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Potatoes (*Solanum tuberosum* L.) grown at “Patata dell’alto Viterbese” PGI have different quality characteristics and storage responses

G. Bedini [a], Ron P. Haff [b], A. Benelli [a], A. Bandiera [a], E. Taormina [a], R. Massantini [a], R. Moscetti [a,*]

[a] *Department for Innovation in Biological, Agro-food and Forest systems, University of Tuscia, Viterbo, Italy*
[b] *United States Department of Agriculture, Agricultural Research Service, Western Regional Research Center, 800 Buchanan St, Albany, CA 94710, USA*

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ABSTRACT

Four pre-selected potato cultivars (*Solanum tuberosum* L.) from the “Patata dell’Alto Viterbese” PGI area underwent physico-chemical and enzymatic characterization to assess their suitability for specific processing line. Key chemical parameters (reducing sugar content (RSC), total phenol content (TPC), dry matter (DM), physical attributes (firmness), physico-chemical aspects (color, browning development), and enzymatic factors (polyphenol oxidase enzyme activity, PPO) were analyzed at harvest and monthly during a 6-month storage period over two production seasons (2020 and 2021). The results of one-way within-subject ANOVA and Principal Component Analysis (PCA) highlighted the superior attributes of the ‘Fontane’ cultivar for the processing industry, particularly for frying applications (e.g., chips, French fries, etc.). In comparison to other tested cultivars, ‘Fontane’ exhibited: i) the highest DM (> 200 g kg^{-1}), ii) the lowest TPC and RSC, iii) the greatest firmness, iv) low susceptibility to browning, and v) high tolerance to Low-Temperature Sweetening (LTS). The ‘Jelly’ cultivar displayed favorable attributes for versatile use, suitable for both fresh market uses (roasting, homemade “gnocchi”, etc.) and industrial applications (fresh-cut or dried potato). It demonstrated high DM content (200 g kg^{-1}) and firmness, the lowest PPO activity, good TPC, but higher RSC than ‘Fontane’. However, elevated RSC for ‘Jelly’ renders it less suitable for industrial frying. ‘Constance’ and ‘Gaudi’ exhibited positive traits for fresh market use such as boiling and steaming, with moderate to low DM content and firmness. Nonetheless, both cultivars displayed low tolerance to LTS, and ‘Gaudi’ exhibited the poorest processing properties, showing the highest susceptibility to browning.

1. Introduction

With 2020 global production of 359 million tons (FAOSTAT, 2022), the potato (*Solanum tuberosum* L.) currently ranks fourth amongst the world’s crops, following maize, wheat, and rice (Gikundi et al., 2022). In Italy, potato production reached 1.38 million tons in 2022, of which about 45,000 tons was produced in the northern part of the Latium region (ISTAT, 2022). While this represents a relatively small share (3.2 %) of the countries’ total, potatoes from this area are known for desirable characteristics and were awarded a Protected Geographical Indication (PGI) (“Patata dell’Alto Viterbese”) by the European Union in 2014. This PGI describes a product with specific attributes associated with its place of origin, i.e. the shores of the Bolsena Lake, a volcanic lake in Central Italy. Traditionally, about twenty potato cultivars have been cultivated in the area. However, in recent years various local cultivars are being replaced with new high-yielding cultivars, threatening the valued uniqueness of the local crop, and contributing to genetic diversity loss, one of the pivotal targets of the United Nations Environment Program (United Nations, 2022). It is thus imperative that traits emphasized in future potato cultivar selection include not only agronomic and economic aspects (yield, disease resistance, water demand, etc.), but also traits that enhance quality, safety, health and sustainability of production.

Potatoes are cultivated in 160 countries with over 4000 known cultivars. Thus, potatoes represent a highly diverse crop with a wide range of physico-chemical and enzymatic characteristics. They are used by virtually all human cultures with numerous methods of processing, storage, preparation, and consumption. Most cultivars are tailored for specific purposes, and perception of potato quality has been related to appropriateness for the intended use (Pinhero and Yada, 2016). A high percentage of cultivars are developed that narrowly select for traits compatible with specific processing streams. However, for cultivars

* Corresponding author.
E-mail address: rmoscetti@unitus.it (R. Moscetti).

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intended for the fresh market (unprocessed), there is limited consumer knowledge or awareness and inadequate information available regarding the critical chemical and physical characteristics that impact quality and safety, which include dry matter content (DM), carbohydrates, textural attributes, and discoloration (Torres and Parreño, 2016).

DM is a critical component of processing quality, which is indirectly measured by industry using the gravimetric method: the higher the tuber density, the higher the DM content. DM significantly influences texture and suitability for specific processing streams. Processing generally requires potatoes with greater than 200 g kg^{-1} DM, while raw product should have DM from 160 g kg^{-1} to 190 g kg^{-1}, signifying medium-firm, marginally floury potatoes that retain structural integrity. DM is subject to multiple factors, e.g. production area, cultivation year, cultivar, and storage conditions (Pritchard and Scanlon, 1997).

Carbohydrate content, i.e. starch and non-/reducing sugars, varies by DM and subsequently by genotype, with high DM correlated with higher sugar. Other (both pre- and post-harvest) factors that impact carbohydrate content include maturity and storage conditions (Kumar et al., 2004). Potatoes with greater than 20 g kg^{-1} dry weight content of reducing sugars are deemed unsuitable for processing, as well as for some fresh market applications (Torres and Parreño, 2016) since required temperatures initiate Maillard's reaction with subsequent nonenzymatic browning, potential acrylamide production and associated health hazards (McKenzie and Corrigan, 2016). It is thus generally advised to limit dry weight sugar content to between one and five g kg^{-1} (Biedermann-Brem et al., 2003; EFSA, 2015).

Textural attributes are affected by tuber chemical composition, microstructure, cultivar, and storage. For processed potatoes, the processing method heavily impacts the texture. Mealy or floury cultivars with high DM have lower cooking times and compression forces than waxy cultivars. Mealy potatoes have greater total loss of solids and gain of water during cooking. Storage temperatures also affect texture characteristics of raw and cooked potatoes.

Tuber discoloration can be caused by many physiological disorders, diseases, or injury/damage. Browning following cutting and darkening after cooking are influenced by phenol content and composition. Oxidative enzyme activity, such as polyphenol oxidase, is critical in enzymatic browning. Susceptibility to browning is thus related to physico-chemical and enzymatic makeup, which varies between cultivars (Wang-Pruski and Nowak, 2004; Cabezas-Serrano et al., 2009).

All potato quality attributes can be affected by storage conditions. In Italy, it is common practice to store potatoes in mobile pallet boxes in low light at 6–8 °C, and 90–95 % relative humidity. Sprout inhibitors are commonly applied (Gómez-Castillo et al., 2013). The effect of storage conditions on product quality and safety attributes varies between cultivars. For instance, potatoes stored around or below 4 °C can be subject to accumulation of reducing sugars, commonly referred to as low-temperature sweetening (Pringle et al., 2009). However, this effect is only of concern in certain cultivars, highlighting the importance of employing cultivar specific storage conditions (Zommick et al., 2014). Thus, to effectively select cultivars for specific utilization it is imperative to study potato cultivars in terms of the effect of storage conditions on quality and safety parameters. This knowledge would guide marketing strategies by producers and processors and improve value for consumers. Furthermore, label information such as optimal applications based on cultivar and storage status could help prevent undesirable outcomes like discoloration or acrylamide contamination.

