

Supplementary material

Table S1

Analysis of the Knowledge Core, Preliminary Identification of Factors

Knowledge area	Horticulture product	Distinctive sign	Tools, methods, methodologies and models.	Scope	Country
Human and Animal Nutrition and Feeding [2] (Petropoulos et al., 2015)	Onion [1] Horticulture [1]	Geographical Indication [2]	• Nutritional Analysis • Analysis of Bioactive Compounds	• Nutritional Content as a Competitive Advantage Factor • Fatty Acid Content and Phenolic Compound Content	Greece [1] Europe [1]
Quality and Safety of Inputs and Products [47] (Bosmali et al., 2012; Ciampa et al., 2010; Feng et al., 2022; Firmani et al., 2019; Muñoz-Falcón et al., 2009; Pascale et al., 2018)	Tea [2] Tomato [3] Lentil [2] Onion [2] Bean [2] Eggplant [2] Radish [2] Garlic [2] Pepper [2]	Geographical Indication [47]	• Near Infrared Spectroscopy (NIRS) • Non-targeted spectroscopic fingerprinting techniques • Illumina MiSeq technology • gas chromatography-mass spectrometry (HS-SPME-GC-MS) • Gas Chromatography-Ion Mobility Spectrometry Headspace • Solid Phase Microextraction-Gas Chromatography-Mass Spectrometry • Análisis de Estadística multivariable • Magnetic resonance imaging (MRI) spectroscopy	• Establish the concentration of elements through chemometric methods • Antioxidant capacity and bioactive content • Non-invasive or destructive assays: Gas Chromatography-Ion Mobility Spectrometry and Headspace Solid Phase Microextraction-Gas Chromatography-Mass Spectrometry • Variation in bioactive compound content due to environmental factors • Molecular characterization of varieties focused on bioactive and volatile compounds • Authenticity traceability to prevent adulteration and differentiation models for alternatives • Authentication through sensory analysis and mineral quantification models • Nutritional, chemical, and antioxidant property authentication • Variability of properties due to edaphoclimatic changes • Metabolomic profiles for authentication and traceability of changes • Differentiation from related varieties • Differentiation from other homologous certified products • Reducing counterfeiting or fraud of certified foods • Metabolic differentiation of associated compounds	China [15] Italy [11] India [2] Spain [7] Greece [1]
Plant Physiology and Nutrition [1] (Tejada & Gonzalez, 2003)	Asparagus [1]	Geographical indication [1]	• Foliar fertilization	• Improve the productivity of cultivars	Spain [1]
Strengthening of Technical and Functional Capacities [1] (Belletti et al., 2016)	Pepper [1]	Geographical indication [1]	• Capacity building	• Agreements among producers, standardization of practices, control mechanisms, and provision of public goods	Africa [1]
Harvest, Post-Harvest, and Processing Management [2] (Róth et al., 2012)	Cauliflower [1] Chili Pepper [1]	Geographical indication [1]	• Analysis of the production system • Conservation technologies (packaging, cooling, and modified atmospheres)	• Shelf-life extension and strengthening of the cold chain • Market niche diversification	Spain [1] China [1]
Soil and Water Management [4] (Borges-Gómez et al., 2014; Domínguez et al., 2013)	Tea [1] Garlic [1] Chili pepper [1] Olive [1]	Geographical indication [3] Origin denomination [1]	• Deep learning models • Irrigation models • Soil analysis	• Relational analysis between soil Quality and product quality based on edaphoclimatic variability. • Consultant services on irrigation • Technological field recommendations are based on Laboratory results.	Spain [2] China [1] Mexico [1]
Productive System Management [1] (Husaini, 2014)	Azafrin [1]	Geographical indication [1]	• Omics • Biotechnology	• Abiotic stressors resistance • Climate change adaptability	Nepal [1]

Knowledge area	Horticulture product	Distinctive sign	Tools, methods, methodologies and models.	Scope	Country
Sanitary and Phytosanitary Management [5] (Cantore et al., 2015; Panebianco et al., 2022; Vitti et al., 2021)	Bean [4] Tomato [1]	Geographical indication [5]	- Eco-compatible measures for disease management - Susceptibility/tolerance of selected varieties - RT-PCR; ELISA MiniON sequence	- Antagonist bacteria selection of phytophagous fungi. - Plagues and diseases control that endanger crop viability in a protected terroir. - Plagues and diseases impact control on product characteristics.	Italy [5]
Planting Material and Genetic Improvement [4] (Bacchi et al., 2010; Moses & Umaharan, 2014)	Barley[2] Lentil [1] Chili pepper [1]	Geographical indication [4]	- Landraces - AFLP-SSR - Varieties - Phylogenetics	- Provide genetic diversity alternatives on species with distinctive signs. - Design selection, Breeding and editing research programs - Determine valuable characteristics - Varieties evolution and distribution	Italy [1] Czech Republic [2] Latin America [1]
Information Systems, Zoning, and Georeferencing [2] (Dokuzlu, 2016)	Olive Aromatic plants	Geographical indication [2]	- Traceability systems - Omics	- Facilitate Information management associated to distinctive signs species. - Facilitate registry, monitoring and evaluation processes.	China [1] Turkey [1]
Socioeconomics, Marketing, and Business Development [40] (Besky, 2014; Quiñones-Ruiz et al., 2017; Schnettler et al., 2015; Urbano et al., 2008)	Tea [17] Horticulture [4] Bean [5] Cinnamon [3] Onion [2] Tomato [2]	Geographical indication [39] Origin denomination and Geographical indication [1]	- Certification process - Market strategy - Intellectual property - Accreditation process - Value and supply chain analysis - Terroir analysis	- Ecotypes recognition - Field data recovery - Strengthening competitiveness and profit overtime - Associativity - Quality perception influences consumer decision - Material and economic fluxes modeling - Quality standardization on products and processes on farms - Geographical, physiological and cultural interaction. - Intangible assets related to cultural heritage. - Certification routes	China [16] Spain [3] India [3] Turkey [3] Greece [2] Italy [2] Indonesia [2]

