63	-10.48	12.89	2.50	-9.99	19.03	-0.59	-7.11	-11.88
White	White cowpea	0.27	-0.56	2.34	-21.86	10.56	0.73	-12.06	17.90	-4.27	-6.36	-7.65
Brown	Green speck. Cowp.	-5.77	-22.68	1.92	28.37	9.94	0.27	-11.92	16.34	-4.06	-6.75	-5.69
Gray	Gray cowpea	-0.84	-3.74	2.70	-5.56	11.57	2.75	-0.61	27.80	-1.95	-2.12	7.00
Seville04	Large faba bean	-15.09	-8.06	-5.36	23.35	3.12	-8.88	-12.78	16.15	-6.45	-15.12	-14.07
SY09	Medium faba bean	4.38	-2.18	8.69	27.98	18.51	6.24	0.76	14.05	5.03	-0.83	-12.79
Malti	Large faba bean	-4.58	-0.40	0.85	81.17	9.34	-3.03	-6.75	4.53	-2.43	-5.47	-18.62
Syrie229/06	Small lentil	-7.35	-7.01	-4.83	-15.15	-1.78	-4.26	-4.97	11.24	-7.68	-5.19	-9.31
Cinq	Medium lentil	-3.11	3.61	-7.70	-67.06	6.70	-4.34	-18.17	11.36	-13.54	-10.31	2.12
SY08	Small lentil	8.29	-19.76	5.16	28.33	25.87	10.45	1.51	26.80	5.57	4.35	-21.46

E. The effects of soaking and boiling on the fatty acids content of pulses

Table 29 reports the percentage of content changes observed in the more representative fatty acids after cooking. As can be seen there is a general reduction in fatty acids, particularly the polyunsaturated ones, in good agreement with the results related to the total fat reported above. As already explained, the reduction of fatty acids during cooking is the effect of the peroxidation process which naturally occurred when unsaturated fatty acids came into contact with the atmospheric oxygen. Another reason explaining the reduction of fatty acids is the complexation of fat in the protein and polysaccharides network created during the cooking process. Overall, the main effect of soaking and boiling on fatty acids content seems to be consistent with the scientific literature(Pal et al., 2017)

Table 29. Fatty acids content changes between raw and boiled pulses.

Country	Variety	Type	C16	C18	C18_1	C18_2	C18_3
Albania	Ecmeniku	White kidney bean	-5,08	-31,58	-33,32	-34,50	-42,04
Albania	Sacme	Navy bean	-18,40	-32,75	-31,87	-37,53	-43,26
Algeria	Praguecoco	Borlotti bean	-3,11	-19,16	-34,94	-35,86	-46,36
Algeria	Whitecoco	Cannellini bean	12,91	-18,34	-42,04	-30,74	-32,71
Morrocco	Ghelid	Navy bean	30,75	27,20	19,92	-2,48	-40,69
Morrocco	Reguig	Cannellini bean	-40,25	-52,53	-58,39	-56,87	-53,32
Serbia	Gradistanac	Cannellini bean	-30,55	-47,31	-50,69	-60,87	-66,50
Serbia	Tetovac	White kidney bean	5,84	-9,61	-16,48	-24,79	-33,22
Jordan	JO02	Kabuli chickpea	10,18	4,38	9,62	3,48	-12,94
Tunisia	Amdoun	Desy chickpea	-0,09	13,50	-3,86	-7,11	-10,55
Morrocco	Hamera	Brown cowpea	-1,42	-11,37	5,80	4,26	-15,46
Mauritania	White	White cowpea	-30,32	-36,73	-29,06	-28,19	-41,63
Mauritania	Brown	Green speck. Cowp.	-7,26	-18,70	-11,84	-9,84	-22,09
Mauritania	Gray	Gray cowpea	10,31	-5,14	26,71	4,93	-12,72
Algeria	Seville04	Large faba bean	-39,62	-37,82	-38,33	-49,01	-56,48
Syria	SY09	Medium faba bean	-20,14	-26,10	-17,77	-30,22	-43,88
Tunisia	Malti	Large faba bean	-23,06	-17,13	-14,52	-31,53	-35,89
Algeria	Syrie229/06	Small lentil	0,34	-7,79	6,50	-12,38	-17,82
Morrocco	Cinq	Medium lentil	8,99	5,37	10,15	-7,20	-24,63
Syria	SY08	Small lentil	4,59	-3,90	-1,67	2,95	-6,70

F. Effects of soaking and boiling on vitamins content of pulses

Pulse consumption is generally advocated for their various and rich essential vitamins content(Kamboj & Nanda, 2018). However, it is well documented that heating causes a decrease in vitamins B content; independently from the food categories considered, and that rising the temperature the vitamins content decrease(Riccio et al., 2006). Here, thiamine (vit. B1), niacin (vit. B3), biotin (vit. B7), and folate (vit. B9) decreased in most of the selected pulses after cooking (Table 30). Moreover, the exacerbated percentage of reduction of vitamin B7 was easily explained by the small content of this compound (express as microgram - μg). On the other hand, the decline in vitamin E (tocopherol) is strictly connected with the fat content reduction by oxidation.

