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Factors behind consumers' choices for healthy fruits: a review of pomegranate and its food derivatives

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Abstract

Due to the rising interest in healthy products, superfoods such as pomegranate have begun to spread widely on the international market in recent years. Identification of the consumer choice determinants is a key factor behind the success of innovative products. Nevertheless, to date, there has been no comprehensive analysis of consumers' preferences for pomegranate. The aim of this study is to understand the characteristics of pomegranate and its derivatives that are most preferred by consumers and to identify the buyers' profiles by performing a systematic review (SR). The results suggest that there is not equal interest in the literature in all areas of the review. Indeed, most efforts have been made in characterizing the products, whereas consumers' profiles and their willingness to pay for the various products features have been scarcely investigated. The SR highlights that consumer preference is first correlated with taste and, in particular, with the sweetness (positively) and astringency (negatively) of the product. The red colour and uniform shape of the husk are attractive attributes for consumers, as is the juiciness of the arils. Some innovative methods of product storage, such as intermittent heating (for fruits) and the use of pectin methyl esterase (for arils), guarantee higher consumer acceptability due to the maintenance of product genuineness. Moreover, familiarity with the product seems to be the main driver influencing consumers' purchase decisions; in addition, people who are more "future oriented" are more willing to pay for pomegranate because of the nutraceutical attributes stressed on the label.

Keywords: Pomegranate, Systematic review, Consumer behaviour, Consumer acceptance, WTP

Introduction

In modern society, consumers seem to attach increasing importance to the nutritional and health characteristics of products, which are, to a large extent, responsible for the prestigious role played by many fruits—the so-called *superfruits*—on the market (Martínez et al. 2012; Sidhu and Zafar 2012). The attempts of the food industry to develop healthy food products should balance technological feasibility with consumer preferences, taking into account the acceptability of innovative products and market segmentation (Coppola and Verneau 2014). As reported by Cano-Lamadrid et al. (2019), current

pomegranate consumers are less interested in tablets or powders; instead, they prefer to enrich their daily diet with essential and healthy ingredients derived from conventional products. In this context, pomegranate, notoriously rich in antioxidants and polyphenols, has found the roots of its success (Faria and Calhau 2011; Gil et al. 2000; Holland and Bar-Ya'akov 2008; Karimi et al. 2017; Kulkarni et al. 2007; Mphahlele et al. 2014).

Pomegranate ranks fourth out of 62 fruits analysed by Fu et al. (2011) in terms of quantities of polyphenols. The arils, namely the edible part of the fruit, contain 3% of polyphenols (Al-Maiman and Ahmad 2002) and, among these, ellagic acid and punicalagine are the most abundant.

Innovative variants of pomegranate-based products, such as ready-to-eat arils, jellies, jams and syrups, are starting to spread worldwide (Alcaraz-Mármol et al. 2015; Calín-Sánchez et al. 2011; Martínez et al. 2012; Rios-Corripio and Guerrero-Beltrán 2019; Sidhu and Zafar 2012; Zaouay et al. 2014), although the most diffused and consumed processed product remains juice, which is the only derived product that has a relevant impact on the market. The industry has focused on this type of product in recent times, proposing juice as fresh, or pasteurized or treated at high pressures to preserve the sensory and nutritional characteristics typical of fresh juice (Reis et al. 2016).

Despite the growing interest in this fruit, it is worth noting that to date, there are no harmonised global production statistics and no official trade data. The most recent available trade statistics include pomegranate in a class of fruits[1] (of which pomegranate is the most important) that have increased their export volumes from 67,000 tonnes in 2013 to 95,000 tonnes in 2017 worldwide. Generally, the northern hemisphere produces almost all the commercial pomegranate from October to February, while in the opposite season (e.g. from March to September), countries of the southern hemisphere supply the product to international markets; South Africa appears to be the largest producer, followed by Chile, Peru and Argentina (Arendse et al. 2015). At European level, Spain has the largest pomegranate production, which is located mainly in the Alicante province (Szychowski et al. 2015). 'Mollar' and 'Valenciana' are the most widespread cultivars in this area and are widely appreciated by Spanish consumers for their sensory properties. Moreover, Mollar de Elche obtained the Protected Designation of Origin (PDO) from the European Union in 2016[2] (Mena et al. 2011). However, despite the widespread use of this fruit, consumer preferences for pomegranate and its food derivatives remain mainly investigated within the literature on pomegranate quality attributes characterization. Given the ongoing global drive for a healthier diet, it can be assumed that the leading reason behind consumers' pomegranate buying habits involves its health benefits. Although consumers are often willing to renounce an item's taste to have guaranteed positive effects on health (Verbeke 2006), in recent years, the belief that healthy and savoury are not necessarily unrelated is increasingly taking root (Jo and Lusk 2018). Personal preferences for a certain taste play a significant role in regard to purchasing decisions. In 2014, Mayuoni-Kirshinbaum and Porat conducted a review with the aim of discussing the sensory quality closely linked with pomegranate flavour in both the

[1] The product code HS-08109075 includes, among others, pomegranates and fruit such as cherimoya, barbary figs and medlars (more information is available at: https://www.cbi.eu/market-information/fresh-fruit-vegetables/pomegranates/europe/#).

[2] https://ec.europa.eu/agriculture/quality/door/registeredName.html?denominationId=11651

fruit and juice. They found that preferred pomegranate varieties are characterized by high sweetness, moderate to low acidity, bitterness and astringency levels, and richness in red wine and pomegranate fruity flavours. However, from the literature analysis, it emerges that in many cases, the economic variables linked to pomegranate purchase are marginally taken into account. Indeed, changes in taste and preferences, which are both affected by product features, as well as variation in disposable income may shift the demand curve for a certain product, which translates into a change in buying decisions and willingness to pay (WTP). Although the Mayuoni-Kirshinbaum and Porat review (2014) describes the taste and aroma profile of the major pomegranate cultivars, to the best of our knowledge, to date, there is no scientific work that aims to review, in a clear and representative way, all the issues related to consumer acceptance of the pomegranate product, integrating analysis of the product attributes with the consumer profile. Hence, the purpose of this research is to review, applying the systematic review (SR) principles, consumers' preferences for pomegranate and its food derivatives, with the aim of understanding which of the product attributes most satisfy different consumer segments and to characterize the profiles of the possible buyers of pomegranate fruits and/or food derivatives.

The article is structured as follows: In the next section, the methodology applied for the SR is illustrated together with the specific research questions; the data obtained from the literature review are then presented, and research questions are lastly answered and discussed.

Data and methods

To achieve the objectives of our review, we decided to follow, as much as possible, the systematic review (SR) model to exhaustively examine the existing literature through a replicable, scientific and transparent approach (Tranfield et al. 2003). The basic difference between the SR and traditional revision methods lies precisely in the review writing process; in this case, the aim is not only to minimize errors through the in-depth research of the published studies but also to provide evidence of all the decisions made, thus ensuring the replicability of the research. Conversely, by conducting the SR, we have considered only the articles that emerged from the research string; some potentially useful papers might therefore not emerge from the search. Furthermore, if on the one hand, the choice to conduct our research only on Scopus and evaluate only peer-review articles results in a greater scientific rigour (for the level of the proposed contents), on the other hand, it does not allow publication bias to be eliminated. This is due to the tendency of journals indexed in Scopus to exclude researches with null/negative results or with marginal interest for the readers.

