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Business potential of bioproducts from cactus pear waste in a semi-arid Mediterranean environment

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ABSTRACT

The circular bioeconomy requires the search for innovative solutions for the management of waste in the food supply chain, especially when it is possible to extract bioproducts with high market demand through innovative green processes. The cactus pear supply chain is not exempt from this process, as its production waste contains pectin (an aggregating additive) and betalaine (a natural colouring agent), which, according to extensive literature and empirical evidence from many countries around the world, can meet the health claims of modern consumers. To this end, a study of the market potential of cactus pear bioproducts was carried out as a preparatory study for the implementation of a production investment for the extraction of pectin and natural colours from cactus pear. The work, developed through secondary data and a survey of a sample of companies interested in adopting these food additives, shows interest in attributes such as proximity of production, absence of residues and contaminants, and willingness to support the local economy, for which a premium price is recognised.

1. Introduction

Green chemistry, circular economy and sustainability are topics at the centre of modern scientific debate and three major global market trends. These three themes are interrelated and interdependent and represent a set of principles that lead to innovations in the management of agri-food production processes linked to the sustainable use of resources (Chen et al., 2020; Silvestri et al., 2021).

Cactus pears are not immune to these trends, being a highly resilient and multifunctional sector capable of providing income and employment worldwide, due to its adaptability to any environment, especially in arid climates with few cultivation alternatives (FAO, 2017). Cactus pear is drought resistant, absorbs carbon dioxide, is nutritious and can be an excellent feed for livestock, and for these reasons the FAO, the Food and Agriculture Organization of the United Nations, calls it the food of the future, not least because of the relentless advance of climate change, desertification and a population boom that will see the human population reach nearly 10 billion by 2050 (Hubert et al., 2010; Fraser et al., 2005).

In Europe, >90 per cent of cactus pear plantations are located in Sicily, Italy. Specifically, as reported by ISTAT (National Institute of Statistics), in 2022 investments would amount to 8.225 hectares and production to 1.51 million quintals (ISTAT, 2023).

Although the Italian production of cactus pears has so far been entirely absorbed by the human consumption market, either fresh or processed (mainly in the form of food derivatives), almost one-third-of the fruit production is wasted because it is small or has problems (physical appearance or because it is affected by phytopathologies) that make it unsuitable for commercial exploitation (Basile et al., 2000). The product that is not suitable for commercialisation, which can be defined as "waste", presents a significant challenge for agricultural and agro-industrial companies. As a residue, it must be disposed of as hazardous waste, which increases the costs of the supply chain (Ramadan et al., 2021). In fact, these cactus pear wastes contain several valuable components, such as pectin and betalaine (a natural dye), which can be enhanced by green industries through the circular bio-economy while improving resource use efficiency (Ciriminna et al., 2017; Timpanaro et al., 2021; Danzì et al., 2020). Today, the circular bio-economy finds concrete realisation through the use of new processing technologies (thermal and non-thermal methods or their combination), despite conventional extraction methods (e.g. acid extraction of pectin) that have limitations such as low yield and witch require high energy intensity with consequent environmental problems. This combination has increased the opportunities for valorisation of natural bioproducts (Torres-Salcido & Sanz-Cañada, 2018; Gavahian et al., 2021).

The growth of the pectin industry worldwide is due to the increasing

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consumption of convenience foods, health claims in consumer choices and the adaptability of pectin to a wide range of applications. Pectin is used in the food and beverage sector for the production of jams, jellies and spreads, bakery and confectionery products, sauces, dressings and meat products, as well as in the pharmaceutical and personal care sectors for the treatment of gastrointestinal disorders. As for betalain, on the other hand, its consumption also seems to be increasing worldwide, due to the increased consumption of foods with natural colourings and consumer awareness of the use of natural, minimally processed or organic products and healthier lifestyles (Guesmi et al., 2012; Beard et al., 2017; Monteiro et al., 2023; Luzardo-Ocampo et al., 2021; Díaz-Delgado et al., 2022).

In summary, the extraction of cactus pear bioproducts in Sicily represents a viable business opportunity due to the region's role in the global cactus pear production scene. Although other natural sources of bioproducts exist in nature, as demonstrated by literature comparisons (for example, the pectin content of cactus pear is lower than that of citrus albedo, but higher than that of apples), and there is variability within the cactus pear itself (between the white, yellow, and red pulp varieties, as well as between cactus pears grown in Sicily and those from other regions of the Mediterranean or the world), the advantages of using bioproducts derived from cactus pear lie in the ability to obtain higher quality products. This is possible owed to the use of green extraction technologies, which enable 'new' bioproducts with higher bioavailability and bioaccessibility, understood as the ease with which compounds are assimilated by the body and have a positive effect on health, and as the readiness to be released from a food matrix. In addition, the bioproducts obtained have high concentrations of antioxidants, making them particularly suitable for nutraceutical and cosmetic applications, thus promoting the sustainable use of agro-food by-products (De Wit et al., 2020; Álvarez et al., 2021; de Freitas Marinho et al., 2023; Kumar et al., 2023; Sarangi et al., 2023).

For a proper strategic planning of a business activity, it is necessary to assess, not only the amount of investment required, but also the potential biomass needed for processing, as well as the possible demand for bioproducts in the relevant markets.

With regard to the biomass available for processing, we roughly estimate, on the basis of ISTAT data, an availability of about 10–15 thousand tonnes of waste fruit (10 per cent of regional production), which could potentially be used for the extraction of bioproducts.

As for green extraction technologies, although they can lead to higher extraction yields, higher quality bioproducts and more in line with modern consumer expectations (environmental protection), the industrial application of these technologies is currently challenging due to relatively high capital investment, limited professional skills and insufficient data on process upscaling.

The overall picture therefore tends towards a production model that, rather than focusing on the economies of scale of large scale production, typical of chemical manufacturing, aims to produce pectin and betalains at the rate of customer demand, with fast, clean and flexible production capable of meeting variable customer demand, without creating inventories in the process. There is some experience to support these assumptions, which is emerging with the emergence of new manufacturing technologies, that there is a similar trend in the shift from centralised to decentralised and distributed production, allowing products to be manufactured and distributed close to the customer. Experience shows that there are greater opportunities for product control and less waste (especially inventory) due to resource savings, the promotion of innovation (partly as a result of regular customer-producer interactions), the use of cheaper equipment and the benefits of the "production as a service model" (Seddon et al., 2011; Rauch et al., 2017; Uhlenbrock et al., 2018).

Therefore, there remain some knowledge gaps in the relevant markets to properly support such an entrepreneurial project. The research questions were therefore as follows:

RQ1. What is the market potential of pectin and betalain to properly validate such a business idea?

RQ2. Are there any barriers to global trade that could prevent one or more competitors from entering the market?

RQ3. What are the characteristics that companies value so much that they prefer Sicilian pectin and betalains to imported ones?

2. Materials and methods

The construction of the cognitive framework on the market potential of bioproducts was carried out through the methodological procedure shown in Fig. 1. Specifically, for each objective, the most appropriate methodological tool was used, ranging from the analysis of secondary data provided by official statistics, to the direct interview of a sample of companies to assess the characteristics of domestic demand.

2.1. Construction of the reference scenario on import/export relations

Official statistical sources included the United Nations (UN) COMTRADE database, produced by the United Nations Statistics Division (UNSD), which collects trade data for >170 countries and territories defined by the FAO and the Organisation for Economic Co-operation and Development (OECD) and is responsible for developing and maintaining these statistics in accordance with the relevant international classifications. The data are organised by customs codes (Common European Tariff) and in particular information on the following codes has been extracted from the database:

- HS 130,220 - Pectic substances, pectinates and pectates.
- HS 32,030,010 - Dyes of vegetable origin, including dye extracts, whether or not chemically defined; preparations based on dyes of vegetable origin of a kind used to dye fabrics or to produce colouring preparations.

