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Switching to bio-based packaging for organic products: supply chain actors' perspectives

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Abstract The use of fossil-based plastics used for packing organic foods is under the lens of the organic movement because of the contrast with the organic farming principles and its negative impact on the environment. Bioplastics, which can be bio-based and biodegradable, are a promising solution to address the various issues, i.e. social and environmental, caused by the intense use of conventional plastics. Nevertheless, using bioplastics as a more sustainable solution in the food packaging industry is still controversial. It involves a variety of opinions, consensus, and disagreements among food supply chain actors. The present study investigated stakeholders' viewpoints regarding the acceptance of bio-based packaging in the Italian organic food supply chain. Individual perspectives from a selected group of organic stakeholders (producers, distributors, and researchers) were captured by applying the Q methodology. Two relevant divergent views were identified, as well as consensus agreements. The study shows how Q methodology can effectively discover the most relevant viewpoints about an emerging topic.

Keywords Bioplastics · Bio-packaging · Circular economy · Sustainability · Organic farming · Stakeholders viewpoints · Q methodology

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Introduction

Packaging is critical in the food supply chain, from production to consumer plates. Its multiple functions (e.g., protection, distribution, communication, information) enable convenience and logistical efficiency and fulfil many economic, environmental, and legal requirements (Cheng et al. 2022; European Union 2004; Karimi Sani et al. 2023; Michaliszyn-Gabryś et al. 2022; Verghese et al. 2015). Fossil-based plastic is the most common food packaging material (e.g., polyethylene PE, polypropylene PP, polyvinylchloride PVC). However, its excessive use has become a significant environmental burden, dramatically damaging climate change and nature (Guillard et al. 2018; Jabeen et al. 2015; Michaliszyn-Gabryś et al. 2022; Molina-Besch and Olsson 2022). By 2050, only in Europe, plastic packaging is expected to increase from 23 million tons to 92 million tons because of rising food demand brought on by an expanding world population, which could reach 9.7 billion people (Gaigbe-Togbe et al. 2022; Guillard et al. 2018). The main problems stem from the fact that the food

packaging is often discarded with the food after consumption (Versino et al. 2023). Most plastic packaging is also characterised by a limited biodegradability, which takes centuries before it degrades, and by a low recycling and re-use rate of plastics (around 9% are recycled) (Abbing 2019; Ángeles-Hurtado et al. 2021; Ncube et al. 2020, 2021; Schnurr et al. 2018; Thushari and Senevirathna 2020; Wen et al. 2021). Added to this, the increase in food consumption has a negative impact on plastic waste management systems, with insufficient collection, sorting, and recycling of plastics (Mahesh Kumar et al. 2016).

Adopting alternative packaging solutions is necessary in light of the pressing need for a more sustainable and healthier world (Bhagwat et al. 2020; Briassoulis and Giannoulis 2018; Guillard et al. 2018; Zhu et al. 2022). According to the New Circular Action Plan (CEAP), the primary goal is reducing packaging waste, favouring reuse and recyclability of packaging (European Commission 2020; Johansen et al. 2022; Michaliszyn-Gabryś et al. 2022). In order to promote circular approaches, the European Commission policy drew attention towards adopting bio-based plastics (Bhagwat et al. 2020; Di Bartolo et al. 2021; Döhler et al. 2022; European Commission 2018, 2020; Harnkarnsujarit et al. 2021; Karan et al. 2019; Karimi Sani et al. 2023; Lamberti et al. 2020; Michaliszyn-Gabryś et al. 2022; Rosenboom et al. 2022). The bio-based plastics sector represents a niche in the market. However, numbers are rapidly increasing. Worldwide production of these alternative materials was around 2.11 million tons in 2020 and will probably reach 2.87 million tons by 2050 (Michaliszyn-Gabryś et al. 2022). Due to a rapid development, consumers and sometimes even experts often misunderstand the definition of 'bioplastic' (Aubin et al. 2022; Bhagwat et al. 2020; Guillard et al. 2018). And despite the European Bioplastics definition ('a plastic material is defined as a bioplastic if it is either bio-based, biodegradable, or features both properties') (European Bioplastics, 2016; Yeh et al. 2015), the term bio-based and biodegradable plastics are often erroneously used interchangeably (Moshood et al. 2022). For the sake of clarity, it should be mentioned that the origin of the material cannot be confused with the capacity to biodegrade. Therefore, the plastics are bio-based if they are produced from renewable raw materials like sugarcane or maize (Döhler et al. 2022; Guillard et al. 2018; Karimi Sani et al. 2023; Michaliszyn-Gabryś et al. 2022), while they are biodegradable when under certain conditions they have the ability to decompose into mainly carbon dioxide, water, and methane. A bio-based material can only be recyclable but not necessarily biodegradable and compostable (Neves et al. 2020). Biodegradation strongly depends on the material's chemical structure and environmental conditions, not the source (Bhagwat et al. 2020). A high level of biodegradability characterises a compostable material under specific aerobic conditions within 6–12 weeks. Numerous bio-based packaging materials are available today, such as PLA, PHA, PBS, and starch blends (Michaliszyn-Gabryś et al. 2022; Reichert et al. 2020). Polylactic acid (PLA), obtained through the bacterial fermentation of hydrolysed corn starch followed by the polymerisation of lactic acid, is one of the most promising materials. Its breathability and ductility make this material the optimal solution for food packaging films (Rapisarda et al. 2020; van den Oever et al. 2017; Yuvaraj et al. 2021). On the market side, both consumers and companies perceive bioplastics positively, but only a few companies are phasing out fossil-based packaging in favour of bio-based packaging (Bhagwat et al. 2020; European Bioplastics 2018; Guillard et al. 2018; Karimi Sani et al. 2023; Meherishi et al. 2019; Michaliszyn-Gabryś et al. 2022; Ncube et al. 2020; Singh et al. 2022). Most of them use these materials primarily as a marketing tool to draw the attention of greener consumers (Kędzia et al. 2022; Mehta et al. 2021; Molina-Besch and Keszleri 2023; Neves et al. 2020; Reichert et al. 2020; Wellenreuther et al. 2022; Yeh et al. 2015; Zhu et al. 2022). The barriers to the adoption of bio-based plastics are regulations, current infrastructures, and the need to know the concrete environmental and social benefits among stakeholders (Fletcher et al. 2021; Kakadellis et al. 2021; Mehta et al. 2021; Molina-Besch and Keszleri 2023; Versino et al. 2023), as well as the lower prices of oil-based plastics materials (Kafel et al. 2021; Mehta et al. 2021; Michaliszyn-Gabryś et al. 2022; Neves et al. 2020; Wellenreuther et al. 2022).

