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Pasta goes green: Consumer preferences for spirulina-enriched pasta in Italy

Tommaso Fantechi, Caterina Contini *, Leonardo Casini

University of Florence, Department of Agriculture, Food, Environment and Forestry (DAGRI), Italy

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ABSTRACT

The increasing interest in functional foods has led to research into nutraceutical sources, which has resulted in the discovery of microalgae, particularly spirulina, as a promising option. Spirulina is unique for its high protein content, essential amino acids, and rich mineral and vitamin content. Additionally, spirulina cultivation is environmentally friendly as it requires only a small area and has minimal emissions. However, despite the significant potential of spirulina-based products, their market penetration remains low due to investment costs. Therefore, assessing market interest and consumer preferences is crucial for promoting development. To understand consumer interest in spirulina-based products, a study was conducted using a representative sample of 326 Italians who participated in a choice experiment involving a pack of pasta that could be spirulina-enriched or not. The study findings indicate that there is a substantial consumer segment interested in spirulina-based pasta and willing to pay an average premium of €1.28 for a 1-kg package. This segment comprises prevalently young, physically active, well-educated men, who are interested in healthy eating and open to trying new foods. They primarily have a plant-based diet and good familiarity with functional foods.

1. Introduction

Growing consumer awareness of the relationship between nutrition and health is driving interest in functional foods for their health benefits and contribution to the prevention of noncommunicable diseases[1] [2–5]. The wide range of functional foods comprises some novel foods that are the result of new production processes or technologies [79]. These foods not only address present health requirements but also contribute to environmental sustainability [6–12]. Microalgae are among the most interesting novel options [13–15]. One such type of microalgae useful for human nutrition is spirulina (*Arthrospira platensis*), one of the best-known species [16,17]. Spirulina offers benefits to consumers for its content of essential amino acids, vitamins (A, B, D, E, K), carotenoids, essential fatty acids, and minerals [18–25]. In addition, it has the highest protein content of any naturally grown product, amounting to 60 %–70 % dry matter [26]. Therefore, spirulina perfectly matches the definition of food supplement [27] because of its protein content and preventive properties against noncommunicable diseases such as cancer, diabetes, kidney disorders, hypertension, and infertility [28–33]. In addition, spirulina cultivation has significant environmental advantages when compared to the production of animal protein or plant alternatives [17], as it is produced under controlled conditions, with low emissions, and has a high areal productivity [34].

Regarding consumer acceptability, in terms of health benefits, spirulina-enriched foods have an advantage over other enriched foods, such as those derived from insects, as they are more likely to be embraced by consumers. This is primarily because spirulina is perceived as a plant-based product [35]. Additionally, when considering sustainability factors, spirulina is preferred over soy, which is currently the popular choice as meat substitute. This preference arises from the negative environmental impact associated with soy cultivation [36,37].

The combination of these characteristics makes spirulina an excellent ingredient for enhancing foods and creating a new food offering that is both healthier and more sustainable.

The market share of spirulina-enriched foods is on the rise. The study conducted by Industry ARC [38] projects a compound annual growth rate of 9.2 % for spirulina powder from 2022 to 2027, estimating its value to reach $897.3 million by 2027. However, studies conducted by

* Corresponding author at: University of Florence, Department of Agriculture, Food, Environment and Forestry (DAGRI), P.le delle Cascine, 18, 50144 Firenze, Italy.

E-mail addresses: tommaso.fantechi@unifi.it (T. Fantechi), caterina.contini@unifi.it (C. Contini), leonardo.casini@unifi.it (L. Casini).

[1] We have chosen to adopt, for the purpose of this paper, the definition of functional food put forth by Diplock et al. [1]: A food that beneficially affects one or more target functions in the body beyond adequate nutritional effects in a way that is relevant to either an improved state of health and well-being and/or reduction of risk of disease. It is consumed as part of a normal food pattern. It is not a pill, a capsule or any form of dietary supplement.

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Lafarga and Acién [39,80] and Grahl et al. [40] indicate that the demand for these products has not yet reached its full potential. The reasons identified are the cost of the investment required for its cultivation [41], which should be covered by adequate demand. Therefore, it is useful to assess whether there is enough market interest to justify investment in large-scale cultivation. Moreover, identifying the traits that differentiate consumers interested in this type of product could be useful in recognising preference drivers to promote consumption.

2. Spirulina and consumers

There are few studies in the literature that have analysed consumer preferences with respect to spirulina. Research studies conducted in Europe have shown that there is limited knowledge of microalgae in general and of spirulina in particular [42–44]. More specifically, Lucas et al. [44] found that more than half of their sample of 442 Swiss respondents had no previous knowledge of spirulina. Kamenidou et al. [42] showed that >50 % of the Greeks surveyed (452 out of 795) were not aware of the product. Lafarga et al. [43] surveyed a large sample in Spain (3084 respondents) to study their knowledge of and attitude toward microalgae. They too found a general lack of knowledge, with <40 % of the sample having tasted spirulina at least once in their life. Grahl et al. [40] showed instead that 59 % of the French they surveyed (337) had heard of microalgae, but only 46 % of the Germans (348) and 33 % of the Dutch (350) they interviewed could say the same.

Iannuzzi et al. [35] addressed the issue of preferences for spirulina and insect based foods, pointing out that products made entirely of unknown components are rejected by consumers due to neophobia, but that the association of novel ingredients with known food tends to reduce disgust. Neophobia has also been identified as a major barrier to microalgae consumption by Moons et al. [17] and Weinrich and Elshiewy [15]. Thomas et al. [45] showed through a focus group conducted in France that the major barriers to spirulina consumption are the lack of experience with the product and the fact that it represents a departure from traditional cooking habits. The significance of habit in evaluating meat substitutes has been corroborated by Weinrich [36] in a study conducted through focus group discussions in German, French, and Dutch.

Besides barriers, the literature highlights some factors driving spirulina consumption, often linked to the interest in healthy eating [15,35,45,46]. Additionally, familiarity positively impacts attitudes toward microalgae [40,43,47]. Finally, Moons et al. [17] identified potential users among individuals who are members of sports clubs, vegetarians, and those who follow new food trends. A vegetarian/vegan diet was also found to be a driver in the study by Rzymski and Jaśkiewicz [47]. Similarly, Weinrich and Elshiewy [15] provided evidence of a negative correlation between meat consumption and attitudes toward microalgae.

