

Watercore in Apple Landraces (*Malus domestica* Borkh.) as a quality indicator

La vitrescencia en cultivares locales de manzano (*Malus domestica* Borkh.) como indicador de calidad

Alberto Arnal¹

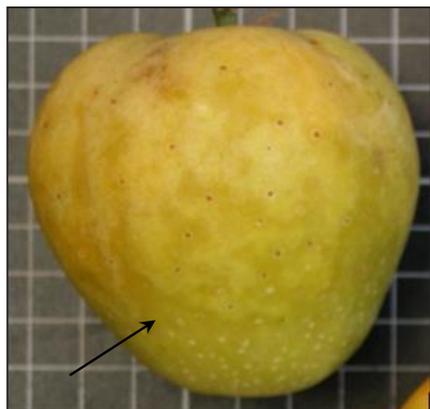
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1. Researcher, Ph.D., IMIDRA, Madrid, Spain, a.arnal@alumnos.upm.es

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ABSTRACT

Watercore is the presence of a vitrified texture intruded in the pulp of the fruit. It is found in fruits from different genus and families; and it has been studied in apples. Watercore was described, in apples, as a texture with differential sensorial characteristics in relationship with the ordinary pulp, and its presence is currently considered a defect in apple production, causing economic losses. In this study, it is described as a dichotomous descriptor. We analysed 641 apples from a region belonging to Central Spain (Guadarrama mountain range and the close Tagus Basin River); it was found that around 30% of those apples shown this characteristic, being practically all of them from landraces. Studies related to traditional cultivars do not analyze such characteristic, considered up today as a defect. Nevertheless, we discuss that watercore can have some potential as it gives to apple a distinct appearance and aroma, all of them of value in differential quality and international seal protection. As a result, we conclude our preliminary analysis that it is highly recommended to take into consideration watercore as a descriptor in apple characterizations.

Keywords: germplasm; morphological descriptor; quality; rural development; traditional cultivars; vitreous texture.

RESUMEN

El corazón acuoso, núcleo acuoso o vitrescencia es la presencia de una textura vitrificada en la pulpa del fruto. Se encuentra en frutas de diferentes géneros y familias, y se ha estudiado en manzano. El corazón acuoso se describió, para la manzana, como una textura con características sensoriales diferenciales en relación con su pulpa ordinaria, y su presencia se considera actualmente un defecto en la producción de manzana, provocando pérdidas económicas. En este estudio, se describe el corazón acuoso como un descriptor dicotómico. Se analizaron 641 manzanas de una zona del centro de España (sierra de Guadarrama y su zona próxima en la cuenca del Tajo), encontrándose que alrededor del 30% de esas manzanas presentaban esta característica, siendo prácticamente todas de

cultivares tradicionales. Los estudios morfológicos de germoplasma relacionados con estos cultivares no analizan tal característica, considerada hoy como un defecto. Sin embargo, discutimos que este corazón acuoso puede tener cierto potencial, ya que le da a la manzana una apariencia y un aroma distintos, todos ellos de posible valor en términos de calidad diferenciada, con el correspondiente sello de protección internacional. Como resultado, se concluye con nuestro análisis preliminar que es muy recomendable tener en cuenta el núcleo de agua como descriptor dentro de las caracterizaciones de manzano.

Palabras clave: calidad; cultivar tradicional; desarrollo rural; descriptor morfológico; germoplasma; textura vítrea.

INTRODUCTION

Watercore, less known as vitrification, is a translucent or glassy texture in the pulp of the apple (Figure 1). According to Beaudry (2014), Paul Sorauer performed the first published description of this phenomenon in apples in 1886. He described it as a *glassy* flesh, which was somewhat distinctly sweeter, firmer, with less intercellular air and starch, smelling differently, but also differed for browning quicker than the unaffected tissue (Beaudry, 2014). Although watercore has been studied in apples, this characteristic has also been identified in peach [*Prunus persica* (L.) Stokes] (Yamane *et al.*, 2020), pear (*Pyrus* spp.) (Liu *et al.*, 2021) and mangosteen (*Garcinia mangostana* L.) (Matra *et al.*, 2019).