It should be noted that the SR approach is widely used in the health sciences for reporting clinical disease care and case studies, but it is still limited in the social sciences. In the latter context, the paper by Tranfield et al. (2003) was a pioneer, suggesting that the systematic method be applied not only for the medical sector but also for the management discipline. Therefore, to avoid bias and achieve scientific quality, we decided to follow the three-phase approach proposed by Tranfield et al. (2003) as much as possible, integrating it with the Preferred Reporting Items for Systematic reviews and Meta-Analyses for Protocols (PRISMA) (Moher et al. 2015), as described below. However, we

emphasize that the field of application of the review does not allow the protocol to be followed exactly (see, for instance, Cantillo et al. 2020).

The three-phase approach is structured as follows:

- Planning the review:

  i) Identification of the need for a review; ii) Preparation of a proposal for a review; iii) Development of a review protocol;
- Conducting the review:
  i) Identification of research; ii) Selection of studies; iii) Study quality assessment; iv) Data extraction; v) Data analysis;
- Reporting and dissemination:
  i) The report and recommendations; ii) Results and discussion.

Stage 1: Planning the review

Identifying the research purpose was the first step performed in the planning phase of the review; this step consisted of defining the final objective of the research by writing the following research questions.

RQ1 What are the product characteristics that are important in the purchasing process?

RQ2 What are the consumer characteristics that influence the probability of purchasing?

RQ3 What is the consumer willingness to pay (WTP) for pomegranate products?

The research objectives were chosen following the PRISMA protocol. In particular, we referred to the SPICE framework (Setting, Population, Intervention, Comparison, Evaluation) (Cleyle and Booth 2006), which has already been applied in the field of consumer preferences evaluation by Cantill et al. (2020), instead of the PICOS (Participant, Interventions, Comparisons, Outcomes, Study design) scheme. The words chosen and used in the search string (which define the objectives) followed a structured approach and were always linked to a clear reason that specified why the word was used (Table 1).

Moreover, the defined objective allowed us to avoid bias and selected data reporting. Indeed, the results of the review gave us an understanding of the level of completeness of scientific research in the different areas linked to the drivers that underlie consumer choice for pomegranate. Splitting the research topics into three distinct objectives, we were able to highlight the completeness of the research for each objective. The same result could not be obtained with a single objective because it would not be possible to distinguish in which areas there are the largest gaps in publications.

To be able to respond to the research questions, we reviewed the existing literature concerning pomegranate products, focusing on the sensory analysis of the fruit, arils and juice regarding the characteristics that make up the profile of pomegranate and/or food derivatives consumers. We chose to focus specifically on fruit, arils and juice

Table 1 Application of the SPICE framework in defining the research objective

Spice element	Search terms assigned	Reason
Setting—where?	No term assigned	The interest of the review includes all the fields
Population—for whom?	Consumer*	Limit the information on consumers
Intervention—what?	Sensory Willingness to pay Preference* Behaviour Behavior Acceptance Opinion	The goal of this review is to understand consumers' preferences for pomegranate. For this reason, we chose a set of keywords that aim to find all the papers in some way linked with consumer preferences in the database
Comparison—compared with what?	No term assigned	Not interested in comparison with different products
Evaluation—with what result?	Pomegranate; Punica granatum	The outcomes of interest are consumers' choices for pomegranate and its food derivatives. Particular attention is given to pomegranate fruit, arils and pomegranate juice. Some references are also made to other by-products (sweets or jam) given that these have additional ingredients (such as sugar and flavourings)

because these are the most consumed food derivative products and because the nutritional profiles of juice and arils allow a full comparison with the fruit.[3]

The review was performed using the Scopus Elsevier scientific article database, which is considered one of the most comprehensive databases of quality (peer-reviewed) scientific articles (Michel-Villarreal et al. 2019; Silva and Sanjuán 2019; Cantill et al. 2020).

The eligible papers had to follow the exclusion and inclusion criteria that are reported below:

- Only research and conference papers published in English were reviewed.
- No restrictions were applied relating to year of publication since interest in this product has only increased in recent years.
- The papers considered were those available until June 2020.
- No restrictions were implemented for the disciplinary sector since numerous articles of interest to the present research were registered in more than one disciplinary area.

Stage 2: Conducting the review

The article selection process is shown in Figure 2. The initial terms of our research included the words "pomegranate" or "Punica granatum" (Identification phase). These words could be contained in the title, abstract or keywords of the paper. From this initial research, 7743 articles emerged, which provide a general indication of the number of published studies related to the pomegranate field and conducted in recent years. We then used a set of keywords to meet the exclusion and inclusion criteria (Table 1) to

[3] It should be noted that there are other food derivatives on the market, such as sweets or jams, but the wide use of other ingredients, such as sugar or flavourings, makes these processed products very different from the original product (pomegranate), which makes a total comparison among products impossible.

Reasons of exclusion	Articles in %
Pomegranate used as extract	32.8%
Agricultural	20.2%
Chemical/Pharmacological	15.8%
Medical	14.0%
Technological	12.6%
Historic	1.4%
Veterinary or of Animal Science	1.2%
Marketing	1.1%
Cosmetic	0.5%
Review	0.3%

Reasons of exclusion	Articles in %
Food sector	64,9%
Chemical-pharmacological	20.0%
Dyeing process	8.1%
Medical	14.0%
Feed sector	2.7%
Veterinary	2.1%
Photography	0.5%

Fig. 1 Articles excluded according to the PRISMA protocol

make the research more specific and more related to the intended objectives (i.e. papers that were expected to be linked to consumers' preferences). The final search string on Scopus was the following: TITLE-ABS-KEY (pomegranate) OR TITLE-ABS-KEY (punica AND granatum) AND TITLE-ABS-KEY (consumer*) OR TITLE-ABS-KEY (sensory) OR TITLE-ABS-KEY (willingness AND to AND pay) OR TITLE-ABS-KEY (preference*) OR TITLE-ABS-KEY (behavior) OR TITLE-ABS-KEY (behaviour) OR TITLE-ABS-KEY (acceptance) OR TITLE-ABS-KEY (opinion) AND LIMIT-TO (LANGUAGE, "English") AND LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "cp").

Thus, 7119 papers were eliminated in the identification phase, and the final selection consisted of 624 papers (*Screening phase*), whose titles and abstracts were analysed to evaluate if they were in line with the research questions. After the abstract analysis, 73 articles were selected with the aim of evaluating the entire text. In this phase (*Eligibility phase*), during the selection process, those that were purely medical, agronomical, chemical, technological, historical, veterinary or focused on trade and cosmetic issues were eliminated, as well as studies in which pomegranate extracts were used instead of fruit, arils or juice[4] (Fig. 1). After analysing the full texts of the selected 73 articles, 28 were excluded because they were not related to the research questions (*Inclusion phase*). The final total number of studies included in the research was therefore 45 (Fig. 2).

The analysis was conducted through the creation of a database in Excel containing a systematic representation of key information obtained from the selected articles. Each one was compared by title, authors, journal, year of publication, country, type of article, research objective, research results, attributes characterizing the product and consumer profile investigation. During all the screening processes, the papers were reviewed independently by the authors, according the previously described inclusion criteria. The

[4] Indeed, thanks to its high antioxidant capacity, pomegranate is widely used by pharmacies and herbalists: fruit extracts are often used in supplements and beauty creams and can be incorporated in food packaging as a natural antimicrobial, but they are also applied in other fields, such as the textile sector, as a natural dye.