Lafarga et al. [43] showed that willingness to taste and willingness to pay for spirulina increases by providing information about its healthiness. The results of Iannuzzi et al. [35] also highlighted that emphasising the positive characteristics of spirulina improves consumer attitude.

Lafarga et al. [43] and Lucas et al. [44] found that carrier knowledge is a driver of consumption, pointing out that the most preferred spirulina-enriched products are pasta and cereal bars. Grahl et al. [40] analysed three products to which spirulina was added as an ingredient, i.e., pasta, sushi, and a vegan jerky. It was shown that pasta has greater liking than the other two options and confirmed that acceptance of spirulina increases with familiarity of the product which it is added to.

Our literature search revealed that to date studies on spirulina have been carried out mostly using qualitative methods and descriptive analyses. They appear to confirm the potential of spirulina as a food supplement, but do not allow for market segmentation on the basis of utility associated with consumption, nor do they enable direct comparison with competing products.

Our study aims to fill this gap with reference to the Italian market, using pasta as the carrier. Pasta is a particularly interesting carrier as various research studies have revealed the high nutritional quality of spirulina-enriched pasta [20,21,48–50]. The choice of pasta is expected to positively impact on the acceptance of the novel ingredient, both because of its familiarity in Italy [51,52] and because the literature recognises it among those carriers with higher acceptance [35,40,44]. On the other hand, the strong attachment of Italians to their traditional food style [53] may reduce the acceptance of the functional product.

Our study aims to answer the following research questions:

RQ1: Is there a segment of Italian consumers willing to pay a premium price for spirulina-enriched pasta?

RQ2: What is Italian consumers' willingness to pay (WTP) for a spirulina-enriched product?

RQ3: What is the profile of Italian consumers interested in purchasing a product containing spirulina?

3. Methodology

3.1. Questionnaire

To address our research questions, we conducted a survey utilizing the Google Forms platform to administer an online questionnaire. Data collection spanned from December 2021 to April 2022, and we utilised social platforms for recruiting participants. Our sample comprised 326 individuals from Italy. To ensure representation across different factors, namely age, gender, and region of residence, we employed quota sampling.

The first section of the questionnaire included a filter question to identify individuals who are responsible or co-responsible for food purchases.

The second section utilised a discrete choice experiment (DCE) methodology, which was well-suited for our research objectives. DCE allowed us to compare a discrete number of alternatives by differentiating them based on attributes and relative levels [54]. In this context, DCE aimed to create a realistic choice scenario, enabling respondents to navigate trade-offs among various attribute levels. By presenting clear and predefined options, DCE provided respondents with a straightforward and intuitive task that was easy to understand. The effectiveness of DCE was demonstrated in capturing diverse preferences among respondents and facilitating the analysis of subgroup preferences and variations in WTP estimates [55].

In our study, participants were asked to imagine themselves in the process of grocery shopping with the intention of purchasing a 1 kg pack, which served as a standardised reference point for evaluating the various alternatives. The selected pasta for the experiment was high-quality fusilli, made from 100 % Italian wheat, and dried at low temperature. In each scenario, participants were presented with two options to choose from, or they had the option to select "No choice" if neither alternative suited their preferences. The two alternatives could be distinguished by the attributes and levels shown in Table 1.

When the pasta is enriched with spirulina, the packaging in the DCE displays the label "3% Spirulina - a Source of Fiber and Protein," while the pasta itself takes on a green colour. This choice stems from the fact that commercially available spirulina-enriched pasta exhibits similar

Table 1
DCE attributes and related levels.

Attribute	Level
Spirulina-enriched	None
	Present
Price	€7.50
	€10
	€12.50
	€15
Organic	None
	Present

compositions, and the green hue is a direct result of the presence of spirulina [20,21,48–50]. Given the lack of knowledge about spirulina and the importance of information highlighted in the literature, the pack of spirulina-enriched pasta used in our study shows the claim authorised by Regulation EC 1924/2006 [78] that the food is a source of protein and a source of fibre.

Attributes were selected based on a literature search related to consumer preferences with respect to pasta. We know from the literature that consumers choose pasta primarily based on price, origin and brand [56]. Consumers were asked to imagine that the brand was the one they usually buy for all alternatives. The price range was determined through a market survey conducted across both traditional physical stores and online retail platforms, taking into account the quantity (1 kg) and high quality of the options presented in the choice experiment. The choice of a high-quality product such as naturally dried bronze-drawn pasta stems from the consideration that adding an ingredient such as spirulina is more plausible in products with quality characteristics that support higher sales prices.

As regards certification, much research emphasizes the importance of organically grown food in consumer choices [57]. In line with this, it has been noted by several authors that over a quarter of Italian consumers choose to eat organic pasta at least once a month [56,58]. This trend has experienced a substantial surge in recent years. According to ISMEA [59], sales within the retail sector saw an 8.9 % increase in 2020 compared to the previous year, solidifying the organic attribute as a pivotal factor influencing consumer preferences for pasta.

The Ngene software (ChoiceMetrics Ltd.) enabled us to create the orthogonal design, with 8 purchasing scenarios to submit to our sample. Each participant has been exposed to all eight scenarios of the experimental design. An example of a purchasing scenario is shown in Fig. 1.

The questionnaire then proceeded to explore psychographic and behavioural traits that have been highlighted in the literature as significant factors in the relationship between consumers and their preferences for spirulina. Research studies by Iannuzzi et al. [35], Moons et al. [17], and Thomas et al. [45] have identified neophobia as a potential barrier, while interest in healthy eating, engagement in physical activity, and adherence to a vegan/vegetarian diet have been recognised as drivers of acceptance [17,35,42,45,47]. Additionally, familiarity with functional foods appears to play a crucial role in acceptance [40,42–44].