Although European organic regulations regulate the food production and transformation (European Union 2007, 2008; IFOAM 2022; Kafel et al. 2021), no mention is made regarding the packaging of organic products (European Union 2007, 2008). A recent version of the IFOAM standards (IFOAM 2019) when referring to the packaging of organic foods specifies a ban on the use of 'nanomaterials', compounds of particle ranging in size from 1 to 100 nm, but there is no explicit ban on GMOs (Griffin et al. 2018; IFOAM 2019; Lammerts Van Bueren et al. 2008). In this framework,

despite the unclear scenario, biodegradable and compostable bioplastics are viewed by organic food companies as an exciting opportunity for limiting the use of oil-based packaging (IFOAM 2022; Kafel et al. 2021; Michaliszyn-Gabryś et al. 2022; Santos et al. 2021; van Herpen et al. 2016; Willer et al. 2022; Yeh et al. 2015; Zanoli and Naspetti 2002). According to recent literature, only a few studies investigated stakeholders' perceptions of bio-based plastics, given the majority focused on the consumer perspective (Aubin et al. 2022; Fletcher et al. 2021; Imbert et al. 2019; Kafel et al. 2021; Kakadellis et al. 2021; Lokesh et al. 2018; Molina-Besch and Keszleri 2023; Neves et al. 2020; Theinsathid et al. 2011; Yeh et al. 2015). This paper aims to reveal how different stakeholders of the organic food sector perceive the adoption of bioplastics and to identify areas of agreement and disagreement. The diverse perspectives held by a selected group of organic stakeholders (producers, distributors, and researchers) were investigated using Q methodology (Brown 1980; Mandolesi et al. 2015; McKeown and Thomas 2013; Röös et al. 2023; Stephenson 1953). The results provided clear information for discussing the most critical aspects of organic food system actors and the common ground of actions to develop more effective policies.

Materials and methods

Q methodology

Q methodology is a mixed method that provides a scientific framework for assessing subjectivity related to viewpoints, perspectives, and personal preferences about any topic (Brown 1980; Stephenson 1935, 1953). Combining the benefits of both qualitative and quantitative approaches, Q methodology facilitates the study of subjective attitudes, which cannot 'be verified as true or false like objective claims because they are internal to a person' (Rhoads et al. 2022; Stefanidou and Skordoulis 2014). In Q methodology, attitudes are 'defined in terms of the behaviour of the subjects as they rank the statements from their own subjective viewpoints' (Brown 1980). In a Q study, participants are asked to sort a sample of statements covering all available opinions about the topic under investigation. During the sorting process, participants are asked to decide 'operantly' what is meaningful and significant from their perspective and produce their Q-sort (Brown 1980; McKeown and Thomas 2013). Each Q sort represents the viewpoint of one individual, and it is statistically examined using an 'inverted' factor analysis (Brown 1980, 1993; Stephenson 1935, 1953). In this unconventional factor analysis, the participants (their views) 'become the the variables of interest' (Watts and Stenner 2005) and the objective is to determine the dominant factors, which resume ways of thinking shared by a group of participants (Brown 1980). Q methodology takes distances from some traditional and more statistical methodologies (i.e. surveys) and allows to reveal consensus and divergence involving small groups of participants (Brown 1980; Previte et al. 2007). Although Q methodology has been traditionally applied in psychology and political science, today, this approach has been increasingly utilised in different research fields (Barry and Proops 1999; Doody et al. 2009; Hall 2008; Leonhardt et al. 2022; Mandolesi, Cubero Dudinskaya et al. 2022; Mandolesi et al. 2015; Naspetti et al. 2016; Nicholas et al. 2014; Röös et al. 2023; Zanoli et al. 2015). The methodology is particularly relevant for exploring controversial issues and for supporting stakeholder thinking process which is essential for having a complete understanding of all relevant dimensions (Cuppen et al. 2010; Derksen and Mithöfer 2022; Iofrida et al. 2018; Zanoli et al. 2018).

Research design

A Q study comprises five steps (McKeown and Thomas 2013): (1) creating the *concourse*; (2) selecting the items which form the 'Q sample'; (3) defining the appropriate participant sample, known as 'P sample'; (4) collecting data ('Q sorts'); and (5) extracting factors and their interpretation.