Trade flows were therefore analysed using the main indices commonly used in the literature. For this purpose, the Degree of coverage of the Italian market (MCD_i) was determined:

$$MCD_i = \left(\sum E \Big/ \sum I\right) * 100$$

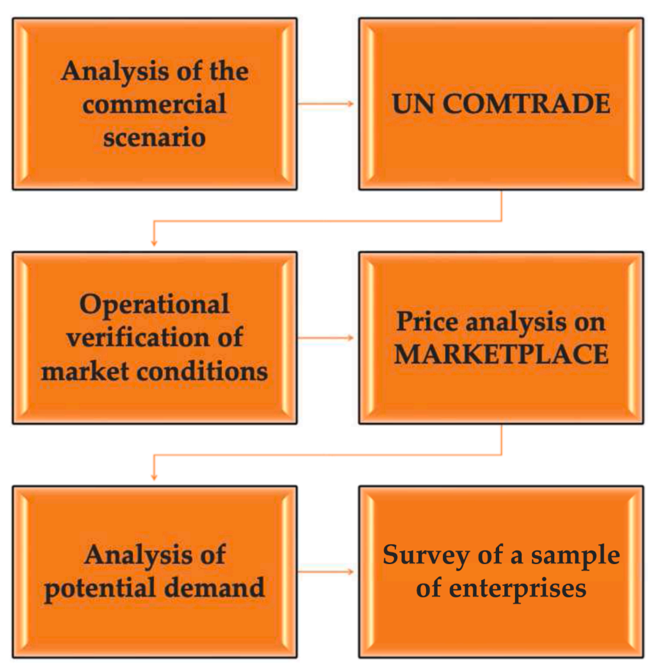

Fig. 1. Research framework followed in the cactus pear bioproduct market assessment project.

Where: MCD_i = Degree of coverage of the Italian market; E = exports; I = imports. The relative value is expressed in %.

For further insight, the Normalised Balance (*NB*), an indicator of a country's trade performance, was, in addition, calculated using the formula:

$$NB = \left(E_{Italy} - I_{Rest\ of\ World} \Big/ E_{Italy} + I_{Rest\ of\ World}\right) * 100$$

Its value varies between −100 in the case where the country is wholly importing and +100 if the country is wholly exporting.

This part of the research aims, therefore, to provide answers on research question Q1, because if domestic demand for bioproducts is not sufficiently saturated, it is possible to imagine some potential for success of the business idea through increased domestic production.

2.2. Market price analysis

In order to construct the knowledge framework useful for the research, price data were collected, again from the same official statistical source, UN COMTRADE, complementing it with a direct survey carried out in the period October - December 2023.

In particular, the direct survey analysed the possible "business-to-business" (B2B) relationships to which the cactus pear bioproducts available in Sicily can be addressed, focusing for this purpose on the activities of the main B2B marketplaces, created as it is known to limit business investments in the various markets, especially foreign ones, and to facilitate trade negotiations at the global level.

The B2B marketplaces considered in terms of import/export trade were "Alibaba" for China, "Amazon Business" and "Ebay Business Supply" for the US and "Agrelma" for Europe.

For each of these, the main data on the terms of trade of cactus pear bioproducts were collected, such as origin, quantity traded, packaging conditions, conditions and guarantees, ancillary costs (e.g. transport), prices, etc., in order to work under conditions of contract homogeneity.

Price data were analysed using the Relative price index (Lapp & Smith, 1992). This index is calculated by dividing the export price index by the import price index and multiplying by 100 to obtain a percentage value, expressed mathematically as follows:

$$RPI = \frac{P_{exp}}{P_{imp}} * 100$$

Where:

RPI = Relative Price Index

P_{exp} = export price index of the good in the year under consideration

P_{imp} = import price index of the good in the same year

Ultimately, the RPI provides a measure of the profitability of exports relative to imports and can be used to assess the competitiveness of a country's trade sector, to understand price movements in the international market and to assess the risks associated with international trade. The aim of this part of the survey was therefore to answer research question Q2.

2.3. Direct analysis and assessment of demand characteristics

This part of the research was carried out by interviewing a sample of Sicilian food processing companies potentially interested in using natural pectins and colours from cactus pear waste in their production processes. This answered research question Q3 and assessed the characteristics of local demand.

The survey was carried out by creating a questionnaire using GOOGLE Forms software and distributing it online to a sample of >100 active companies whose main activity is the production of semi-finished products for the confectionery industry, handicraft, pastry, ice cream, yoghurt and milk drinks, oils and fats in general, jams, jellies and marmalades, sauces and dressings, drinks, etc. The overall sample intercepts 11 % of the universe of enterprises operating in Sicily in 2023 (i.e. using labour or generating turnover) with ISTAT Ateco code "10.80 Production of other food products", which includes the production of confectionery, meals and ready-to-eat meals, perishable packaged foods, specialised food products, etc. (ISTAT, 2020; Ciriminna et al., 2019a).

The questionnaire was divided into two parts, the first of which aimed to collect structural (about the companies), organisational and production data in order to identify the product areas, the volumes of products used, the areas of application and the factors that condition the companies' choices in approaching the market of pectins and natural colours. The second part, on the other hand, aimed to assess the willingness to pay a premium price for cactus pear bioproducts, given that they are differentiated on the market by quality attributes (absence of chemical residues), territoriality (origin and seasonality) and a possible quality mark to guarantee the quality of the production system, processing, transformation and intrinsic characteristics closely linked to the production method.

This survey was considered important for two aspects of the market analysis:

1. To establish a price for the product, since there is currently no direct market;
2. To characterise the product and to propose a market of monopolistic competition in which Sicilian bioproducts can escape from price competition and aim to compete on quality aspects related to intrinsic product characteristics and ethical/social, economic and environmental quality aspects.

2.4. Economic analysis and determination of the possible market price of cactus pear bioproducts

Economic evaluation in market surveys prior to the implementation of a productive investment is particularly appropriate in the case of goods for which there is no market and therefore no corresponding price, as in the case of catus pear bioproducts from marketing waste. In the case under study, discrete choice experiments based on stated preferences were chosen because a set of alternatives was proposed to the respondents in a hypothetical market scenario.

As is widely known in the literature, the following steps were taken: the goods to be evaluated was disaggregated into several attributes and levels; then the choice posed to the stakeholder was made among several alternative (contingent) supply scenarios characterised by different levels of the attributes. Thus, repeated choices were made on choice cores composed of the alternatives, from which the data necessary to estimate a random utility model, and the mean and median willingness to pay for bioproducts derived from cactus pear waste, according to circular economy principles, were obtained (Blandon et al., 2009; Skinner & Blake, 2023).

Finally, the choice experiment consisted of simulating the actual mental process followed by entrepreneurs when purchasing bioproducts, while using an econometric model to estimate the relative importance of different attributes in the choice process and the willingness to pay for the waste-derived bioproduct (Lusk & Hudson, 2004).

The choice experiment was designed to include five attributes, including origin, price for a minimum purchase quantity (1 kg), brand of the manufacturing company that produced the bioproduct, certifications and guarantees (Table 1). As already used in the literature (Huber & Zwerina, 1996), the efficient experimental design finally constructed included four three-level factors and one two-level factor.