As a result, the survey included targeted questions to assess participants' level of exercise, familiarity with functional foods, and the type of diet they follow. Food neophobia was measured using the food neophobia scale developed by Pliner & Hobden [60], while the estimated interest in healthy eating was obtained using the scale developed by Pieniak et al. [61]. Both scales utilised a 5-level Likert scale ranging from "strongly disagree" to "strongly agree." Table A1 in the appendix provides details of the scale items, their respective Cronbach's α coefficients (both exceeding 0.7), and key descriptive statistics.

The questionnaire concluded by surveying sociodemographic characteristics (gender, age, education level, area of origin, employment status and size of city of residence).

3.2. Discrete choice experiment

The theoretical foundation of the DCE can be traced back to Lancaster's [62] consumer studies and McFadden's [63] Random Utility Theory. Lancaster's work posited that the utility of a good is determined by the sum of its characteristics, while McFadden's theory argued that consumers act as rational individuals by selecting the option that offers them the highest utility. As a result, the probability of choosing an alternative from a given set depends on its utility relative to the others [64].

Utility can be defined as follows:

$$U_{nij} = \boldsymbol{\beta}' \boldsymbol{X}_{nij} + ASC + \varepsilon_{nij} \quad (1)$$

In Eq. (1), U represents the utility that individual n obtains by choosing alternative i in choice set j, $\boldsymbol{\beta}'$ is the vector of coefficients representing the weight of each level $\boldsymbol{X}_{nij}$ of each attribute in forming the utility, and ε_{nij} represents the independently and identically distributed stochastic component. Finally, *ASC* (Alternative Specific Constant) is a fixed value that accounts for the influence of the good's attributes not included in the experimental design but described in the scenario. In this

Fig. 1. An example of a purchasing scenario proposed in the DCE.

specific case, the scenario describes a 1 kg pack of fusilli from the brand regularly consumed, made from 100 % Italian wheat and dried at a low temperature. Spirulina and organic attributes were analysed as dummy variables, while price was analysed as a continuous variable.

If the residuals (ε_{nij}) are identically and independently distributed, the probability that individual n chooses alternative i is given by Eq. (2):

$$Pr_{ni} = \frac{e^{\beta' X_{ni}}}{\sum_{1}^{J} e^{\beta' X_{nj}}}, \quad (2)$$

where $\boldsymbol{X}_{ni}$ is the vector of attributes of alternative i for individual n and $\boldsymbol{X}_{nj}$ the vector of attributes of alternative j. The probability that an individual will choose alternative i is equal to the ratio of the exponential of the deterministic utility component for alternative i to the sum of the exponentials of the deterministic utility components for alternatives j.

To address preference heterogeneity, we incorporated latent class analysis (LCA) into our methodology. LCA allowed us to estimate distinct latent classes based on observed response patterns. LCA was conducted using the Latent Gold Choice 4.5 software (Statistical Innovation Inc.).

3.3. Profiling

With the aim of characterising the respondents belonging to the identified classes, we conducted profiling by chi-squared automatic interaction detection (CHAID) analysis [65]. This technique, through an iterative process of chi-squared tests, identifies the variables that differ statistically between the classes. The analysis, carried out with the SI-CHAID Define software (version 4.0.5.18305), included sociodemographic variables (gender, age, area of origin, education, and employment status), psychographic variables (food neophobia, interest in healthy eating, familiarity with foods enriched with functional foods), and behavioural variables (level of exercise and type of diet). For neophobia and interest in healthy eating, the mean of the items was calculated for each respondent and was standardised relative to a standard normal distribution. Operations on the scales, including calculation of Cronbach's Alphas and key descriptive statistics, were carried out with STATA 15.1.

4. Results

4.1. The sample

Our sample comprised 326 Italian individuals whose characteristics were compared with those of the Italian population in Table 2. The sample demonstrated representativeness across age, gender, region of residence, and employment. However, it did exhibit a higher level of education compared to the broader Italian population.

Furthermore, our sample predominantly consisted of individuals who engage in infrequent physical activity, follow an omnivorous diet, and demonstrate a good level of familiarity with enriched foods. (Table 3).

4.2. Discrete choice experiment

The model selection process was guided by an analysis in which the evaluation of information criteria (Table 4) was balanced with the analyst's subjective evaluation. Specifically, we followed the approach proposed by Scarpa & Thiene [67] and considered both the statistical significance of parameter estimates and the meaningfulness of the parameter signs. This approach enabled us to identify two substantial consumer segments with contrasting preferences toward spirulina. As a result, our investigation maintained a focused and effective approach in addressing our research question.

Specifically, Class 1, representing 60 % of the sample, consisted of

Table 2
Main sociodemographic characteristics of the sample.

Variable	Sample	Italy
Gender		
Male	47 %	49 %
Female	53 %	51 %
Age		
18–33	25 %	24 %
34–53	36 %	38 %
>54	39 %	38 %
Region of residence		
Northern Italy	40 %	45 %
Central Italy	25 %	20 %
Southern Italy	35 %	35 %
Education		
Junior high school or below	17 %	36 %
High school diploma	36 %	43 %
College education or higher	47 %	21 %
Employment		
Employed	65 %	61 %
Student	14 %	5 %
Unemployed	10 %	8 %
Retiree	11 %	26 %

NB: Source: Data on the Italian adult population from ISTAT [66].

Table 3
Sample characteristics with respect to level of exercise, diet type, familiarity with foods enriched with functional foods.

	Variable	Frequency
	Level of exercise	
	Less than once a month	17%
	At least once a month but less than once a week	49%
	Once a week	18%
	More than once a week	16%
	Type of diet	
	Vegan/vegetarian	18%
	Omnivorous	82%
	Familiarity with foods enriched with functional foods	
None or low	I've never heard of them	5%
None or low	I've heard of them, but I've never tasted them	7%
None or low	I've tasted them, but I don't buy them	11%
None or low	I buy them, but only occasionally	33%
Good	I buy them routinely	44%

Table 4
Parameters characterising the different models.

Number of classes	LL	BIC	AIC	Npar	R^2
1	−2311	4644	4629	4	0.20
2	−1902	3855	3821	9	0.44
3	−1636	3353	3300	14	0.59
4	−1558	3226	3155	19	0.64
5	−1473	3084	2994	24	0.68
6	−1433	3034	2924	29	0.71

NB: LL = log likelihood, BIC = Bayesian information criterion, N. Par = number of parameters.

individuals who favoured traditional pasta. In contrast, Class 2, accounting for 40 % of the sample, comprised consumers who expressed a preference for the incorporation of spirulina in pasta (refer to Table 5).