The first step is the definition of the concourse, which refers to 'the flow of communicability surrounding any topic' (Brown 1980, 1993). The *concourse* includes all possible opinions (i.e. written items, known as 'statements') about the topic under investigation (Brown 1993). For this study, any divergent opinion regarding the acceptability of bio-based packaging for the organic food sector was included in our *concourse*. The statements drawn from newspapers, reports, social networks, and expert interviews allowed a comprehensive picture of the topic. Statements were adjected to be 'as subjective as opposed', understandable, and representative of the topic (Brown 1993;

Table 1 Theoretical basis for generating the Q sample and matrix reporting the number of statements

Q sample (n = 36 statements)		Two categories	
		Perceived usefulness (PU)*: the degree to which a stakeholder believes that adopting bio-packaging for organic foods would…*	***Perceived ease of use (PEOU)****: the degree to which a stakeholder believes that using bio-packaging for organic foods would require…*
Levels	***Economic***: Statements related to profits, costs, market competitiveness and technological efficiencies.	Statements #1, 2, 3, 4, 5, 6	Statements #7, 8, 9, 10, 11, 12
	Societal: Statements related to legislation, transparency, consumers' awareness, trust, food safety, health and ethics.	Statements #13, 14, 15, 16, 17, 18	Statements #19, 20, 21, 22, 23, 24

Webler et al. 2009). Finally, 180 statements formed the *concourse*. The *concourse* was then reduced following a structured approach to determine the Q sample (McKeown and Thomas 2013). Fisher's design of experiments was used to provide a miniature of the concourse, ensuring comprehensiveness without sacrificing the overall representation (Brown 1970, 1993; Fisher 1960; Kramer et al. 2003; McKeown and Thomas 2013). Two primary predictors (or categories) and the three dimensions of sustainability were used to select relevant statements and cover the topic sufficiently. To make more straightforward the process of classification of the statements, two categories[1] were theoretically derived from the Technology Acceptance Model of Davis (TAM) (Davis 1989), widely applied to explore determinants of the acceptance of a given technology or any other innovative production strategies: 'perceived usefulness' (PU) and the 'perceived ease of use' (PEOU) (Gerli et al. 2022; Kolade et al. 2022; Naspetti et al. 2017; Ntaliani et al. 2010; Otter and Beer 2021; Venkatesh et al. 2003). The TAM model suggests that both PU and PEOU may influence attitudes towards use, which affects behavioural intention to use and actual use (Davis 1989). A three-level structured matrix was used (Table 1). The three levels were the main dimensions of sustainability: economy, society, and environment (Food and Agriculture Organization of the United Nations (FAO) 2014). The final factorial design included $2\times3=6$ cells. To provide enough diversity and to reduce redundancy, both practical and theoretical considerations were taken into account, and finally, six statements were selected for each cell of the matrix. The number of the thirty-six statements ($N=2\times3\times6=36$ statements) composing the Q sample is shown in Table 1. Each matrix cell was assigned a different colour to facilitate the analysis. This way, from now on, statements belonging to a cell will be identified by the same colour and number.

In a Q study, the selection of participants should not be random but theoretical (McKeown and Thomas 2013). Q methodology uses small participant samples ('P sample'), and single-case studies are not rare (Brown 1978; McKeown and Thomas 2013). According to Brown (1980), more effort should be made to provide more variability and quality in the composition of the participant sample, avoiding approaches merely based on too many participants (Watts and Stenner 2005). Of course, nothing precludes the use of higher numbers; however, increasing the number of participants has a very low impact on the robustness of the final factor solution (Brown 1980). Variability can be guaranteed by strategically sampling people who might have a pivotal viewpoint and strong interest in the topic (Watts and Stenner 2005). In this case, a purposive sampling assumes that different groups of stakeholders (i.e. farmers, retailers) embrace and support divergent viewpoints on the

[1] In the original version, the two primary determinants were defined as follows: 'perceived usefulness' is 'the degree to which a person believes that using a particular system would enhance his or her job performance'. In contrast, 'perceived ease of use' is 'the degree to which a person believes that using a particular system would be free of effort' (Davis 1989).

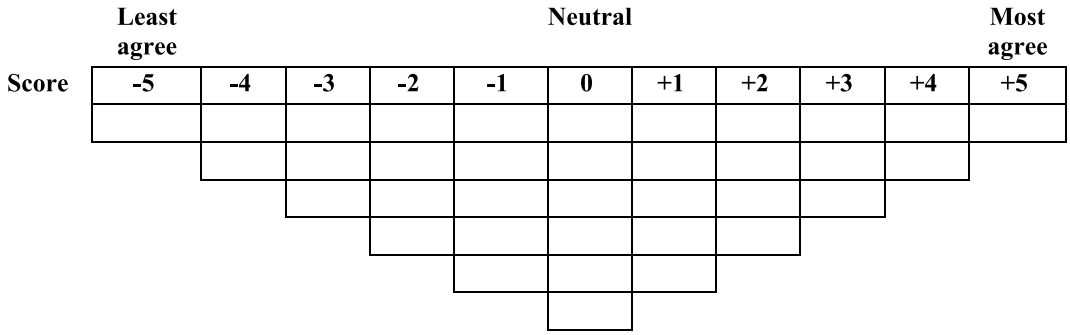

Fig. 1 Graphical visualisation of the shape of a 'Q sort' (Q sorting distribution)

adoption of bio-based packaging (Maniatakou et al. 2020). Also, since the propensity to adopt an innovation strongly depends on the stakeholders' involvement, the participant sample included people working in the organic food supply chain's fourth-range vegetable sector. A convenience sampling was followed to reach a sufficient number of participants. Participants were recruited by sending invitations, via mail or phone, to project partners and other stakeholders who are active in the fourth-range organic vegetable sector in Italy. Other experts, such as researchers and technicians, were also included to increase the representativeness of viewpoints. Qualtrics' online platform was used for recruiting participants (www.qualtrics.com). Finally, fourteen participants completed the Q sorting task. The detailed composition of the final P-sample is 'researcher' (4 participants); 'producer' (4 participants); 'distributor/retailer' (6 participants).