The combination of these 5 attributes with their 14 levels resulted in a large number of different profiles, which represented a large number of stimuli to be presented to the respondents, with the risk of compromising the results of the survey. Therefore, an orthogonal design was adopted to facilitate the respondents' evaluation, which allowed the different combinations to be reduced to 13 items/choice options, greatly simplifying the evaluation process (Annunziata & Vecchio, 2013). This approach has the advantage of presenting only 13 items to each

Table 1
Attributes and levels in choice experiment [(*)].

Attribute	Level
Origin	Extra EU
	EU
	Local
Price (for minimum quantities)	Pectin
	12 EURO/Kg
	16 EURO/Kg
	20 EURO/Kg
	Betalain (Natural dye)
	15 EURO/Kg
	20 EURO/Kg
	25 EURO/Kg
Brand name manufacturing company	Brand leading company
	New StartUP Sicilian Brand
	None
Certification & Warranty	Standards (food legislation)
	Standard + ISO
	Standard + ISO + Other
Pesticide/contaminant residues	Compliance with Regs. 396/2005/EC and 1881/2006/EC et seq.
	No indication

[(*)] Elaborated from data collected by direct survey.

participant, which also helps to reduce collinearity between variables (Steenkamp, 1987). Table 2 shows the combinations of attributes used and the preference expressed by the sample surveyed.

Finally, the marginal willingness to pay was determined in the form of the surplus of the economic unit that participated in the survey as follows (Fu et al., 2024):

$$WTP_i = -\frac{\partial U/\partial X_i}{\partial U/\partial P}$$

Where:

∂U derivative of the utility function of the entrepreneur interested in the cactus pear bioproduct;

∂Xi derivative calculated for the i th level of the X attribute of the cactus pear bioproduct;

∂P derived cactus pear bioproduct price.

Thus, WTP a premium price for pectin and betanin (dye) obtained from waste fruits is obtained:

$$WTP_i = -\frac{\beta_i}{\beta_c}$$

where: β_i is the coefficient of each attribute and β_c is the coefficient of the attribute "price".

The computations were carried out by SPSS software for Windows, version 29.0.

Table 2
Combinations of attributes used and preference expressed in the Choice experiment on pectin and natural dye extracted from waste cactus pears [(*)].

No. of cases (%)	Origin	Price	Brand Name	Certification	Residues
6.1	1	1	3	1	1
7.6	1	1	3	1	2
1.5	1	2	1	1	1
4.5	1	3	1	2	1
2.3	1	3	1	3	2
10.6	2	1	3	1	1
7.6	2	1	3	1	2
6.8	2	2	1	2	1
12.1	3	1	3	1	1
10.6	3	1	3	1	2
10.6	3	2	2	2	2
9.1	3	2	2	3	2
10.6	3	3	2	3	1

[(*)] Elaborated from data collected by direct survey.

3. Results and discussion

3.1. Analysis of import/export movements

The market analyses of the bioproducts derived from the processing of cactus pear waste, necessary to determine the relative placement opportunities, were separated for pectins and betalains, both of which belong to the category of "other food additives".

Moreover, at this stage, no commercial transactions of cactus pear pectin were detected at national and international levels, and therefore, for the "commodity" analogy, reference was made to pectin obtained from citrus fruits, as the latter also belongs to the commercial category of high methoxyl pectin (HM) (Ciriminna et al., 2019b). A similar consideration was made for betalains from cactus pear, another product that is not established on the market in terms of exchanges traceable by official statistics, except for quantities limited to a small number of trades; for these reasons, the predominant part of the world market is represented by the bioproduct obtained from *Beta vulgaris* beets.

Italy is heavily indebted to the rest of the world, as shown by UN COMTRADE data, as its imports exceed its exports. Although these data refer to a variety of pectic products, they give a good indication of the potential for development of the domestic market (Table 3).

Over the period available, Italian imports have increased relative to the rest of the world, both in volume and in value, albeit with a fluctuating trend, while the absolute values of exports are rather low. Italian exports, on the other hand, were modest in the period analysed, the latest available for these statistics.

Different countries and geographical areas of the world are involved in the import/export relations, with a clear European predominance for imports, with Germany (37 %), France (24 %), Denmark (24 %), the Czech Republic (11 %) and other countries standing out, while for exports the situation changes to more diversified destinations. In this case, looking at countries within continents, we find Switzerland (36 %), Algeria (24 %) and China (12 %), as shown in Fig. 2. These are not always producing countries, but often re-exporting countries to which production from North America, Brazil, etc. flows.

A detailed study of the trade flows is presented in Table 4 and shows Italy's dependence on the rest of the world, despite the availability of raw materials from which pectin and pectic substances can be extracted.

In fact, it can be seen that Italy is largely dependent on imports to meet domestic demand for pectin, due to the limitations of domestic production and user preferences for foreign products. In addition, other external factors can have a significant impact on the pectin market, such as:

- Raw material prices, as fluctuations in the prices of raw materials used in the production of pectins, such as citrus fruits or apples, can affect the cost of production and thus the competitiveness of Italian producers in relation to foreign producers;
- The global demand for pectins, which can influence supply and demand at national level. Some recent changes in international consumption trends, the interest in natural products and the growth of applications (e.g. in addition to food components also in pharmaceuticals and nutraceuticals) have certainly had an impact on pectin exports and imports to Italy;
- National and international trade policies, such as tariffs and trade agreements, affecting pectin trade between Italy and other countries.

In fact, even the normalised balance shown in Table 4 continues to indicate the large trade deficit, less extreme but still negative at times, for Italy in the pectin sector compared to the rest of the world. This indicator not only reflects the dynamics of the pectin market, but can also provide broader insights into trade strategies, the competitiveness of the Italian industry, and global market trends indicating challenges or opportunities in the sector.

On the other hand, with regards to natural colours derived from a

Table 3
International trade in pectic substances, pectinates and pectates from Italy vs. the rest of the world (HS6 130,220) (*).

Years	Import			Export		
	Quantity, quintals q	Value, dollars $	Index 2015 = 100	Quantity, quintals q	Value, dollars $	Index 2015 = 100
2015	15,828.9	21,549,330.0	100	39.3	68,649.0	100
2016	17,960.8	27,805,046.0	113	254.6	401,719.0	648
2017	15,965.2	26,092,670.0	101	126.0	170,477.0	321
2018	19,301.7	28,572,361.0	122	143.9	162,026.0	367
2019	16,528.5	24,415,356.0	104	146.8	285,036.0	374

(*) Elaborated on UN COMTRADE data. The historical series is limited to 2019.

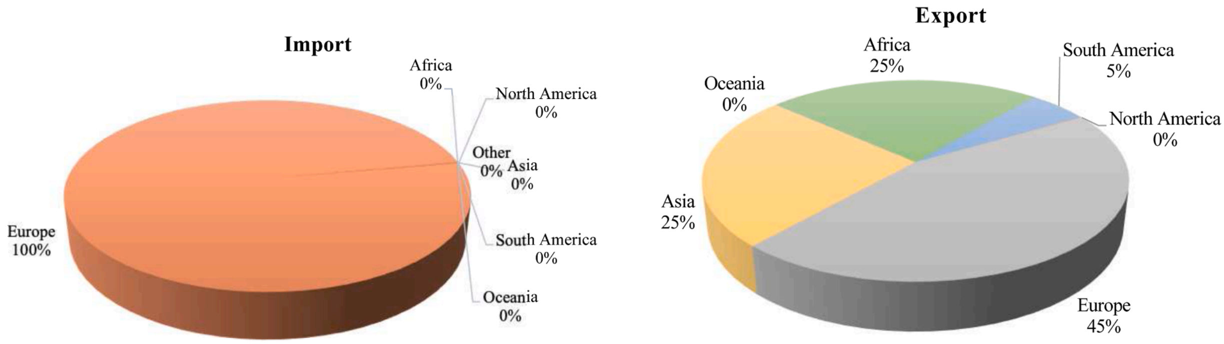

Fig. 2. Import and export detail of Italian pectin and pectic substances by country of origin of trade contracting (processing on quantity data).