Price had a negative utility for both (i.e., as price increases, utility for consumers decreases), while being organic increased utility throughout the sample. In terms of the magnitude of the β coefficients, which indicate the contribution of attributes to the utility function, the class that preferred spirulina demonstrated a significantly higher weight on utility for the presence of this ingredient in pasta compared to the weight attributed to organic certification, exceeding it by more than double.

For class 2, the WTP, obtained by calculating the absolute value of the ratio of the β coefficient of the presence of spirulina with the β coefficient of the price, was €1.28 per kg for the addition of spirulina to pasta.

4.3. Profiling

Table 6 shows the profiling of the classes in the CHAID analysis.

The class consisting of consumers who choose enriched pasta comprised predominantly males under 40, residing in Northern Italy, with an advanced level of education and a vegan or vegetarian diet. They have low food neophobia, are attentive to healthy eating, exercise regularly and are familiar with functional foods.

5. Discussion

To address our research questions, we designed a choice experiment that, to the best of our knowledge, is the first of its kind in the existing literature. This simulation allowed us to categorise the market based on the utility people associate with consuming spirulina. Specifically, the purpose of RQ1 was to test whether there is a segment of the Italian population willing to pay a premium price for spirulina-enriched pasta. Our results allow us to answer the question affirmatively, as 40 % of respondents showed positive utility from the addition of spirulina. Our data are in line with the study by Lafarga et al. [43], in which 42.7 % of respondents had given an affirmative answer when asked if they were interested in consuming spirulina. The identified segment is highly relevant, especially considering the barriers highlighted in the literature concerning novel foods [12,68], as well as Italians' strong attachment to their traditional food style, which could have potentially contributed to additional resistance. It is worth highlighting that the utility associated with spirulina surpasses that of organic certification by more than double. This observation is notable, given that organic certification is acknowledged in the literature as a driver of food preferences [69].

We proceeded to estimate the WTP of Italian consumers for spirulina-enriched pasta compared with traditional pasta, thus answering RQ2. Consumers in the second class would pay €1.28 per kg more for spirulina-enriched pasta than for the basic pack. Our findings align with the study conducted by Weinrich and Gassler [25], where they assessed price sensitivity regarding different variants of algae-based meat substitutes. Furthermore, our results are consistent with the research conducted by Lafarga et al. [43], who found that 40 % of the participants expressed a willingness to pay an additional 6–10 % compared to the base product price for an enriched alternative.

Our work then focused on profiling the segment that would buy spirulina-enriched pasta in order to determine the personal traits associated with this type of behaviour (RQ3). Looking at the socio-demographic characteristics, we observed that distinctive trait of the class that chooses spirulina is that it is mainly composed of males under 40 years of age, who live in Northern Italy, and have an advanced level of education. In terms of gender, our findings were consistent with the studies conducted by Weinrich and Gassler [25] and Weickert et al. [46]. This adds to the existing literature on microalgae, as previous studies such as Grahl et al. [20], Kamenidou et al. [42], Lucas et al. [44], and Rzymski et al. 47 have not found any significant differences between genders. Therefore, our research offers a novel perspective to the literature by identifying gender-related distinctions. Our result can be explained by taking into consideration the fact that men and women have different nutritional preferences and dietary goals, which may contribute to men displaying a greater interest in spirulina [70,71]. In

Table 5
β coefficients of the classes.

Attribute	Class 1	Class 2
Price	−0.46***	−0.83***
Spirulina-enriched	−2.44***	1.06***
Organic	0.38***	0.49***
ASC	4.37***	11.18***

NB: The notation *** indicates a significant result at a p-value < 0.01.

Table 6
Profiling of the two latent classes. The underlined values indicate in which of the two classes a higher relative frequency of the characteristics displayed in the table can be observed. The percentages are to be read horizontally and should be compared with the size of the two classes.

Variable	Class 1 (60 %)	Class 2 (40 %)	Total
Gender			
Male	49 %	51 %	152
Female	68 %	32 %	174
Age			
Under 40	34 %	66 %	128
Over 40	76 %	24 %	198
Region of residence			
Central/Southern Italy	69 %	31 %	194
Northern Italy	46 %	54 %	132
Education level			
High school diploma or lower	68 %	32 %	172
University	50 %	50 %	154
Neophobia			
Medium-low (standardised mean value<0.25)	40 %	60 %	174
High (standardised mean value >0.25)	82 %	18 %	152
Level of exercise			
Less than once a week	75 %	25 %	212
At least once a week	32 %	68 %	114
Type of diet			
Vegan/vegetarian	33 %	67 %	61
Omnivorous	66 %	34 %	265
Familiarity with functional foods			
None or low	70 %	30 %	181
Good	46 %	54 %	145
Interest in healthy eating			
Medium-low (standardised mean value<0.25)	73 %	27 %	108
High (standardised mean value >0.25)	53 %	47 %	218

NB: Gender (LR Chi-Squared 12.26, df 1, P-value 0.00); Age (LR Chi-Squared 56.01, df 1, P-value 0.00); Region of residence (LR Chi-Squared 16.27, df 1, P-value 0.00); Education level (LR Chi-Squared 11.00, df 1, P-value 0.00); Neophobia (LR Chi-Squared 64.15, df 1, P-value 0.00); Level of exercise (LR Chi-Squared 57.27, df 1, P-value 0.00); Type of diet (LR Chi-Squared 21.95, df 1, P-value 0.00); Familiarity with functional foods (LR Chi-Squared 19.27, df 1, P-value 0.00); Interest in healthy eating (LR Chi-Squared 12.85, df 1, P-value 0.00); Sociodemographic and psychographic variables that were not significant are not shown in the table.