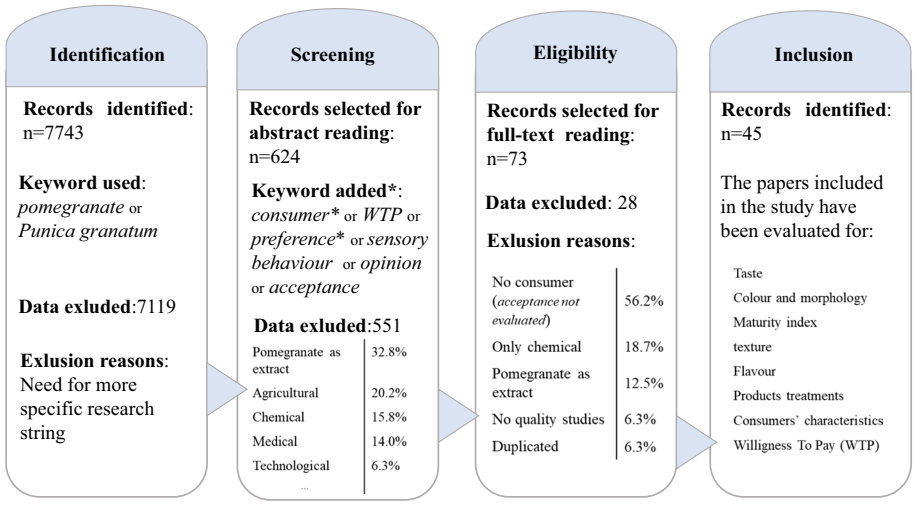

Fig. 2 Article selection process according to the PRISMA flow diagram

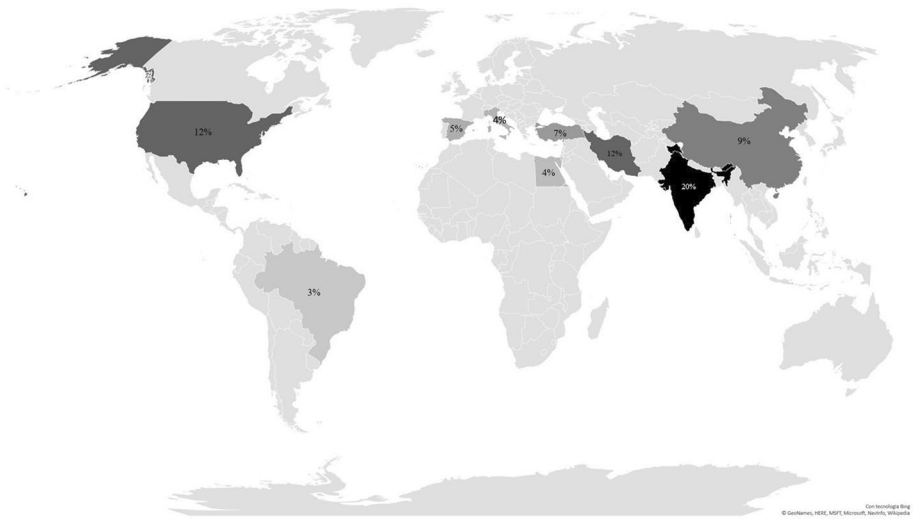

Fig. 3 Number of publications by country (7743: first 10 countries). Note: the percentages of articles published by the first 10 countries (for quantity of articles) are as follows: India–20%; USA–12%; Iran–12%; China–9%; Turkey–7%; Spain–5%; Italy–5%; Egypt–4%; Israel–3%; Brazil–3%

divergences that emerged in this phase were solved by discussing the differences, and the inclusion standards were finally agreed by all authors.

Stage 3: Reporting and dissemination

In line with what was reported by Tranfield et al. (2003), this last stage aimed to analyse the extracted data.

The interest in pomegranate is reflected in recent research and is concentrated in producing countries (Fig. 3). 2005 was the first year in which there was a considerable increase in the number of publications on the subject (122 articles against 78 in the previous year). The maximum number of publications per year was registered

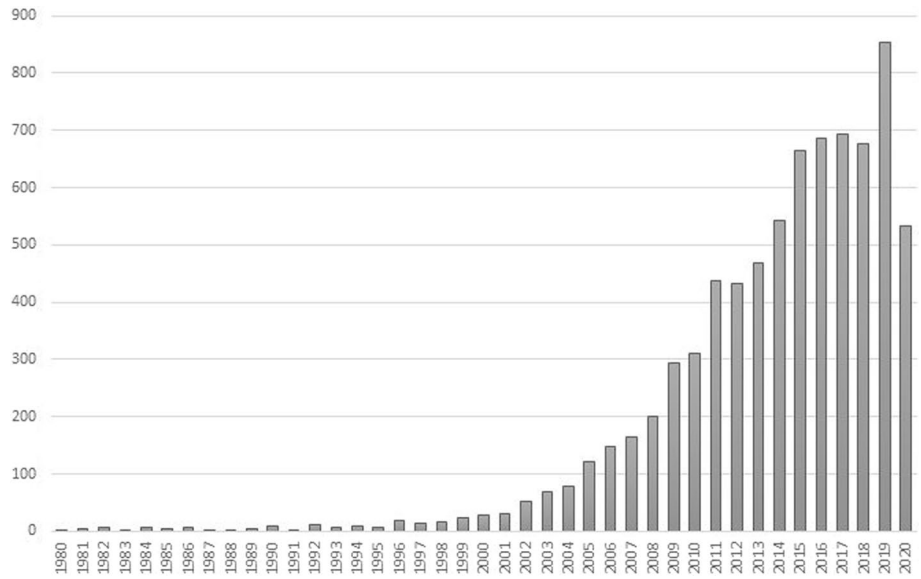

Fig. 4 Number of reviewed publications distributed by year (7743). In 2020, data refer only to the first half of the year

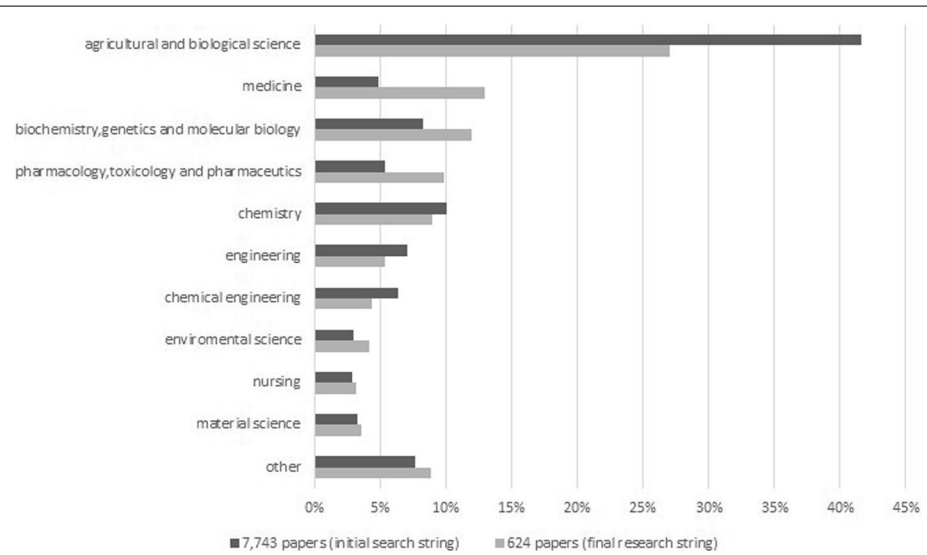

Fig. 5 Publications by subject area. Note: for each category, the bars above refer to the total number of papers (i.e. 7743 derived from the initial search string), while the bars below refer to the selected papers (i.e. 624 derived from the final search string)

in 2019, with a total of 853. It should be recalled that 2019 is the last year for which there are complete statistics (whole year), given that the statistics refer only to the first six months of 2020 (Fig. 4).