Table 30. Effect of soaking and boiling on vitamins content of pulses.

Country	Variety	Type	Vit_B1	Vit_B3	Vit_B7	Vit_B9	Vit_E
Albania	Ecmeniku	White kidney bean	-12,52	48,12	-38,34	-11,31	-31,92
Albania	Sacme	Navy bean	-23,24	53,57	-11,14	112,30	-35,22
Algeria	Praguecoco	Borlotti bean	-3,58	-10,92	-47,57	-22,13	-31,78
Algeria	Whitecoco	Cannellini bean	-16,38	14,56	-44,58	-38,21	-16,29
Morrocco	Ghelid	Navy bean	5,16	-18,80	-36,71	-13,55	-1,00
Morrocco	Reguig	Cannellini bean	39,47	-13,20	-39,02	-12,25	-45,78
Serbia	Gradistanac	Cannellini bean	-8,72	36,21	-23,88	-11,78	-49,57
Serbia	Tetovac	White kidney bean	-41,81	-13,09	-25,99	-6,46	-22,03
Jordan	JO02	Kabuli chickpea	-19,48	-42,85	-14,85	-30,45	-33,71
Tunisia	Amdoun	Desy chickpea	-36,19	-61,02	-9,30	-12,53	-18,15
Morrocco	Hamera	Brown cowpea	-16,76	43,16	-28,52	-7,24	-31,35
Mauritania	White	White cowpea	-32,45	-26,48	-32,94	-5,23	-37,58
Mauritania	Brown	Green speck. Cowp.	-29,18	-5,60	-26,57	3,32	-26,29
Mauritania	Gray	Gray cowpea	-20,35	-36,29	-26,19	-5,55	-34,12
Algeria	Seville04	Large faba bean	-37,62	-20,20	-15,24	-38,68	-43,12
Syria	SY09	Medium faba bean	-16,04	11,52	-34,15	-30,46	-37,82
Tunisia	Malti	Large faba bean	-9,53	19,75	-32,82	-29,84	-27,22
Algeria	Syrie229/06	Small lentil	33,78	-30,25	-51,32	-44,33	-15,08
Morrocco	Cinq	Medium lentil	83,03	-14,19	-60,58	-42,28	-9,83
Syria	SY08	Small lentil	-17,95	-24,71	-35,18	-32,44	-48,04

G. Effects of soaking and boiling on the antioxidants and antinutritional factors

The effects of soaking and boiling on the antioxidants content and on the antinutritional factors are summarized in Table 31. Trypsin inhibitor activity importantly decreased in all samples by at least 90%. This was quite predictable, since the wide variety of trypsin-inhibitor compounds are all characterized by heat lability; thus, any cooking procedure such as boiling enables the higher digestibility of food (Kadam & Smithard, 1987). In turn this parameter was strictly connected with tannins content because of their coherent negative trend in whole samples and because these latter compounds displayed trypsin inhibitory activity (Jadwigaoê & Podsdek, 2004). However, it should be underlined that TUI and tannins content could not be completely overlapped since tannins are not the unique trypsin inhibitor compounds present in pulses. In 5 out of 8 bean samples and in 2 out of 2 chickpea samples polyphenols quantified were higher in boiled samples than raw ones, furthermore the total antioxidant capacity increased passing from raw to boiled. This finding stood out since polyphenols are the heaviest responsible of antioxidant activity in pulses (Wang et al., 2016). Therefore, having samples that lost some of the *malus* factors after boiling (as TUI and tannins) but increase the polyphenols content deserved to be highlighted. The same 5 bean samples that had an increased polyphenols content resulted in higher Trolox equivalent antioxidant capacity (TEAC), supporting the added value that these samples revealed. Concerning the phytate content, it should be underlined that this compound has been considered as antinutritional factor since its transition in the gastrointestinal tract may reduce the absorption of some minerals (i.e. calcium, iron, magnesium, and zinc) inducing a potential deficiency of minerals-tailored diets (Schlemmer et al., 2009). Therefore, according to this viewpoint an increase in phytate content after cooking procedure, as in our case, may become a burden on the value of selected pulses. However, more resent research underlined that dietary phytate reduce starch digestion, thus decreasing blood glucose response and becoming beneficial for diabetes patients (Kumar et al., 2010).

