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Plant-based Eggs: Views of Industry Practitioners and Experts

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ABSTRACT

Plant-based eggs have been recently developed by food practitioners as an alternative to conventional eggs. However, there is uncertainty on how the current egg market will react to plant-based eggs, as well as lack of knowledge about product development and regulations. In this manuscript, we explored this issue by conducting in-depth interviews with egg industries and retailers, as well as with plant-based egg manufacturers. Results show that despite egg manufacturers are struggling to provide an alternative to people who do not consume eggs, they are skeptical that plant-based eggs can replicate all eggs' nutrients and functionalities. Furthermore, egg industries do not see plant-based eggs as potential competitors to their products, while plant-based egg manufactures argue that they will directly compete with eggs. Also, there is uncertainty on how to label and name plant-based eggs, which has important implications in terms of marketing and policy labeling of these new products.

KEYWORDS

Egg practitioners; in-depth interview; plant-based eggs

Introduction

In Europe, egg demand is estimated to increase by 20% by 2030 (International Egg Commission, 2013). However, during the last decades, several critical issues have affected the egg industry (Rondoni, Asioli, & Millan, 2020). First, the growing problems related to egg allergies (Savage, Matsui, Skripak, & Wood, 2007) and the discussion about whether egg intake has effects on the level of cholesterol in humans (McNamara, 2015), have increased consumers' concern toward the consumption of eggs. Second, in the European Union, consumers' increasing interest in animal welfare standards led to the banning of cage systems in 2012 (Bray & Ankeny, 2017; Heng & Peterson, 2018) and since then, only barn, free-range, and organic are allowed as production methods (UEP, 2017). Third, several food safety scandals, such as for example, the salmonella outbreak

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in 2015 in the United States (Whiley & Ross, 2015) and the Fipronil scandal in 2017 in the European Union (European Commission, 2017) contributed to increase consumers' skepticism for eggs. Fourth, the egg industry is responsible alone for about 10% of total livestock emissions (FAO, 2016), which creates concern in regard to how to meet the expected growing egg demand in a sustainable manner (FAO, 2017). These critical issues have prompted the egg industry to review its production system and increased the variety of egg products offered in the market, for example, in terms of production method (e.g., organic eggs, free-range eggs, etc.) and nutritional properties (e.g., omega-3 eggs, etc.) (Baba, Kallas, & Realini, 2017; Chang, Lusk, & Norwood, 2010).

In addition to these new products, another solution to the growing and complex demand for eggs is the so-called "plant-based eggs," also defined as "vegan eggs," "egg substitutes," or "egg replacers" (The Good Food Institute, 2018). Plant-based eggs are an alternative to conventional eggs that are not produced from hens but use raw materials that originate from plants, such as, for example, legumes, cereals, or algae, which are able to replicate similar functionalities to eggs, like stabilization, emulsification, gelation, etc. (The Good Food Institute, 2018). In the last few years, several prototypes of plant-based eggs have been developed in different countries, including the United States, Brazil, and Italy, from both startup businesses and research centers (Rondoni, Millan & Asioli, 2021). For instance, examples of liquid plant-based eggs produced through a process of protein isolation and sold in bottles are already available to consumers in the US market (Watson & Shoup, 2019). Other types of plant-based eggs (e.g., powder or egg-shaped) are developed through protein fermentation or isolation processes but are not yet available in the market (Carrington, 2018). Compared to conventional eggs, plant-based eggs have several advantages. First, since plant-based eggs are produced without hens, they are allergen-free and cholesterol-free, hence could offer a solution for consumers who suffer from egg allergy or have health issues related to cholesterol (Brown & Schrader, 2006). Second, plant-based eggs are not produced by hens, and thus they are not affected by animal-related diseases (e.g., salmonella or the avian-flu) (Whiley & Ross, 2015), which are critical issues in conventional egg production. Third, as food safety scandals have an impact on the industry economy, plant-based eggs also offer a stable solution to the high price volatility that affects the egg market (Tu et al., 2019). Last, the manufacture of plant-based eggs is claimed to be more environmentally sustainable than conventional egg production, although accurate data about its environmental impact are not yet available (The Good Food Institute, 2018).

Since the development and production of plant-based eggs is still at the beginning stage, the issues in terms of production, marketing, and regulations in relation to these new products are still unknown. To the best knowledge of the authors, no previous studies have investigated practitioners' perceptions, experiences, and challenges regarding plant-based eggs. In addition, how egg industries and retailers are responding to plant-based eggs, as well as to the new and more complex consumer demand, remains unexplored. Hence, the present study aims at shedding light on these issues by investigating (i) what are future trends and barriers in today's conventional egg market; (ii) egg industry and retailer's perception for plant-based eggs; (iii) what challenges are startup businesses and researchers experiencing in terms of product development, marketing, and policy regulations for plant-based eggs.