Table 4
Trade flow analysis of pectins and pectic substances, degree of market coverage and Italian trade performance (HS6 130,220) (*).

Years	Market Coverage Degree MCD_i q	Market Coverage Degree MCD_i $	Normalised Balance NB q	Normalised Balance NB $
2015	0.25	0.32	−99.5	−99.4
2016	1.42	1.44	−97.2	−97.2
2017	0.79	0.65	−98.4	−98.7
2018	0.75	0.57	−98.5	−98.9
2019	0.89	1.17	−98.2	−97.7

(*) Elaborated on UN COMTRADE data. The historical series is limited to 2019.

group of phytonutrients known as betalains, Italy, as shown in Table 5, they show an increasing trend for both imports (+62 percent) and exports (+38 percent) over the period considered (2015–2022).

In particular, in 2022, imports will be worth well over 96 thousand quintals and over 86 million dollars; in the same year, exports will reach almost 77 thousand quintals and over 92 million dollars.

The drivers of the betalain market appear to be population growth, disposable income, growing demand in developed and developing countries such as China, India and Eastern Europe, and increasing consumer awareness of its health benefits.

As shown in Fig. 3, Italian imports come mainly from Europe (Austria, 20 per cent; Spain, 18 per cent; the Netherlands, France and Germany, 11 per cent each) and Asia (China, 8 per cent; India, 7 per cent).

Exports are even more fragmented than imports, with half the value going to Europe and a quarter to the USA. The betalain market is segmented by end-use and product form i.e., liquid and powder. On the basis of end-use, the market is segmented between the food industry, where the colour is used in confectionery, dairy and beverages, the cosmetics industry and the health industry.

Table 6 highlights two background periods in the import/export trade dynamics of natural plant dyes.

On the one hand, there are the years 2015, 2016 and 2017, in which the trade balances for Italy are negative, showing that more quantities were imported than exported, almost as a sign of reduced demand or more intense competition on the international market.

In the subsequent period up to 2022, imports and exports fluctuate,

Table 5
International trade in coloring matter of vegetable origin from Italy vs. the rest of the world (HS6 32,030,010) (*).

Years	Import			Export		
	Quantity, quintals q	Value, dollars $	Index 2015 = 100	Quantity, quintals q	Value, dollars $	Index 2015 = 100
2015	59,593.5	43,338,366.0	100	55,693.8	55,143,737.0	100
2016	82,138.7	56,715,519.0	138	59,907.8	56,378,878.0	108
2017	72,764.9	56,739,423.0	122	74,242.7	64,957,441.0	133
2018	88,159.7	73,371,535.0	148	69,707.6	75,378,662.0	125
2019	88,052.9	70,295,162.0	148	75,127.1	81,053,806.0	135
2020	80,001.7	74,249,941.0	134	70,100.0	94,197,517.0	126
2021	92,012.3	82,246,423.0	154	76,134.0	96,550,668.0	137
2022	96,425.9	86,258,643.0	162	76,905.9	92,191,526.0	138

(*) Elaborated on UN COMTRADE data. The historical series is limited to 2022.

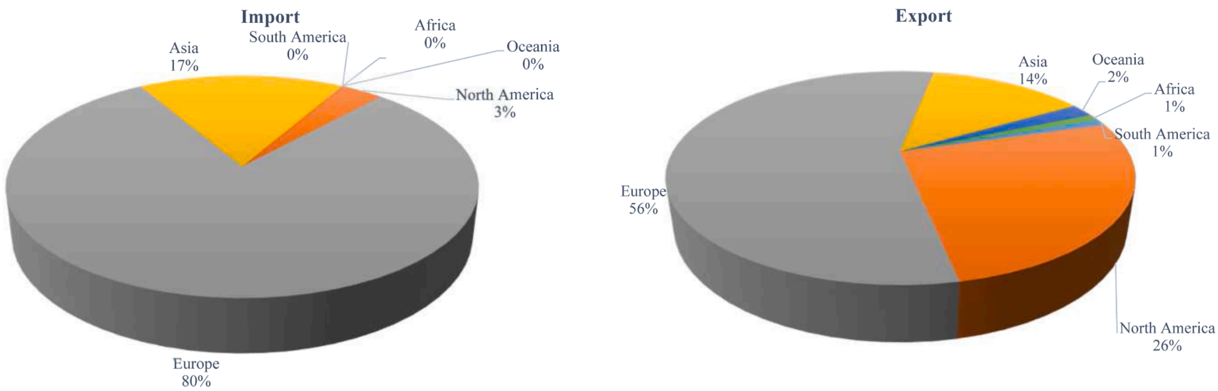

Fig. 3. Detail of imports and exports of Italian natural vegetable dyes by country of origin of trade contract (processing on quantity data).

Table 6
Trade flow analysis of natural vegetable dyes, degree of market coverage and Italian trade performance (HS6 32,030,010) [(*)].

Years	Market Coverage Degree MCD q	Market Coverage Degree MCD $	Normalised Balance NB q	Normalised Balance NB $
2015	93.5	127.2	−3.38	12.0
2016	72.9	99.4	−15.65	−0.3
2017	102.0	114.5	1.01	6.8
2018	79.1	102.7	−11.69	1.3
2019	85.3	115.3	−7.92	7.1
2020	87.6	126.9	−6.60	11.8
2021	82.7	117.4	−9.44	8.0
2022	79.8	106.9	−11.26	3.3

(*) Elaborated on UN COMTRADE data. The historical series is limited to 2022.

with slight variations in value. However, the Italian trade balance in value terms remains positive, indicating that Italy continues to export more natural vegetable colours than it imports, although the margin has decreased over the years. This could be a point of interest when studying supply and demand trends in the natural vegetable dyes sector and related Italian trade strategies.

3.2. Competitive analysis and sales prices

Import prices of pectin and pectic substances show fluctuations over the years, with values ranging from $13.6/kg in 2015 to $16.3/kg in 2017. Export prices also show some variability, with values ranging from $11.3/kg in 2018 to $19.4/kg in 2019. This variability suggests changes in demand, supply and market dynamics that influence pricing strategies. In fact, in 2015 the RPI was 128.4 %, indicating a 28.4 % increase in prices compared to the base year; its value falls below 100 % in 2017 and 2018, indicating a decrease in prices, and then jumps to 131.5 %, almost highlighting the volatility of the Italian pectin and pectic substances trade (Table 7).

Table 7
Variability of import, export prices and relative price index value in Italian trade of pectin and pectic substances (HS6 130,220) [(*)].

Years	Import $/kg	Export $/kg	Relative Price Index RPI %
2015	13.6	17.5	128.4
2016	15.5	15.8	101.9
2017	16.3	13.5	82.8
2018	14.8	11.3	76.1
2019	14.8	19.4	131.5

(*) Elaborated on UN COMTRADE data. The historical series is limited to 2019.

The price analysis of natural colours shows some significant trends (Table 8):

- Import and export prices show significant variations over the years;
- Export prices tend to be higher than import prices, reflecting an added value at the stage of processing and preparing the product for export;
- The price trends are erratic; in 2015, the export price was significantly higher than the import price, with an RPI of 136.1 %, indicating an increase of 36.1 % compared to the base year, in contrast to 2017, a year in which a significant decrease compared to the previous year is observed, indicating clear changes in demand or supply; however, in 2020, the highest peak is observed in both import and export prices, indicating a significant increase compared to the base year;
- The relative price index (RPI) shows an overall fluctuating trend over the years, with some significant fluctuations from the base year.