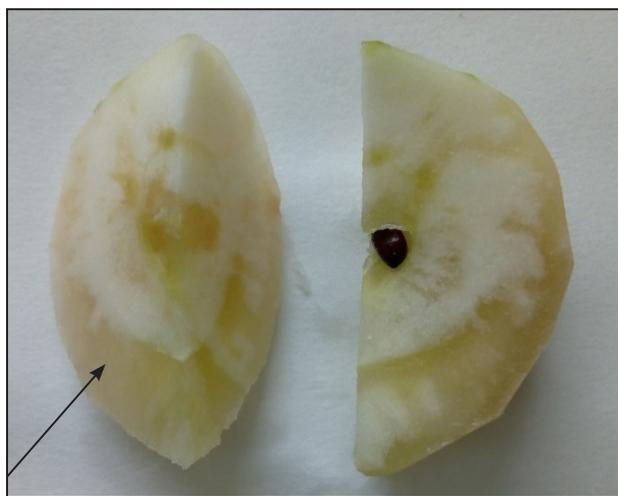


Figure 1. Watercore in a madrilean landrace apple (black arrow) in a freshly cut apple.

The vitreous appearance is due to an invasion of a liquid rich in sorbitol. Sorbitol is polyhydric sugar alcohol synthesized from glucose by hydrogenation. This liquid fills the intercellular spaces, which are normally occupied by air (Beaudry, 2014; Liu *et al.*, 2021). Vitrification is currently considered a defect in fruit crops, alleging that a deficiency of calcium in the soil might be the main cause (Calvo and Candan, 2013), being problems in storage one of the most negative consequences (Saquet, 2020). Nevertheless, susceptibility to watercore also depends on the cultivar, cultural practices, disorders in the water regime, contrasts in temperature, high radiation, and an unbalanced ratio source to sink ratio (Beaudry, 2014). As apples are one of the major temperate crops (Pereira-Lorenzo *et al.*, 2018), there exist many techniques to detect watercore such as light transmission, infrared spectroscopy, thermography, nuclear magnetic resonance, X-ray computed tomography, and even fruit density (Beaudry, 2014; Huang *et al.*, 2020).

Although this defect is important in crops and depends on the cultivar, international authorities such as the International Union for the Protection of Plant Varieties (UPOV, 2018) does not include this characteristic in their manual. In addition, research published on apple landraces is not considering watercore, although the great effort done on phenotyping. Some examples of those works are the one from India (Dolker *et al.*, 2021) and from Greece (Ganopoulos *et al.*, 2018).

Among other purposes, research in traditional cultivars is oriented towards the characteristics' detection of agronomic interest, sensory evaluation, and ultimately, their possible commercialization as in the case of the 'Pero de Ceheguín' (Martínez *et al.*, 2020). There is a European legal framework favourable to the use of local agricultural resources through the Rural Development (UE Regulation n °1305/2013) and labelling on quality regimes (UE Regulation n °1151/2012). The legal framework is manifested in the product with a seal that guarantees superior characteristics compared to a general set of products of the same type. As a result, there is the Protected Designation of Origin (PDO) 'Reineta del Bierzo' and the Protected Geographical Indication (PGI) 'Poma de Girona'. These two products added in 2017 an economic value in the destination market of more than three and a half million euros (MAPA, 2020). Furthermore, 'Esperiega de Ademuz', 'Pero de Ceheguín', and 'Pero de La Hiruela' are also some apple cultivars with certain rename in Spain (specially the

first one), but they are not enjoying any international seal yet.

The aim of this research is to analyse the presence and extent of watercore in traditional cultivars from the region of Madrid (Spain) to consider this characteristic in both, germplasm characterisation, and in sensorial analysis.