The effect of storage conditions on quality traits and destination of use of potato tubers was extensively studied for many cultivars (Biedermann-Brem et al., 2003; Cabezas-Serrano et al., 2009; Elmore et al., 2015; Silveira et al., 2017). However, no investigations have been conducted on "Patata dell'Alto Viterbese" PGI tubers, which are grown in a distinct terroir located on the shores of Bolsena Lake. This distinctive setting confers unique quality traits to PGI-designed cultivars, which are particularly appreciated in Central Italy, and may also affect their storability and suitability for various processing streams. Therefore, the present study aims to: i) elucidate the changes in quality during storage observed in four selected PGI-designated cultivars (i.e. 'Fontane', 'Jelly', 'Contance' and 'Gaudi'); and ii) provide essential insights into their optimal fresh market and industrial use. The Authors believe in defining an analytical approach that can be adopted by the PGI consortium also for additional cultivars, ensuring the preservation of "Patata dell'Alto Viterbese" PGI uniqueness and contributing to its novelty, sustainability and economic viability.

2. Material and methods

2.1. Plant material and storage conditions

Potato tubers (*Solanum tuberosum* L.) were provided by the "Patata dell'Alto Viterbese" PGI consortia, specifically C.C.OR.A.V. and Coop. Centro Agricolo Alto Viterbese, located in Viterbo, Latium, Italy. Of thirteen cultivars grown in the area, four were selected after considering multiple factors, including preliminary testing of DM content analysis and susceptibility to post-cut browning, consortia surveys mainly focused on performance and economic impact, literature searches, input from seed tuber vendors, and databases including the European Cultivated Potato Database (ECPD, 2023). 'Constance', 'Fontane', and 'Jelly' were chosen for medium to high DM content (180–220 g kg^{-1}) and low susceptibility to post-cut browning. These are medium/late-cultivars, recommended for a cultivar of uses, particularly industrial or homemade frying (especially 'Fontane' and 'Jelly'), as well as all culinary applications (especially 'Jelly' and 'Constance'). In contrast, 'Gaudi' was selected for its low to medium DM content (170 g kg^{-1}). 'Gaudi' is an early cultivar, suggested for fresh market use such as boiling or steaming.

Samples were collected and analyzed at harvest (August/September) of 2020 and 2021, as well as monthly during a six-month storage period (i.e., up to sprouting). Specifically, approximately 200 kg of raw tubers of each cultivar, selected to be uniform in shape and size, were stored in separate pallet boxes in the same dark room at 7.2 ± 1 °C and ~95 % relative humidity, utilizing an ethylene-based anti-sprouting system (20 % C_2H_4 concentration) (Restrain Company Ltd, Breda, Netherlands).

2.2. Sample preparation

The experimental procedures for each potato batch are shown in the flowchart of Fig. 1. At each sampling time, 25 tubers (~ 5 kg) were sampled from each cultivar batch. The tubers were washed with tap water and divided into two sub-batches. One sub-batch (1) consisting of 10 tubers was allocated for firmness analysis, while the other sub-batch (2) containing 15 tubers was designated for all remaining analyses. Dry matter content, color assessment and firmness were assessed using fresh samples. During these analyses, a slice was obtained from each potato tuber, which was then diced and subjected to freeze-drying for subsequent storage until further physico-chemical and enzymatic analyses.

2.3. Potato cultivars characterization

2.3.1. Firmness

Tuber firmness was assessed by cutting two slices (~1 cm thick) and puncturing each slice at five points (four measurements on the outer medulla and one on the inner medulla) using an Instron Universal Testing Instrument (Model 4301, Instron Corporation, Norwood, MA, USA). The crosshead speed was set at 10 mm min^{-1}, and an 8-mm diameter convex-tip Magness-Taylor type probe was employed with a penetration depth of 6 mm. A total of 100 measurements were taken for each potato cultivar (5 punctures × 2 slices × 10 tubers) per storage period.

2.3.2. Colorimetric assessment

Each tuber was halved, and color of the surface exposed to air was

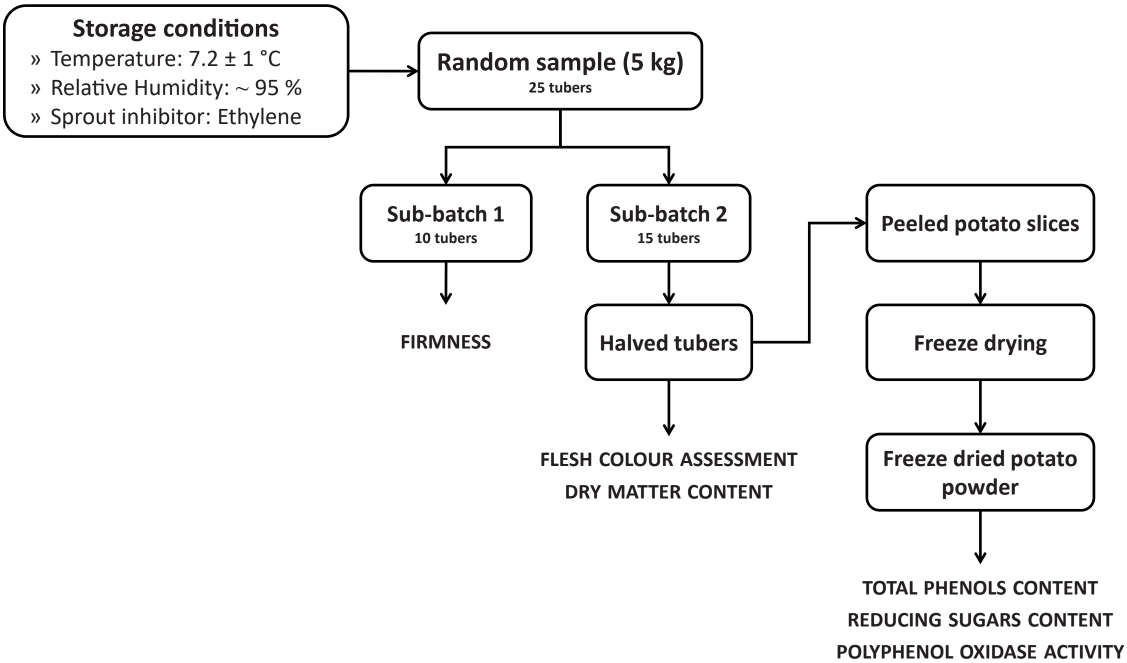

Fig. 1. Flow chart of sample preparation and characterization applied to each cultivar.

measured (CIE Standard Illuminant D65 with a 10° standard observer) using a colorimeter (Model CM-2600d, Konica Minolta Inc, Chiyoda, Japan). Five measurements were made for each surface (four on the outer and one on the inner medulla). Colorimetric coordinates (L^*, a^*, b^*) were recorded after 120 min of air exposure. Finally, the CIELab color difference (ΔE^*) was calculated relative to time 0 using Eq. (1):

$$\Delta E^* = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}} \quad (1)$$

2.3.3. Dry matter content

Approximately 10 g of tubers were peeled, homogenized, and dried at 65 °C for 72 hours (Karathanos, 1999). DM was determined in triplicate as grams (dried) / 100 g (fresh).

2.3.4. Total Phenol Content (TPC)

One gram of freeze-dried potato powder was homogenized with 20 mL of a methanol:water solution (80:20 v/v) in an orbital shaker (model 711, Tecnochimica Moderna S.r.l., Italy) in the dark at ambient temperature for 24 h. The extract was then centrifuged (model PK121R, ALC, Italy) at approximately 3400 × g for 10 min at 4 ± 0.5 °C, filtered, and stored at 4 ± 1 °C before the assay. TPC was determined using the Folin–Ciocâlteu method with slight modifications (Singleton and Rossi, 1965). A volume of 1.44 mL deionized water was mixed with 0.16 mL of extract, 0.1 mL of Folin–Ciocâlteu reagent, and 0.3 mL of sodium carbonate solution (75 g L^{-1}). The mixture was kept in the dark at room temperature for 2 h. Absorbance was measured at 760 nm using a UV-Vis spectrophotometer (ONDA UV-20, Giorgio Bormac s.r.l., Carpi, Italy) against a blank comprised of the same mixture with an 80:20 v/v methanol:water solution in place of the extract. The total phenol content was calculated based on the calibration curves of gallic acid and expressed as grams of Gallic Acid Equivalents per kg of dry weight (g kg^{-1}). The TPC was measured in triplicate.