The price surveys were complemented by data collection on the main marketplaces, focusing on "pectin" (CAS 9000–69–5 or Chemical Abstracts Service - a numerical identifier used to uniquely identify a chemical substance) destined for the cosmetic and food industries from different markets, with a shelf life of 12/24 months and different certifications (HALAL, COA, MSDS, ISO, Kosher, etc.) and on "betalains" (CAS 7659–95–2) destined for the food and pharmaceutical industries, with a shelf life of 48 months and ISO 22,000 (food safety) and ISO 9001 certifications.) and "betalaines" (CAS 7659–95–2) intended for the food and pharmaceutical industries with a shelf life of 48 months and ISO 22,000 (food safety) and ISO 9001 certifications, as shown in Table 9.

This analysis revealed a wide range of prices for bioproducts complying with the reference regulation in Europe (EC Reg. 133/08, as amended by Reg. 1129/11 et seq.) and approved by the EFSA (European Food Safety Authority) and the FDA (Food and Drug Administration) in the USA, in terms of:

Table 8
Variability of import, export prices and relative price index value in Italian trade of natural vegetable dyes (HS6 32,030,010) [(*)].

Years	Import $/kg	Export $/kg	Relative Price Index RPI %
2015	7.3	9.9	136.1
2016	6.9	9.4	136.3
2017	7.8	8.7	112.2
2018	8.3	10.8	129.9
2019	8.0	10.8	135.1
2020	9.3	13.4	144.8
2021	8.9	12.7	141.9
2022	8.9	12.0	134.0

(*) Elaborated on UN COMTRADE data. The historical series is limited to 2022.

Table 9
Variability of wholesale prices of citrus pectin and red beet betanin on some wholesale marketplaces [(*)].

Goods	Country of origin	Minimum sales unit per single contract	Price	Marketplace	Dates
Pectin (CAS 9000–69–5)	China	100 kg	15 $/kg	Alibaba.com	2023, december
Pectin (CAS 9000–69–5)	China	100 kg	18 $/kg	Alibaba.com	2023, december
Pectin (CAS 9000–69–5)	China	1 kg	100 $/kg	Alibaba.com	2023, december
Pectin (CAS 9000–69–5)	China	1 kg	30 $/kg	Alibaba.com	2023, december
Pectin (CAS 9000–69–5)	China	1 kg	25 $/kg	Alibaba.com	2023, december
Pectin (CAS 9000–69–5)	China	500 kg	15 $ /kg	Alibaba.com	2023, december
Pectin (CAS 9000–69–5)	China	100 kg	15 $/kg	Alibaba.com	2023, december
Pectin (CAS 9000–69–5)	China	10 kg	15 $/kg	Alibaba.com	2023, december
Pectin (CAS 9000–69–5)	China	1 kg	20 $/kg	Alibaba.com	2023, december
Pectin (CAS 9000–69–5)	China	1 kg	19.50 $/kg	Alibaba.com	2023, december
Pectin (CAS 9000–69–5)	China	1 kg	25 $/kg	Alibaba.com	2023, december
Pectin (CAS 9000–69–5)	China	1 kg	35 $/kg	Alibaba.com	2023, december
Pectin (CAS 9000–69–5)	Canada	500 g	15.71 $/kg	Amazon.com	2023, december
Pectin (CAS 9000–69–5)	USA	500 g	14.36 $/kg	Ebay.com	2023, december
Betalain (CAS 7659–95–2)	China	1 g	1 $/g	Alibaba.com	2023, december
Betalain (CAS 7659–95–2)	China	1 kg	50 $/kg	Alibaba.com	2023, december
Betalain (CAS 7659–95–2)	China	1 kg	25 $/kg	Alibaba.com	2023, december
Betalain (CAS 7659–95–2)	China	1 kg	100 $/kg	Alibaba.com	2023, december
Betalain (CAS 7659–95–2)	China	25 Kg	12.70 $/kg	Alibaba.com	2023, december
Betalain (CAS 7659–95–2)	China	1 kg	40 $/kg	Alibaba.com	2023, december
Betalain (CAS 7659–95–2)	China	25 Kg	30 $/kg	Agrelma.com	2023, december
Betalain (CAS 7659–95–2)	China	2 Kg	12.60 $/kg	Alibaba.com	2023, december
Betalain (CAS 7659–95–2)	Argentina	500 g	560 $/Kg	Amazon.com	2023, december
Betalain (CAS 7659–95–2)	USA	500 g	530 $/Kg	Amazon.com	2023, december

[(*)] Elaborated on data from the marketplaces shown in the table.

- Country of origin of the organic product;
- Quantity traded;
- Technical specifications such as
  - Organoleptic characteristics (colour, appearance, texture, flavour);
  - Chemical and physical characteristics of the bioproduct (pH, moisture, nitrogen content, residues, particle size, calcium reactivity, etc.);
  - Microbiological characteristics of the bioproduct (yeasts, moulds, mesophilic load, E. coli, Staphylococcus aureus, etc.);
- Certifications and assurances required by regulations and ancillary;
- Type of packaging;
- Transport costs.

3.3. *Results of direct demand analysis*

The distribution of the sample of enterprises by main activity (Fig. 4) shows a predominance of activities related to the production of jams and jellies, followed by handicraft enterprises and producers of ice cream and yoghurt and milk drinks. Confectionery and semi-finished products for this industry have a moderate presence, while sauces and condiments

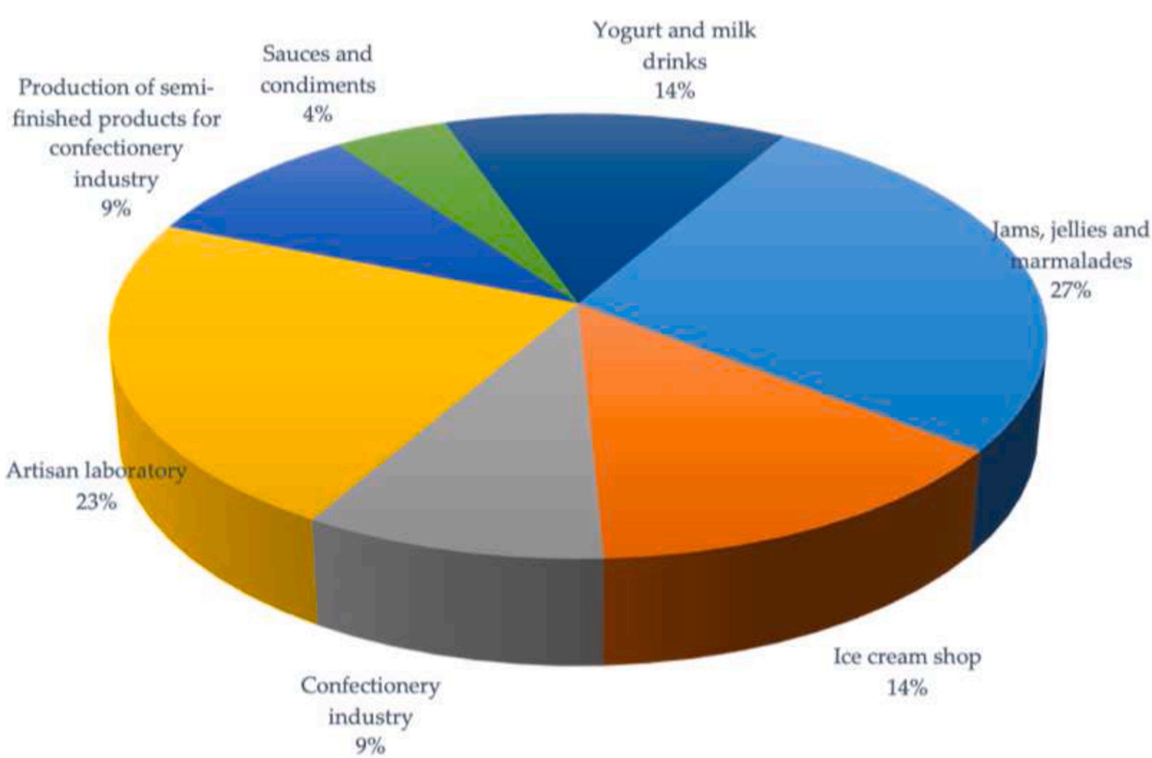

Fig. 4. Type of core business activity of the enterprise.

are the least represented. These findings are consistent with the use of pectin as a common gelling agent in confectionery, the use of natural ingredients to create high quality products, often associated with a more traditional and natural approach to food production, and the use of colorant to achieve vibrant colours in ice cream without artificial additives or more generally to improve visual appeal.