MATERIAL AND METHODS

A set of 463 apples from 51 trees belonging to 20 apple landraces from rural regions of Madrid Spain (Table 1) were evaluated with 178 apples from 6 references (Table 2) for the 'watercore' trait. Apple trees belong to several rural areas that belong to the region of Madrid (Guadarrama mountain range and the Tagus Basin River). The Guadarrama area is 1.200 m a.s.l. on average, although it can reach 2.000 m a.s.l., with a temperate climate that still retains some Mediterranean traits from the surrounding such as hot summers and summer drought.

Table 1. Number of apples sampled by landrace.

Landrace	Apples	Landrace	Apples
Agridulce	10	Pero gordo	15
Amarillo de el Paular	24	Pero pardo	37
Camueso	35	Pero real	28
Camueso tardío	8	Rabudas	0
Camueso temprano	10	Reineta	35
De Chapa	30	Rojillo	9
De Rosa	15	Rojillo temprano	4
Del Ortel	10	Rojo	34
Esperiega	11	San Felipe	0
Hojancas	33	Temprano	5
Pepita de melón	62	Verde Doncella	10
Pero de Aragón	38	Total	463

Besides, their soils are composed of granites, slates, and schists, which gives rather an acidic pH. On the other hand, the Tagus area is around 450-700 m a.s.l., with a typical Mediterranean climate. Soils on this area are quaternary alluvial terraces with detritic materials, margous and calcareous, with a basic pH.

Table 2. Number of apples sampled by reference.

Reference	Apples
Fuji	30
Gala	48
Golden	30
Granny Smith	20
Reineta Blanca	25
Verde Doncella	25
Total	178

The cultivars are conserved in a regional collection. As this germplasm bank is located in the area of the Tagus basin, the soil of the experimental station is a calcareous Fluvisol with a pH around 8.5 and a calcium concentration around 23mEq/100g in the first 90cm. As the climate from the collection is Mediterranean, trees were irrigated from May to September every two weeks due to the existence of droughts during the summer. Apples were collected when ripening, during September-October 2016 to 2019 and preserved at around 4 - 7°C until characterisation, which was performed in the following days or weeks. Apple ripening was considered achieved after skin colour turns

into red, yellow or light green, depending on the cultivar.

As we did not find any similar method for this trait in bibliography, in this research, we considered watercore as a dichotomous character (absence/presence) with a binary output (0 and 1, respectively); it was evaluated by visual inspection through two cuts in each apple, one parallel to its pedicel and other perpendicular to the first cut. Apples were evaluated during the following days after harvested to prevent apples from spoiling.

In this descriptive analysis, the central value considered for the chi-squared test (χ^2) was the mode, and the significance level (α) was set at 0.05. This statistical analysis was run with JMP 9 software (SAS, 2019), and graphic outputs were processed with Inkscape (Inkscape Project, 2020).

RESULTS AND DISCUSSION

A vitreous texture was observed in 137 apples (21% out of 641 samples, Figure 2). Nevertheless, this percentage raised to 29% considering only traditional landraces, as no references shown this character. Only one 'Verde Doncella' from references shown watercore. Although this cultivar is considered as a reference in this study, 'Verde Doncella' is a Spanish traditional cultivar (Arnal *et al.*, 2020). In consequence, there existed significant differences between both type of cultivars, as χ^2 was 92.155 ($P < 0.0001$; Figure 2).