2.3.5. Reducing Sugar Content (RSC)

One gram of freeze-dried potato powder was homogenized with 20 mL of distilled water using an orbital shaker (model 711, Tecnochimica Moderna S.r.l., Italy) at ambient temperature for 15 min. The extract was then centrifuged (model PK121R, ALC, Italy) at approximately 3400 × g for 10 min at 4 ± 0.5 °C and stored at 4 ± 1 °C before the assay.

RSC was determined using the 3,5-dinitrosalicylic acid (DNS) reagent according to Lindsay (1973), with slight modifications. The DNS reagent was prepared by dissolving 1 g of DNS, 0.05 g of sodium sulphite, and 20 g of sodium potassium tartrate (Rochelle salt) in 50 mL of NaOH (20 g L^{-1}) at room temperature. The volume was then adjusted to 100 mL with distilled water. The assay was conducted by mixing 1.5 mL of DNS reagent and 0.75 mL of each extract in tubes. The DNS extract ratio was adjusted case by case based on the estimated concentration of reducing sugar in the sample. The tubes were placed in a thermoblock (TD 200 P1, Falc Instruments S.r.l., Treviglio, Italy) set at 90 °C for 15 min, transferred to ice for rapid cooling for 10 min, and then brought to room temperature. Prior to readings, all samples were diluted with 5 mL of distilled water. The absorbance was measured at 540 nm using a UV-Vis spectrophotometer (ONDA UV-20, Giorgio Bormac S.r.l., Carpi, Italy) against a blank prepared by mixing 1.5 mL of DNS reagent and 0.75 mL of distilled water. RSC was calculated based on the calibration curves of glucose and expressed as percentage (w/w). The reducing sugar content was measured in triplicate.

2.3.6. Polyphenol oxidase (PPO) activity

PPO enzyme activity was determined following the method of Moscetti et al. (2019) with several modifications. One and a half grams of freeze-dried potato powder were homogenized with 15 mL of PBS (Phosphate Buffer Saline 0.1 M, pH 6.5) containing 2 g L^{-1} of polyvinylpolypyrrolidone (PVPP). The mixture was centrifuged at approximately 6300 × g for 20 min at 4 ± 0.5 °C and the resulting supernatant was collected and stored at 4 ± 1 °C prior to the enzymatic assay. The assay was conducted using a UV-Vis spectrophotometer (ONDA UV-20, Giorgio Bormac S.r.l, Carpi, Italy) at 420 nm for 2 min. Before the enzymatic assays, PBS was equilibrated in a water bath at 27 ± 0.5 °C, with temperature control by a refrigerated/heated bath circulator (HAAKE K10, Thermo Fisher Scientific, Waltham, MA). The final reaction mixture consisted of 0.6 mL of crude enzyme, 2.2 mL of PBS (0.1 M, pH 6.5), and 0.2 mL of catechol (2 mmol). One unit of enzyme activity (U) was defined as an increase in absorbance of 0.001 per minute. Enzyme activity was measured in triplicate.

2.4. Statistical analysis

Data handling and statistical analyses were performed using R software v4.2.2, in conjunction with the 'Agricolae', 'Hmisc', and 'Rtsne' packages, v1.3.5, v4.7.2, and v0.16, respectively.

For each storage time, the data underwent One-Way within-subject ANOVA to evaluate differences among cultivars. An additional One-Way within-subject ANOVA was conducted for each cultivar to investigate compositional changes during storage. ANOVA was carried out for both production seasons, with the season treated as a within-subject factor. The Fisher's pairwise comparison method was utilized, and the Least Significant Difference (LSD) was calculated at an appropriate level of significance ($p \leq 0.05$).

Pearson's linear correlation test was employed to identify significant bivariate correlations between the measured features. The linear correlation test was applied to the entire dataset (i.e., data from all cultivars) and separately for each cultivar. The strength of correlation was categorized as follows: $0.95 \leq r \leq 1$, excellent; $0.90 \leq r < 0.95$, very good; $0.80 \leq r < 0.90$, good; $0.70 \leq r < 0.80$, weak.

Additionally, both Principal Component Analysis (PCA) and t-Distributed Stochastic Neighbour Embedding (t-SNE) algorithms were independently applied to provide a graphical overview of the differences among cultivars over the 6-month storage period. The dataset was standardized through autoscaling to account for the varying magnitudes and units of measurement across features and, thus, to prevent features with larger scales from dominating the others. For PCA, the original data were transformed into score and loading vectors, and the scree-plot criterion was used to determine the necessary number of principal components (PCs). t-SNE is a non-linear Feature Extraction Algorithm (FEA) based on manifold learning, known for its ability to capture global and local structures of high-dimensional data and to identify clusters at various scales (Luo et al., 2021). Initially, the algorithm reduces high-dimensional Euclidean distances into conditional probabilities based on similarities between two data points. Subsequently, the Student's t-distribution is utilized to further transform probabilities into a low-dimensional space with a single degree of freedom. For dimensionality reduction using t-SNE, the 'perplexity' was set to 18, and the 'output dimensionality' was set to 2. The 'perplexity' parameter determines the effective number of neighbors used in the t-SNE algorithm and may impact data visualization when outside the range of 5–50 (Luo et al., 2021). The 'output dimensionality' refers to the number of dimensions in the low-dimensional space where data are reduced.

Table 1
Chemical, physico-chemical, physical, and enzymatic characteristics of four potato cultivars at the harvest. Within the same row, values followed by the same letter are not significantly different (LSD test, $p \leq 0.05$).

Physico-chemical and enzymatic parameters	Constance		Fontane		Gaudi		Jelly	
Dry matter content (DM, g kg^{-1})	177.70	c	197.00	a	171.30	c	186.30	b
Total Phenol Content (TPC, g kg^{-1})	0.80	b	0.56	c	1.07	a	0.77	b
Reducing Sugar Content (RSC, g kg^{-1})	11.60	b	2.80	c	27.10	a	21.70	a
Firmness (N)	64.51	c	92.51	a	75.01	b	77.82	b
CIELab colour difference (ΔE*)	2.31	b	2.12	b	5.75	a	2.23	b
PPO activity (U)	0.46	b	0.50	b	0.93	a	0.27	c

3. Results and discussion

3.1. Cultivars characterization at harvest

The four potato cultivars exhibited significant variability in terms of physico-chemical and enzymatic composition at harvest, as detailed in Table 1. DM content ranged from 171.3 g kg^{-1} in 'Gaudi' to 197.0 g kg^{-1} in 'Fontane'. Although 'Gaudi' demonstrated the highest TPC (1.07 g kg^{-1}) and RSC (27.1 g kg^{-1}), the latter value did not differ significantly from that of 'Jelly' (21.7 g kg^{-1}). Conversely, 'Fontane' exhibited the lowest TPC (0.56 g kg^{-1}) and RSC (2.8 g kg^{-1}), while also recording the highest firmness (92.51 N), followed by 'Jelly' and 'Gaudi' (77.82 N and 75.01 N, respectively). In contrast, 'Constance' displayed the lowest firmness value (64.51 N). Concerning CIELab color difference, 'Gaudi' showed the highest susceptibility to post-cut browning, with a ΔE* value (5.75) surpassing the perceptibility threshold (ΔE* = 3.5) after 120 min of air exposure, in accordance with Mokrzycki and Tatol (2011). Additionally, 'Gaudi' exhibited the highest PPO activity (0.93 U), implying a plausible positive correlation with the colorimetric parameter ΔE* for this specific cultivar. Finally, 'Jelly' showcased the lowest PPO activity among the cultivars.