However, in terms of the origin of the products used in food production, the majority come from the European Union, followed by a significant share of imports from non-EU countries and a minority of products of domestic origin (Fig. 5). This distribution reflects logistical, economic and qualitative considerations in the choice of sources of supply. Indeed, enterprises find the resources available within the EU more accessible, probably for reasons of proximity, regulatory quality and production standards.

On the other hand, with regards to the importance attached to different factors when selecting and purchasing pectin and natural colours for production processes in the food industry, some significant indications emerged, as shown in Table 10. Texture and particle size are the factors most frequently considered very important, with 50 % and 52.4 % of respondents, respectively, giving a score of 4. In addition, certifications (score 5, 38.1 %), local origin (score 5, 33.3 %) and fiduciary relationships (score 5, 38.1 %) with suppliers are also highly valued. Finally, appearance is the least polarising factor, with the highest score of 3 (42.9 %), while colour is divisive, with high scores of both 1 (30.0 %) and 5 (25.0 %). This analysis suggests that companies place more importance on factors related to quality and supplier confidence, as well as product-specific criteria such as texture instead and particle size, than on aspects such as colour, which has a more variable rating.

With regard to the expected impact of the choice and purchase of pectin and natural colours in agricultural production processes, based on the scores elaborated in Table 11, it appears that improving firmness is the highest rated factor, with 57.1 % of respondents considering it very important (score 4) and 33.3 % considering it extremely important (score 5).

In addition, the ability to promote products with the low-fat label is considered very important, with 38.1 % of respondents giving it the highest importance. Finally, from a marketing perspective, this analysis shows that companies focus mainly on specific product quality improvements, such as firmness and flavour retention, and highly value the opportunity to promote products as low-fat.

Looking at the distribution of purchasing channels for natural pectin and natural colours used by companies, it appears that the most

Table 10
Importance attached to certain factors when choosing and purchasing pectin and natural dye for its production processes [(*)].

Attributes	Score 1 = Limited %	Score 2 %	Score 3 %	Score 4 %	Score 5 = very much %
Color	30.0	20.0	15.0	10.0	25.0
Appearance	0.0	23.8	42.9	19.0	14.3
Texture	10.0	0.0	25.0	50.0	15.0
Taste	14.3	23.8	4.8	23.8	33.3
pH	0.0	9.5	33.3	33.3	23.8
Moisture	0.0	19.0	9.5	42.9	28.6
Residue	4.8	9.5	33.3	9.5	42.9
Microbial load	14.3	9.5	33.3	28.6	14.3
Particle size	0.0	4.8	28.6	52.4	14.3
Certifications	0.0	19.0	14.3	28.6	38.1
Guarantees	0.0	9.5	42.9	28.6	19.0
Price	4.8	9.5	4.8	47.6	33.3
Provenance	9.5	9.5	19.0	33.3	28.6
Local origin	0.0	23.8	14.3	28.6	33.3
Fiduciary relationships with suppliers	0.0	9.5	19.0	33.3	38.1

(*) Elaborated from data collected by direct survey.

Table 11
Expected impacts of choosing and purchasing pectin and natural dye for their production processes [(*)].

Expected impacts	Score 1 = Limited %	Score 2 %	Score 3 %	Score 4 %	Score 5 = very much %
Improves color	9.5	19.0	28.6	33.3	9.5
Improves flavor persistence	0.0	14.3	28.6	47.6	9.5
Improves odor	0.0	5.0	30.0	45.0	20.0
Improves sweetness	4.8	19.0	14.3	38.1	23.8
Improves adhesion to the palate	4.8	0.0	28.6	42.9	23.8
Improves crunchiness	4.8	9.5	19.0	38.1	28.6
Improves crispness	0.0	4.8	38.1	28.6	28.6
Improves firmness	4.8	0.0	4.8	57.1	33.3
Improves flavor	4.8	4.8	33.3	38.1	19.0
I can promote my products with a "low-fat" label	0.0	9.5	19.0	33.3	38.1

(*) Elaborated from data collected by direct survey.

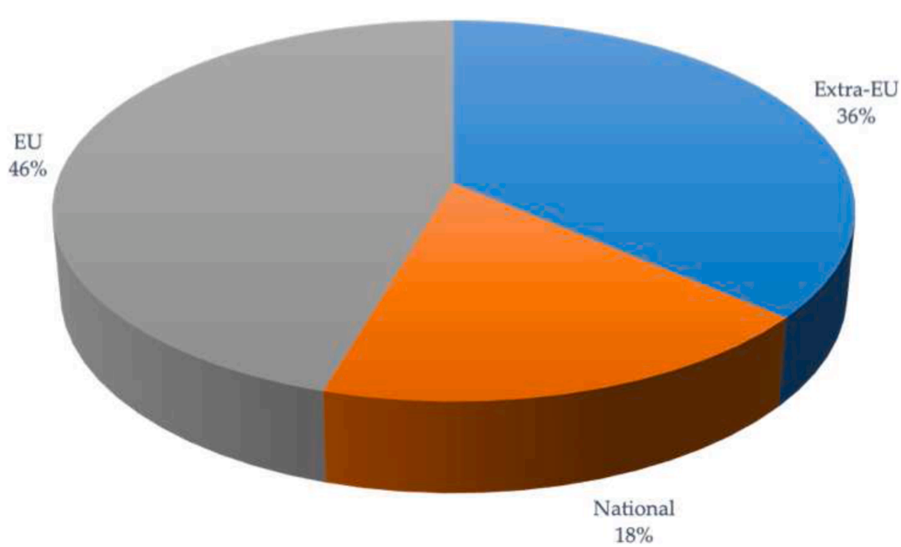

Fig. 5. Origin of pectins and natural dyes used in its production activities.

commonly used channel is Wholesalers, as they are likely to provide a balance between price and availability of adequate product volumes (Fig. 6). Also of interest is the use of Marketplace, a channel that offers flexibility and access to a wide range of suppliers, which is useful for companies seeking variety and price comparisons. Finally, Retailers appear to be used less frequently, probably chosen for specific needs or for products that are difficult to find through wholesalers or marketplaces. This distribution shows that companies tend to prefer to buy in large quantities and under favourable economic conditions, but they also appreciate the flexibility and variety offered by marketplaces. Retailers, although less used, still play an important role for specific needs.