Before starting with the task, participants received a brief explanation of the research purpose and the definition of bio-packaging. The text provided to participants is reported in the Appendix. Participants were asked to rank-order the set of statements according to a specific sorting distribution and instruction conditions provided by the researcher. This original form of data is known as 'Q sort,' i.e. the distribution of statements of a participant (Watts and Stenner 2005). Every single Q sort represents a means for naturally capturing the participant's viewpoint about the topic under investigation. While ranking, the participant compares each statement in relation to the others, in a dynamic and natural way. The result of this ranking process is just a picture of the individual's subjectivity, using Brown's words: 'there is obviously no right or wrong way to provide my point of view about anything' (Brown 1993)In this study, each participant was asked to sort the 36 statements 'according to those with which you most agree (+5) to those with which you least agree (-5)' (Fig. 1). To facilitate the sorting process, firstly, participants sorted the statements into three groups ('most agree'; 'least agree'; 'neutral'), and then they finalised the ranking according to the quasi-normal Q sorting distribution (Brown 1980). To complete the task, participants provided their opinions and explanations concerning the extreme positions of the Q distribution (that is, statements ranked under the '+5' and the '−5'). Finally, to provide the most 'informative solution' (Watts and Stenner 2005), post-sort interviews were collected to aid in the final interpretation of the factors. Both Q sorts and post-sorts interviews were collected online from March to May 2022 using the Easy-HtmlQ software (Banasick 2016).

Data analysis starts with calculating the correlation matrix that reflects the relationship between each Q sort and constitutes the raw material of the 'Q factor analysis' (McKeown and Thomas 2013). In this matrix, all Q sorts are cross-correlated. Then, factor analysis is applied. Factor analysis produces a set of factors in which participants load according to their ranking of the statements. Consequently, factor analysis in Q methodology groups people who ranked similar statements into the same factor. There is no unique way to extract the appropriate set of factors (Brown 1980). The principal component factor analysis (PCA) is the most applied (Brown 1980; McKeown and Thomas 2013; Röös et al. 2023; Sneegas et al. 2021). Concerning the selection of the number of factors to retain, there is no unique criterion to follow; the point is defining factors qualitatively different from the others

and realistic (Brown 1980; Mandolesi, Naspetti, et al. 2022a, b; McKeown and Thomas 2013; Sneegas et al. 2021; Watts and Stenner 2005; Zabala et al. 2018). There is no 'objectively correct number of factors' to extract; however, a more straightforward solution with a few factors is generally preferred over more complex solutions (Sneegas et al. 2021).

Factor loadings represent the correlation between each Q sort and the factor and are calculated to begin data analysis. Typically, factor loadings are shown in a table where Q sorts are the rows and factors extracted are the columns. Factors may also be rotated to facilitate interpretation (Brown 1980). Varimax or judgemental rotations are both possible; however, for Brown, the by-hand rotation is considered to be the most appropriate to observe 'reality, represented by the Q sorts performed, from the theoretical vantage point of the observer' and to indulge 'the nature of data' (Brown 1980; Watts and Stenner 2005). Q sorts are then flagged to define each factor, i.e. those sorts which significantly load on that perspective and not others (Mandolesi, Cubero Dudinskaya et al., 2022; Zabala et al. 2018). Flagged Q sorts are considered the 'most representative of a given factor' or 'defining Q sorts' (Watts and Stenner 2012). However, even if a Q sort is defining for one factor, it can still partially support the other factors with lower factor loadings to some extent. The other coefficients for interpreting results are the factor scores which indicate the relationship between statements and factors. Factor scores are used to determine whether a statement is a *consensus* (that means it has a similar z-score across all factors) and whether a statement *distinguishes* a factor (that means it has a significantly different z-score in a factor compared to the other factors) (Brown 1980; Zabala et al. 2018). Furthermore, one statement can be a distinguishing one for one or more factors (Zabala 2014). The factor score of a statement for each factor is calculated as a weighted average of the scores given by the flagged Q sorts to that statement (Zabala et al. 2018; Zanoli et al. 2015). Using Watts and Stenner's words (Watts and Stenner 2005), 'the Q sorts of all participants that load significantly on a given factor are merged together to yield a single (factor exemplifying) Q sort which serves as an interpretable 'best-estimate' of the pattern or item configuration which characterises that factor'. In this calculation, confounded Q sorts, those which significantly load into two or more factors, are usually excluded (Watts and Stenner 2005). Factor scores can be used as z-scores or normalised scores, an integer approximation of the original values. Usually, the normalised scores are used to create a 'factor array': an 'ideal' Q-sort computed for each factor which represents 'how a hypothetical person representing a group of similar respondents (the factor) would rank the items' (Zabala et al. 2018). This 'ideal' view or factor allows interpretation of a factor by identifying differences with the others. The interpretation is the last step, where the researcher is asked to seek patterns across views and capture each factor's essential nature. An informative label can be assigned to each factor for a brief snapshot of the view.

Results

Q sorts were analysed using the KADE software (Banasick 2019). The principal component factor analysis (PCA) was used to define significant factors, which were then rotated using a combination of varimax and a hand-rotations (Röös et al. 2023; Sneegas et al. 2021). Multiple solutions were generated and compared. Brown's rule (1980) was used to extract the most relevant factors, i.e. those with at least two statistically significant factor loadings, at the 0.01 level (i.e. those exceeding $\pm 2.58 \times$ standard error (S.E.), where S.E. $= 1/\sqrt{}$ (no. of statements)) (Brown 1980). For this study, the standard error of the correlation is given by $1/\sqrt{(36)} = 0.167$; and ± 2.58 x $(0.167) = \pm 0.430$, indicating that correlations exceeding ± 0.430 are significant ($p < 0.01$). After inspecting the scree plot (i.e. a line-graph reporting eigenvalue for each factor) and analysing results, the more straightforward two-factor solution was preferred over the others with more than two factors (Sneegas et al. 2021). Factor loadings of each participant are reported in Table 2. The total variance explained by the two factors is 51%, distributed as follows: 29% for Factor 1 and 22% for Factor 2. One participant was not associated with any of the factors. Variance explained for a Q study is not considered a critical measure since the researcher is not interested in finding the percentage of a perspective in the population nor generalising results. However, the relatively 'low' explained variance might suggest the high variation of viewpoints and uncertainty regarding this technology. Despite a positive correlation between factors