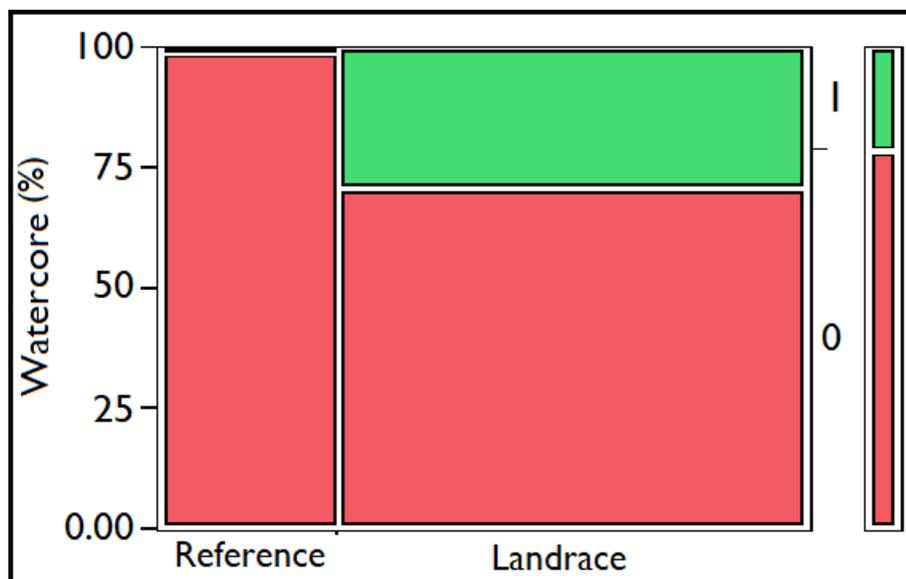


Figure 2. Contingency table between types of cultivar. 0, Red, no watercore; 1, green, watercore presence. The larger the green square, the more watercore counted.

This vitreous texture was seen in all parts of the pulp of the fruit as we noted vitreous texture intrusions around the inner core (including the loculi), in the middle of the pulp following the nerves, and below the peel of the apple (Figure 3) independently of the cultivar. Our results are in agreement with Beaudry (2014) who reported that this texture can be radial and gathered in vascular strands. We also detected free liquid accumulations surrounding the seeds in apples with severe watercore.

The presence of watercore in the pulp of traditional apples is noticed in works compiling traditional knowledge under the name of *ice apples* or *frozen apples*, such as 'Ciri' or 'Cirio', 'Cor glaçat' (Centre de Conservació de Plantes Cultivades, 2020), 'Gelata' and 'Gelato Cola' in Italy (Marconi *et al.*, 2018; Slow Food Foundation, 2019). Thus, it seems a trait circumscribed to the distribution of the traditional apple tree crop.

As noted before, a deficiency of calcium in the soil is linked to vitescence. In this study, there were no differences in soil condition, including pH, cultural practices, radiation, temperature and irrigation between landraces, and traditional individuals, as all of them were managed under the same conditions and planted in the same experimental station. Related to soils, the pH of the experimental station was around 8.5 with no calcium limitation. Consequently, the differences found might be linked to cultivar and/or variations in physiology due to the relationship between leaf area surface and fruit production, as the references are supposedly susceptible to Watercore (Beaudry, 2014). Nevertheless, the effect of temperature could explain in some extent the vitrification detected, since Calvo and Candan (2013) indicate that one type of watercore can appear under unusual and very hot conditions like the ones existing in the Mediterranean summer.