The results indicate excellent suitability of the 'Fontane' cultivar for processing. 'Jelly' exhibited favorable attributes for both processing and fresh market use, qualifying it as a dual-purpose cultivar. 'Constance' exhibited favorable qualities for fresh market use, with medium DM, good TPC, and low RSC. Results for the 'Gaudi' indicated unfavorable characteristics for processing, including a low-medium DM, high RSC, and pronounced susceptibility to post-cut discolorations.

3.2. Cultivars characterization during storage

Only minimal changes in DM (Fig. 2A) and firmness (Fig. 2B) were observed during storage. 'Fontane' had the highest (200–210 g kg^{-1}) for three months, after which it was not significantly different from 'Jelly', which had an initial medium-high DM (190–200 g kg^{-1}). In contrast, 'Constance' and 'Gaudi' were significantly lower with DM below 180 g kg^{-1}, with no significant difference between the two cultivars. DM influences resistance to disintegration during cooking. "Waxy" cultivars with low DM (150–170 g kg^{-1}) have a moist appearance and disintegrate less, making them suitable for boiling or steaming. On the other hand, "mealy" potatoes, characterized by higher starch and DM (> 200 g kg^{-1}), experience greater water uptake and loss during cooking, resulting in a dry-appearing tissue that crumbles readily. Consumers and industry alike prefer "mealy" potatoes for baking and frying (McComber et al., 1988). For processing, DM also impacts process yield. Furthermore, for dried potatoes, low DM prolongs drying time, increasing both cost and environmental impact of the process.

'Fontane' consistently displayed the highest firmness values, 'Gaudi' and 'Jelly' exhibited intermediate values, while 'Constance' was less firm. The results confirm that DM strongly influences textural properties, but it is not the sole influencing factor. Indeed, starch content and distribution, cell size, and cell wall structure also contribute (Taylor et al., 2007). Consequently, a well-developed cell wall structure often corresponds to good firmness. Additionally, as suggested by Cabezas-Serrano et al. (2009), higher membrane stability may contribute to the favorable performance of 'Fontane' and 'Jelly' in terms of browning susceptibility, delaying the interaction between the PPO enzyme and substrates.

The trends in DM and firmness during storage primarily stem from two biochemical changes: respiration and water loss. Potato tubers continue to respire during storage, utilizing sugars generated from starch hydrolysis. Consequently, the loss of DM occurs due to starch hydrolysis, leading to weight reduction. Another significant biochemical change during storage is water loss. About 98 % of lost tuber moisture during storage is due to evaporation through the skin. Both processes are influenced by storage conditions, such as temperature and relative

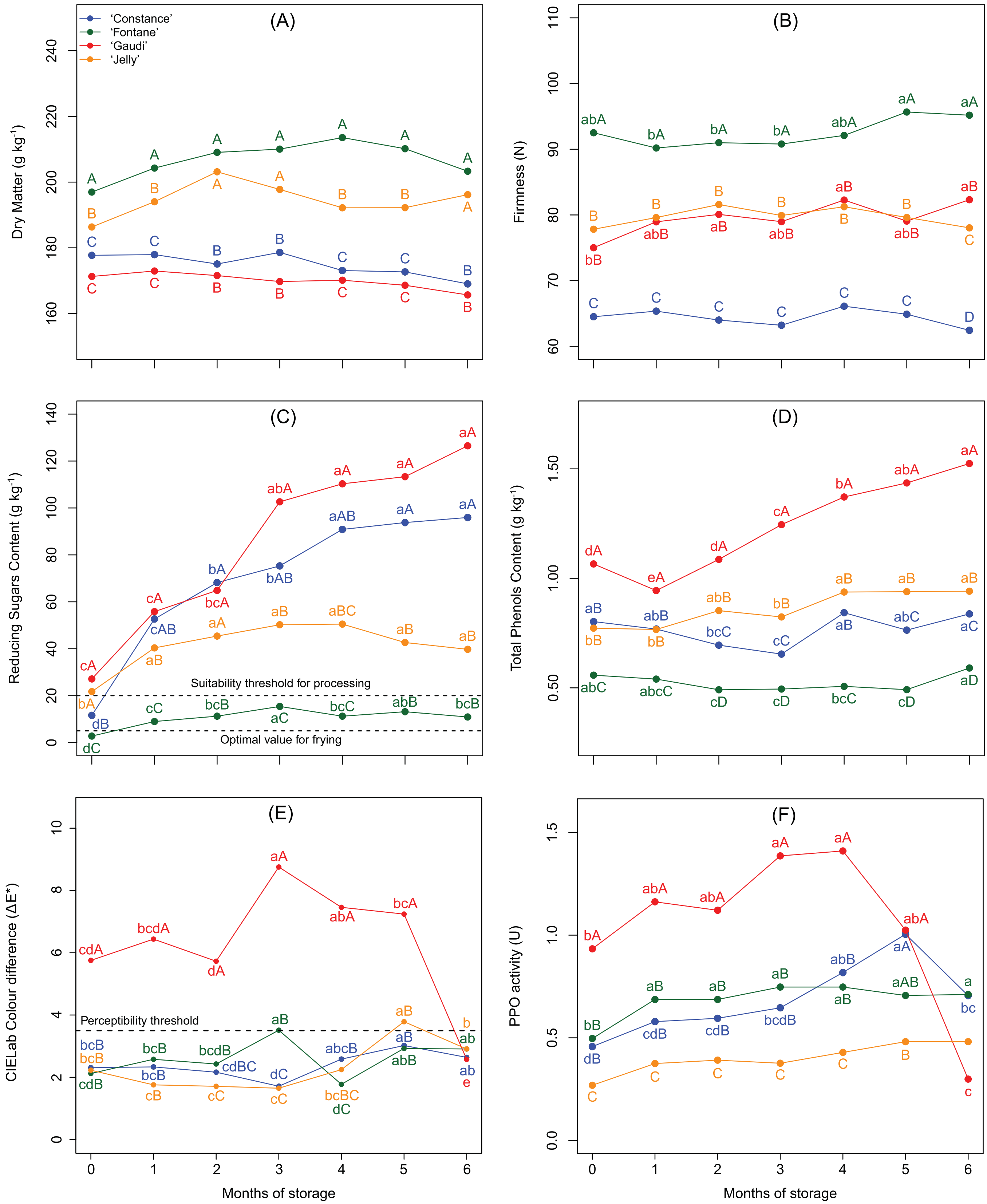

Fig. 2. Trends in dry matter content (A), firmness (B), reducing sugar content (C), total phenol content (D), CIELab colour difference (E) and PPO activity (F) of four potato cultivars over 6 months of storage at 7.2 ± 1 °C and ~90 % of RH. Lowercase letters of significance refer to within-cultivar variations during the 6 months of storage, while capital letters of significance refer to between-cultivar variations within each month of storage (LSD test, $p < 0.05$). Average values sharing the same letter are considered statistically non-significant.

humidity, as well as potato cultivar. Water loss is also influenced by other factors, including heat generation within potatoes, the quality of the potato skin, sprout growth, and ventilation. The equilibrium between DM loss via respiration and water loss via evaporation determines alterations in DM and firmness of tubers, thereby affecting weight loss. Results indicate that storage at 7.2 °C and controlling relative humidity stabilizes DM and firmness, potentially preserving tuber weights, as corroborated by Gikundi et al. (2022).

Trends in RSC and TPC (Fig. 2C and D, respectively) revealed significant differences among cultivars during storage. However, it is important to consider that ethylene was used to control sprouting during the storage of the four cultivars. It can provoke starch hydrolysis and, thus, changes in RSC, potentially influencing the observed differences across the cultivars (Tosetti et al., 2021).

RSC of 'Fontane' increased significantly, but remained within an acceptable range (8–15 g kg^{-1}), demonstrating the high tolerance of this cultivar to long-term storage, as reported by Elmore et al. (2015). In contrast, other cultivars exceeded the acceptability threshold for processing (20 g kg^{-1}) after only one month of storage. The results confirmed the suitability of the 'Fontane' cultivar for crisps or French fries, not only at harvest but also throughout the storage period. In fact, its RSC stabilized at lower than 20 g kg^{-1}, resulting in low acrylamide levels in the final product, as demonstrated by Biedermann-Brem et al. (2003) and Elmore et al. (2015).