Most of the screened articles were in the subject area of agricultural and biological science (41.6%); 10.0% referred to the chemical field, and 8.2% referred to biochemistry, genetics and molecular biology and engineering (Fig. 5).

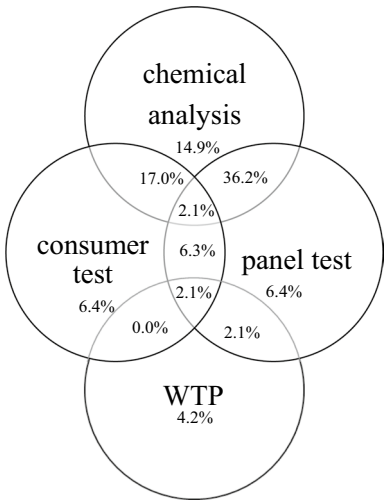

Fig. 6 Research topics of articles included in the review (45)

Most of the articles examined combined sensory analysis (panel test) with chemical analysis to provide objective evidence of the quantity of sugars and acids, seed hardness or colour of the juice and/or arils (Fig. 6). Only 6.3% of the papers combined a panel test with a consumer test, and only 2.1% combine the three dimensions: panel tests, chemical analysis and consumer preferences. Willingness to pay (WTP) was investigated in 4.2% of the articles separately from the other survey methods, while only one article combined panel tests with consumers' willingness to pay, and only one focused on WTP in association with consumer and panel tests.

Almost half of the studies analysed were conducted on juice (which is the most widespread pomegranate product); almost 25% focussed on the arils, with chemical, physical and sensorial analyses, while 22% assessed both the whole fruit and edible part of the pomegranate, and only 2% analysed pomegranate by-products, such as sweets or jam.

Results and discussion

In line with our research objectives, we extracted various types of information from the selected articles, summarized in Appendix (Table 2), which will be discussed in this section with the aim of responding to the three research questions.

RQ1 What are the product characteristics (fruit, arils and juice) that are important in the purchasing process?

We classified the characteristics that influence this issue into primary and secondary features.

The primary attributes refer to physical traits of the product, such as sweetness, flavour, texture, shape of the fruit, colour, size and ripeness index. The secondary characteristics can be described as the conditions that influence the sensory aspect of the product, such as preservation methods or shelf life (Fig. 6).

Sweetness, acidity, astringency and bitterness

To contextualize consumer preferences for pomegranate, we provide below the main product characteristics responsible for the typical taste. The taste mainly results from sensations of sweetness and sourness and, to a lesser extent, from bitterness. The sweetness is closely linked to the presence of glucose and fructose and, in a minor way, to sucrose, maltose and arabinose. The sourness depends on citric and malic acids and on succinic, oxalic, tartaric and ascorbic acids, which are present in minor amounts. Bitterness is due to the presence of polyphenols: this attribute is not predominant in the arils, but could increase during the pressing treatment for juice, as the peel, albedo and membrane are components rich in polyphenols that are dissolved in juice and could modify the sensory profile of the product (Mayuoni-Kirshinbaum and Porat 2014).

From a consumer perspective, during the SR, it was found that sweetness can be considered the main factor affecting acceptance of both the fruit and juice. Several studies showed that in general, the sweeter the product is, the more it is appreciated (Chater et al. 2018; Gadže et al. 2012; Hernández et al. 2012; Lawless et al. 2013a; Martínez et al. 2012; Mayuoni-Kirshenbaum and Porat 2015; Mayuoni-Kirshinbaum et al. 2013; Reis et al. 2017; Romano et al. 2016). Indeed, Chater et al. (2018) reported that consumer acceptability is higher for sweet cultivars. With regard to the juice, Zaouay et al. (2014) found that the most appreciated is derived from sweet cultivars. They compared juices extracted from four Tunisian pomegranate varieties, reporting that the highest level of consumers' overall appreciation was attributed to those obtained from the sweetest cultivars. It should be noted, however, that sometimes the excessive sweetness of the product, with respect to the juice, can negatively influence consumer acceptability; Carbonell-Barrachina et al. (2012) reported that the typical acidity of Spanish "sour–sweet" cultivars can be an important tool to dampen the excessive sweetness of some Hispanic cultivars, such as the Mollar de Elche PDO. This is in line with evidence highlighted by Zaouay et al. (2014) that suggested creating blends with extracts obtained from sweet varieties to make the juices extracted from sour cultivars more appealing to the consumer. Generally, however, high levels of acidity seemed not to be particularly appreciated by consumers, in both the fruit and juice (Arendse et al. 2015; Chater et al. 2018; Martínez et al. 2012; Koppel et al. 2014; Mayuoni-Kirshenbaum and Porat 2015; Mayuoni-Kirshinbaum et al. 2013; Mena et al. 2011; Yanclo et al. 2018; Zaouay et al. 2014), and may reduce consumers' WTP (Threlfall et al. 2015).

Astringency is also a parameter that negatively influences the acceptability of the product, for both the juice and fruit (Calín-Sánchez et al. 2011; Koppel et al. 2014; Mayuoni-Kirshenbaum and Porat 2015; Mayuoni-Kirshinbaum et al. 2013; Mena et al. 2011; Yanclo et al. 2018). Similarly, excessive bitterness levels, often linked with the polyphenol content (responsible for the astringency features), may reduce consumer overall appreciation (Mayuoni-Kirshenbaum et al. 2016).

Flavour

Flavour can affect consumer preferences and is correlated not only with the type of cultivar (Mayuoni-Kirshenbaum and Porat 2015) but also with the ripening stage of the fruit and its storage temperature (Arendse et al. 2015). Familiarity with specific flavours may affect consumer choices (Carbonell-Barrachina et al. 2012). Cano-Lamadrid et al. (2018)

reported that the most appreciated dried arils have flavours of fruit, pineapple, apple and grapes. The fruity and red wine notes are the most preferred in the fresh fruit, as suggested by Mayuoni-Kirshenbaum and Porat (2015).

With regard to the juice, one of the main problems that characterize this product lies in the reduced concentration of volatile compounds, which leads to a weak aromatic intensity. The volatile compounds most present are as follows:

- monoterpenes, such as *3-carene,* which has a typical lemon aroma, or *α-terpinene*, which is reminiscent of lemon or wood;
- aldehydes, such as the *trans-2-hexanal*, with a fruity or green aroma;
- alcohols, such as *α-terpineol*, with a floral aroma (Calín-Sánchez et al. 2011).

In general, notes of blueberry and grape-like hints[5] are the most appreciated by consumers (Koppel et al. 2014), while the caramel aroma seems to be the least appreciated (Carbonell-Barrachina et al. 2012).

In addition, the extraction method has an important effect on the aromatic profile of the juice: heat treatments, such as pasteurization, deprive the juice of the typical pomegranate aroma, which causes a decrease in consumer acceptability. It should be remembered, however, that PEF-treated juices better preserve their sensory profile and do not show undesirable fermentation aromas (Mayuoni-Kirshinbaum et al. 2013).

Fruit colour and morphology

Visual appeal is a key feature for consumers at the time of purchase (Mphahlele et al. 2018b). According to Cano-Lamadrid et al. (2018), the fruit colour and size uniformity, such as a bright and intense colour of the husk, are particularly appreciated parameters; fruit shape is closely related to the type of cultivar and pedo-climatic aspects (Ferrara et al. 2011), while the red colour, correlated with the anthocyanin content, is an emblem of quality for most consumers with regard to both the fruit and juice (Chater et al. 2018; Guo et al. 2013; Martínez et al. 2012; Rios-Corripio and Guerrero-Beltrán 2019; Romano et al. 2016; Vázquez-Araújo et al. 2014; Zaouay et al. 2014). Consumers also seem to better appreciate large fruits (Gadže et al. 2012; Vázquez-Araújo et al. 2014), with a uniform appearance (Cano-Lamadrid et al. 2018) and a thin skin that are rich in juice arils (Drogoudi et al. 2005).