contrast, young age had already been cited as a driver in previous studies ([42–44]; Rzymski et al., 2016; [25]). This may be due to the fact that older people are more conservative, while younger people are more open to novelties, including in food choices [72,73]. Education had already been shown to be a distinguishing characteristic of consumers choosing spirulina pasta ([42,43]; Rzymski et al., 2016; [46]). This finding can be explained by the fact that greater education is associated with greater openness to change [74,75]. The prevalence of educated individuals in our sample compared with the Italian population suggests that the class preferring spirulina pasta might be more represented in our sample than in the broader Italian population, potentially introducing a bias. However, considering the noteworthy presence of this class in our sample, it is reasonable to assume that it remains substantial within the Italian population as well. This assumption is supported by the representative nature of our sample in terms of age, gender, region of residence, and employment. As regards the area of residence, there are no related studies in the literature. However, we are aware of differences between Northern Italy and the rest of the country, with Northern Italy showing a greater interest in a healthy diet [76]. This trend is also reflected in our sample, where residents in the North exhibit more health-conscious behaviour compared to other participants. Therefore, the higher prevalence of Northern consumers in the group selecting spirulina pasta could be attributed to this factor.

With respect to behavioural and psychographic characteristics, significant differences between the two classes relate to type of diet, level of exercise, food neophobia, interest in healthy eating, and familiarity with functional foods. As regards behavioural characteristics, in the class that chooses enriched pasta we found predominantly those who do not consume meat and physically active individuals. Our findings align with other studies conducted by Weinrich and Elshiewy [15] and Weinrich and Elshiewy [77], which have highlighted a negative correlation between higher meat consumption and attitudes toward microalgae. These findings are further supported by the research conducted by Moons et al. [17] who from a-priori segmentation showed that sporting individuals and vegetarians are more likely to consume spirulina than individuals who prioritise taste and hedonic aspects of foods. Physically active individuals form an intriguing segment. Considering the potential benefits of increased protein intake during and after workouts, spirulina could serve as a valuable natural supplement for those who engage in regular exercise. The result for neophobia is consistent with the findings of Iannuzzi et al. [35], Moons et al. [17], and Thomas et al. [45] and Weinrich and Elshiewy [15], confirming that this is the major barrier to the consumption of novel foods. Our findings are also in line with those reported by Siegrist and Hartmann [68] who showed that potential adopters of novel foods are those who are most open to change. When it comes to interest in healthy eating, the connection with spirulina shows great promise. Its positive attributes appeal to individuals who prioritise a health-conscious diet. The existing literature highlights the association between spirulina and interest in healthy eating, underscoring the significance of promoting spirulina by emphasising this aspect ([17,35,42]; Rzymski et al., 2016; [45]). Finally, our results show the importance of familiarity with functional foods. Prior knowledge and use of these seems crucial in the consumption of different functional foods, as also highlighted by other authors [40,42–44].

Our findings carry implications for policymakers, food industry stakeholders, and public health professionals. They shed light on two crucial factors influencing consumption behaviour: exercise level and dietary choices. These determinants are linked to the personal relevance of the product's benefits for consumers, as adequate intake of high-quality proteins is beneficial for the well-being of both physically active individuals and non-meat consumers. This corroborates the existing literature [35,43,44], emphasising the importance of promoting these products by highlighting the nutritional benefits they offer to consumers. The use of an indication on protein and fibre content on the label was employed in our study as a means of informing consumers about the product's benefits. However, other communication strategies, like those that leverage internet social media channels, could be particularly effective considering the young age of those potentially interested in the product. Furthermore, targeted communication campaigns can be designed to specifically address the most promising consumer segments identified in our study. More precisely, with reference to the target group of physically active individuals, promoting spirulina in gyms, sports facilities and blogs about exercise could be helpful. Similarly, newspapers and online pages devoted to vegetarian and vegan diets or with a focus on healthy eating could be leveraged.

Based on our findings, which emphasise food neophobia as the primary obstacle to the acceptance of spirulina-enriched functional foods, we propose that conducting taste tests could effectively promote these products and address the challenges associated with neophobia. Furthermore, the involvement of restaurants is crucial as they can incorporate spirulina into their recipes, presenting it in a delectable and enticing way to consumers.

One limitation of our study is the absence of taste testing. Previous research has indicated a generally positive reception of these products [20,21,48–50]. This favourable response may contribute to broader acceptance and adoption of the product in the future. However, it would be beneficial to further investigate this aspect through research that combines choice experiments with taste tests.

Two key factors that present additional opportunities for future research developments are the choice of country and the selection of a carrier. For our study, we conducted research in Italy and utilised pasta as the carrier. Pasta is widely consumed and familiar among Italian consumers. The literature suggests that the popularity of pasta as a common food product likely facilitated its easy acceptance among participants [35,40,44]. To advance this field, it would be worth investigating whether similar results can be achieved using products with different characteristics in various countries.

6. Conclusions

The results of our study demonstrate the existence of a substantial segment of the Italian population who is willing to pay a premium price for spirulina-enriched pasta. This finding supports the potential development of new spirulina-based products by agribusiness companies.

The study also shows that the segment of consumers who prefer pasta with spirulina is different from the rest of the population. Agribusiness companies and policymakers can leverage this finding to develop targeted strategies that cater to this specific segment.

In conclusion, our study applied a choice experiment to study the demand for spirulina-enriched foods. Studies comparing traditional and microalgae-containing products conducted in other countries and on foods other than pasta will be needed to direct policymakers and market players toward creating value through the development of new foods, their distribution, and the implementation of communication campaigns to launch a food with untapped potential in the marketplace.

CRediT authorship contribution statement

Tommaso Fantechi: Conceptualization, Methodology, Data curation, Formal Analysis, Writing-Original draft preparation.

Caterina Contini: Conceptualization, Methodology, Formal Analysis, Writing-Original draft preparation.

Leonardo Casini: Conceptualization, Supervision.

Declaration of competing interest

None

Data availability

Data will be made available on request.

Appendix A

Table A1
Items of the scales used and their statistics.