Table 2 Participants type and related factor loadings for each factor (In *bold* participants' loading that represents each factor)

Participant #	Type	F1	F2
P1	Researcher	**0.5759**	-0.05
P2	Researcher	**0.6821**	0.4853
P3	Distributor/retailer	0.2715	**0.6429**
P4	Producer	**0.7697**	-0.0396
P5	Researcher	**0.4909**	0.3117
P6	Distributor/retailer	0.4727	**0.6396**
P7	Producer	0.4167	0.0581
P8	Researcher	0.5994	**0.6256**
P9	Distributor/retailer	0.2484	**0.5494**
P10	Producer	**0.6793**	0.304
P11	Distributor/retailer	**0.7457**	0.1974
P12	Producer	**0.7487**	0.0633
P13	Distributor/retailer	0.1307	**0.6867**
P14	Distributor/retailer	0.0148	**0.758**
No. of Q sorts		7	6

(correlation coefficient of 0.55), which may indicate some agreement, the two factors represent two distinct viewpoints on accepting bio-based packaging for organic foods. Factor scores for each perspective are reported in Table 3. The signs preceding each factor score indicate agreement (+) or disagreement (−). Visual factor arrays for both factors are reported respectively in Figs. 2 and 3.

Factor 1: the 'Early Adopters'

Seven participants ('researcher': 3 participants; 'producer': 3 participants; 'distributor/retailer': 1 participant) loaded on Factor 1, labelled the 'Early Adopters'. This optimistic view perceives bio-based packaging as a valuable organic food supply chain technology. The positive perception is supported by considerations mostly related to ethical and environmental aspects. From this view, adopting bio-based packaging may allow organic companies to distinguish themselves from others, improving their ethical responsibility (**14**: +5**; 0).[2] Bio-packaging can reduce pollution of water (e.g. 'plastic soup') and soil (**27**: −5**, 0; **28**: −3**, −2) and limit adverse effects on climate change by reducing the use of fossil fuels (**34**: −4*, −3). Despite this, some participants in their post-sorts interviews declared to be aware that producing any packaging (bio-based or not) without ecological impacts is almost impossible. For this view, the desire to adopt this alternative technology conflicts with how to match positive intentions and practical adoption. Concerns about how to facilitate bioplastic adoption emerged from Q sorts. For example, high prices and costs represent a relevant barrier to adoption since bio-based materials are still perceived as 'too much costly'. The lower cost of conventional plastic is considered another economic obstacle (**9**: +1*, 0). However, from this view, the global rise in production capacities of packaging producers is not so far and will contribute to reducing costs by spreading access to this technology (**8**: +3**, 0).

Factor 2: the 'Sceptical Utilisers

Six participants were loaded into this second factor: The 'Sceptical Utilisers' ('research': 1 participant; 'distributor/retailer': 5 participants). Overall, Factor 2 almost supports bio-based packaging for environmental aspects (**34**: −4, −3*; **28**: −3, −2**). Also, from this view, biomass production for bio-packaging should belong to local supply chains to optimise overall environmental benefits (**33**: −1, +1). However, contrary to Factor 1, this second factor embodies a more 'sceptical' viewpoint towards their adoption. From this view, substituting oil-based plastics with bioplastics is insufficient to prevent climate change and reduce environmental damage since the production and the use of any packaging 'contribute to consuming limited resources' (**25**: 0, +5**). Results showed concerns at a broader level about the lack of a clear definition of bio-based packaging (**24**: -2, +3**) and certifications (**17**: +1, +3). These two aspects are essential to increase the supply chain perception of the ease of use of bio-based packaging. According to this view, consumers will not be willing to pay more for organic products packaged with bio-packaging (**3**: 0, −1*).

Consensus statements

Results showed that several statements were given a similar ranking across both factors. These consensus statements reveal the 'common ground' between

[2] In brackets from this point on, the statement number (in bold) and the related Factor 1 and Factor 2 scores.

Table 3 Factor scores for Factors 1 and 2 (Factor scores marked with ** ($p < 0.01$) or with * ($p < 0.05$) indicate a distinguishing statement). The sign preceding each factor score indicates agreement (+) or disagreement (−)