'Jelly' is not recommended for industrial frying. However, its good tolerance to LTS (RSC stabilized at 40–50 g kg^{-1}) makes it suitable for fresh market use, avoiding excessive sweetness in the final product, which is historically considered an undesirable trait for potatoes (Burton, 1969). Moreover, even after a few months of storage, 'Jelly' can be roasted or fried, following cooking tips provided by the European Food Safety Authority (EFSA), such as i) using hot-air fryers instead of conventional deep oil fryers (Zaghi et al., 2019); and ii) frying at temperatures below 175 °C.

'Gaudi' and 'Constance' cultivars exhibited a low tolerance to LTS (RSC of 90 and 120 g kg^{-1}, respectively). Especially in the last months of storage, the high levels of RSC observed can result in a sweet taste, even for boiled or steamed potatoes. 'Gaudi' and 'Constance' were unsuitable for frying and roasting. In fact, the elevated levels of glucose and fructose result in unacceptable darkening of finished fried or roasted potatoes, leading to increased acrylamide production.TPC (Fig. 2D) did not exhibit clear trends, except for 'Gaudi', where it notably increased starting from the first month of storage (from 0.95 to 1.50 g kg^{-1}). Moreover, 'Gaudi' consistently reported the highest TPC. 'Jelly' often displayed a TPC statistically higher than 'Constance' (from 0.76 to 0.94 and 0.65–0.84 g kg^{-1}, respectively), while 'Fontane' consistently reported the lowest values (from 0.49 to 0.59 g kg^{-1}).

In addition to their contribution to nutritional value, phenol content can also help explain the susceptibility to browning of certain cultivars. Brecht et al. (2004) reported that vegetable products with higher TPC are more susceptible to browning. Hasegawa et al. (1966) indicated that chlorogenic acid, the principal phenolic compound in the inner tissue of potato tubers, was the only phenolic compound that increased significantly during the storage of potatoes at 4 °C. The authors postulated that chlorogenic acid content is positively related to the accumulation of reducing sugars. Consistent with this statement, 'Gaudi' exhibited a significant increase in both RSC and TPC starting after the first month of cold storage. However, this speculation needs to be verified through further investigations focusing on determining the chlorogenic acid content in tubers, which is also responsible for discoloration known as after-cooking darkening (Wang-Pruski and Nowak, 2004). This browning affects both the processing industry (crisps, dried or pre-cooked potato) and fresh market use (frying, boiling, etc.). The authors reported that the severity of darkening is always higher in the cortex tissue, where the highest concentration of chlorogenic acid is detected.

Fig. 2E illustrates the post-cut browning development after 120 min of air exposure. 'Gaudi' consistently exhibited the highest susceptibility for discoloration, consistently reporting the highest ΔE* values, except for the last month of storage, during which a significant decrease was observed. According to the ΔE* classification proposed by Mokrzycki and Tatol (2011), ΔE* values for 'Gaudi' remained higher than the perceptibility threshold ($\Delta E^* > 3.5$) until the 5th month, indicating a "clear difference" of color. In contrast, the other cultivars displayed some fluctuations without a distinct pattern, with ΔE* values consistently ranging between "minor" (detectable by a trained observer) and "just perceptible" color differences (detectable by an untrained observer).

The PPO activity (Fig. 2F) exhibited a similar trend to ΔE*. Specifically, 'Gaudi' showed the highest PPO activity throughout the storage period, except for the last two months. Subsequently, the enzyme activity dropped to the same level as observed in other cultivars. Notably, when PPO activity decreased, the ΔE*shifted to being "just perceptible", despite the increase in TPC. These findings suggest the possibility that the decline in PPO activity could be linked to an increase in phenol content, particularly of chlorogenic acid, which is a major phenolic compound in potatoes. Chlorogenic acid is known to interact with PPO activity (Thybo et al., 2006), but when its concentration exceeds a certain threshold, it may become an inhibitory factor. Indeed, Cheng et al. (2020) reported a significant reduction in relative PPO activity of fresh-cut potato slices with increasing chlorogenic acid concentration. Another potential explanation for the decline in enzyme activity could be associated with the onset of sprouting. Sprouting can alter the physico-chemical and nutritional characteristics of potatoes and may lead to the production of toxic compounds in the flesh, such as solanine and chaconine (Visse-Mansiaux et al., 2021). These changes could potentially impact protein components, including enzymes, by causing structural modifications and denaturation.

'Jelly' exhibited the lowest PPO activity, which remained relatively stable during storage. 'Fontane' showed a more consistent trend compared to 'Constance'. In 'Constance', there was a significant increase in PPO activity from the 3rd to the 5th month of storage, followed by a decrease in the last month. Despite 'Constance' and 'Fontane' both having significantly higher PPO activity than 'Jelly', these cultivars demonstrated similar susceptibility to post-cut browning. This observation can be elucidated by considering phenol content and composition. Both cultivars reported lower TPC compared to 'Jelly', resulting in a reduced substrate availability for the enzyme. Furthermore, as noted by Thybo et al. (2006), not all potato phenols exhibit the same affinity for PPO enzymes. The authors specifically documented a positive correlation between enzymatic browning and PPO activity with tyrosine and chlorogenic acid, and a negative correlation with caffeic acid. Another influential factor impacting enzymatic browning is the content of citric acid. Ingallina et al. (2020) reported that potato cultivars with elevated levels of citric acid experience inhibition of enzymatic browning in fresh-cut potatoes.

Susceptibility to browning is an important factor in the suitability of a potato cultivar for certain processing streams, especially fresh-cut and dried. All cultivars except 'Gaudi' showed low susceptibility throughout the storage period. For susceptible cultivars, like 'Gaudi', chemical browning inhibitors (e.g., citric acid, ascorbic acid, L-cysteine, sulfites, etc.) are available to regulate enzymatic reactions. Also, recent studies have reported the efficacy of novel anti-browning agents (Ru et al., 2020; Feng et al., 2022). However, these substances can impact the quality and composition of the fresh-cut product (Rocculi et al., 2007), as well as consumer health. For instance, the allergenic effects of sulfites on certain individuals are well-documented (Taylor et al., 1986). Consequently, potato cultivars with low susceptibility to browning are key to producing a high-quality product and realizing cost savings by minimizing chemical applications.