To achieve these objectives, we conducted two studies, hereafter called Study One and Study Two. In Study One, we investigated future trends and barriers in today's egg market and how the egg industry and retailers perceive plant-based eggs by interviewing egg industries and retailers from the United Kingdom and Italy. We chose the United Kingdom and Italy because they are the next largest egg producers in Europe after France and Germany, producing about 1.2 and 1.1 million tonnes of eggs per year, respectively (International Egg Commission, 2014). In detail, the British egg market is worth about US $1.01 billion (UK Government, 2020), with 39 million commercial laying hens and 1.200 commercial farms (International Egg Commission, 2013). Most of these are concentrated in the south of the country (UK Government, 2020). In Italy, the egg market has a value of US $1.13 billion, with 38.9 million commercial laying hens and 1.800 commercial farms (International Egg Commission, 2015). The two regions of Veneto and Lombardy in the north account for more than 50% of production. The remaining 50% is distributed between the center and the south of Italy (ISMEA, 2019). In Study Two, we investigated challenges in terms of product development, marketing, and policy regulations for plant-based eggs by interviewing plant-based egg startups and researchers. In Study Two, we did not limit the research to any country in order to get enough material as to the best knowledge of the authors, only a few scientists and businesses are yet working on these products.

This exploratory research provides unique insights for practitioners about the production, marketing, and regulatory challenges that plant-based eggs might face in today's dynamic market and contributes to advance the research on new animal-based food substitutes like the plant-based eggs.

This paper is structured as follows. The next section describes the methodology used to achieve the study's objectives. The results are presented in

section three, which is followed by a discussion and conclusion presented in the final section four.

Methodology

Exploratory research: in-depth interviews

Exploratory research based on qualitative data collection techniques was adopted because of its suitability due to the absence of previous studies investigating plant-based eggs from a supply perspective. The exploratory research enables the evaluation of the complexity and rich diversity of the practitioners' experiences and perceptions relying upon the collection of a large amount of information from few subjects, rather than only small pieces of information from a large sample. Exploratory research is useful to provide guidance and generate hypotheses for further research since it provides in-depth and context-rich information, although in most cases the findings cannot be considered conclusive because of the qualitative nature (Myers, 2009).

Among the different types of qualitative research methods, in-depth interview was chosen because it is optimal for collecting data on individuals' histories, perspectives, expectations, and experiences (Molteni & Troilo, 2007), and because it allows the use of some pre-formulated questions, covering the aspects that are expected to be discussed (Malhotra, 2017). In-depth interview is "an unstructured, direct, personal interview in which a single participant is probed by an experienced interviewer to uncover underlying motivations, feelings, and beliefs on a topic" (Malhotra, 2017, p. 209). Furthermore, we used the semi-structured qualitative interview schedule because its flexibility and validity are proven by the fact that it is the most widely used interviewing format for qualitative research (DiCicco-Bloom & Crabtree, 2006; Madsen & Petermans, 2019; Theerachun, Speece, & Zimmermann, 2013; Wongprawmas, Canavari, Haas, & Asioli, 2012). As indicated in the introduction, in order to achieve the research's aims, we conducted two different studies (Study One and Study Two). Given the objectives of Study One to explore new trends and barriers in the egg market, and egg stakeholder's opinions about plant-based eggs, marketing managers and/or owners from the egg industries and buyers from the retailers were chosen as interviewees. Specifically, marketing managers were identified as the best respondents because they are responsible for the marketing, communication, promotion, and sales activities within the company, and thus, they are likely to be the most informed about future market trends, as well as about possible consumers' reactions for plant-based eggs. Similarly, the owners are responsible for making the strategic decisions within the company and so they are knowledgeable about the current and future market trends. Because most egg

industries are small-medium enterprises (SMEs), either marketing managers and owners were suitable given that in SMEs, the ownership and marketing management activities are often performed by the same person. Regarding the retailers, the buyers are responsible for sourcing and introducing products in the stores, so they are aware about consumers' preferences for eggs and may be able to predict consumers' opinion about plant-based eggs. For Study Two, startup owners and researchers working on plant-based eggs were identified as the best respondents for our research purposes. In particular, the companies' owners and marketing managers are responsible for the marketing and the promotion of plant-based eggs and deal with policy regulations. Thus, they are likely to be the most knowledgeable in terms of current and future trends in the plant-based egg market, as well as about possible policy issues that might impact the plant-based eggs. In addition, the scientists are responsible for the development of the plant-based eggs, hence they have in-depth knowledge about current challenges and future development of these products.

In the semi-structured interview, interviewer and interviewee are engaged in a formal discussion by using an interview guideline, which is basically a set of predetermined open-ended questions/topics (DiCicco-Bloom & Crabtree, 2006), previously designed for this study to serve as a non-binding outline of the discussion, following the research aims mentioned above. The guidelines developed for Study One, and to be addressed to egg industries and retailers, were structured beginning with a series of ice-breaking questions about the company and the role of the interviewee in the company. This was followed by a series of questions related to their experience with the sales and marketing of their eggs and egg products. The last part of the guidelines was composed of questions aiming at investigating their perceptions of plant-based eggs, after a brief presentation of the products using short videos and images. The guidelines were developed in English and then translated into Italian for the interviews with the egg industries and retailers from Italy. The guidelines for Study Two were also developed in English and were still composed of a series of ice-breaking questions, followed by some questions on the marketing, research and production, and regulation of plant-based eggs.

Recruitment of the respondents

A list of egg industries and retailers from the United Kingdom and Italy for Study One and plant-based egg startup businesses and researchers for Study Two was drawn after conducting an extensive search, and the most appropriate respondents able to answer the study research questions were identified. All respondents were recruited by purposive non-stochastic

Table 1. Respondents' sample and position for Studies One and Two.