N	Statement	F1	F2
1	I think the use of bio-packaging is an effective solution for extending the shelf-life of products naturally	−1	0
2	I believe that bio-packaging represents an added value for organic production	+2	+1
3	I think that consumers will be willing to pay more for products from a company that adopts bio-packaging	0*	−1*
4	For me, the use of a certificate for bio-packaging that distinguishes it from plastic ensures that the material complies with the specific requirements	+1	+2
5	I think that bio-packaging represents a solution that is more than desirable and a good example of a circular economy	+4	+2
6	I think that it is important to obtain bio-packaging with coupled materials to meet home composting parameters	−2**	+3**
7	I think today, a structured waste collection and management system dedicated to bio-packaging is missing	0	−1
8	I think that in the next decade, thanks to an increase in production capacities, the costs for bio-packaging are destined to decrease	3**	0**
9	I think traditional plastic hinders the spread of bio-packaging because it costs less	+1*	0*
10	I think that more incentives are needed for a real transition to bio-packaging adoption	+2	+2
11	I think the number of suppliers which can meet the technical characteristics to produce bio-packaging is still limited	+1	0
12	I think that the time necessary for supplying the raw material represents one of the main limits for the adoption of bio-packaging	−1**	−4**
13	I think exploiting the crops to produce bio-packaging risks compromising the availability of food	−3	−3
14	I believe that the use of bio-packaging is an ethical necessity for many companies which want to be distinguished	+5**	0**
15	I think especially for an organic product, the bio-packaging is in line with the principles of organic production	+4	+4
16	I think that a cultural revolution is necessary for the common use of bio-packaging	+2	+4
17	I think that the use of a clear certificate for bio-packaging is essential to avoid confusion among citizens	+1	+3
18	I think that bio-packaging guarantees health benefits, thanks to the reduction of pollutant emissions	+2	+1
19	I think that there are no adequate facilities that are capable to manage waste deriving from massive quantities of bio-packaging	0**	−2**
20	I believe that Italian legislation is very restrictive on the use of bio-packaging	−2	−2
21	For me, the management of waste which is derived from bio-packaging is complicated	−4	−4
22	I think that the use of bio-packaging with coupled materials hinders the possibility of recycling	0**	−3**
23	As far as I am concerned, I do not believe in the existence of any application of bio-packaging which is easier to utilise than paper	−1**	−5**
24	I think that the absence of an official definition of the term bio-packaging is a source of confusion for all the players in the supply chain	−2**	+3**
25	I believe that to protect the environment we need to reduce the use of all types of packaging	+0**	+5**
26	I think that only biodegradable bio-packaging provides an alternative for product disposal, reducing the volume of waste	0	+1
27	I think that bio-packaging also contributes to water and soil pollution	−5**	0**
28	I believe that bio-packaging is not the solution to the 'plastic soup' in the oceans	−3**	−2**
29	I think it is more sustainable to improve the recycling system for plastics rather than using bio-packaging	−3	−2
30	Bio-packaging ensures benefits for the climate, by reducing the use of fossil fuels	+3	+2
31	I think that to obtain concrete environmental benefits there is a lack of adequate investments aimed at recycling and reusing bio-packaging	+1	+1
32	I think that most of the currently available technologies do not allow to the production of bio-packaging entirely with a renewable material	−1	−1
33	I think that the local supply of bio-packaging should be favoured to reduce the environmental impact	−1	+1
34	I think replacing plastic with bioplastic in packaging is not the best solution for the environment	-4*	−3*
35	I think that bio-packaging films make current composting processes easier, even for domestic ones	+3**	−1**
36	I think that the environmental impact of bio-packaging is reduced given the increasing availability of raw materials in nature	−2	−1

F1 Factor Array											
Score	**-5**	**-4**	**-3**	**-2**	**-1**	**0**	**+1**	**+2**	**+3**	**+4**	**+5**
Statement number	27	21	28	24	33	25	9	10	8	15	14
		34	13	6	32	26	31	2	35	5	
			29	36	1	3	11	18	30		
				20	23	7	4	16			
					12	22	17				
						19					
Category-Level	PU-Economic		PU-Societal		PU-Environmental		PEOU-Economic		PEOU-Societal		PEOU-Environmental
Relevant quotes from post-Q-sort interviews	*"For me, consumers are always oriented to purchasing products that cost less"*										(P1, Researcher)
	"I believe that replacing plastic with bioplastic is the best solution"										(P2, Researcher)
	"For me (bio-packaging) are organic materials that do not pollute"										(P4, Producer)
	"I think organic packaging containing an organic product represents a desirable achievement as soon as possible"										(P10, Producer)

Fig. 2 The 'Early Adopters': F1 factor array and most relevant post-sorts interviews

factors (Zabala et al. 2018). For both views, bio-packaging was perceived as a promising alternative to oil-based plastic, more in line with organic farming principles (**15**: +4, +4) and an excellent application of circular economy (**5**: +4, +2). This positive perception is supported by the idea that adopting bio-packaging can help reduce environmental impact and contrast climate change (**30**: +3, +2)

F2 Factor Array											
Score	**-5**	**-4**	**-3**	**-2**	**-1**	**0**	**+1**	**+2**	**+3**	**+4**	**+5**
Statement number	23	12	13	28	35	27	18	10	6	16	25
		21	34	19	36	9	31	5	17	15	
			22	20	32	11	2	30	24		
				29	7	14	26	4			
					3	1	33				
						8					
Category-Level	PU-Economic		PU-Societal		PU-Environmental		PEOU-Economic		PEOU-Societal		PEOU-Environmental
Relevant quotes from post-Q-sort interviews	*"For me even bio-based packaging contributes to consuming limited resources"*										(P3, Distributor/Retailer)
	"Without economic incentives, I do not believe that bio-based packaging will be adopted by many"										(P9, Distributor/Retailer)
	"I think that the most important thing for the environment would be to reduce all types of packaging only to the fundamentals; this, regardless of the material, would reduce waste and pollution"										(P14, Distributor/Retailer)

Fig. 3 The 'Sceptical Utilisers': F2 factor array and most relevant post-sorts interviews

with relevant indirect health benefits (**18**: + 2, + 1). Overall, both views shared the idea that the management of bioplastics is not complicated (**21**, − 4, − 4). However, for participants, the necessity of a cultural change was indicated as a solid barrier to adopting bio-based packaging (**16**: + 2, + 4). Both views indicated the importance of establishing specific certificates for bio-packaging to make them distinguishable from those using conventional plastic (**4**: + 1, + 2). Results showed that economic barriers are perceived as drivers hindering the transition to bio-packaging solutions (**10**: + 2, + 2; **31**: + 1, + 1). Finally, no concerns emerged about the risk of compromising food provision caused by the growing production of biomass used in the lifecycle of bio-based packaging (**13**, − 3, − 3).