Source: Own elaboration based on data retrieved from Scopus®, Web of Science®, SciELO®, Dimensions®, and The Lens® in April 2024. Analysis software: Microsoft Excel®

[] Number of research articles related to knowledge area, horticulture product, distinctive sign or research related country.

Table S2

Analysis of the Knowledge Core, Key Factors in Homologous Products

Knowledge area	Product	Distinctive signs	Tool, methods, methodologies and models	Scope	Country	Normative agreement
Human and Animal Nutrition and Feeding (Petropoulos et al., 2015)	Red onion variety "Vatikiotiko"	Potential for Achieving Designation of Origin or Geographical Indication	- Genetic material collection - Bulbs morphological analysis - Compositional analysis - Atomic absorption spectrometry - HPLC - Statistical analysis	- Chemical composition analysis versus three commercial varieties - Comparing nutritional value and mineral, organic acids, sugars, fatty acids and tocopherols content. - Antioxidant properties assessment - Dry bulbs quality assessment	Greece	REGULATION (EU) No 1151/2012
Quality and safety of inputs and products (Furia et al., 2011; Nie et al., 2021; Taglienti et al., 2020;	Red onion variety "Tropea" Rossa di Tropea	PGI granted by the European Union: "Cipolla Rossa di Tropea Calabria"	- Artificial Neural Network (ANN) of ICP-MS, Linear Discriminant Analysis (LDA), and Soft Independent Modeling of Class Analogy (SIMCA). - Chemometric Treatments.	- High flavonoids content - Anti-inflammatory, antineoplastic and cardiovascular adjuvant functionalities - High quercetin and delphinidins derivatives (anthocyanins) - Fraud risk	Italy	REGULATION (EU) No 1151/2012

Knowledge area	Product	Distinctive signs	Tool, methods, methodologies and models	Scope	Country	Normative agreement
Vijayalakshmi et al., 2021)				- Authenticity valuation of organoleptic and nutritional characteristics - Authentication and Quality assessment techniques selection.		
	Red onion variety “ <i>Krishnapuram</i> ”	Potential for Achieving Designation of Origin or Geographical indication	- Total phenolics content - Antioxidant capacity - HPLC analysis and calibration standards - ESI (<i>Electrospray Ionization</i>)- with ITMS (<i>Ion Trap Mass Spectrometry</i>) multistep	- Antioxidant capacities on specific varieties - Bioactive compounds occurrence influenced by varieties characteristics, microclimatic and agroecological conditions, crop management techniques and crop physiological stages. - Bioactive compounds experimental detection.	India	The geographical identification of goods (registration and protection) ACT, 1999. N° 48 de 1999
	Garlic variety “ <i>Chinese Jinxiang</i> ”	PGI granted by China	- Determining stable isotope associated to geographical factors - Carbon, sulfur, oxygen and nitrogen stable isotopes. - Multivariate statistical analysis	- Guarantee product organoleptic quality - Maintain importation dynamics from current market niches - Benchmarking framework considering regions and species. - Recurring tools for authentication and screening of products with geographical indication.	China	Provisions for the Protection of Products of Geographical Indication Promulgated by the General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China on May 16 2005
	Garlic variety “ <i>Taşköprü Garlic</i> ”	PGI granted by EU	- Soil chemical compounds analysis - Morphological characteristics - Spectrometry analysis.	Variability of bioactive compounds such as pigments, secondary metabolites, nitrogenous compounds, reduced sugars, pyruvic acid, according to crop management (field and greenhouse)	Turkey	REGULATION (EU) No 1151/2012
	Onion red variety “ <i>Tropea</i> ”, Rossa di Tropea	PGI granted by EU “Cipolla Rossa di Tropea Calabria”	- Magnetic resonance micro-images (MRI) - DAS-ELISA	- Disease susceptibility to <i>Onion yellow dwarf virus</i> (OYDV, <i>genus Potyvirus, family Potyviridae</i>). - Extended shelf-life conservation - Assessment of modifications and ultrastructure alterations on water content and disease traceability - Guarantee postharvest quality - Quality control assessment during stock inventory.	Italy	REGULATION (EU) No 1151/2012
Socioeconomics, marketing and business development (Hu et al., 2013; Tregear et al., 2016)	Chinese green onion (<i>Allium Fistulosum</i>) <i>Nine varieties</i>	PGI granted by China	Legal framework analysis	- Key recommendations for PGI granting related to quality and innocuity - Quality standards definition - PGI recognition, appropriation and use of standards - Unifying trademarks between distinctive signs. - Dual protection PGCT and UPOV breeder rights - Potential added value activities like agrotourism	China	Provisions for the Protection of Products of Geographical Indication Promulgated by the General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China on May 16 2005
	Mako onion	PGI granted by EU	- Value chain analysis - Vertical integration between stakeholders - Normative and institutional frameworks analysis - Stakeholders mapping - Structured interviews - Qualitative analysis	- Enabling small producers’ associative schemes through value chains - Promote alternative associative schemes - Quality and volume responsiveness capacity - Products and market niches diversification	Hungary	REGULATION (EU) No 1151/2012