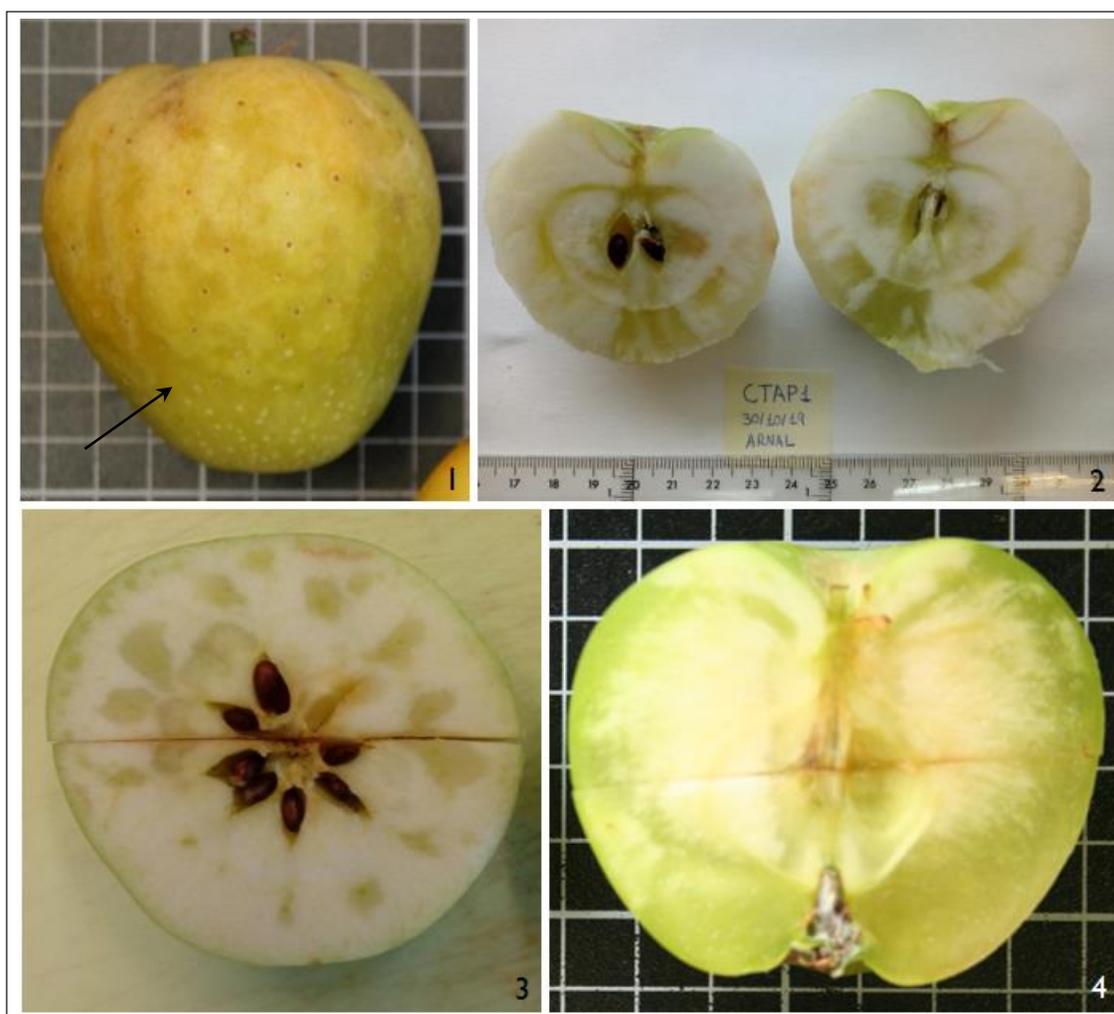


Figure 3. Watercore detected in traditional apples. 1, from the outside; 2 and 4, from a cut along pedicel, and 3, from a cut across the loculi.

So far, watercore has not been included in morphological characterizations despite its effect on marketability and sensory qualities, as noted early by Beaudry (2014) and recently by Tanaka *et al.* (2020), who found that watercored apples were more valued than ordinary apples in a sensorial analysis. Russetting is an example of a defect that highly devaluates fruit quality of modern glossy apples, but it may be interesting in traditional cultivars due to its visual appearance and link to flavour (Orange Pippin Ltd., 2020).

As a result, watercore information should be considered in germplasm evaluations to detect cultivar potential. Following to Beaudry (2014) and Liu *et al.* (2021), vitrescence gives to the apple a marble appearance, a crunchy texture, a delicate aroma, and an intense sweetness, which might be interesting in terms of differentiated quality. The efforts to promote local products adapted to regional environmental conditions also impulse rural development within the European Rural Development and the Sustainable Development Goals (SDGs) of the 2030 Agenda.

CONCLUSIONS

Watercore is a common characteristic shared in traditional apple cultivars from rural regions of Madrid (Spain). Due to its impact on agronomy and fruit quality, it is highly recommended to consider this descriptor in the accession documentation of apple germplasm characterization and in sensorial descriptions.

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Conflict of interests: The author declare that there is no conflict of interest.

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