3.4. Choice experiment and willingness to pay for cactus pear bioproducts

The descriptive statistical analysis of the purchasing preferences for pectin and natural colours extracted from cactus waste in Sicily (Table 12) revealed some aspects of particular interest. On the one hand, the preferences for products of extra-EU origin show a relatively high variability, especially for price (CV=54.1 %) and certification (CV=47.4 %), proving the existence of significant differences in respondents' opinions on these attributes. Opinions on products of EU origin, on the other hand, show less variability, with a CV of around 35 per cent for all attributes, in contrast to local origin, with medium variability. For local products, the lower CV for brand name (20.4 per cent) suggests that there is a stronger consensus on the preference for local product brands, just as the relatively high CV for certification (45.9 per cent) indicates different views on the importance of certification for local products.

In general, companies seem to prefer local products because of consistency in brand preferences, while EU products are valued for their reliability in terms of price and residuals. Non-EU products show greater variability in preferences, indicating significant differences in respondents' opinions.

With regard to the attributes covered by the choice experiment, Table 13 confirms the strong preference for local products, followed by EU products and finally extra-EU products, underlining the importance of perceived quality, regulatory compliance and support for local brands in companies' purchasing decisions.

In fact, local origin is the only attribute associated with the highest price (20 Eur/Kg) compared to leading brands, certifications and residue compliance, showing that companies are willing to value local products for their perceived quality and safety standards. In contrast, EU origin is moderately preferred, particularly for lower price and standard certifications, and less so for more comprehensive certifications and leading brand. Finally, extra-EU origin is less preferred overall, with some preference for lower prices and residue compliance. Leading brands and certifications also show limited preferences.

Table 12
Main statistics on purchase preferences for pectin and natural dyes extracted from cactus pear waste in Sicily [(*)].

	Origin	Price	Brand Name	Certification	Residues
Media	Extra EU	1.6897	2.2414	1.4138	1.4483
Standard deviation		0.9136	0.9704	0.6704	0.4973
Coefficient of variation		54.1	43.3	47.4	34.3
Media	EU	1.2727	2.4545	1.2727	1.3030
Standard deviation		0.4454	0.8907	0.4454	0.4596
Coefficient of variation		35.0	36.3	35.0	35.3
Media	Local	1.7714	2.4286	1.9429	1.5714
Standard deviation		0.7592	0.4949	0.8926	0.4949
Coefficient of variation		42.9	20.4	45.9	31.5

[(*)] Elaborated from data collected by direct survey.

As with the WTP (Willingness To Pay) analysis, the value used to demonstrate the significance of the variables is the p-value, which represents the level of significance assigned and it measures the evidence against the null hypothesis. Thus, in Table 14 it can be seen that all the estimated parameters are statistically significant at the 0.05 level and have scores and values consistent with our hypotheses. In particular, the estimated coefficients represent the influence of each attribute level on the individual utility functions. Thus, these coefficients indicate how the different characteristics of the biocomponents that can be extracted from the waste cactus pear plant influence the utility function of the entrepreneur interested in using them in his or her production processes. All the variables in the model are significant and have a positive scores, with the exception of brand name and certification. Moreover, all scores are consistent with economic expectations of behaviour.

More specifically, it was found that the average WTP was 18.4 EURO/kg and that product origin, pectin price and residue were positively correlated with WTP, indicating that consumers value these

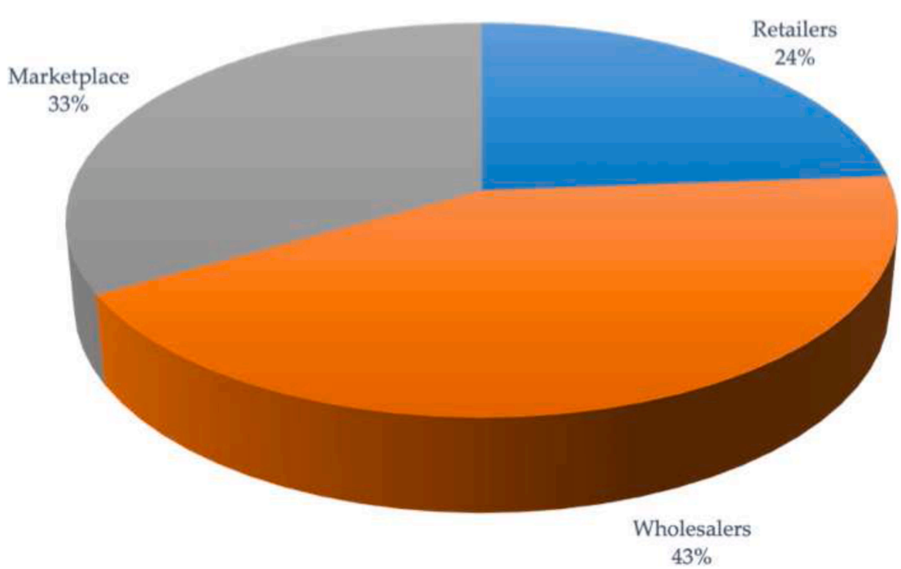

Fig. 6. Purchase channel of pectins and natural dyes used in its production activities.

Table 13
Result of the choice experiment on the purchase preferences of pectin and natural dyes extracted from cactus pear waste in Sicily [(*)].

ORIGIN	PRICE			BRAND NAME			CERTIFICATION			RESIDUES	
	12 Eur/Kg	16 Eur/Kg	20 Eur/Kg	Brand leading company	New StartUP Sicilian Brand	None	Standard	Standard + ISO	Standard + ISO + Other	Compliance Regs. 396/2005/EC and 1881/2006/EC and amendments	None
Extra EU	0.1364	0.0152	0.0682	0.0833	0.0000	0.1364	0.1515	0.0455	0.0227	0.1212	0.0985
EU	0.1818	0.0682	0.0000	0.0682	0.0000	0.1818	0.1818	0.0682	0.0000	0.1742	0.0758
Local	0.1061	0.1970	0.2273	0.1515	0.1515	0.2273	0.2273	0.1061	0.1970	0.2273	0.3030

[(*)] Elaborated from data collected by direct survey.

Table 14
Regression model results for choice factors of cactus pear bioproducts [(*)].

Variables	Coefficient	Std. error	z	p-value
const	18.3824	0,830,279	22,14	<0,0001
ORIGIN	0.281245	0.0124194	14.900	<0.0001
PRICE (pectin)	0.318046	0.0182851	17.390	<0.0001
PRICE (betanin)	0,271,621	0.0391334	2.628	0.0000
BRANDNAME	−0.092704	0.0348114	−2.954	0.0031
CERTIFICATION	−0.102841	0.036372	−2.549	0.0108
RESIDUES	0.185017	0.0169985	16.55	<0.0001
Log-Likelihood	55.09747		Akaike Criterion	−98.19493
Schwarz Criterion	−80.89812		Hannan-Quinn	−91.16630

[(*)] Elaborated from data collected by direct survey.

aspects. In contrast, brand name and certification have a negative effect on WTP, suggesting that consumers may not see added value in these factors. The model has good fit parameters such as log-likelihood, Akaike's criterion, Schwarz's criterion and Hannan-Quinn, indicating a good fit to the data.

The coefficients of each attribute included in the model have different scales of measurement and are therefore not directly comparable. Instead, by dividing this value by the price coefficient, the unit of measurement becomes the monetary unit, which facilitates the interpretation of the relative importance of attributes and the comparison between attributes. In order to analyse the different degrees of influence that each variable has on the utility function associated with the purchase of cactus pear bioproducts, the willingness to pay (WTP) for each attribute was calculated, as widely recognised in the literature (Fu et al., 2024).

The results are shown in Table 15. As can be seen, when choosing a bioproduct, entrepreneurs mainly pay attention to the origin and the compliance or non-compliance of residues in them.