Knowledge area	Product	Distinctive signs	Tool, methods, methodologies and models	Scope	Country	Normative agreement
Management of the production system (Thi et al., 2013; Verjel Sánchez, 2016)	Red onion "Ocaña variety"	Potential for Achieving Designation of Origin or Geographical indication	• Impact Analysis of Economic Liberalization • Creating the Need to opt for Protection Mechanisms such as Designation of Origin, Collective Marks, or Certification	• Linking Product Characteristics to Those of the Terroir • Territorial Strategy for Conservation and Promotion	Colombia	Decision 486 of 2000 of the Andean Community Commission, a regulation applicable to all member countries of the Andean Community
	Violet Onion "Vinhchau"	Geographical indication	• Planting Densities	• Cost Reduction in Seeds • Reduction in the Incidence of Pests and Diseases • Improvement in Yield and Profitability	Vietnam	National Office of Intellectual Property has issued Decision No.2665/QĐ-SHTT granting Geographical Indication registration certificate No.00075
Seed Material and Genetic Improvement (Antofie & Sava Sand, 2017; Delvento et al., 2022; Ricciardi et al., 2020)	Red onions: "Buzău" variety and "De Turda" variety	UPOV Potential for Achieving Designation of Origin or Geographical indication	• Evaluation of Morphometric Characteristics • Analysis of Fresh and Dry Matter • Historical Analysis of Conservation Status	• Challenges for In Situ Conservation • Conservation Status Regarding UPOV Registration • Registration of Varieties in Conservation Bank Systems	Romania	REGULATION (EU) No 1151/2012
	Red onion "Acquaviva"	Potential for Achieving Designation of Origin or Geographical indication	• Analysis of Genetic Structure Using Parametric and Non-Parametric Methods • Evaluation of Soluble Solids Content and Pungency in Onion Bulbs	• The "Red Onion of Acquaviva" (ARO) is a Distinct Genetic Group. ARO Has Superior Sweetness Compared to Other Local Varieties • ARO is Distinct from Other Local Varieties and Has Greater Sweetness • Genetic Contamination of the Local ARO Variety with the Local M Variety Detected • Identification of a Molecular Barcode Based on SNP for ARO Traceability	Italy	REGULATION (EU) No 1151/2012
Soil and Water Management (Domínguez et al., 2013; Preethi et al., 2022)	Purple Garlic "Las Pedroñeras"	PGI granted by EU	• MOPECO Model • Field Experiments Under Different Irrigation Schemes	• Typical Meteorological Year Methodology • Design of Irrigation Strategies • Simulation of Agroclimatological Conditions to Optimize Crop Cultivation	Spain	REGULATION (EU) No 1151/2012
	Red onion "Lasalgaon light" variety (Niphad red, Nashik red.)	Geographical indication	• Fertilization with Organic Amendments • Mixed Formulations	• Effects of Using Amendments on Growth Parameters Such as Plant Height • Effects on Crop Yield • Influence on Ascorbic Acid Content and Total Soluble Solids • Efficiency Under Specific Agroclimatic Conditions	India	The geographical identification of goods (registration and protection) ACT, 1999. N° 48 de 1999
Harvest and Post-Harvest Management (Russo et al., 2013)	Onion red variety "Tropea", Rossa di Tropea	PGI granted by EU "Cipolla Rossa di Tropea Calabria"	• Electronic Nose-Based Approach • Non-Destructive Flavor Evaluation in Red Onion Ecotypes	• The Electronic Nose Can Differentiate Red Onion Ecotypes Based on Their Aroma • Investigating the Impact of Environmental Factors on Onion Flavor • Non-Destructive Method for Flavor Evaluation in Red Onions	Italy	REGULATION (EU) No 1151/2012

Source: Own elaboration based on data retrieved from Scopus®, Web of Science®, SciELO®, Dimensions®, and The Lens® in April 2024. Analysis software: Microsoft Excel®.

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