Recent studies highlighted that industry has often used the colour driver as a quality indicator for improving their commercial products, given that for most consumers, the red colour is one of the most important parameters for pomegranate-based products, such as sweets or jellies (Cano-Lamadrid et al. 2020). Regarding the processed products, such as juice or ready-to-eat arils, technological treatments can change the colour of the product (Cano-Lamadrid et al. 2019). Guo et al. (2013) compared pasteurized, unpasteurized and pulsed electric field (PEF) juices to understand how the chemical, physical and microbiological characteristics, besides consumer acceptability, changed after the technological treatments. Indeed, the purpose of the PEF treatment is to reduce the typical negative effects of heat pasteurization while guaranteeing the microbiological safety

[5] The lexicon used was developed by Koppel and Chambers (2010).

of heat treatments. The PEF technique makes the juice slightly less bright but causes an increase in the red index and an increase in consumer acceptability compared to other types of treatment. Similarly, the high hydrostatic pressure (HHP) production processes (used for fermented pomegranate juices) lead to a reduction in red colour loss compared to the classic thermal pasteurisation: this leads to greater consumer acceptability (Rios-Corripio et al. 2020).

With the typical juice extraction method, the colour remains more unchanged if extracted from separated arils (Oziyci et al. 2013), while it loses its intensity if clarified and stored at high temperatures.

Maturity index

A parameter that affects taste is certainly represented by the maturity index, defined as the ratio of $\frac{TSS}{TA}$, i.e. between $\frac{\text{Total Soluble Solids}}{\text{Titratable Acidity}}$ (Mphahlele et al. 2018a), which affects not only visual parameters, such as colour of the peel and arils but also the flavour profile of the product (Fawole et al. 2016). In relation to the maturity index, cultivars can be characterized as "sweet", "sour" and "semi-sour" (Szychowski et al. 2015).

Fruits with high TSS levels (namely, total soluble solids by %, mostly represented by fruit sugars) and high sweetness levels described by the panel may also have high acidity values; the consumer is therefore able to perceive, consider and appreciate a certain level of sweetness, even if the fruit acidity is high.

The sweetness level may depend not only on the fruit ripening index (Mphahlele et al. 2018a) but also on the storage temperature: importantly, sweetness increases during the shelf life (Arendse et al. 2015) due to moisture loss by the arils and the consequent concentration of sugars.

Texture

The texture of the arils is another fundamental parameter that influences consumer acceptability; this term refers not only to their hardness and compactness but also to a general perception of intrusiveness of their seeds. To confirm this point, Alcaraz-Mármol et al. (2015) and Szychowski et al. (2015) reported that seed hardness is a criterion used to classify and distinguish cultivars. From several studies in this area, it emerged that the varieties most appreciated and suitable for fresh consumption are soft-seed cultivars (Martínez et al. 2012; Cano-Lamadrid et al. 2018), while the hard-seed varieties seem not to be appreciated by consumers (Mayuoni-Kirshenbaum and Porat 2015). However, the latter can be used for the industrial production of juices (Alcaraz-Mármol et al. 2015) since they do not have the characteristics required for fresh consumption (Vázquez-Araújo et al. 2014).

Product treatments

In line with consumer demands, some companies have begun to offer innovative pomegranate products on the international markets, such as ready-to-eat arils (Continella et al. 2018). Ease of consumption is a characteristic that positively influences purchasing

decisions, especially for those consumers who are willing to spend less time on food preparation (Lawless et al. 2015). Other secondary product characteristics, such as those derived from technological treatments or storage conditions, can also have a significant effect on the sensory profile of the product.

In traditional refrigerated storage conditions, the fruit preserves its organoleptic characteristics for 12 weeks; after this time, the off-flavours gradually replace the typical fruit aromas (Mayuoni-Kirshinbaum et al. 2013). As an alternative to refrigeration, different preservation techniques can be applied to the whole fruit, such as hot air or intermittent heating, with the aim of extending the shelf life without affecting the typical organoleptic characteristics of the fresh product (Yanclo et al. 2018). Asrey et al. (2020) shed some light on another innovative preservation method: preharvest bagging. The authors investigated the effects of preharvest bagging and bag colour, applied on fruits 60 days after flowering, on physicochemical, nutraceutical quality and consumer acceptability of pomegranate arils. They found that fruit bagging has a positive effect on pomegranate and improves the most desirable features, such as thin and attractive red peel of the fruit and soft, juicy and red arils. Red bags were associated the most with quality attributes of pomegranate, according to consumers' preferences.

Regarding arils, Kumar et al. (2016) reported that innovative treatments, such as the use of pectin methyl esterase (PME) and calcium (2+) ions, have a positive effect on prolonging the shelf life of the product. This treatment, in fact, preserves the arils for 20 days, thus extending the shelf life by 8 days, without affecting the sensory characteristics. Moreover, Hasheminejad and Khodaiyan (2020) found that the arils coated with clove essential oil (CEO) or chitosan (Ch) improve consumer acceptability because they control fungal decay and retain the amount of anthocyanins that naturally contribute to extending the shelf life.

Juice extraction techniques also have an impact on the organoleptic characteristics of the product: production of the juice by pressing the whole fruit extracts an excessive amount of polyphenols, which interact with the proteins present in the juice. The agglomerate becomes so large that suspension is no longer possible. This causes precipitation of the complex, with consequent changes in the juice colour and flavour profile, which decreases consumer acceptability (Mayuoni Kirshenbaum et al. 2016).

RQ2 What are the consumer characteristics that influence the probability of purchasing?

RQ3 What is the consumer willingness to pay (WTP) for the pomegranate product and its food derivatives?

While conducting the SR, it emerged that there is limited research that allows us to answer to RQ2 and RQ3. Hence, we decided to discuss them proposing a theoretical framework based on the purchasing process model, adopted from Grunert (1995) (Fig. 7). This allowed us to highlight the area of research covered by the current literature and to point out where there is a need for future research.

According to Grunert (1995), consumers' buying decisions may depend on different aspects, including household characteristics, product specifications and environmental factors; these affect the consumers' acceptability (WTA) and subsequently influence their willingness to pay (WTP). Household characteristics can be split into demographics and resource characteristics: the former includes households' position in the life cycle, social class and geographical characteristics, while the latter includes disposable income and time.

Household characteristics

The SR highlights that demographic characteristics have a significant influence on consumers' WTP for pomegranate. Romano et al. (2016) investigated the behaviour of five hundred consumers in Rio de Janeiro with regard to vitamin-rich pomegranate juices that preserve the level of antioxidants and typical flavours of the fresh juice. The results suggested that consumer age negatively affects the WTP (*demographic-household*), as also found by Stiletto et al. (2020) (Fig. 7). Therefore, with increasing age, the WTP decreases. Furthermore, both previous experience (which could improve familiarity with the product) and income are positively correlated with the WTP (*resources characteristics*). In contrast, education level (*demographic*) has a negative effect on WTP, as does knowledge of the product (*resources*), which contrasts with the results for previous experience. Gender (*demographic*) also affects purchasing intentions: males seem to be willing to pay less than women. These results are in contrast to what Lawless et al. (2013a, b, 2015) found regarding demographic variables, such as income and gender: the authors stressed the fact that these variables did not significantly affect the WTP for the nutraceutical-rich juice blend (Fig. 8).