Respondents position	Sample
Study One	
United Kingdom egg industries	7
Owner	4
Sales and marketing manager	3
Italian egg industries	5
Owner	4
Brand manager	1
United Kingdom retailers	4
Buyer	3
Innovation manager	1
Italian retailers	6
Buyer	5
Marketing manager	1
Study Two	
Plant-based egg startup businesses	6
Marketing manager	1
Owner	4
Director of strategy and analytics	1
Plant-based egg researchers	3
Food scientists	1
Senior research scientist	1
Professor	1

sampling. The snowball sampling procedure was also applied (Malhotra, 2017). Potential respondents were contacted in advance via email and phone. In total, for Study One, 22 interviews were conducted, including 12 with egg industries, of which 7 were from the United Kingdom and 5 from Italy, and 10 participants from the retail sector, including 4 from the United Kingdom and 6 from Italy. For Study Two 6 plant-based egg startup businesses and 3 researchers were interviewed (see Table 1).

Interview procedure

Twenty-two interviews from Study One and nine interviews from Study Two were administered during summer 2019. The interview schedule was sent to respondents in advance together with the participatory information sheet, and interviews ranged between 30 and 45 min in duration. For convenience, the interviews were settled at respondents' best time and location and were conducted in person or using Skype/phone by an experienced researcher, while an assistant took notes. Interviews were audio-recorded if permitted by the respondent. The interviews in the United Kingdom were conducted in English and in Italy in Italian. Records were then archived. Interviews' audio-records were transcribed verbatim and then read and re-read singularly to get a deep understanding of their meaning. The interviews conducted in Italian were first transcribed in the original language and then translated into English. Given the exploratory nature of this

research, it was decided not to impose a theoretical model or framework on the data acquisition and data analysis.

Informed consent was obtained by all participants and the study was approved by a university ethical committee.

Data analysis

In qualitative research, data collection and data analysis may happen at the same time, and the researcher may need to go back and forth between different steps (Thorne, 2000). In this research, some preliminary data analysis was done immediately after each interview by identifying emerging themes and constructing initial conceptual maps from each interview. When all the data was collected, thematic analysis of the participants' responses was developed to analyze them. Thematic analysis "is a method for identifying, analysing, organizing, describing, and reporting themes found within a data set" (Nowell, Norris, White, & Moules, 2017, p. 1). Nvivo 12 (Burlington, United States) qualitative software for data management was used to facilitate the data analysis. During the first step of thematic analysis, the researchers started to familiarize themselves with the results by reading and re-reading the entire data set and trying to become well acquainted with the data (Braun & Clarke, 2006). In the next step, a preliminary coding was performed aiming to identify information related to the research questions. Coding is a way of "indexing or mapping data, to provide an overview of disparate data that allows the researcher to make sense of them in relation to their research questions" (Elliott, 2018, p. 2850). Inductive coding was applied for data analysis, which is when codes are developed by directly examining the data (Blair, 2015). This process is also defined as "data-driven" coding (Braun & Clarke, 2006). To ensure reliability and consistency in the coding process, data has been coded twice by the researcher and another member of the research team independently and results compared. Coded information was read again, code names were redefined where necessary, and codes with similar meanings were merged. Once the data had been coded, themes were identified in order to include a series of similar concepts contained in the dataset under a single, more specific theme that could help to summarize the text (Attride-Stirling, 2001). The themes were reviewed separately by the research team members and, later, together to discuss possible different points of view. Eventually, themes were deleted if they were not supported by enough data, while others were added when the data allowed doing so. Sub-themes also emerged and were recorded after consensus amongst the researchers was reached. The data analysis showed that a level of saturation was achieved

Table 2. Key themes and outcomes emerged from Study One.

No.	Themes	Outcomes
1	Future trends in the egg market	• Growing market segment for organic and free-range eggs in the United Kingdom and Italy, respectively.
2	Barriers in the egg market	• High competitiveness in the egg market both in the United Kingdom and Italy. • Challenges in providing an alternative to conventional eggs. • Logistic limitations.
3	Introduction of new products	• Development of new products that are richer in nutrients in the United Kingdom. • Development of new of new ready-to-eat egg products both in the United Kingdom and Italy.
4	Reaction to plant-based eggs	• Conventional eggs are perceived to be healthier than plant-based eggs by the United Kingdom industries. • Plant-based eggs are expected to be more expensive than conventional eggs by both Italy and the United Kingdom industries. • Plant-based eggs are expected to be less natural than conventional eggs by both Italy and the United Kingdom industries. • Industries from both the United Kingdom and Italy were not willing to introduce plant-based eggs in their portfolio of products. • Italian retailers are skeptical about whether plant-based eggs will be able to replicate all eggs' functionalities in cooking. • The liquid plant-based eggs could be the most suitable for consumers as it is easier to use. • The United Kingdom retailers were more interested in the plant-based eggs than the Italians.

(e.g., new data did not bring additional insights from those already captured).