3.3. Results overview through unsupervised analysis of analytical data

Results presented in Sections 3.1 and 3.2 are summarized in Fig. 3,

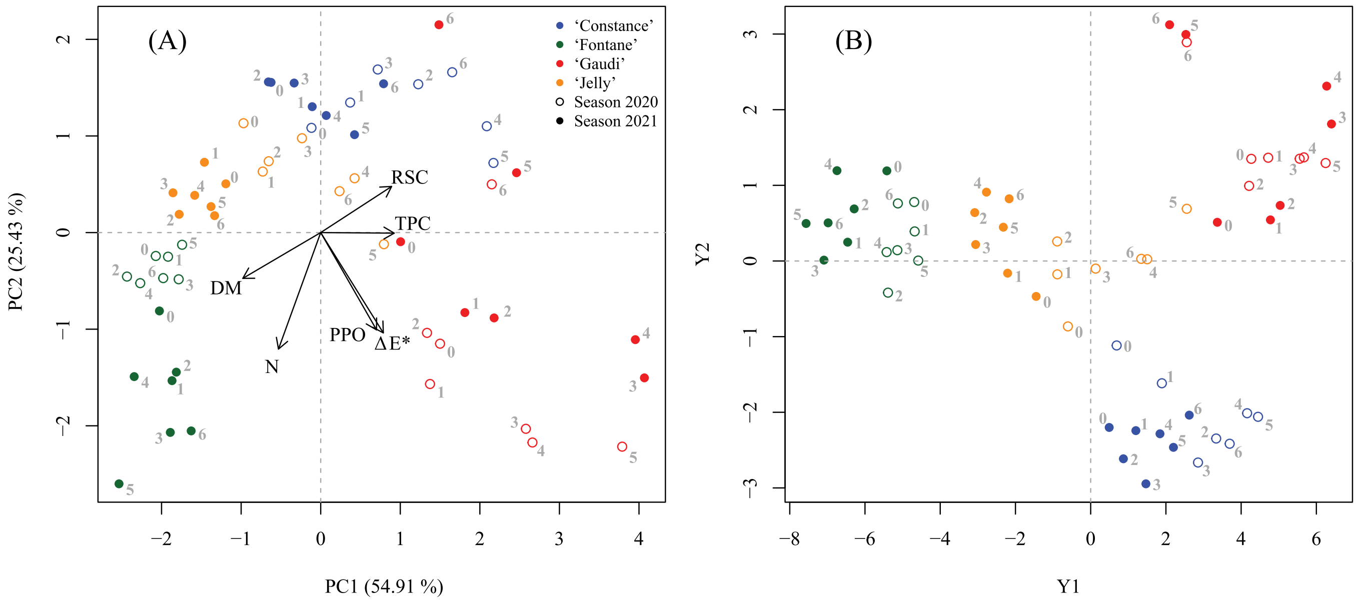

Fig. 3. Principal Component Analysis bi-plot (A) and t-Distributed Stochastic Neighbour Embedding plot (B) computed using data from physicochemical and enzymatic analyses of four potato cultivars conducted over 6 months of storage at 7.2 ± 1 °C and ~90 % of RH for the two production seasons. The use of empty (○) and full (•) dots served to distinguish between the two seasons (2020 and 2021, respectively), while the number in proximity to the dot indicated the corresponding storage month.

which shows outcomes from both linear (PCA) and non-linear (t-SNE) feature extraction algorithms. In general, results from both methods were consistent with ANOVA results, and were instrumental in comprehending i) the potential of each cultivar for processing and ii) the shifts in quality attributes during storage.

Concerning PCA (Fig. 3A), the two primary principal components (PCs) collectively explained 80.38 % of the total variance. Despite some overlapping, the score plot allowed for a rough identification of a distinct cluster for each cultivar. 'Fontane' clusters were positively correlated with both DM and firmness, while showing a negative correlation with both RSC and TPC. Additionally, 'Fontane' exhibited a tightly-knit cluster, underscoring the higher stability of this cultivar during storage. On the contrary, 'Constance' displayed a positive correlation with RSC and TPC, but a negative correlation with DM and firmness. 'Gaudi' exhibited a robust positive correlation with factors related to post-cut browning, particularly evident up to the 4–5th months of storage. 'Gaudi' scores were positively correlated with RSC and TPC, especially in the later storage months, when its physicochemical and enzymatic attributes resembled those of 'Constance'. 'Jelly' had a strong negative correlation with susceptibility to browning, but a positive correlation with RSC. PPO activity and ΔE* were positively correlated, as indicated by their position in the fourth quadrant of the PCA plot. TPC exhibited a positive correlation with both PPO activity and ΔE*, as well as with RSC. These results were in line with the PCA conducted by Cabezas-Serrano et al. (2009). DM content and firmness resided in the third quadrant, demonstrating a positive correlation between them. Additionally, DM content and RSC displayed a negative correlation with each other, corroborating observations made by Iritani (1981) during the latter stages of tuber maturation.

Furthermore, the t-SNE analysis was employed as a non-linear method for visualizing the cultivar characterization data (Fig. 3B). The enhanced clustering capabilities of this technique were readily apparent even in the two-dimensional space. t-SNE outperformed PCA in terms of cluster visualization for subsequent analyses, in line with observations made by Luo et al. (2021).

3.4. *Linear correlation insights*

The potential correlations speculated in the PCA plot were statistically confirmed by the outcomes of the Pearson's linear correlation test (Table 2). In general, good correlation metrics ($0.80 \leq r < 0.90$) were established for cultivars exhibiting medium to high variability throughout the storage months. Indeed, 'Fontane' showcased only a few correlation coefficients that were unsatisfactory ($r < 0.70$) or of limited interest.

'Constance' displayed a significant negative correlation between ΔE* and DM ($r = -0.84$) and a notable positive correlation between PPO activity and RSC ($r = 0.81$). The declining trend in DM corresponded with an increase in ΔE*, PPO activity, and RSC. In particular, the noteworthy albeit imperfect ($r = -0.67$) negative correlation between DM and RSC substantiated the findings of both PCA and Iritani (1981).

'Gaudi', identified as the most browning-susceptible cultivar, revealed a good positive correlation ($r = 0.84$) between ΔE* and PPO activity.

For the 'Jelly' cultivar, a good positive correlation emerged between DM and firmness ($r = 0.81$), confirming the contribution of DM, primarily composed of starch, to its textural properties as emphasized by Taylor et al. (2007). Weak positive correlations were evident between ΔE* and TPC, as well as between PPO activity and TPC ($r = 0.77$ and 0.78, respectively). These coefficients underscored the influence of phenol content on enzymatic browning and PPO activity, a phenomenon outlined by Thybo et al. (2006).

3.5. *Optimizing potato cultivar utilization: from processing excellence to consumer preferences*

An optimal end-use plan for potato cultivars was developed based on the results of physico-chemical and enzymatic analyses (Fig. 4). This schedule recommends the monthly allocation of each cultivar for both processing industry and fresh market use. Optimal stability of potato cultivars during storage is crucial as it ensures that the industry processes a suitable product throughout the storage period. Additionally, maintaining consistent qualities in potatoes akin to those at harvest portrays a positive company (or consortium) image while safeguarding consumer satisfaction and health. In this context, 'Fontane' is an excellent choice, remaining stable during storage and therefore suitable for various fresh market uses such as frying, roasting, or "gnocchi", along with the most important industrial processing. 'Jelly' also

Table 2
Correlation matrix depicting the relationships among physical, chemical, physicochemical, and enzymatic parameters based on data from each potato cultivar during a 6-month storage period at 7.2 ± 1 °C and ~90 % RH for two production seasons.

Cultivar		ΔE*		DM		Firmness		PPO		RSC	
'Constance'	**ΔE***	-		-		-		-		-	
	DM	-0.84	***	-		-		-		-	
	Firmness	0.12		0.11		-		-		-	
	PPO	0.70	**	-0.62	*	-0.02		-		-	
	RSC	0.55	*	-0.67	**	-0.08		0.81	***	-	
	TPC	0.61	*	-0.52		0.43		0.27		0.24	
'Fontane'	**ΔE***	-		-		-		-		-	
	DM	0.52		-		-		-		-	
	Firmness	0.66	**	0.54	*	-		-		-	
	PPO	0.61	*	0.64	*	0.65	*	-		-	
	RSC	-0.23		-0.14		-0.51		-0.14		-	
	TPC	0.01		-0.33		0.34		0.13		-0.47	
'Gaudi'	**ΔE***	-		-		-		-		-	
	DM	-0.09		-		-		-		-	
	Firmness	0.13		-0.03		-		-		-	
	PPO	0.84	***	-0.15		-0.03		-		-	
	RSC	-0.26		-0.15		0.05		-0.26		-	
	TPC	-0.23		-0.42		0.31		-0.31		0.78	**
'Jelly'	**ΔE***	-		-		-		-		-	
	DM	-0.66	*	-		-		-		-	
	Firmness	-0.56	*	0.81	***	-		-		-	
	PPO	0.68	**	-0.51		-0.40		-		-	
	RSC	0.08		0.02		0.10		0.49		-	
	TPC	0.77	**	-0.64	*	-0.55	*	0.78	**	0.49	