Reis et al. (2016) found that individuals who spend less time in shops and who are therefore more subject to time constraints (*resources characteristics*) are more influenced by the purchasing conditions and visual appeal of the product. For these consumers, at the moment of purchasing juice, for example, the most important variable is the design of the bottle. This is probably because the bottle design allows consumers

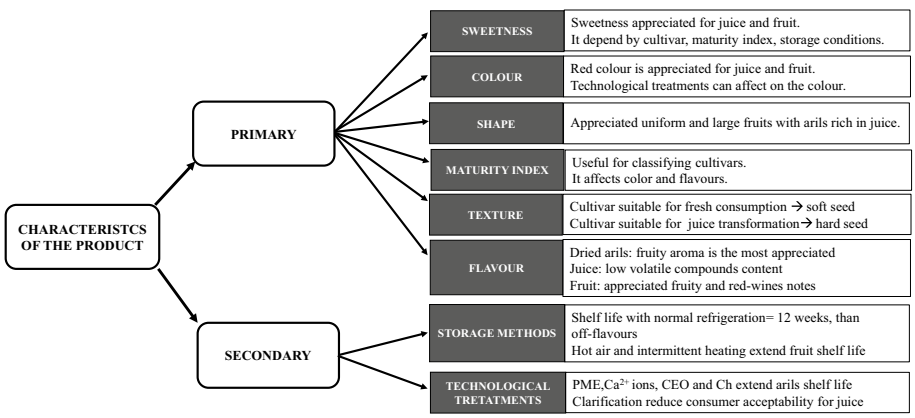

Fig. 7 Comprehensive outline of the pomegranate primary and secondary characteristics most appreciated by consumers

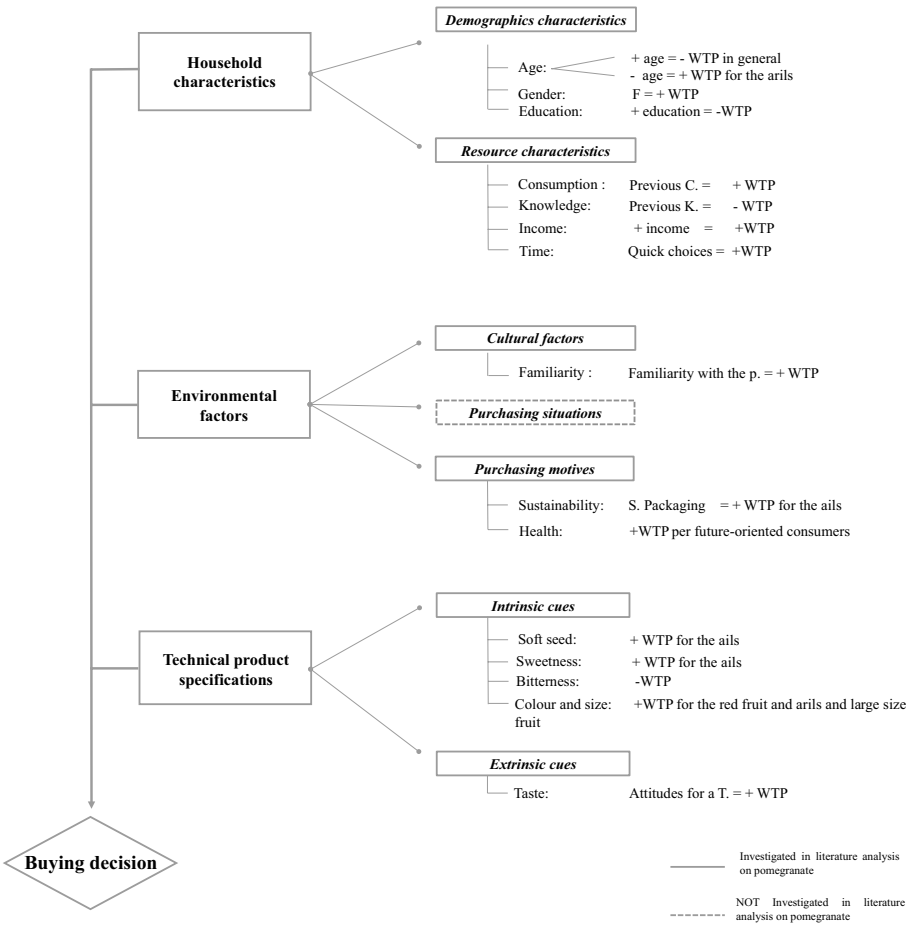

Fig. 8 Buying decision process and impact on consumers' willingness to pay. Sources: Our elaboration adapted from Grunert et al. (1995)

to make quick choices even if they do not have much time and do not spend a lot of effort in the buying process. A more careful analysis of the product, in terms of both its nutritional profile and other characteristics (credence attributes), would require a more thorough analysis and therefore be more time-consuming. Likewise, Stiletto et al. (2020) found that the highest WTP for ready-to-eat arils is expressed by those consumers who can be defined as "time-saving lovers", given that they are used to making quick purchases (*resource characteristics*). Indeed, these consumers are willing to pay €4 more for 100 g of ready-to-eat arils instead of 250 g of pomegranate (the equivalent of 100 g of arils, considering the waste resulting from the shelling of the fruit). Moreover, they underlined the heterogeneity of consumers' preferences and found that those most prone to buy ready-to-eat arils are in general young (*demographic*), with a higher predisposition to try innovative products (i.e. those with a lower value of neophobia), price-sensitive (*resources characteristics*) and attracted by sustainable packaging (*purchasing motives*).

Environmental factors

There are other aspects that can influence the consumer's perception of food value and, thus, the buying decision process. Indeed, according to Grunert (1995), there are many self-relevant consequences of eating irrespective of mere nutrition, such as pleasing the family, socializing with friends or enjoying a good meal; these attributes can be associated with the purchasing motives. Moreover, the author stressed the fact that the purchasing situation and cultural factors can play a role in the buying decision process. Indeed, in a society that is increasingly attentive to healthy eating, the so-called "future-oriented consumers" (Lawless et al. 2015), looking for positive effects from food, are more willing to buy and to pay for products with healthy properties reported on the label (pomegranate juice); according to Lawless et al. (2015), this result occurs because their food choices are aimed at ensuring positive long-term repercussions, so the purchase of products with healthy properties takes on a greater value (*purchasing motives*). In this context, a noteworthy study conducted by Reis et al. (2017) on 196 consumers in Uruguay aimed at determining how nutritional information on pomegranate juice blended with orange affects sensory evaluation. The results showed that the products for which the label reports a sugar reduction obtained a slightly higher overall liking score (*purchasing motives*). Generally, it emerged that information relating to the nutritional characteristics of the product has a positive effect on consumer acceptability; a product with natural sweeteners added is appreciated by consumers and leads to better sales prospects. Indeed, the status of nutraceutical products increases the utility that the consumer can draw from the product and, consequently, increases his/her WTP. It is therefore interesting to know how much consumers are willing to pay for products with added value, such as vitamin-enriched juices or those obtained through innovative technologies that guarantee authenticity of the product (Mena et al. 2011) (*purchasing motives*).

Technical product specifications

Although the presence of positive information on health can increase the purchase intention, taste remains one of the fundamental parameters regarding the acceptability of such nutraceutical products. Ranasingha et al. (2019) evaluated consumers' stated preferences for different attributes of pomegranates, oranges, grapes and pears through a choice experiment in Sri Lanka. The authors found that the most relevant (positive and negative) features of pomegranates are hardness of the seeds and bitterness and size of the fruit (*intrinsic cues*). The highest WTP reflects the bitterness-free attribute: consumers, in fact, are willing to pay Rs. 2.44 more for bitter-free fruits and Rs. 2.29 more for soft-seed fruits. In this case, sweetness and size seem to be less important than bitterness and the hardness of seeds: according to the WTP values calculated, consumers prefer large-sized (Rs. 0.93) and very sweet (Rs. −0.27) fruits. External colour and aril colour are the least important attributes, contrasting with the RQ1 results (*intrinsic cues*).