Results

In this section, the results that emerged from the in-depth interviews of Studies One and Two are presented. Table 2 provides a summary of the key themes and outcomes that emerged from Study One. In both studies, results are structured based on different themes that emerged during the in-depth interviews. It is worth noting that the data were collected prior to the Covid-19 pandemic, which has had an impact on the egg market. In the United Kingdom, for example, consumers appear to be more conscious about the safety and the quality of the food they eat compared to prior the pandemic and reduced the consumption of animal-based food products (e.g., meat, milk, eggs, etc.) in favor of plant-based meat alternatives (e.g., the sales of plant-based burger and minced meat substitutes rose of 50% in

the last year) (Office for National Statistics, 2020). If this trend continues, the demand for new plant-based food alternatives may increase in the future, facilitating the access into the market of products like the plant-based eggs. On the contrary, in Italy, the sale of eggs increased of 56% since the Covid-19 outbreak, due to the increment of at home cooking (Office for National Statistics, 2020). In this regard, if plant-based eggs can replicate the same cooking applications as conventional eggs, it might be pleasantly welcomed by consumers as an alternative to conventional eggs. In addition, during the pandemic, the egg supply chain has suffered from the closure of restaurants and caterings, which account for the 21% and 29% of the egg market in the United Kingdom and Italy, respectively (Office for National Statistics, 2020; UK Government, 2020). However, this demand is expected to raise again once the foodservice sector will reopen, although these businesses should be able to adapt to the new preferences and habits that consumers have adopted during the past year. This might include the consumption of healthier and more sustainable food products, such as for example the plant-based eggs, which represent a healthier, more sustainable, and versatile product compared to conventional eggs.

Study One—results from interviews with egg industries and retailers

In order to preserve their anonymity, participants have been renamed as indicated in Table 3 below and numbered in chronological order based on when the interviews were conducted.

Theme 1: future trends in the egg market

Results show that Italian industries and retailers are foreseeing a growing market segment for organic eggs, whereas, in the United Kingdom, the fastest growing market segment is expected to be free-range eggs. In addition, both countries (the United Kingdom and Italy) have shown a growing demand for higher animal welfare and sustainability standards in egg production, also attributable to the "cage-free by 2025" initiative promoted by several supermarket chains across Europe, which aim to sell only cage-free eggs (e.g., barn, free-range, etc.) within the next five years (The Guardian, 2016). A United Kingdom industry mentioned:

> By 2025 the aim in Europe is to reach "no cage at all" in production, so that is sort of where I think the market and the industry is going. (Industry 7 ENG)

Moreover, the market segment of liquid eggs and liquid egg whites is expected to increase both in the United Kingdom and Italy, although it will remain a niche market, which serves those consumers who seek

Table 3. Respondents interviewed for Study One.

United Kingdom	No. employees	Italy	No. employees
Industries			
Industry 1 ENG	65	Industry 1 ITA	50
Industry 2 ENG	8	Industry 2 ITA	766
Industry 3 ENG	24	Industry 3 ITA	41
Industry 4 ENG	13	Industry 4 ITA	12
Industry 5 ENG	58	Industry 5 ITA	55
Industry 6 ENG	625	–	
Industry 7 ENG	27	–	
Retailers			
Retailer 1 ENG	>110k	Retailer 1 ITA	>10k
Retailer 2 ENG	>180k	Retailer 2 ITA	>5k
Retailer 3 ENG	>165k	Retailer 3 ITA	>5k
Retailer 4 ENG	>120k	Retailer 4 ITA	>5k
–	–	Retailer 5 ITA	>7k
–	–	Retailer 6 ITA	>10k

convenience products because they are quick and easy to prepare compared to the conventional eggshell eggs. A United Kingdom retailer indicated:

> The segment of liquid egg and egg whites in bottles is going very well, too, although I do not think it will ever cover a big share of the market. (Retailer 3 ENG)

Theme 2: barriers in the egg market

A barrier that emerged from egg industries for both the United Kingdom and Italy is related to the high competitiveness in the egg sector, which forces egg industries to sell their products at lower prices, as mentioned by a United Kingdom industry:

> The egg market is a saturated market and there are loads of competitors, especially out there and supermarkets ask for more at the lower price. (Industry 7 ENG)

Interestingly, another barrier that emerged from both egg industries and retailers for both the United Kingdom and Italy is the challenge of providing an alternative to conventional eggs to the growing segment of vegetarian and vegan consumers, as mentioned by a United Kingdom industry and an Italian retailer:

> We also had a few vegetarians who came to us asking if they can eat our eggs, so I think this is in fact a limitation. (Industry 6 UK)

> The thing I am noticing is that some vegan consumers ask us if they can eat our eggs and ask about who the producers is/are. (Retailer 1 ITA)

An additional issue, which has been raised by both egg producers and retailers who participated in this study, is related to the logistics of eggs. Indeed, eggs are an extremely fragile product, which limits the possibility for the industries to expand and reach supermarkets/shops located far from the farms, as well as the chance of expanding their products' portfolio from the retailers' perspective, as noted in the United Kingdom by an industry and a retailer:

> Sometimes we need to get rid of a line of egg or we cannot include it in our portfolio because the producers are located too far away from us and the delivery may be too risky. (Retailer 1 ENG)

> For us as business, the main barrier is about delivering the food at the right time in good condition. (Industry 5 ENG)

Theme 3: introduction of new products

From the interviews with the United Kingdom egg industries and retailers, it emerged that product development is focused on developing new products that are richer in nutrients and, therefore, have improved health appeal (e.g., eggs from chickens fed with algae,[1] etc.):

> Then we have a line of eggs whose hens are fed with algae … they have a very high nutritional value. (Industry 6 ENG)