Scale	Alpha	Item	Average	Standard deviation
Food neophobia	0.71	I am constantly sampling new and different foods (R)	3.08	1.35
		I don't trust new foods	2.87	1.37
		If I don't know what is in a food, I won't try it	2.91	1.43
		I like foods from different countries (R)	3.22	1.48
		Ethnic food looks too weird to eat	2.79	1.36
		At dinner, I will try a new food (R)	3.43	1.21
		I am afraid to eat things I have never had before	2.74	1.36
		I am very particular about the foods I will eat	3.59	1.28
		I like to try new ethnic restaurants (R)	2.73	1.48
Interest in healthy eating	0.95	It is important to me that the food I eat on a typical day is good for my physical and mental health	4.51	0.88
		It is important to me that the food I eat on a typical day keeps me healthy	4.55	0.87
		It is important to me that the food I eat on a typical day is nutritious	4.52	0.89

References

[1] A. Diplock, P. Aggett, M. Ashwell, F. Bornet, E. Fern, M. Roberfroid, The European Commission concerted action on functional foods science in Europe (FUFOSE). Scientific concepts of functional foods in Europe. Consensus document, Br. J. Nutr. 81 (1999) 1–27.

[2] C.S. Birch, G.A. Bonwick, Ensuring the future of functional foods, Int. J. Food Sci. Technol. 54 (5) (2019) 1467–1485.

[3] P. Chrysochou, A. Tiganis, I.T. Trigui, K.G. Grunert, A cross-cultural study on consumer preferences for olive oil, Food Quality Preference 97 (2022) 104460.

[4] C. Contini, K. Grunert, R.N. Christensen, F. Boncinelli, G. Scozzafava, L. Casini, Does attitude moderate the effect of labelling information when choosing functional foods? Food Quality Preference 106 (2023) 104795.

[5] K. Topolska, A. Florkiewicz, A. Filipiak-Florkiewicz, Functional food—consumer motivations and expectations, Int. J. Environ. Res. Public Health 18 (10) (2021) 5327.

[6] A. Balatsas-Lekkas, A. Arvola, H. Kotilainen, N. Meneses, K. Pennanen, Effect of labelling fresh cultivated blueberry products with information about irradiation technologies and related benefits on Finnish, German, and Spanish consumers' product acceptance, Food Control 118 (2020) 107387.

[7] F. Branca, A. Lartey, S. Oenema, V. Aguayo, G.A. Stordalen, R. Richardson, M. Arvelo, A. Afshin, Transforming the food system to fight non-communicable diseases, Bmj 364 (2019).

[8] G. Califano, M. Furno, F. Caracciolo, Beyond one-size-fits-all: consumers react differently to packaging colors and names of cultured meat in Italy, Appetite 182 (2023) 106434.

[9] J. de Boer, H. Aiking, Pursuing a low meat diet to improve both health and sustainability: how can we use the frames that shape our meals? Ecol. Econ. 142 (2017) 238–248.

[10] T. Garnett, Food sustainability: problems, perspectives and solutions, Proc. Nutr. Soc. 72 (1) (2013) 29–39.

[11] F. La Barbera, F. Verneau, P.N. Videbæk, M. Amato, K.G. Grunert, A self-report measure of attitudes toward the eating of insects: construction and validation of the Entomophagy Attitude Questionnaire, Food Quality Preference 79 (2020) 103757.

[12] H. Tuorila, C. Hartmann, Consumer responses to novel and unfamiliar foods, Curr. Opin. Food Sci. 33 (2020) 1–8.

[13] J. de Boer, H. Aiking, On the merits of plant-based proteins for global food security: marrying macro and micro perspectives, Ecol. Econ. 70 (7) (2011) 1259–1265.

[14] M.C. Onwezen, E.P. Bouwman, M.J. Reinders, H. Dagevos, A systematic review on consumer acceptance of alternative proteins: pulses, algae, insects, plant-based meat alternatives, and cultured meat, Appetite 159 (2021) 105058.

[15] R. Weinrich, O. Elshiewy, A cross-country analysis of how food-related lifestyles impact consumers' attitudes towards microalgae consumption, Algal Res. 70 (2023) 102999.

[16] T. Lafarga, J.M. Fernández-Sevilla, C. González-López, F.G. Acién-Fernández, Spirulina for the food and functional food industries, Food Res. Int. 137 (2020) 109356.

[17] I. Moons, C. Barbarossa, P. De Pelsmacker, The determinants of the adoption intention of eco-friendly functional food in different market segments, Ecol. Econ. 151 (2018) 151–161.

[18] F.M. Andrica, T.D. Marţi, I. Pânzaru, D. Coricovac, C. Dehelean, S. Drăgan, Preliminary study on the evaluation of spirulina on TPA induced mouse ear inflammation, J. Agroaliment. Process. Technol. 21 (3) (2015) 268–273.

[19] M. Barkallah, M. Dammak, I. Louati, F. Hentati, B. Hadrich, T. Mechichi, M. A. Ayadi, I. Fendri, H. Attia, S. Abdelkafi, Effect of Spirulina platensis fortification on physicochemical, textural, antioxidant and sensory properties of yogurt during fermentation and storage, LWT 84 (2017) 323–330.

[20] S. Grahl, M. Strack, A. Mensching, D. Mörlein, Alternative protein sources in Western diets: food product development and consumer acceptance of spirulina-filled pasta, Food Quality Preference 84 (2020) 103933.

[21] C. Muresan, A. Pop, S. Man, S. Socaci, A. Fărcas, M. Nagy, B. Rus, The influence of different proportions of Spirulina (Arthrospiraplantensis) on the quality of pasta, J. Agroalimentary Process. Technol. 22 (1) (2016) 24–27.

[22] G.G. Salmeán, L.H.F. Castillo, G. Chamorro-Cevallos, Nutritional and toxicological aspects of Spirulina (Arthrospira), Nutrición hospitalaria: Organo oficial de la Sociedad española de nutrición parenteral y enteral 32 (1) (2015) 34–40.

[23] H. Shimamatsu, Mass production of Spirulina, an edible microalga, Hydrobiologia 512 (1–3) (2004) 39–44.

[24] S.M. Tibbetts, M.J. MacPherson, K.C. Park, R.J. Melanson, S.J. Patelakis, Composition and apparent digestibility coefficients of essential nutrients and energy of cyanobacterium meal produced from Spirulina (Arthrospira platensis) for freshwater-phase Atlantic salmon (Salmo salar L.) pre-smolts, Algal Res. 70 (2023) 103017.