Table 31. Effects of soaking and cooking on the nutraceuticals and antinutritional factors.

Country	Variety	Type	TUI	TEAC	Polyph	Tannins	Phytate
Albania	Ecmeniku	White kidney bean	-93,78	63,69	58,96	-37,48	5,19
Albania	Sacme	Navy bean	-93,56	68,66	8,72	-67,28	15,47
Algeria	Praguecoco	Borlotti bean	-100,00	-20,66	-62,01	-98,69	21,79
Algeria	Whitecoco	Cannellini bean	-96,29	-67,54	-17,36	-47,58	40,98
Morrocco	Ghelid	Navy bean	-97,75	65,98	39,22	-42,61	28,21
Morrocco	Reguig	Cannellini bean	-99,11	99,38	32,77	-62,28	35,32
Serbia	Gradistanac	Cannellini bean	-98,31	39,09	7,57	-61,16	33,78
Serbia	Tetovac	White kidney bean	-100,00	15,81	-5,13	-58,99	93,31
Jordan	JO02	Kabuli chickpea	-90,35	-5,16	42,14	-94,59	17,57
Tunisia	Amdoun	Desy chickpea	-90,06	2,76	40,20	-87,86	-24,37
Morrocco	Hamera	Brown cowpea	-97,38	-10,56	-70,51	-96,57	26,15
Mauritania	White	White cowpea	-96,09	-7,83	-15,27	-41,85	36,80
Mauritania	Brown	Green speck. Cowp.	-97,66	-19,74	-33,27	-78,53	23,66
Mauritania	Gray	Gray cowpea	-92,18	14,12	-29,70	-77,21	6,80
Algeria	Seville04	Large faba bean	-93,33	-11,22	-57,06	-92,35	-12,15
Syria	SY09	Medium faba bean	-93,63	-26,54	-52,54	-89,95	6,28
Tunisia	Malti	Large faba bean	-94,00	-25,15	-38,57	-96,84	-49,38
Algeria	Syrie229/06	Small lentil	-100,00	-31,25	-69,90	-91,60	9,88
Morrocco	Cinq	Medium lentil	-100,00	-14,57	-64,46	-98,29	4,09
Syria	SY08	Small lentil	-100,00	-45,55	-50,97	-97,22	-6,58

V – Conclusions

The presented results are a thorough investigation on the variability of nutritional composition of pulses cultivated in the mediterranean basin, and particularly in the Maghreb, Mashreq and Balkans countries. The main positive features revealed by each selected accession of legume collected during the third year are highlighted in Table 32.

Table 32. Main positive attributes of the selected legumes samples collected and analysed during the third year of the project.

Country	Variety	Type	Main features
Albania	Ecmeniku	White kidney bean	High proteins, high dietary fibres; high tyrosine and histidine; increase of TEAC after cooking.
Albania	Sacme	Navy bean	high proteins, high dietary fibres; high tyrosine, phenylalanine, histidine and lysine; low TUI; increase of TEAC after cooking.
Algeria	Praguecoco	Borlotti bean	High TEAC and TP; high vit. B3
Algeria	Whitecoco	Cannellini bean	Low cooking time; high cysteine, tyrosine and lysine; high TEAC; high vit. B3
Morrocco	Ghelid	Navy bean	Low cooking time, good proteins and dietary fibers; low tannins; increase of TEAC after cooking.
Morrocco	Reguig	Cannellini bean	Low tannins; increase of TEAC after cooking.
Serbia	Gradistanac	Cannellini bean	High tyrosine, and good level of cysteine; good level of P and Ca; increase of TEAC after cooking.
Serbia	Tetovac	White kidney bean	High dietary fibers, average proteins; low TUI; low phytates; high vit. E
Jordan	JO02	Kabuli chickpea	Good dietary fibres; high P, Ca, K and Mg; good cysteine level; low TUI; low phytates; good TEAC, B1 and B3, high vit. E;
Tunisia	Amdoun	Desi chickpea	High proteins and TDF; high cystein, tyrosine, histidine and lysine; low tannins and phytates; High TEAC, Vit. B1, B3, B7 and E;
Morrocco	Hamera	Brown cowpea	Low cooking time; high proteins and TDF; high cysteine, and good level of histidine and lysine; high TEAC and TP; high vit. B9 and E
Mauritania	White	White cowpea	Good protein content; high P, Ca, K, and Mg; low tannins; good level of vit. B9;
Mauritania	Brown	Green speckled cowpea	Good TDF; high P, K, Mg and Zn; low level of TUI; high vit. B3, B7 and B9;
Mauritania	Gray	Gray cowpea	Low cooking time; good protein content; high P, Ca, K, and Mg; low tannins;
Algeria	Seville04	Large faba bean	Low cooking time; high proteins; high content histidine and lysine; high vit. B3 and E;
Syria	SY09	Medium faba bean	High P, K, Cu; low TUI; good TEAC ant TP; high vit. B7 and E.