This means that entrepreneurs are active and aware when choosing what to buy and what to use in the formulation of ingredients in their food products, and this can be a stimulus for companies and marketers in the organic sector to better understand consumer preferences and to develop more effective pricing and marketing strategies. In fact, these factors together represent a significant competitive advantage, as they capitalise on the image that cactus pear has with consumers in terms of sustainability and health benefits, and because they express the ability of companies to meet the growing demand for natural and safe products.

Table 15
Premium price recognized for waste cactus pear bioproducts [(*)].

Willingness To Pay (WTP)	Pectin (EUR/kg)	Betanin (EUR/kg)
ORIGIN	0.88	1.04
BRANDNAME	0.29	0.34
CERTIFICATION	0.32	0.38
RESIDUES	0.58	0.68

[(*)] Elaborated from data collected by direct survey.

4. Discussion

The idea of activity and/or processing out in Sicily, directly on the territory where the cactus pear is cultivated, the transformation of waste into bioproducts is certainly of great interest, given the spread of the cactus pear in terms of areas and productions. Not only that, but historically, the marketing activities are located in well-defined territorial poles (in the eastern and western parts of the island), which, by virtue of the activity carried out, offer the availability of waste biomass to be used for starting processing. Thus, the proximity conditions are created to increase the opportunities for new businesses and new business start-ups and job creation at the local level (Tell et al., 2016).

The levers that can be exploited are the growing demand for functional, low-calorie and high-quality food; the increasing use of natural ingredients by the cosmetics, nutraceutical and pharmaceutical industries; the existence of more "green" extraction technologies that allow the positive properties and components of the derivatives to be maintained; and the increased circularity of production processes, with the reduction of waste and by-products from the food industry, which is essential for sustainable development (García et al., 2020; Villamiel, 2021).

Some threats to the realisation of such a business design can be traced back to climate change, the irregularity and aggressiveness of some events that can lead to variability in yields, strong international competition (e.g. Morocco and other Mediterranean countries because they pay particular attention to the dynamics of the cactus pear market) and the ability to adapt to economies of scale and selling price in the international market, as well as the evolution of regulations on food additives.

Research has shown that a competitive advantage in the case of cactus pear derivatives is related to the close link with the territory, which allows the production of food with local ingredients, the possibility of using a product not polluted by pesticide residues, contaminants and other chemicals, to the point that several initiatives are starting to increase the value of cactus pear derivatives.

It follows that the most appropriate strategy for the success of cactus pear bioproducts is linked to origin, quality claims and adaptability to specific uses of the bioproduct:

- To the origin of the product, in order to obtain a premium price recognised by the link with the local area and traditions;
- Guarantees, not only in terms of food safety, but above all the possibility of offering bioproducts free of pesticides and contaminants, which research has shown to be particularly welcome by the market;
- The characteristics and specific features of the bioproducts, which in the case of pectins are expressed by the high degree of methoxyl, whose solubility and gelatinisation conditions make it suitable for use in the food industry, and in the case of natural colourings, for their long-recognised value in the production of food, textiles and cosmetics.

The importance of an entrepreneurial project for the valorisation of cactus pear waste should be placed in the current historical moment, as there is a strong institutional interest in the promotion of a green, sustainable and circular economy, called for by the EU Green Deal, the new EU Circular Economy Action Plan, public opinion, the consequences of the COVID pandemic and the launch of national plans for economic recovery, such as the EU Nex Generation (NRP). Effective responses to the fragility of economic-territorial systems, leading on the one hand to sustainable business models and on the other hand to increased demand for green, natural and health-conscious products and attention to personal health and well-being, etc., are needed to turn these policy challenges into reality (Roor & Maas, 2024).

This is compounded by the high volatility of prices, so that companies wishing to invest in this sector must consider several possible strategies to increase their competitive advantage:

- Expanding into new markets or diversifying the customer base to mitigate the impact of price fluctuations in specific regions. This strategy reduces dependence on a single market and spreads the risks associated with market volatility;
- Investing in research and development to create value-added products or innovative formulations that can justify a higher price, thereby reducing sensitivity to price fluctuations (e.g. the development of organic pectin products targeted at niche markets can command higher prices and increase profit margins);
- Vertical integration upstream in the supply chain, through acquisition or collaboration with raw material suppliers, to achieve greater control over costs and reduce exposure to price fluctuations;
- Risk management strategies, such as forward contracts, which allow companies to lock in prices for future transactions to stabilise revenues and mitigate the impact of adverse price changes;
- Investment in marketing activities to promote the quality, sustainability and strengths of bioproducts to differentiate products in the market and justify a higher price (building a strong brand reputation can also instead create customer loyalty and insulate against price sensitivity);
- Working with industry stakeholders, including producers, exporters, trade associations and research institutes, to share knowledge, market information and joint efforts to address common challenges and take advantage of emerging opportunities.

5. Conclusions

There is an important need to promote the reorientation of the "production-consumption" system of Italian cactus pears, from a model mainly oriented to the use of fruits/derivatives for human consumption (rosolio, mustards, jams, juices, IV range fruits, etc.), from which two types of products are actually produced, such as "fruit and derivatives" and "waste", to a circular bioeconomy model, with the aim of obtaining "fruit and derivatives" and "biomass to be exploited". In this way, the potential biomass (fresh cladodes from pruning residues, flowers and scozzolatura residues, peel, pulp, seeds, etc.) can express "biochemicals" for high-value uses in food, novel foods, nutraceuticals, but also for green chemistry applications in cosmetics, phytotherapy, bio-building, bioremediation and other technical applications that are particularly in demand by the market (Pulina & Timpanaro, 2012; Kassim et al., 2022; Kataya et al., 2023; Das et al., 2024; Mei et al., 2024).

Around the world, the cactus pear bioeconomy is now a reality, and some initiatives have also emerged in Sicily thanks to the diligence of several entrepreneurs (Ciriminna et al., 2018, 2019b; Dubeux et al., 2022; Dávila et al., 2015; Shetty et al., 2012). The advantage to be seized is the opportunity to create a local zero-kilometre supply chain based on the proximity of biomass production and processing through artisanal green mini-plants, generating stable value and employment by catering to a potentially growing market demand (Alkaraan et al., 2024).

Therefore, the research showed:

- import/export data are currently fluctuating for pectin and natural dyes, probably due to changes in the needs of the Italian market and the global dynamics of the sector;
- there is concrete and growing competition from other countries, especially in the Mediterranean basin;
- Italy's dependence on external sources to meet domestic demand for bioproducts exposes it to risks related to the stability of external suppliers or changes in global trade policies.

Ultimately, all this bodes well for the start-up of cactus pear waste transformation processes in Sicily, also because a potential national demand for quality bioproducts and the willingness to recognise price premiums for origin, absence of residues and certification has been noted. This means that if potential users of bioproducts in the food sector are willing to pay a higher price than the market average, it means that they perceive the cactus pear waste bioproduct as better or significantly different from similar products on the market.

However, the work carried out has some limitations as the secondary data do not relate to cactus pear bioproducts, but to products that are commodity related and present on the market (as specified, citrus pectin and natural colour from beet). This element of variability may cause some differences in the analyses carried out. On the other hand, direct research provides a high degree of realism in the determinants of the phenomenon analysed.

Finally, future research will focus on the concrete implementation of the business idea, on overcoming some technical and technological problems (monomer extraction and its purification, for instance) and on the economic validation of this innovation (investment and operating costs), in order to support interested private investors in the implementation of a cactus pear waste recycling plant according to the circular economy.

Ethical statement - Studies in humans and animals

I have nothing to declare.

CRediT authorship contribution statement

Giuseppe Timpanaro: Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Vera Teresa Foti:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis.

Declaration of competing interest

The authors 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

No data was used for the research described in the article.

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