[25] R. Weinrich, B. Gassler, Beyond classical van Westendorp: assessing price sensitivity for variants of algae-based meat substitutes, J. Retail. Consum. Serv. 63 (2021) 102719.

[26] A. Piccolo, Spirulina—A Livelihood and a Business Venture, 2012 (REPORT/ RAPPORT: SF/2011/16).

[27] L.M.R. Almeida, L.F. da Silva Cruz, B.A.S. Machado, I.L. Nunes, J.A.V. Costa, E. de Souza Ferreira, P.V.F. Lemos, J.I. Druzian, C.O. de Souza, Effect of the addition of Spirulina sp. biomass on the development and characterization of functional food, Algal Res. 58 (2021) 102387.

[28] H. Beheshtipour, A.M. Mortazavian, P. Haratian, K.K. Darani, Effects of Chlorella vulgaris and Arthrospira platensis addition on viability of probiotic bacteria in yogurt and its biochemical properties, Eur. Food Res. Technol. 235 (2012) 719–728.

[29] S. Buono, A.L. Langellotti, A. Martello, F. Rinna, V. Fogliano, Functional ingredients from microalgae, Food Funct. 5 (8) (2014) 1669–1685.

[30] A.C. Lemes, K.P. Takeuchi, J.C.M.D. Carvalho, E.D.G. Danesi, Fresh pasta production enriched with Spirulina platensis biomass, Braz. Arch. Biol. Technol. 55 (2012) 741–750.

[31] J. Sulibursk, M. Szulińska, A.A. Tinkov, P. Bogdański, Effect of Spirulina maxima supplementation on calcium, magnesium, iron, and zinc status in obese patients with treated hypertension, Biol. Trace Elem. Res. 173 (2016) 1–6.

[32] D. Wan, Q. Wu, K. Kuča, Spirulina, in: Nutraceuticals, Academic Press, 2021, pp. 959–974.

[33] T. Winarni Agustini, W. Farid Ma'ruf, W. Widayat, M. Suzery, H. Hadiyanto, S. Benjakul, Application of Spirulina platensis on ice cream and soft cheese with respect to their nutritional and sensory perspectives, J. Teknol. 78 (4–2) (2016) 245–251.

[34] R.B. Draaisma, R.H. Wijffels, P.E. Slegers, L.B. Brentner, A. Roy, M.J. Barbosa, Food commodities from microalgae, Curr. Opin. Biotechnol. 24 (2) (2013) 169–177.

[35] E. Iannuzzi, R. Sisto, C. Nigro, The willingness to consume insect-based food: an empirical research on Italian consumers, Agric. Econ. 65 (10) (2019) 454–462.

[36] R. Weinrich, Cross-cultural comparison between German, French and Dutch consumer preferences for meat substitutes, Sustainability 10 (6) (2018) 1819.

[37] R. Weinrich, G. Busch, Consumer knowledge about protein sources and consumers' openness to feeding micro-algae and insects to pigs and poultry, Future Foods 4 (2021) 100100.

[38] Industry ARC, Spirulina Powder Market – Forecast (2022–2027), Available at, https://www.industryarc.com/Report/19629/spirulina-powder-market.html, 2021. (Accessed 5 July 2023).

[39] T. Lafarga, G. Acién, Microalgae for the food industry: from biomass production to the development of functional foods, Foods 11 (5) (2022) 765.

[40] S. Grahl, M. Strack, R. Weinrich, D. Mörlein, Consumer-oriented product development: the conceptualization of novel food products based on spirulina