Taste perception depends, in addition to the typical product characteristics (Benjamin and Gamrasni 2016) (*intrinsic cues*), on consumers' predisposition for a certain taste and on their attitude (*extrinsic cues*). According to Malek et al. (2019), there are many factors that could affect consumers' food acceptance and their evaluation of food taste, such as body state (thirst, hunger) (*extrinsic cues*); learning and memory; psycho-social and cultural influences and familiarity (*cultural factors*) with the different flavours (Koppel et al. 2014). Therefore, we can say that taste perception is closely linked with cultural factors and household characteristics, as discussed below. Consumers tend to assign higher overall liking scores to products consumed more frequently (Lawless et al. 2013a). This result underlines that taste is indispensable, as is familiarity with the product: according to Lawless et al. (2013a), consumers prefer to buy products they have already experienced (*resources characteristics*). In fact, according to Romano et al. (2016), consumers are likely to develop a form of neophobia towards products that are not very well known, such as pomegranates, which leads to a reduction in their WTP. Rios-Corripio et al. (2020) evaluated the physicochemical, antioxidant and sensory characteristics of fresh pomegranate juice and fermented beverages. The authors stressed the fact that, in general, the best-liked product was fresh pomegranate juice. This could be partly explained by the greater familiarity that consumers have with fresh and unfermented juices (*cultural factor*). In summary, looking at the Grunert (1995) framework, this SR revealed research areas where further efforts need to be developed. Hence, it became clear that future research in this area should be focused on the determination of consumers' WTP for pomegranate and, in general, on the analysis of consumers' purchasing choices for this product. Furthermore, it became very important to understand consumer acceptability for processed products and to explain clearly whether the changes made to the products are actually accepted by consumers.

Conclusion

The purpose of this article was to shed light on what the current literature reports regarding consumer preferences for pomegranate, which will be a useful tool for both producers and the industry to better identify consumer targets for pomegranate products. In fact, due to the increasing interest in pomegranate, mainly related to its renowned health properties, an understanding of the product attributes and consumer characteristics that drive pomegranate demand is becoming increasingly important. Generally, the bulk of research is built around the health benefits of pomegranate, but, as these benefits are linked to merely medical aspects, this feature was not investigated in our review.

Indeed, the results from the SR highlight that not all potential sources of information about consumer preferences for pomegranate and purchasing behaviour are currently included in the scientific research.

The main evidence raised by our SR concerns the role of technological and sensory attributes of the product on consumers' preferences, while very few studies attempt to

explain how these attributes, together with personal or environmental factors, translate into a purchase decision and a certain WTP. Conversely, preferences on the purchasing choice occasions remain barely investigated in the literature.

The strongest evidence from this review allows it to be stated that consumer preference is first correlated with taste and, in particular, the sweetness (positively) and the astringency (negatively) of the product. However, tastes must be balanced to be appreciated by consumers: excessive sweetness levels are not accepted. A red colour and uniform shape of the husk are attractive attributes for consumers, as is the juiciness of the arils. Thus, innovative storage treatments, such as hot air, intermittent heating and fruit bagging, as well as the implementation of pectin methyl esterase (PME) and calcium ions or clove essential oil for arils, can be useful to preserve the preferred organoleptic characteristics and avoid a loss in consumer appreciation. Moreover, the level of seed intrusiveness can be considered a product feature that is particularly important for fresh consumption: consumers prefer soft-seed cultivars.

With regard to consumer profiles, it emerges that the most important trait in consumers is familiarity with the products. The health benefit information given on the label has a positive effect for *future-oriented consumers* and leads to an increment in their WTP. However, the literature analysis emphasizes a fairly persistent gap: in most of the selected articles, the heterogeneity of consumer preferences is not assessed, but the acceptability of a small sample of people is often evaluated on the assumption that their preferences for the product are equal and extendable to the population.

Furthermore, we found some open questions from the analysis of the studies conducted to date. The majority concerned the product characteristics (especially technological), but there are very few studies that assessed links between product attributes and consumers' choices. The review highlights the existence of rare attempts to link WTP to sensory or instrumental analysis of pomegranate or to cluster the profile of consumers in terms of their preferences. Therefore, although the review is not completely exhaustive for RQ2 and RQ3, we believe that our SR contributes to providing valid assistance for producers to understand which cultivars are preferred by consumers (and are thus more profitable) and industries to identify the most suitable consumer targets for the various product formats.

Finally, health properties of pomegranate being "so abundant that cannot be neglected" (Karimi et al. 2017), the relationship between health and consumer choice cannot be ignored. To date, such health claims cannot often be communicated via labels (e.g. in the European Union), due to the lack of rigorous researches. Consequently, consumer interest in the healthy attributes of food and its potential impact on public health, makes clear the need for more comprehensive studies on human health. Nevertheless, the collective nature of such findings limits the context of implementation of these researches to public institutions, as investments by a private company would not be profitable.

Appendix

See Table 2.

Table 2 List of included studies with details on country, products investigated, research topic, aim and research question (RQ) answered

Authors and year	Country	Focus of articles	Research topic	Aim of the study	RQ
Alcaraz-Mármol et al. (2015)	Spain	Arils	Panel test; chemical analysis	To establish a correlation between instrumental and sensory data in aril hardness and wood perception	1
Arendse et al. (2015)	South Africa	Fruit; arils	Panel test; chemical analysis	To determine a suitable storage temperature and shelf life for the optimal postharvest storage of pomegranate (sensory and instrumental analysis)	1
Asrey et al. (2020)	India	Arils	Consumer test; chemical analysis	To investigate the effect of preharvest bagging and Bag colour on physicochemical, nutraceutical quality and consumer acceptability of pomegranate arils	1
Benjamin et al. (2016)	Israel	Juice	Panel test; chemical analysis	To evaluate the use of e-tongue (objective method) to measure the intensity scales of the pomegranate juice taste profile by comparing them to a sensory panel	1;2
Calín-Sánchez et al. (2011)	Spain	Arils	Panel test; chemical analysis	To describe the volatile composition of nine Spanish cultivars and its relation to the main quality parameters	1
Cano-Lamadrid et al. (2018)	Spain	Fruit; arils	panel test; Chemical analysis; consumer test	To determine consumer preference for dried pomegranate arils by linking consumer liking to panel tests and the composition of the products	1
Cano-Lamadrid et al. (2019)	Spain	Juice	panel test; Chemical analysis	To compare the phytochemical contents in and the sensory profiling of pomegranate juices	1
Cano-Lamadrid et al. (2020)	Spain	By-products	Consumer test; chemical analysis	To determine consumer insights about pomegranate-based jellies and to link consumer data to descriptive sensory analysis	1

Table 2 (continued)