Discussion

Replacing plastic packaging with more sustainable alternatives is critical for favouring a low-carbon future and overcoming the challenge caused by the intense use of petroleum-based plastics (European Commission 2020; Guillard et al. 2018; Johansen et al. 2022; Ncube et al. 2020). Among possible strategies, the adoption of bioplastics has been recognised as a possible solution to address a variety of sustainability issues caused by the intense use of conventional plastics (Filho et al. 2021; Imbert et al. 2019; Yuvaraj et al. 2021). Nonetheless, replacing conventional plastics with bio-based alternatives in the organic agri-food sector requires the involvement of stakeholders and a radical change in the current economic model (Molina-Besch and Keszleri 2023; Zhu et al. 2022). The results showed that the perceived usefulness, compared to the perceived ease of use, exerts slightly more influence on adopting bio-packaging. This result confirms how perceived usefulness represents the primary determinant of the acceptance of new technology (Naspetti et al. 2017).

Q methodology, applied to identify salient perspectives regarding adopting bio-packaging among a group of stakeholders all belonging to the organic food supply chain (Brown 1980), reveals two distinct viewpoints: Factor 1 labelled the 'Early Adopters', and Factor 2 the 'Sceptical Utilisers'. On one side, the first perspective aimed at phasing out the use of conventional plastics in organic farming and considering bio-packaging as an essential part of solving environmental pollution and climate change. Conversely, the second perspective emphasised the global reduction of food packaging materials, raising several concerns about adopting bio-packaging.

In terms of consensus points, similar to previous studies, all stakeholders showed high levels of expectations of bio-based packaging solutions (Fletcher et al. 2021; Imbert et al. 2019; Kakadellis et al. 2021; Karimi Sani et al. 2023; Mehta et al. 2021; Michaliszyn-Gabryś et al. 2022; Molina-Besch and Keszleri 2023; Yeh et al. 2015). Results showed that bio-packaging is perceived as more in line with an organic production method, based on a responsible use of natural resources to reduce environmental impact (IFOAM 2021). Although the debate on the sustainability of bio-based packaging is still ongoing, bio-packaging is considered an opportunity to act on circular economy principles, especially if those materials are biodegradable and compostable, either at home or in industrial sites (Michaliszyn-Gabryś et al. 2022; Molina-Besch and Keszleri 2023; Yeh et al. 2015).

Moreover, another entry point is represented by the perception that managing bio-packaging waste is simple. This result diverges from previous studies, which identified concerns concerning the waste collection of bio-packaging and recycling using the current infrastructures (Kakadellis et al. 2021; Mehta et al. 2021; Molina-Besch and Keszleri 2023).

The possible competition between food and non-food usage of agricultural recourses such as land is another aspect for which stakeholders of both factors were reassured. Reichert et al. (2020) and Yeh et al. (2015) reported that the land used to cultivate raw materials for bioplastic is minimal, and no critical competition with crops for food requirements is assumed.

Similar to previous studies, economic incentives for adopting new technologies like bio-packaging have already been identified as an essential driver for organic stakeholders (Centobelli et al. 2021; Derchi et al. 2023). Proponents of both views that emerged in the study ask for concrete solutions to activate a transition towards bioplastics. Despite the current circular economy policy is stimulating many companies (both conventional and organic) to seek and adopt sustainable packaging, all stakeholders required more incentives to support a faster transition (Fletcher et al.

2021; Kędzia et al. 2022; Molina-Besch and Keszleri 2023). The issue of incentives is the most critical aspect; also a recent study showed how more investments are necessary to improve the management system for compostable waste, which can provide higher environmental benefits than incineration and landfill (Kędzia et al. 2022). Moreover, the findings suggested that achieving economic sustainability appears to be a challenging-to-reach but highly desirable goal because of the urgent matter to reduce costs and facilitate access to financing by stakeholders (Kafel et al. 2021; Meherishi et al. 2019; Neves et al. 2020; Wellenreuther et al. 2022). Notably, the importance of reducing final prices seemed more evident for Factor 2, which included most distributors and resellers and no organic producers. Given their lower purchasing power, companies are worried consumers would not accept a higher price for bio-based packaging (Mehta et al. 2021; Molina-Besch and Keszleri 2023).

Another consensus point was the call for a clearer definition of specific EU certification and regulations, which would reduce confusion and promote the adoption of bio-packaging (Kafel et al. 2021; Yeh et al. 2015). It is known that when introducing new technologies, regulations can stimulate their adoption, like an increase in consumer awareness (Kędzia et al. 2022). Better policies and certification standards could be used to consolidate current knowledge and avoid missing sustainability information on bio-packaging (Mehta et al. 2021; Michaliszyn-Gabryś et al. 2022; Molina-Besch and Keszleri 2023; Wurster and Schulze 2020). More knowledge should be conveyed to make people understand bio-packaging advantages (Fletcher et al. 2021). Nevertheless, the lack of clear evidence that bioplastics are more eco-friendly than conventional plastics could be a barrier to their adoption and also have a negative impact on willingness to pay (Herrmann et al. 2022; Ketelsen et al. 2020; Lynch et al. 2017; Mehta et al. 2021).

Minor concerns, only relevant for Factor 2, were related to the misunderstanding of the bioplastics definition (Aubin et al. 2022; Yeh et al. 2015). According to the stakeholders' perspectives, the complexity associated with the bioplastic definition may confuse consumers that might not be able to handle bioplastics well (Aubin et al. 2022; Bhagwat et al. 2020; Fletcher et al. 2021; Guillard et al. 2018; Molina-Besch and Keszleri 2023). Other studies highlight how the idea of a circular economy should be adequately communicated to consumers to gain full acceptance (Zhu et al. 2022). As occurred with the acceptance of new technologies, consumers have a central role in product innovation success (Siegrist 2008; Zhu et al. 2022). Investments in education and communication, as well as clarifications on how to dispose of these materials, are needed, especially given the relevance of recycling this type of waste (Bhagwat et al. 2020; Fletcher et al. 2021; Mehta et al. 2021; Molina-Besch and Keszleri 2023; Neves et al. 2020; Wurster and Schulze 2020). Adequate communication about the potential environmental benefits of bio-based packaging is essential in increasing acceptance, market value, and consumers' willingness to pay (Molina-Besch and Olsson 2022).