Country	Variety	Type	Main features
Tunisia	Malti	Large faba bean	High proteins; high Ca and Zn; high level of cysteine, histidine and lysine; low tannins; high vit. B3;
Algeria	Syrie229/06	Small lentil	High proteins and TDF; Low TUI, tannins and phytates; high vit. B3
Morrocco	Cinq	Medium lentil	High TDF; High P and K; good histidine content; low TUI; High TP; high vit. B3, B9 and E
Syria	SY08	Small lentil	High proteins; high tyrosine; low TUI and phytate; high TEAC; good level of vit. B1, B3, B9 and E

As can be seen each selected accession showed peculiar characteristics, highlighting the importance to safeguard the genetic resources, fostering biodiversity. The reported results showed also the important effects of the geographical area of production on the nutritional features of pulses, and the main effect of cooking on these characteristics, mainly confirming the scientific literature.

References

Abeysekara S., Chilibeck P.D., Vatanparast H., and Zello G.A., 2012. A pulse-based diet is effective for reducing total and LDL-cholesterol in older adults. *The British Journal of Nutrition*, 108 (1). https://doi.org/10.1017/S0007114512000748

Guillamón E., Pedrosa M.M., Burbano C., Cuadrado C., Sánchez M. de C., and Muzquiz M., 2008. The trypsin inhibitors present in seed of different grain legume species and cultivar. *Food Chemistry*, 107(1): 68–74. https://doi.org/10.1016/J.FOODCHEM.2007.07.029

Han H., and Baik B.K., 2008. Antioxidant activity and phenolic content of lentils (*Lens culinaris*), chickpeas (*Cicer arietinum* L.), peas (*Pisum sativum* L.) and soybeans (*Glycine max*), and their quantitative changes during processing. *International Journal of Food Science & Technology*, 43(11): 1971–1978. https://doi.org/10.1111/J.1365-2621.2008.01800.X

Hwalla N., Al Bakain R., Trani A., Mondelli D., Di Terlizzi B., and Hamzé M., 2025. Exploring the nutritional and nutraceutical significance of legumes: A comparative analysis across Mashreq countries**.** *New Medit*, 2: 73-87. https://doi.org/10.30682/nm2502e

Jadwigaoê J., and Podsdek A., 2004. Tannins from different foodstuffs as trypsin inhibitors. *Polish Journal of Food and Nutrition Sciences*, 54(1): 51–55.

Kadam S.S., and Smithard R.R., 1987. Effects of heat treatments on trypsin inhibitor and hemagglutinating activities in winged bean. *Qualitas Plantarum Plant Foods for Human Nutrition*, 37(2), 151–159. https://doi.org/10.1007/BF01092051/METRICS

Kamboj R., and Nanda V., 2018. Proximate composition, nutritional profile and health benefits of legumes – A review. *Legume Research*, 41(3): 325–332. https://doi.org/10.18805/LR-3748

Kan L., Nie S., Hu J., Wang S., Cui S.W., Li Y., Xu S., Wu Y., Wang J., Bai Z., and Xie M., 2017. Nutrients, phytochemicals and antioxidant activities of 26 kidney bean cultivars. *Food and Chemical Toxicology*, 108: 467–477. https://doi.org/10.1016/J.FCT.2016.09.007

Kumar V., Sinha A.K., Makkar H.P.S., and Becker K., 2010. Dietary roles of phytate and phytase in human nutrition: A review. *Food Chemistry*, 120(4): 945–959. https://doi.org/10.1016/J.FOODCHEM.2009.11.052

Maia F.M., Oliveira J.T., Matos M.R., Moreira R.A., and Vasconcelos I.M., 2000. Proximate composition, amino acid content and haemagglutinating and trypsin-inhibiting activities of some Brazilian *Vigna unguiculata* (L.) Walp cultivars. *Journal of the Science of Food and Agriculture*, 80(4): 453–458. https://doi.org/10.1002/(SICI)1097-0010(200003)80:4<453:AID-JSFA548>3.0.CO;2-X