Authors and year	Country	Focus of articles	Research topic	Aim of the study	RQ
Carbonell-Barrachina et al. (2012)	Spain	Fruit; juice	Panel test; chemical analysis	To evaluate the potential use of sour–sweet pomegranate fruit in the juice industry	1
Chater et al. (2018)	USA	Fruit; juice	Chemical analysis	To evaluate the fruit and juice quality traits of different pomegranate cultivars compared with those of Wonderful as a standard	1
Chater et al. (2018)	USA	Arils	Panel test; consumer test	To compare consumer acceptance among preselected cultivars to the industry standard (i.e. Wonderful)	1
Continella et al. (2018)	Italy	Arils	Chemical analysis	To determine if two Italian cultivars are suitable for ready-to-eat arils	1
Drogoudi et al. (2005)	Greece	Fruit; arils	Panel test; chemical analysis	To determine the variability in the juice antioxidant activity and chemical properties and to find a correlation between fruit chemical and physical properties	1
Fawole et al. (2016)	South Africa	Fruit; arils	Panel test; chemical analysis	To determine a harvest maturity indicator for the optimum postharvest performance of Bhagwafruit based on sensory and instrumentalquality attributes	1
Ferrara et al. (2011)	Italy	Fruit; arils	Chemical analysis	To characterize different cultivars for future pomegranate cultivation	1
Gadže et al. (2013)	Croatia	Fruit; arils	Chemical analysis	To characterize external and internal quality attributes of different cultivars from Croatia and to evaluate which cultivar has the best quality characteristics	1

Table 2 (continued)

Authors and year	Country	Focus of articles	Research topic	Aim of the study	RQ
Guo et al. (2014)	USA	juice	chemical analysis; consumer test	To evaluate microbial stability, bioactive compounds, physicochemical properties and consumer acceptance of unpasteurized, pasteurized, double heat processed and pulsed electric juices	1
Hasheminejad and Khodaiyan (2020)	Iran	arils	Consumer test; chemical analysis	To compare the effect of clove and chitosan on improving the microbial, physicochemical and sensory qualities of ready to eat pomegranate arils	1
Koppel et al. (2010)	Estonia	juices	panel test	To describe the typical aroma attributes of 33 pomegranate juices (no blends are included) using a trained panel	1
Koppel et al. (2014)	USA; Estonia; Spain; Thailand	juice	panel test; consumer test	To evaluate consumer acceptance of different pomegranate flavour combinations across countries and to determine what drives flavour liking among consumers	1;2
Kumar et al. (2016)	India	arils	panel test; chemical analysis	To optimize PME (pectin methyl esterase) and $CaCl_2$ concentration and treatment time on minimally processed pomegranate arils to prolong their shelf life	1
Lawless et al. (2013a)	USA	juice	WTP; panel test; consumer test	To investigate how consumer profiles and juice features (blends with pomegranate) such as nutraceutical status and sensory characteristics can affect the overall liking and purchase intent	1;2;3
Lawless et al. (2013b)	USA	juice	consumer test	To discover the most preferred blend of pomegranate, black cherry and concord grape juices	2

Table 2 (continued)

Authors and year	Country	Focus of articles	Research topic	Aim of the study	RQ
Lawless et al. (2015)	USA	juice	panel test; WTP	To identify consumer characteristics, attitudinal factors and product sensory attributes that affect consumer WTP for juice blends with pomegranate	1;2;3
Malek et al. (2019)	Malaysia	juice	chemical analysis; consumer test	To determine the nutrient, antioxidant and polyphenol content and consumers' acceptance of a new pomegranate blend juice	2
Martínez et al. (2012)	Morocco	fruit; arils	chemical analysis	To determine the physicochemical characteristics of six pomegranate cultivars grown in Morocco	1
Mayuoni Kirshenbaum et al. (2016)	Israel	juice	panel test; consumer test	To compare the sensory attributes of pomegranate juice extracted from separated arils with juice pressed from whole fruit	1
Mayuoni-Kirshenbaum and Porat (2013)	Israel	arils	panel test	To reveal differences in sensory quality and perception among pomegranate cultivars	1
Mayuoni-Kirshinbaum et al. (2013)	Israel	fruit; arils	panel test; chemical analysis	To evaluate flavour acceptance of pomegranate arils (cv Wonderful) during prolonged storage	1
Mena et al. (2011)	Spain	juice	panel test; chemical analysis	To characterize Spanish pomegranate cultivars in terms of bioactive compounds	1;2
Mphahlele et al. (2018a)	South Africa	juice	panel test; chemical analysis	To evaluate the sensory and chemical attributes of pomegranate juice in association with the method of extraction	1
Mphahlele et al. (2018b)	South Africa	fruit; arils	chemical analysis	To investigate the relationships between colour and the different fruit parts (skin/peel/aril/juice) during pomegranate maturation	1

Table 2 (continued)

Authors and year	Country	Focus of articles	Research topic	Aim of the study	RQ
Yanclo et al. (2018)	South Africa	arils	panel test	To investigate the effect that hot water, hot air and intermittent warming treatments have on the sensory attributes of pomegranate	1
Oziyci et al. (2013)	Turkey	juice	chemical analysis	To evaluate how turbidity and colour change in clear pomegranate juice samples produced by two extractions (pressing whole fruits or by separated arils), two clarification (cold and hot) and two filtration (kieselguhr and active charcoal) techniques over six months of storage	1
Ranasingha et al. (2019)	Sri-Lanka	fruit	WTP	To make a quantitative measurement of consumer preference for search, experience and credence attributes of grapes, pears, oranges and pomegranates through a choice experiment	3
Reis et al. (2016)	Uruguay	juice	consumer test	To evaluate the influence of a time constraint on the purchase of pomegranate–orange juice	2
Reis et al. (2017)	Uruguay	juice	consumer test	To investigate the effect that information of sugar reduction and use of natural sweeteners has on consumer wellbeing and sensory perception using orange/pomegranate juices as a case study	1;2
Rios-Corripio and Guerrero-Beltrán (2019)	Mexico	juice	Consumer test; chemical analysis	To evaluate the physicochemical, antioxidant, and sensory characteristics of fresh pomegranate juice and fermented beverages	1;2

Table 2 (continued)

Authors and year	Country	Focus of articles	Research topic	Aim of the study	RQ
Rios-Corripio et al. (2020)	India	juice	panel test; chemical analysis	To evaluate the physicochemical, antioxidant and sensory characteristics of fresh and fermented pomegranate beverages	1
Romano et al. (2016)	Brazil	juice	WTP	To estimate the consumer's WTP for a non-traditional pomegranate juice process that preserves vitamins, antioxidants and the flavour of fresh juice	3
Stiletto et al. (2020)	Italy	arils	Consumer test	To investigate consumer preferences and WTP for several pomegranate attributes including arils	2;3
Szychowski et al. (2015)	Spain	arils	panel test; chemical analysis	To evaluate the texture of 15 Spanish pomegranate cultivars with the aim of categorizing different cultivars according to their arils and seed hardness	1
Vázquez-Araújo et al. (2011)	USA	juices	panel test; chemical analysis	To describe the sensory and instrumental aroma characteristics of different pomegranate juices	1
Vázquez-Araújo et al. (2014)	Spain	arils	panel test; chemical analysis	To determine which pomegranate cultivars (of 20 selected) are the most suitable for fresh consumption (chemical + sensory analysis + aroma)	1
Zaouay et al. (2014)	Tunisia	juice	panel test; chemical analysis	To design a new pomegranate juice through the evaluation of physiochemical properties and consumer acceptance	1

Abbreviations
PDO: Protected Designation of Origin; SR: Systematic Review; RQ: Research Question; WTP: Willingness To Pay; PEF: Pulsed Electric Field; TSS: Total Soluble Solids; TA: Titratable Acidity; PME: Pectin Methyl Esterase; WTA: Willingness to Accept, i.e. consumers' acceptability; HHP: High Hydrostatic Pressure.

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AS is the main author. ST is the principal investigator of the project. Both authors actively participated in defining the research questions, selecting the appropriate articles from the relevant database and then writing the final paper. Both authors read and approved the final manuscript.

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