Another theme that emerged was the introduction of new ready-to-eat egg products, which are convenient because they could be easily and quickly cooked to satisfy consumers' demand for simple and quick cooking but are also healthy at the same time. According to two industries, one in the United Kingdom and one in Italy:

> We introduced poached egg, which you either know how to do it or not. And even if you do know, you may not have enough time to prepare it. (Industry 1 ENG)

> In the last few years, we have introduced about 15 products, all egg-processed, such as ready-made omelettes, crepes, and pancakes. We made them in different versions, five cereals, hemp flour, classic. (Industry 2 ITA)

Theme 4: reaction to plant-based eggs

Potential limitations of plant-based eggs. From the interviews conducted in the United Kingdom with egg industries, it emerged that one issue with plant-based eggs is related to its perceived limited healthiness compared to conventional eggs:

> I think in terms of cholesterol, at least in the UK. According to the British Heart Foundation, eggs would not contribute to cholesterol, so I don't see any benefits in this sense. In terms of being healthier, I very much feel that eating good quality of eggs would be probably healthier than plant-based egg because they are natural. (Industry 2 ENG)

> I think that people will continue liking natural products. I believe it is quite unlikely that people will stop using conventional eggs and will just use plant-based egg because it is a processed and artificial food. And it also is not very recommendable for humans' health. (Industry 7 ENG)

In addition, the predicted high difference in price of plant-based eggs compared to conventional eggs emerged as another potential limitation. An Italian industry asserted:

> The price. If people are happy with the costing side, then the chances are that it may work, mostly in Western countries in the next ten years; otherwise, it will simply not have any chance to work. (Industry 6 ITA)

Industries are also skeptical about the actual environmental friendliness of plant-based eggs' production as pointed out by a United Kingdom industry:

> Until someone comes and says, "This is your footprint for your plant-based egg", I am not going to be able to trust this kind of production. (Industry 6 ENG)

From the interviews with retailers in the United Kingdom and Italy, it emerged that another limitation of plant-based eggs may be linked to the difficulties of these new products to replicate all eggs' functionalities in cooking (e.g., emulsifying, etc.) and whether they have a large number of ingredients. Indeed, consumers have started to read the ingredients list more carefully prior to purchasing food products to infer their naturalness and healthiness: the shorter the ingredients list, the more likely the product will be judged as "natural" and "healthy," sometimes called "clean labels" (Asioli et al., 2017). These views are captured in the following excerpts from one United Kingdom retailer and one Italian retailer:

> Egg is a very flexible product, and it is used in a lot of recipes. So, if the use of the plant-based egg is limited to just a few, for example, I do not think that people will continue buying it and that is because it just does not have all the functionalities they need. (Retailer 4 ITA)

> The list of ingredients of the vegan substitutes until now was quite long and this makes the product look less natural. (Retailer 2 ENG)

Positive characteristics of plant-based eggs. With regard to respondents' beliefs about the positive characteristics of plant-based eggs, respondents highlighted the importance of developing an alternative to an important staple food, such as eggs, that is allergen- and cholesterol-free and, therefore, could be a suitable product for vegans, vegetarians, and flexitarian consumers but also to consumers with health-related issues (e.g., allergies, high cholesterol, etc.) as pointed out by two retailers from the United Kingdom and Italy:

> I think it can be an option for the flexitarian consumers who are looking for alternative sources of proteins other than meat. (Retailer 3 ITA)

> I think, of course, if you are a vegan customer and cannot eat eggs, it gives you the opportunity to kind of enjoy the same thing … But also, another key element is allergens … egg allergy is a real issue. So, I think the great thing about plant-based eggs is when you can make the consumers still enjoy special things like a birthday cake … that is the key. (Retailer 2 ENG)

Potential market competition between plant-based and conventional eggs. In terms of whether plant-based eggs could be a potential competitor to

conventional eggs, respondents argued that, due to the fact that plant-based eggs are not yet in the market, it is not possible to compare those products. However, respondents think that consumers will continue to prefer buying natural food, such as conventional eggs because the plant-based eggs will target consumers that have different needs (e.g., consumers that have allergies to eggs or that are vegans). Therefore, the conventional egg and the plant-based egg are expected to serve different market segments, as mentioned by an Italian industry:

> I do not think they will necessarily compete. I think there may be two separate markets for them. One for people who have allergies or who are more concerned about the impact that the food they eat has on the environment and one for all the other consumers. (Industry 4 ITA)

Potential form of sales. Between the different prototypes of plant-based eggs available (liquid, powder, and egg-shaped), respondents identified the liquid version as more suitable because consumers are already familiar with liquid eggs, and they know how to use it, as pointed out by an Italian industry:

> Liquid, because everyone knows what it is and how to use a liquid egg. (Industry 4 ITA)

However, in the Italian market, the inability of separating the yolk and the albumen in the liquid version of plant-based egg is foreseen as a possible limitation for this product, as it limits its flexibility and usage, as pointed out by an Italian retailer:

> Italian consumers, especially women who still prepare handmade pasta or cakes … they may need to separate the yolk from the albumen to make some cakes etc. (Retailer 3 ITA)

Willingness to introduce plant-based eggs in industries and retailers' portfolios. The egg industries who participated in this study, from both the United Kingdom and Italy, were unwilling to consider introducing plant-based eggs in their portfolio because they see it as an "unnatural" product, and they claimed not to have the right technologies to support this type of business. As two industries indicated:

> We only produce and sell what it is naturally produced by our hens. (Industry 2 ENG)

> We would not even have the technologies needed for that. (Industry 2 ITA)

From the retailers' perspective, buyers from the United Kingdom showed a higher level of interest in plant-based eggs than Italians. Indeed, Italian retailers have noted a drop in the sales of vegan products, and, therefore,

Table 4. Key themes and outcomes emerged from Study Two.