(Arthrospira platensis) and resulting consumer expectations, J. Food Quality 2018 (2018).
[41] B. Thevarajah, G.K.S.H. Nishshanka, M. Premaratne, P.H.V. Nimarshana, D. Nagarajan, J.S. Chang, T.U. Ariyadasa, Large-scale production of Spirulina-based proteins and c-phycocyanin: a biorefinery approach, Biochem. Eng. J. (2022) 108541.
[42] I. Kamenidou, S. Aggelopoulos, A.C. Batzios, Natural medical attributes and benefits of Spirulina: segmentation based on consumers' knowledge, J. Med. Plants Res 5 (2011) 3192–3199.
[43] T. Lafarga, R. Rodríguez-Bermúdez, A. Morillas-España, S. Villaró, M. García-Vaquero, L. Morán, A. Sánchez-Zurano, C. González-López, F.G. Acién-Fernández, Consumer knowledge and attitudes towards microalgae as food: the case of Spain, Algal Res. 54 (2021) 102174.
[44] B.F. Lucas, J.A.V. Costa, T.A. Brunner, Attitudes of consumers toward Spirulina and açaí and their use as a food ingredient, LWT 178 (2023) 114600.
[45] C. Thomas, R. Symoneaux, G. Pantin-Sohier, P. Picouet, I. Maître, Perceptions of Spirulina From French Consumers of Organic Products, 2020.
[46] S. Weickert, S. Grahl, R. Weinrich, Algae production technology: effect of framing on German consumer acceptance, Algal Res. 58 (2021) 102401.
[47] P. Rzymski, M. Jaśkiewicz, Microalgal food supplements from the perspective of Polish consumers: patterns of use, adverse events, and beneficial effects, J. Appl. Phycol. 29 (2017) 1841–1850.
[48] M.C. Messia, F. Cuomo, L. Falasca, M.C. Trivisonno, E. De Arcangelis, E. Marconi, Nutritional and technological quality of high protein pasta, Foods 10 (3) (2021) 589.
[49] G. Özyurt, L. Uslu, I. Yuvka, S. Gökdoğan, G. Atci, B. Ak, O. Işik, Evaluation of the cooking quality characteristics of pasta enriched with Spirulina platensis, J. Food Qual. 38 (4) (2015) 268–272.
[50] M. Raczyk, K. Polanowska, B. Kruszewski, A. Grygier, D. Michałowska, Effect of spirulina (Arthrospira platensis) supplementation on physical and chemical properties of semolina (Triticum durum) based fresh pasta, Molecules 27 (2) (2022) 355.
[51] M. Dello Russo, C. Spagnuolo, S. Moccia, D. Angelino, N. Pellegrini, D. Martini, Italian Society of Human Nutrition (SINU) Young Working Group, Nutritional quality of pasta sold on the Italian market: the Food Labelling of Italian Products (FLIP) study, Nutrients 13 (1) (2021) 171.
[52] F. Gerini, T. Fantechi, C. Contini, L. Casini, G. Scozzafava, Adherence to the Mediterranean diet and COVID-19: a segmentation analysis of Italian and US consumers, Sustainability 14 (7) (2022) 3823.
[53] G. Mascarello, A. Pinto, V. Rizzoli, B. Tiozzo, S. Crovato, L. Ravarotto, Ethnic food consumption in Italy: the role of food neophobia and openness to different cultures, Foods 9 (2) (2020) 112.
[54] T. Fantechi, C. Contini, G. Scozzafava, L. Casini, Consumer preferences for wild game meat: evidence from a hybrid choice model on wild boar meat in Italy, Agric. Food Econ. 10 (1) (2022) 23.
[55] S.R. Jaeger, J.M. Rose, Stated choice experimentation, contextual influences and food choice: a case study, Food Qual. Prefer. 19 (6) (2008) 539–564.
[56] L. Altamore, M. Ingrassia, P. Columba, S. Chironi, S. Bacarella, Italian consumers' preferences for pasta and consumption trends: tradition or innovation? J. Int. Food Agribusiness Market. 32 (4) (2020) 337–360.
[57] G.A. Eyinade, A. Mushunje, S.F.G. Yusuf, The willingness to consume organic food: a review, Food Agric. Immunol. 32 (1) (2021) 78–104.
[58] N. Palmieri, A. Suardi, W. Stefanoni, L. Pari, Opuntia ficus-indica as an ingredient in new functional pasta: consumer preferences in Italy, Foods 10 (4) (2021) 803.
[59] ISMEA, Prodotti Bio - Ultime dal settore. L'analisi della catena del valore della pasta biologica nella filiera italiana, Available at, https://www.ismeamercati.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/11493, 2021. (Accessed 4 July 2023).
[60] P. Pliner, K. Hobden, Development of a scale to measure the trait of food neophobia in humans, Appetite 19 (2) (1992) 105–120.
[61] Z. Pieniak, W. Verbeke, S.O. Olsen, K.B. Hansen, K. Brunsø, Health-related attitudes as a basis for segmenting European fish consumers, Food Policy 35 (5) (2010) 448–455.
[62] K.J. Lancaster, A new approach to consumer theory, J. Polit. Econ. 74 (2) (1966) 132–157.
[63] D. McFadden, Conditional Logit Analysis of Qualitative Choice Behavior, 1973.
[64] K.E. Train, Discrete Choice Methods With Simulation, Cambridge university press, 2009.
[65] G.V. Kass, An exploratory technique for investigating large quantities of categorical data, J. R. Stat. Soc. Ser. C. Appl. Stat. 29 (2) (1980) 119–127.
[66] ISTAT, Italian Warehouse of Statistics, Avaible at, http://dati.istat.it/, 2023. (Accessed 4 July 2023).
[67] R. Scarpa, M. Thiene, Destination choice models for rock climbing in the Northeastern Alps: a latent-class approach based on intensity of preferences, Land Econ. 81 (3) (2005) 426–444.
[68] M. Siegrist, C. Hartmann, Consumer acceptance of novel food technologies, Nat. Food 1 (6) (2020) 343–350.
[69] F. Katt, O. Meixner, A systematic review of drivers influencing consumer willingness to pay for organic food, Trends Food Sci. Technol. 100 (2020) 374–388.
[70] C. Arganini, A. Saba, R. Comitato, F. Virgili, A. Turrini, Gender differences in food choice and dietary intake in modern western societies, Public Health-Soc. Behav. Health 4 (2012) 83–102.
[71] J. Hallam, R.G. Boswell, E.E. DeVito, H. Kober, Focus: sex and gender health: gender-related differences in food craving and obesity, Yale J. Biol. Med. 89 (2) (2016) 161.
[72] R. Barrena, T. García, D. Camarena, An analysis of the decision structure for food innovation on the basis of consumer age, Int. Food Agribusiness Manag. Rev. 18 (3) (2015).
[73] A. Gonera, E. Svanes, A.B. Bugge, M.M. Hatlebakk, K.M. Prexl, Ø. Ueland, Moving consumers along the innovation adoption curve: a new approach to accelerate the shift toward a more sustainable diet, Sustainability 13 (8) (2021) 4477.
[74] C. Cattaneo, V. Lavelli, C. Proserpio, M. Laureati, E. Pagliarini, Consumers' attitude towards food by-products: the influence of food technology neophobia, education and information, Int. J. Food Sci. Technol. 54 (3) (2019) 679–687.
[75] M.C. Vidigal, V.P. Minim, A.A. Simiqueli, P.H. Souza, D.F. Balbino, L.A. Minim, Food technology neophobia and consumer attitudes toward foods produced by new and conventional technologies: a case study in Brazil, LWT–Food Sci. Technol. 60 (2) (2015) 832–840.
[76] F.W. Damen, P.A. Luning, N. Pellegrini, P. Vitaglione, G.J. Hofstede, V. Fogliano, B. L. Steenbekkers, Mothers' considerations in snack choice for their children: differences between the North and the South of Italy, Food Quality Preference 85 (2020) 103965.
[77] R. Weinrich, O. Elshiewy, Preference and willingness to pay for meat substitutes based on micro-algae, Appetite 142 (2019) 104353.
[78] Regulation (EC) No 1924/2006 of the European Parliament and of the Council of 20 December 2006 on nutrition and health claims made on foods.
[79] Regulation (EU) 2015/2283 of the European Parliament and of the Council of 25 November 2015 on novel foods, amending Regulation (EU) No 1169/2011 of the European Parliament and of the Council and repealing Regulation (EC) No 258/97 of the European Parliament and of the Council and Commission Regulation (EC) No 1852/2001.
[80] Regulation (EU) 2015/2283 of the European Parliament and of the Council on Novel Foods." Official Journal of the European Union, Series L, 327 (2015), pp. 1-22.