Despite the high agreement in considering bio-packaging a positive alternative to fossil-based plastic, some relevant differences emerged (between Factors 1 and 2). The divergent perspective towards bio-packing can be synthesised by the position of factors towards statement number 14 and statement 25. These two statements distinguish the views of Factors 1 and 2 and cause factors to think differently. Hence, stakeholders from the first perspective consider bio-based packaging as a determinant aspect in distinguishing a 'more sustainable' organic company from competitors. For Factor 1, bio-packaging is an essential fundamental issue for organic farmers and suppliers because of its ethical importance. While for Factor 2, the perceived usefulness of bio-packaging is related to the more general goal of reducing the plastic use and the overall amount of food packaging. According to these stakeholders, a global packaging reduction is necessary for the transition to bio-based materials not to be a drop in the ocean (Kafel et al. 2021). Moreover, reducing the amount of packaging is much more significant for distributors and resellers (more present in Factor 2) who would benefit in both logistics and costs of packaging, handling, and transporting foods.

Conclusion

In conclusion, although Q study results cannot be generalised to a broader population, this methodology showed its efficacy in revealing the most relevant viewpoints and common and divergent views on such a debated issue as bio-based packaging. This study

represents the first step in exploring the perceptions of a group of organic Italian stakeholders towards bio-based plastic packaging. Nevertheless, a larger pool of potential stakeholders may be necessary for confirming results or finding other 'missing' perspectives. Also, future studies in different countries can contribute to defining the European context and finding differences between countries.

On higher levels, the outcome of this research study indicates the importance of developing circular economy-oriented solutions to accelerate the transition of the packaging industry. The findings showed how Q methodology is a valuable approach for driving attention towards consensus-related strategies that are more sensible to the supply-chain actors. Overall, the results showed that most organic stakeholders are ready to adopt bio-based packaging despite the economic and bureaucratic contests that might only sometimes support adopting these alternative solutions (Molina-Besch and Keszleri 2023). This non-negative perception among the group of stakeholders towards bio-based packaging is essential to promote a wider use (Davis 1989; Mehta et al. 2021; Venkatesh et al. 2003). More specifically, the findings suggested that the most relevant barriers are not related to technological feasibility (e.g. improving performances, reducing packaging waste, increasing industrial infrastructure) but to economic and commercial aspects. In other words, the relatively high acceptability of bio-based solutions among organic stakeholders will not lead to increased adoption without specific incentives and increased demand from retailers. Regarding incentives (i.e. taxation incentives), policymakers should solve this point to trigger the change, lowering materials cost production and, consequently, the impact on the final price of organic food products (Kafel et al. 2021; Molina-Besch and Keszleri 2023; Wellenreuther et al. 2022). The other point is how to drive product adoption in the market, even if it is known how any bio-based packaging solutions will probably increase final prices. According to the results, concerns among stakeholders regarding consumers' unwillingness to pay a premium price are a strong deterrent which explains why the demand from the retailer side is essentially absent. An appropriate marketing strategy should be intensified to overcome social barriers (mainly a low consumer awareness) and create new needs and wants by making the use of bio-based packaging more 'attractive' among consumers (not only among organic consumers). Switching the perspective from the technological field to the demand field could represent an alternative strategy to adopt bio-based solutions as the next step to be more sustainable, independent of the actual performances. Moreover, the findings highlighted how participatory practices, including all strategic actors (i.e. governments, distributors, producers, farmers), should be encouraged to explore the theme from different perspectives. Also, the results underlined the need for transparent and standardised certificates and legal regulations, which institutions and policy makers cannot ignore (Kędzia et al. 2022; Marzantowicz and Wieteska-Rosiak 2021; Meherishi et al. 2019; Naspetti et al. 2017). A conscious and faster adoption of bio-based packaging will be possible only if organic regulation updates its standards, removing confusion for stakeholders (Kędzia et al. 2022; Molina-Besch and Keszleri 2023; Neves et al. 2020). Regarding this point, the position towards GM materials used for producing bioplastics should be regulated. Currently, the lack of precise indications has led to the generation of some private standards (i.e. Soil Association, Naturland, and Demeter) where the ban on GM technologies has been clearly defined for packaging materials. As a result, acting according to their own knowledge and voluntarily, some organic companies avoided using bio-based packaging when 'suspected' to be produced using GM raw materials or any other of their derivates, obtaining the opposite effect for which the bio-based packaging materials were developed (Kafel et al. 2021; Yeh et al. 2015).

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Data availability Data will be made available on request.

Declarations

Competing interests The authors declare no competing interests.

Conflict of interest The authors declare no competing interests.

Appendix

Text including the definition of 'bio-packaging' shown to participants

According to the definition given by European Bioplastics, the term 'bioplastic' refers to the type of plastics that can be biodegradable (that is, it can be completely decomposed by microorganisms into carbon dioxide, water, and biomass without leaving harmful or toxic residues), can be derived by biomass (i.e. from renewable raw materials), or can be possessed both characteristics.

Regarding the organic agri-food sector, there is currently no specific legislation relating to packaging such foods. In general, it can be said that 'bio-packaging' is an alternative packaging to traditional plastic suited for organic products. Bio-packaging is made with bioplastics obtained from renewable sources that are biodegradable and compostable or that can be disposed of in organic waste because it is capable of being transformed by composting together with the organic waste into compost. Some examples of 'bio-packaging' are those based on PLA (based on polylactic acid).

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