No.	Themes	Outcomes
1	Challenges in product development of plant-based eggs	• Replicating all the functionalities and taste of conventional eggs. • High costs of the ingredients. • Limited capacity of startup producers to scale the product.
2	Future developments of plant-based eggs	• Increasing the flexibility of plant-based eggs. • Increasing the palatability of plant-based eggs.
3	Future marketing strategies for plant-based eggs	• Positioning plant-based eggs close to conventional eggs in the supermarkets.
4	Potential market competition between plant-based and conventional eggs	• Plant-based eggs will directly compete with conventional eggs according to the startups.
5	Policy regulations	• Policy regulations might limit the possibility of using "eggs" to name the plant-based eggs. • The European Union safety authority will have to approve plant-based eggs before they are launched into the market.

they would not be willing to include this new product on their shelves, as pointed out by a retailer:

> The sale of the vegan food is dropping down … Therefore, we are not very willing to think about introducing another plant-based product like the vegan egg in this moment. (Retailer 3 ITA)

Study Two—results from interviews with researchers and startup businesses

As for Study One, in order to preserve their anonymity, respondents of Study Two have been renamed numbered in chronological order based on when the interviews were conducted (e.g., Researcher 1, Researcher 2, Startup 1, Startup 2 etc.). Table 4 provides an overview of the key themes and outcomes that emerged from Study Two.

Theme 1: challenges in product development of plant-based eggs

According to the researchers and startup businesses interviewed, the main challenge about plant-based eggs lies in the difficulties of replicating all the functionalities and taste of conventional eggs. Product development requires significant long-term investments, which not all companies are able to sustain, particularly small businesses. In addition, given the novelty of the plant-based egg, there are no consumer research studies about their acceptance and the potential market for plant-based eggs, which contributes to creating uncertainties, as pointed out by a startup business and a researcher:

> I think of it as a big product development challenge because in order to get all the functionalities of egg with one product … if the research really requires a lot of time then there is no quick return on investment and most companies are not in the position to do that … I think that there is not the marketing research either to show

> that the consumers want this product and would go and buy it if it is being produced. (Researcher 1)

> The main challenge was to find the right formulation, keep consistency with the taste and the functionality of the egg. (Start-up 6)

Other challenges that emerged are related to the high costs of the ingredients and the ability of small industries to scale the product, which makes the overall costs to produce plant-based eggs still significantly higher than conventional eggs as indicated by a startup business:

> The critical issue in the production and actually the most challenging, I would say is "scale". For the small companies like us, it is hard to compete in the beginning, purely in the base of price, because you do not have the scale yet. (Start-up 2)

Theme 2: future developments of plant-based eggs

Our study revealed a difference of opinions between the startup businesses who are producing plant-based eggs for food manufacturers and those producing them for consumers. Specifically, the former are interested in increasing the flexibility of their product to make them usable for different types of final purposes (e.g., for baking, scrambled eggs, etc.) whereas the latter aim to continue improving their product in order to meet consumers' expectations and increase the palatability of their plant-based eggs by enhancing the level of taste and texture. The first excerpt below captures the views of the startup businesses serving the food industry market, whereas the second excerpt reflects the views of the startups targeting the consumer market.

> Our goal is not to produce a single, standalone product, but really to make a much greater impact in B2B suppliers to the industry … for us the bigger damage that we see is food safety. We do want price stability; we want the same product with the same functionalities every single time. All these things are unimaginable in the egg industry today. (Start-up 2)

> It must meet the consumers' expectations, as a stand-alone product. It is important that the taste and texture do not go too far from those of a conventional egg. (Start-up 1)

Theme 3: future marketing strategies for plant-based eggs

The startup businesses interviewed that sell plant-based eggs to consumers aim to position plant-based eggs close to conventional eggs in the stores to increase the familiarity of these new products, as pointed out by a startup business:

> Potentially, omnivorous consumers may like the plant-based egg more than others, because vegan people, they already do not eat eggs … That is why we want to place the plant-based egg just side-by-side to the conventional eggs in the retailer's shops'

> shelves. So, when you go to the supermarket you will find the plant-based egg right next to the conventional boxes of eggs so that people can see it and think "why not try this one?" (Start-up 1)

Theme 4: potential market competition between plant-based and conventional eggs

In terms of whether plant-based eggs could compete with conventional eggs, it emerged that the main purpose for the development of plant-based eggs was to provide consumers with an alternative to eggs. Thus, they will necessarily compete with conventional eggs to obtain higher market share, as mentioned by a startup business:

> We develop our product to offer an alternative to conventional eggs, so I would say eggs should be our main competitor. (Start-up 5)

Theme 5: labeling regulations

The startup businesses interviewed believe that the new proposal amended by animal food producers, proposing a ban on the use of animal-related foods' names to name plant-based alternatives, will also affect them if it becomes an effective law in the future as stated by a startup business:

> I think regulation is a problem for every company in this sector because you have countries like France where they are making it illegal to consider all the vegan protein products to call it like "veggie burgers", "vegan egg", and "vegan milk", and I think that is a risk for every company, including us. (Start-up 2)

European startup businesses are using algae and fermentation processes to produce ingredients for plant-based eggs, but these have not been extensively used yet in the European Union market and are being adversely affected by the stipulations of the Novel Food Policy regulation (EU Regulation, 2015). Specifically, startup businesses need to wait until they get approval from the European Union in order to market their product, as pointed out by a startup business:

> For us, the main challenge is legislation, because we are under the novel food procedure, so we must go through this, and this basically means that we have waiting time for one and a half years. If it was not for this novel food procedure, I would just start preparing and ordering for the factories in three months. We have to wait for a year and a half to get approval from the European Union before marketing our product. (Start-up 3)

Discussion and conclusion

The main goals of this research were to explore the opinions of egg industries and retailers as well as startup businesses and researchers for conventional and plant-based eggs. Specifically, we had three main objectives.

First, we investigated future trends and barriers in today's egg market and found that there is an increasing supply and demand for eggs produced with higher animal welfare and sustainability standards. These findings are corroborated by Pettersson, Weeks, Wilson, and Nicol (2016), who found that consumers from the United Kingdom were willing to pay a premium price for eggs produced in cage-free systems. Regarding the barriers, the increasing competition in the egg industry forces producers to sell their products at lower prices, which affects the capacity particularly of SMEs to be competitive in the market. In addition, egg industries struggle to provide an alternative to conventional eggs to the growing consumer segments of flexitarians, vegetarians, and vegans (Mintel, 2017), as well as those people suffering from health problems related to egg consumption. Thus, in a saturated eggs market, plant-based eggs may contribute further to market differentiation. Indeed, given the limitations in providing an alternative to conventional eggs to those people who do not want or cannot consume conventional eggs, plant-based eggs may not directly cannibalize the conventional egg market, but instead both conventional and plant-based eggs could coexist together and target different consumer segments. Moreover, the fact that conventional eggs are a fragile product creates difficulties for retailers to expand their offerings to eggs produced by farms that are located far from the point of sales. Also, there is an increasing consumer demand for more nutritious and convenient eggs.

Second, we explored egg practitioners' reactions to plant-based eggs. Relevant differences emerged between egg industries and retailers. The egg industries expect higher costs of production for plant-based eggs compared to conventional eggs, as well as the perceived lower healthiness and naturalness of plant-based eggs to be potential limitations to the development and marketing of these new products. In fact, processed food is often seen as less natural and even harmful to humans' health by consumers (Coppola & Verneau, 2010). This is also in line with the results that emerged in research from Vainio, Niva, Jallinoja, and Latvala (2016), who found that consumers are still concerned about the perceived lack of naturalness of plant-based meat. However, it should also be argued that consumers still struggle to define what they perceive as "natural" or "unnatural" when it comes to food (Siipi, 2013). Also, the higher price of plant-based foods compared to conventional animal-based food emerged in the literature as a factor that negatively influences consumers' purchases (Peschel, Kazemi, Liebichová, Mangaard Sarraf, & Aschemann-Witzel, 2019). In this sense, implementing the so-called practice "value-informed pricing," in which consumers help enterprises to settle the price for a new product based on its perceived benefits could help to increase the performance of the plant-

based egg, as confirmed by existing literature (Ingenbleek, Frambach, & Verhallen, 2010). Furthermore, there is skepticism about the actual environmental friendliness of plant-based eggs. Interestingly, past research revealed that giving consumers evidence of higher sustainability standards of plant-based food compared to animal-based food would positively influence consumers' attitudes toward them (Hoek et al., 2011). Moreover, plant-based egg firms are advised to promote sustainability orientation messages which have been shown to positively affect new product performance (Claudy, Peterson, & Pagell, 2016). In addition, the United Kingdom industries claimed that the cholesterol-free characteristic of plant-based eggs should not be seen as a plus of these products, as the British Heart Foundation has recently shown that the consumption of eggs does not affect the level of cholesterol in a human's body (British Heart Foundation, 2018). However, egg industries' opinions on plant-based eggs can be biased as they may perceive them as potential future competitors for their market. On the contrary, we found that retailers from both the United Kingdom and Italy believed that the plant-based eggs could be a valuable alternative to eggs, although they are skeptical about plant-based eggs' ability to replicate all eggs' functionalities. For example, the impossibility to separate the yolk and the albumen in the liquid version of plant-based eggs is foreseen as a possible issue for this product, as it limits its flexibility and usage. Past research confirms that the limited cooking versatility of plant-based meats was found to be a limitation for consumers (Jallinoja, Niva, & Latvala, 2016). In addition, respondents identified the liquid version as the most suitable because consumers are already familiar with liquid egg, and they know how to use it.