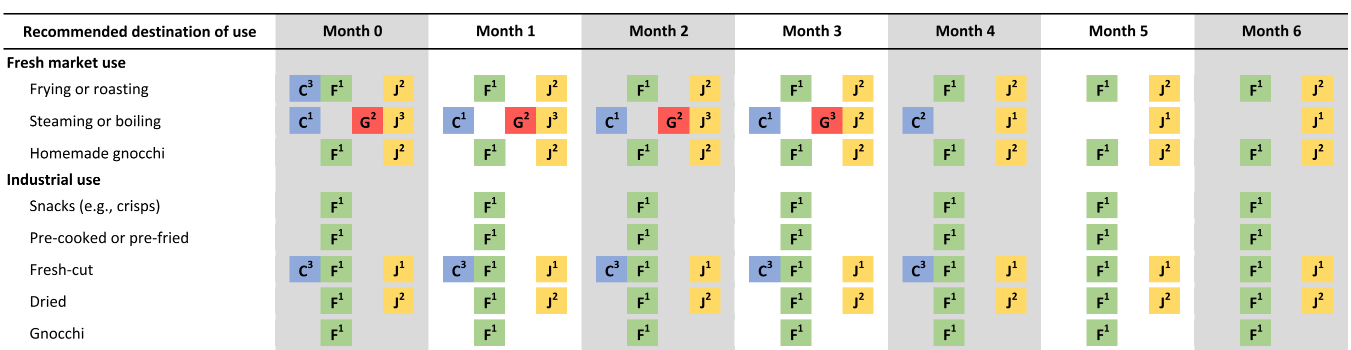

Fig. 4. Optimal use schedule for each analyzed potato cultivar during 6 months of storage at 7.2 ± 1 °C and ~90 % RH. Superscripts indicate monthly cultivar rankings for specific end uses. C: 'Constance'; F: 'Fontane'; G: 'Gaudi'; J: 'Jelly'.

demonstrates good stability during storage and a favorable processing profile. Particularly for fresh-cut products, 'Jelly' exhibits superior attributes compared to 'Fontane' in terms of nutritional properties, TPC, PPO activity, and susceptibility to browning. This latter aspect is significant in extending the product's shelf life while minimizing the need for anti-browning pre-treatments. Nonetheless, given the versatile ways consumers use fresh-cut potatoes (e.g., frying, baking, salads, etc.), it is crucial to label for the optimal final use along with appropriate tips and precautions. In this regard, 'Fontane' is recommended for frying, while 'Jelly' is suitable for multipurpose use, with specific guidelines for reducing acrylamide production during frying. Furthermore, investigating the effect of reconditioning on 'Jelly' is necessary. Zommick et al. (2014) revealed that reconditioning tubers at 16 °C for 21 days enhanced their color after frying due to reduced RSC levels. This process could render 'Jelly' more suitable and safer for frying. 'Constance' is an appropriate choice for boiling and steaming and can also be processed into fresh-cut products. However, selling and consuming this cultivar by the 3rd month is preferable due to its low tolerance to long-term storage. 'Gaudi' is marketable only as a raw product until the 2nd month of storage, with boiling or steaming specified as the optimal usage. To extend the sale period for 'Constance' and 'Gaudi' beyond January and December, respectively, the impact of reconditioning must be explored. Reduction in RSC tends to be more noticeable for LTS-susceptible potato cultivars (Zommick et al., 2014). Furthermore, sensory analysis to determine the level of reducing sugars that results in unacceptable sweetness is essential.

Regarding other end uses, such as mashed potatoes, the suitability of cultivars is also influenced by consumer preferences and habits. Creamy and dense mashed potatoes are best achieved with cultivars possessing medium DM-content (e.g., 'Constance' and 'Gaudi'). On the other hand, for "featherlight" mashed potatoes, cultivars with high starch and low moisture content are ideal (e.g., 'Fontane' and 'Jelly'). These types of potato tubers yield a light, soft mash due to increased water absorption during cooking.

4. Conclusions

The potato processing industry must identify and select diverse raw materials based on the desired final product. In terms of fresh market consumption, providing detailed information on potato packaging labels is crucial to inform consumers about the optimal usage of fresh tubers, thereby preventing improper cooking and potential health concerns. Typically, descriptions of potato cultivars encompass both pre- and post-harvest aspects. However, this study primarily focused on the key quality parameters pertaining to post-harvest conditions. The comprehensive analysis of physico-chemical and enzymatic characteristics of four potato cultivars, conducted at both harvest and during storage, revealed substantial and cultivar-specific disparities.

Specifically, among the “Patata dell'Alto Viterbese” PGI cultivars examined in this experiment, 'Fontane' exhibited the most favorable traits for processing, followed by 'Jelly'. 'Constance' and 'Gaudi' displayed favorable attributes for fresh market use, particularly for boiling or steaming. Unlike 'Gaudi', 'Constance' also exhibited qualities conducive to processing as a fresh-cut product. These findings highlight the significant disparities among the PGI potato cultivars in terms of post-harvest performance and represent an important step toward optimizing of the supply chain by the PGI consortium. However, further investigations are needed to assess other vital cultivars cultivated in the “Patata dell'Alto Viterbese” PGI region. Analyzing changes in quality parameters during storage, including fresh weight loss, phenol composition (e.g. chlorogenic acid), citric acid content, ascorbic acid content, antioxidant activity, phenylalanine ammonia-lyase (PAL) and peroxidase (POD) activity, the impact of the reconditioning process and frying-induced acrylamide production, will be crucial for having the full picture of impact of the PGI terroir on the quality, storability and processability of the product. Last but not least, sensory analysis could shed light on the influence of LTS on potato flavor and aid in evaluating PGI potato cultivars based on their organoleptic attributes.

Declaration of Competing Interest

Roberto Moscetti reports financial support was provided by Lazio Region. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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References

Biedermann-Brem, S., Noti, A., Grob, K., Imhof, D., Bazzocco, D., Pfefferle, A., 2003. How much reducing sugar may potatoes contain to avoid excessive acrylamide formation during roasting and baking? Eur. Food Res. Technol. 217, 369–373. https://doi.org/10.1007/s00217-003-0779-z.

Burton, W.G., 1969. The sugar balance in some British potato varieties during storage. II. The effects of tuber age, previous storage temperature, and intermittent refrigeration upon low-temperature sweetening. Eur. Potato J. 12, 81–95. https://doi.org/10.1007/BF02364726.

Cabezas-Serrano, A.B., Amodio, M.L., Cornacchia, R., Rinaldi, R., Colelli, G., 2009. Suitability of five different potato cultivars (*Solanum tuberosum* L.) to be processed as fresh-cut products. Postharvest Biol. Technol. 53, 138–144. https://doi.org/10.1016/j.postharvbio.2009.03.009.

Cheng, D., Wang, G., Tang, J., Yao, C., Li, P., Song, Q., Wang, C., 2020. Inhibitory effect of chlorogenic acid on polyphenol oxidase and browning of fresh-cut potatoes. Postharvest Biol. Technol. 168, 111282 https://doi.org/10.1016/j.postharvbio.2020.111282.

ECPD, 2023. The European cultivated potato database [WWW Document]. URL https://www.europotato.org/ (accessed 11.21.22).

EFSA, 2015. Acrylamide Food EFSA Explains Risk Assess. 2015, 4.

Elmore, J.S., Briddon, A., Dodson, A.T., Muttucumaru, N., Halford, N.G., Mottram, D.S., 2015. Acrylamide in potato crisps prepared from 20 UK-grown varieties: Effects of variety and tuber storage time. Food Chem. 182, 1–8. https://doi.org/10.1016/j.foodchem.2015.02.103.

FAOSTAT, 2022. Food and Agriculture Organization of the United Nations [WWW Document]. URL https://www.fao.org/faostat/en/#data/QCL/visualize. Accessed 21 Nov 2022 (accessed 11.21.22).