Mananga M.J., Noah J.K.E., Taptue C.K., Ndjigoui B.D.K., and Elie F., 2022. Effect of Different Processing Methods on the Nutritional Value of Red and White Bean Cultivars of *Phaseolus vulgaris* L. *Journal of Food and Nutrition Sciences*, 10(1): 27. https://doi.org/10.11648/j.jfns.20221001.15

Mudryj A.N., Yu N., and Aukema H.M., 2014. Nutritional and health benefits of pulses. *Applied Physiology, Nutrition, and Metabolism = Physiologie Appliquee, Nutrition et Metabolisme*, 39(11): 1197–1204. https://doi.org/10.1139/APNM-2013-0557

Pal R.S., Bhartiya A., Yadav P., Kant L., Mishra K.K., Aditya J.P., and Pattanayak A., 2017. Effect of dehulling, germination and cooking on nutrients, anti-nutrients, fatty acid composition and antioxidant properties in lentil (*Lens culinaris*). *Journal of Food Science and Technology*, 54(4): 909–920. https://doi.org/10.1007/S13197-016-2351-4

Riccio F., Mennella C., and Fogliano V., 2006. Effect of cooking on the concentration of Vitamins B in fortified meat products. *Journal of Pharmaceutical and Biomedical Analysis*, 41(5): 1592–1595. https://doi.org/10.1016/J.JPBA.2006.01.061

Schlemmer U., Frølich W., Prieto R.M., and Grases F. 2009. Phytate in foods and significance for humans: food sources, intake, processing, bioavailability, protective role and analysis. *Molecular Nutrition & Food Research*, 53 (S2): S330–S375. https://doi.org/10.1002/MNFR.200900099

Siah S., Konczak I., Wood J.A., Agboola S., and Blanchard C.L., 2014. Effects of Roasting on Phenolic Composition and In vitro Antioxidant Capacity of Australian Grown Faba Beans

(*Vicia faba* L.). *Plant Foods for Human Nutrition*, 69(1): 85–91. https://doi.org/10.1007/S11130-013-0400-Y/TABLES/2
Singh B., Singh J.P., Kaur A., and Singh N., 2017. Phenolic composition and antioxidant potential of grain legume seeds: A review. *Food Research International*, 101: 1–16. https://doi.org/10.1016/J.FOODRES.2017.09.026
Wang N., Hatcher D.W., Toews R., and Gawalko E.J., 2009. Influence of cooking and dehulling on nutritional composition of several varieties of lentils (*Lens culinaris*). *LWT - Food Science and Technology*, 42(4): 842–848. https://doi.org/10.1016/J.LWT.2008.10.007
Wang N., Hatcher D. W., Tyler R.T., Toews R., and Gawalko E.J., 2010. Effect of cooking on the composition of beans (*Phaseolus vulgaris* L.) and chickpeas (*Cicer arietinum* L.). *Food Research International*, 43(2): 589–594. https://doi.org/10.1016/J.FOODRES.2009.07.012
Wang Y.K., Zhang X., Chen G.L., Yu J., Yang L.Q., and Gao Y.Q., 2016. Antioxidant property and their free, soluble conjugate and insoluble-bound phenolic contents in selected beans. *Journal of Functional Foods*, 24: 359–372. https://doi.org/10.1016/J.JFF.2016.04.026
Wrolstad R.E., Acree T.E., Decker E.A., Penner M.H., Reid D.S., Schwartz S.J., Shoemaker C.F., Smith D. M., and Sporns P., 2005. Handbook of Food Analytical Chemistry. In *Handbook of Food Analytical Chemistry* (Vols 1–2). https://doi.org/10.1002/0471709085

OPTIONS méditerranéennes

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Final results of the MEDIET project, sustainability assessment and nutritional evaluation of legumes produced in the Mediterranean basin

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The present booklet reports the results of the project named MEDIET, funded by the Italian Ministry of Foreign Affairs and International Cooperation, and conducted by the CIHEAM Bari during the years 2023-2025. The project was aimed to investigate, in the mediterranean countries, about: i) the environmental and socio-economic sustainability of legume production; ii) the nutritional, anti-nutritional, and nutraceutical characteristics of local cultivated legumes varieties. The target legumes were beans, chickpeas, cowpeas, faba beans and lentils. Fifteen countries were involved belonging to Maghreb, Mashreq and Balkan regions. Results clearly show important differences in terms of environmental impact and economical sustainability in the legume production, according to the legume species and production area. Finally, the report shows the important existing variability of nutritional data within the same species as the effect of the different locally cultivated varieties. The main objective of the work consisted in improving the knowledge level related to the benefits deriving from the inclusion of legume consumption in human's diet both in terms of human's and planet health.

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