Third, we explored challenges in terms of product development, marketing, and policy regulations for plant-based eggs by interviewing startup businesses and researchers. In terms of R&D and production, the main problem is related to the difficulties for plant-based eggs to replicate the functionalities and taste of conventional eggs, which could limit their appeal as corroborated by Rondoni, Millan & Asioli (2021). This finding is corroborated by previous studies on plant-based meat, which revealed that poor taste and texture still act as major barriers for consumers' acceptance for plant-based foods (Cliceri, Spinelli, Dinnella, Prescott, & Monteleone, 2018), particularly among people who are not vegan or vegetarian and consume plant-based meat alternatives never or rarely (Hoek et al., 2011). Regarding marketing issues, plant-based egg startup businesses aim to position plant-based eggs close to conventional eggs' shelves in retail markets, which can be useful to increase familiarity with the new products. Concerning policy regulations, one of the main issues that create uncertainty is related to how plant-based eggs will be labeled and named. Similar issues have been investigated also in

relation to plant-based meat, and it was found that the name and labeling affect consumers' acceptance of these new products (Carrenõ & Dolle, 2018).

Implications for policy makers, plant-based egg manufacturers and food services

This study provides several relevant implications and recommendations for producers and policy makers. First, given consumers' concern about animal welfare and sustainability standards in egg production, policy makers should work with producers to better inform consumers about the different types of cage-free eggs, supporting, for example, the adoption of standards and certifications so that consumers can make more informed choices. Similarly, policy makers and egg producers should better advise consumers about the environmental benefits that can be derived from purchasing eggs produced with higher sustainability standards. Also, because of the high price competitiveness, new policies should be developed to regulate pricing standards in the egg market. Second, the production of plant-based eggs needs large investments in terms of R&D and experts in order to develop products that could have nutritional and sensory properties that meet consumers' expectations and needs. In addition, it is very important that plant-based eggs producers identify cheap but appropriate raw materials to produce plant-based eggs, to keep the price low and increase their business competitiveness. Third, with the increasing negative concerns that animal food consumption is raising among consumers, plant-based food companies are advised to carefully decide how to position their products in the market. Indeed, by emphasizing the similarities between animal foods and plant-based alternatives, they may lose the animal-friendly and sustainability messages, which have been major drivers for the marketing and sales of other plant-based foods (Sexton, 2016). Similarly, plant-based egg producers should be aware that vegetarian and vegan consumers, who are accustomed to plant-based foods, may seek alternatives that do not remind them of animal food tastes and textures, as they have usually developed a strong dislike for animal foods' sensory properties (Fessler, Arguello, Mekdara, & Macias, 2003). Fourth, given the limited applications of plant-based eggs in cooking compared to conventional eggs, plant-based egg manufacturers are advised to indicate to consumers how to use it, for example, by adding instructions on their packaging explaining which applications plant-based eggs are suitable for and how to prepare them. Fifth, because of the evidence that emerged in past studies about the positive influence that information on higher sustainability standards has on the purchase of plant-based foods (Hoek et al., 2011), policy makers and plant-based egg producers are advised to work closely to provide consumers with

information about the sustainability of these new products, using for example, carbon footprint labels. Sixth, policy makers need to regulate plant-based eggs, particularly in terms of labeling policies to clearly define how plant-based eggs should be labeled, for example, if these new products could be called "egg" or not. Seventh, the food and catering services will have to adapt to new consumers' demands when the lockdown due to the COVID-19 pandemic is eased. Recent studies show that as consequence of the pandemic, consumers are looking for food products that are richer in nutrients and health benefits, together with higher food safety standards (Butu et al., 2020). In particular, there is a growing demand for plant-based foods which are perceived safer and healthier than meat products (Datassentail, 2020). In addition, food services are advised to expand their range of options in order to attract consumers and get them used to eat out again. Plant-based eggs have the potential to increase the variety of products offered to consumers if they will be able to replicate all egg's functionalities, given the high flexibility in cooking of the latter.

Future research directions

Several research avenues emerged from this study. First, there is a need to perform research to test different plant-based raw materials to identify the most suitable ingredients, able to produce plant-based eggs that have good food properties but are, at the same time, of low cost to make them affordable for consumers to purchase. Second, given that the success of plant-based eggs will be determined by consumers' reaction to these new products, research on consumers' acceptance for plant-based eggs should be conducted. For example, consumers' perception for plant-based eggs could be explored using methodologies such as concept mapping, which allow to visualize costumers' associations with these new products graphically (Grebitus & Bruhn, 2008). Furthermore, there is a need to investigate consumers' willingness to pay (WTP) for plant-based eggs, and to explore specific consumer segments, such as vegans, vegetarians, or flexitarians, as possible consumer targets for these new products. It would be also interesting to compare consumers' acceptance of plant-based eggs in both developed and developing countries, given the increasing protein demand in the latter in recent years. In addition, the effect of different communication framings and channels on consumers' WTP for plant-based eggs could also be explored, in order for plant-based egg companies to develop efficient marketing communications. Consumers' reaction to different names for plant-based eggs that do or do not include the word "egg" are also worth investigated. Last, it would be interesting to conduct sensory tests coupled with real choice experiments or experimental auctions in a real market scenario and using real products (Alfnes & Rickertsen, 2010; Asioli,

Mignani, & Alfnes, 2020; Lusk & Shogren, 2007) to investigate consumers' WTP for plant-based eggs in more realistic settings.

To conclude, our research identified several critical issues that should be addressed and investigated more in-depth, which have important implications for R&D, production, marketing and future labeling policies both for plant-based egg producers and policy makers.

Note

1. Eggs from hens fed with algae have reduced cholesterol level in the yolk and increased linoleic acid and arachidonic acid levels (Ginzberg et al., 2000).

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