Feng, Y., Zhang, D., Sun, Y., Meng, Z., Malik, A.U., Zhang, S., Yan, H., Wang, Q., 2022. A novel anti-browning agent S-furfuryl thioacetate for fresh-cut potato screened from food-derived sulfur compounds. Postharvest Biol. Technol. 192, 112007 https://doi.org/10.1016/j.postharvbio.2022.112007.

Gikundi, E.N., Buzera, A.K., Orina, I.N., Sila, D.N., 2022. Storability of Irish potato (*Solanum tuberosum* L.) varieties grown in Kenya, under different storage conditions. Potato Res. https://doi.org/10.1007/s11540-022-09575-8.

Gómez-Castillo, D., Cruz, E., Iguaz, A., Arroqui, C., Vírseda, P., 2013. Effects of essential oils on sprout suppression and quality of potato cultivars. Postharvest Biol. Technol. 82, 15–21. https://doi.org/10.1016/j.postharvbio.2013.02.017.

Hasegawa, S., Johnson, R.M., Gould, W.A., 1966. Effect of cold storage on chlorogenic acid content of potatoes. J. Agric. Food Chem. 14, 165–169. https://doi.org/10.1021/jf60144a020.

Iritani, W.M., 1981. Growth and preharvest stress and processing quality of potatoes. Am. Potato J. 58, 71–80. https://doi.org/10.1007/BF02855381.

ISTAT, 2022. Italian National Institute of Statistics [WWW Document]. URL http://dati.istat.it/Index.aspx?DataSetCode=DCSP_COLTIVAZIONI# (accessed 11.21.22).

Karathanos, V.T., 1999. Determination of water content of dried fruits by drying kinetics. J. Food Eng. 39, 337–344. https://doi.org/10.1016/S0260-8774(98)00132-0.

Kumar, D., Singh, B.P., Kumar, P., 2004. An overview of the factors affecting sugar content of potatoes. Ann. Appl. Biol. 145, 247–256. https://doi.org/10.1111/j.1744-7348.2004.tb00380.x.

Lindsay, H., 1973. A colorimetric estimation of reducing sugars in potatoes with 3,5-dinitrosalicylic acid. Potato Res. 16, 176–179. https://doi.org/10.1007/BF02356048.

Luo, N., Yang, X., Sun, C., Xing, B., Han, J., Zhao, C., 2021. Visualization of vibrational spectroscopy for agro-food samples using t-Distributed Stochastic Neighbor Embedding. Food Control 126, 107812. https://doi.org/10.1016/j.foodcont.2020.107812.

McComber, D.R., Osman, E.M., Lohnes, R.A., 1988. Factors related to potato mealiness. J. Food Sci. 53, 1423–1425. https://doi.org/10.1111/j.1365-2621.1988.tb09291.x.

McKenzie, M., Corrigan, V., 2016. Potato flavor. In: Singh, J., Kaur, L. (Eds.), Advances in Potato Chemistry and Technology. Academic Press, pp. 339–367.

Mokrzycki, W.S., Tatol, M., 2011. Colour difference ΔE - a survey Mokrzycki. Mach. Graph. Vis. 20, 383–411.

Moscetti, R., Raponi, F., Monarca, D., Bedini, G., Ferri, S., Massantini, R., 2019. Effects of hot-water and steam blanching of sliced potato on polyphenol oxidase activity. Int. J. Food Sci. Technol. 54, 403–411. https://doi.org/10.1111/ijfs.13951.

Pinhero, R.G., Yada, R.Y., 2016. Postharvest storage of potatoes, in: Singh, J., Kaur, L. (Eds.), Advances in Potato Chemistry and Technology. Academic Press, pp. 283–309. doi:10.1016/B978-0-12-800002-1.01001-3.

Pringle, R., Bishop, C., Clayton, R., 2009. Potatoes Postharvest. CABI.

Pritchard, M.K., Scanlon, M.G., 1997. Mapping dry matter and sugars in potato tubers for prediction of whole tuber process quality. Can. J. Plant Sci. 77, 461–467. https://doi.org/10.4141/P96-111.

Rocculi, P., Galindo, F.G., Mendoza, F., Wadsö, L., Romani, S., Rosa, M.D., Sjöholm, I., 2007. Effects of the application of anti-browning substances on the metabolic activity and sugar composition of fresh-cut potatoes. Postharvest Biol. Technol. 43, 151–157. https://doi.org/10.1016/j.postharvbio.2006.08.002.

Ru, X., Tao, N., Feng, Y., Li, Q., Wang, Q., 2020. A novel anti-browning agent 3-mercapto-2-butanol for inhibition of fresh-cut potato browning. Postharvest Biol. Technol. 170, 111324 https://doi.org/10.1016/j.postharvbio.2020.111324.

Silveira, A.C., Oyarzún, D., Sepúlveda, A., Escalona, V., 2017. Effect of genotype, raw-material storage time and cut type on native potato suitability for fresh-cut elaboration. Postharvest Biol. Technol. 128, 1–10. https://doi.org/10.1016/j.postharvbio.2017.01.011.

Singleton, V.L., Rossi, J.A., 1965. Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. Am. J. Enol. Vitic. 16, 144–158. https://doi.org/10.5344/AJEV.1965.16.3.144.

Taylor, M.A., McDougall, G.J., Stewart, D., 2007. Potato Flavour and Texture, Potato Biology and Biotechnology: Advances and Perspectives. Elsevier B.V. https://doi.org/10.1016/B978-044451018-1/50066-X.

Taylor, S.L., Higley, N.A., Bush, R.K., 1986. Sulfites in foods: uses, analytical methods, residues, fate, exposure assessment, metabolism, toxicity, and hypersensitivity 1–76.

Thybo, A.K., Christiansen, J., Kaack, K., Petersen, M.A., 2006. Effect of cultivars, wound healing and storage on sensory quality and chemical components in pre-peeled potatoes, 39, 166–176. https://doi.org/10.1016/j.lwt.2004.11.010.

Torres, M.D.Á., Parreño, W.C., 2016. Thermal processing of potatoes. In: Singh, J., Kaur, L. (Eds.), Advances in Potato Chemistry and Technology. Academic Press, pp. 403–457.

Tosetti, R., Waters, A., Chope, G.A., Cools, K., Alamar, M.C., McWilliam, S., Thompson, A.J., Terry, L.A., 2021. New insights into the effects of ethylene on ABA catabolism, sweetening and dormancy in stored potato tubers. Postharvest Biol. Technol. 173, 111420 https://doi.org/10.1016/j.postharvbio.2020.111420.

United Nations, 2022. Sustainable Development Goals [WWW Document]. URL https://sdgs.un.org/goals (accessed 11.21.22).

Visse-Mansiaux, M., Tallant, M., Brostaux, Y., Delaplace, P., Vanderschuren, H., Dupuis, B., 2021. Assessment of pre- and post-harvest anti-sprouting treatments to replace CIPC for potato storage. Postharvest Biol. Technol. 178 https://doi.org/10.1016/j.postharvbio.2021.111540.

Wang-Pruski, G., Nowak, J., 2004. Potato after-cooking darkening. Am. J. Potato Res. 81, 7–16. https://doi.org/10.1007/BF02853831.

Zaghi, A.N., Barbalho, S.M., Guiguer, E.L., Otoboni, A.M., 2019. Frying process: from conventional to air frying technology. Food Rev. Int. 35, 763–777. https://doi.org/10.1080/87559129.2019.1600541.

Zommick, D.H., Knowles, L.O., Knowles, N.R., 2014. Tuber respiratory profiles during low temperature sweetening (LTS) and reconditioning of LTS-resistant and susceptible potato (*Solanum tuberosum* L.) cultivars. Postharvest Biol. Technol. 92, 128–138. https://doi.org/10.1016/j.postharvbio.2014.01.020.