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► **To cite this version:**

Chloé Thomas, Ronan Symoneaux, Gaelle Pantin-Sohier, Pierre Picouet, Isabelle Maître. Perceptions of spirulina from French consumers of organic products. 2020. hal-02615769

**HAL Id: hal-02615769**

**<https://hal.science/hal-02615769>**

Preprint submitted on 23 May 2020

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# Perceptions of spirulina from French consumers of organic products

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## Abstract

In recent years the microalga spirulina has attracted attention due to its high nutritional value and ability to be cultivated with little impact on the environment. It could be developed in agri-food industries, but a significant obstacle to its development is a lack of consumer knowledge. Is spirulina perceived as a food? What images does it convey? Previous research has evaluated the production parameters of spirulina and its medicinal effects, but little is known about consumers' views of spirulina and the widespread acceptability of this product. Here, representations and perceptions of spirulina by consumers of organic foods were explored. Four focus groups provided insights from both consumers and non-consumers of spirulina, and the discussions were analyzed using thematic and lexical analyses. Our results are presented in the context of well-known behavioral theories in order to explain the patterns of representation and consumption that we observed. Overall, this study highlighted distinct differences in consumers' knowledge and product experience. Two general representations of spirulina were prevalent, those of a dietary supplement and of a seaweed, with the latter image presenting an obstacle to its adoption because of its discordance with traditional French cuisine. The motives for and obstacles to consuming spirulina helped subjects identify tradeoffs; the main tradeoff reported was between its nutritional/health benefits and its distasteful sensory properties. The subjects in this study also expressed conflicting views about spirulina's environmental impacts. Based on our results, we propose strategies to increase the potential use of spirulina as a food by French consumers.

**Keywords :** seaweed; functional food; representations; focus group; acceptance

# Introduction

Consumers in Western countries are increasingly interested in healthy, natural, and nutritious foods (1). In this context, aquaculture products, and seaweeds in particular, represent a potentially profitable and environmentally sustainable source of ingredients (2,3). However, only a few studies have examined consumers' attitudes towards the inclusion of seaweed in their diet. In Canada the acceptability of seaweed production for food was investigated by Flaherty et al. (4); study subjects demonstrated a lack of knowledge but generally positive opinions. In France, algae are rarely present in the diet, but a national survey highlighted that they were perceived as good for health and a food for the future, preferable to insects (5). Widespread acceptance of a novel, nontraditional food is shaped by consumer expectations (6). It is therefore critical to first understand consumer perspectives in order to improve the response to and the market performance of innovative food products such as algae.

Among novel foods with potential for widespread market acceptance, the microalga spirulina demonstrates particular promise. In recent years, production of spirulina has increased substantially. The use of biomass as a biofuel and as a nutraceutical ingredient are being researched (7–10). Spirulina is highly nutritious; it is a complete source of protein as well as rich in vitamins (type E, K, and B group, including B<sub>12</sub>), antioxidant pigments (phycocyanin, carotenoids, chlorophyll), and minerals (e.g. calcium, iron, magnesium, potassium). These qualities have made it particularly interesting for the feed industries (11) and the food industries, mainly as dietary supplements (3,7,12–14). Studies have been made of parameters that might increase production, such as temperature and mixotrophic cultivation conditions (15,16). The European Commission has made it a goal to further develop its production, but the market remains a niche (17).

In the food sector, consumers of organic foods are more receptive to functional foods that promote well-being (18). Spirulina should therefore represent a natural choice for this market segment. However, the adoption of spirulina is often hindered by its sensory qualities, mainly its dark green color and peculiar smell and taste, which are apparent to the consumer when the alga is used as a nutritional supplement in powder or flake form (19). In addition, spirulina is extremely unfamiliar in traditional French cuisine. Consumers evaluate familiar products based on past experiences, but new products are evaluated using visual characteristics and product representations (20), that is, individual perceptions stored in memory that influence a product's acceptance and adoption (21). Such representations are then used as filters during further

interaction with an unfamiliar product. Despite growing interest in functional foods, the adoption of novel foods such as spirulina is often hampered by their unfamiliarity. This probably explains why the literature on spirulina has focused more on its medicinal uses (22,23) than on its use as an ingredient. Two studies that have examined the acceptability of spirulina in food products found that the degree to which consumers liked a product decreased with an increased amount of spirulina (up to 15%) in extruded snacks (24,25). However, other studies reported no differences in acceptability compared to controls, or a good acceptability of consumer panels, when less than 2.5% of spirulina powder was used (26–29).

Overall, identifying the acceptability of spirulina as a food and anticipating consumer behavior remains challenging. To address this, research from the field of behavioral science may prove useful. In particular, efforts have been made to understand how consumers view new products such as spirulina, how they decide between adoption and rejection, and which factors influence this decision-making process. Much of this work is based on Rogers' (30) theory of the “innovation-decision process”, which describes five stages that consumers experience when confronted with a new product. The first stage, “initial knowledge”, is the amount of individual knowledge about a new product, and is dependent on individual variables (representations) and previous product experiences. In the “persuasion” stage, the consumer forms a positive or negative opinion based on his or her perceptions of the product’s characteristics, then makes a decision to try the product or not (the “decision” stage). The product is used in the “implementation” stage, and “confirmation” is the final stage, when the individual decides to either continue the adoption/rejection or to reconsider the initial decision. Thus, previous product knowledge and product experience both influence a consumer’s final decision (30). Other concepts relevant to the introduction of a new product include “acceptability”, a phenomenological response that depends on the links between sensory attributes and individual information, and “adoption”, the behavioral result of this response (6). According to Rogers (30), a product’s acceptability is influenced not only by its sensory attributes, but also by five other global aspects of a product: its “relative advantage”, the degree of economic and social advantage compared to similar products; “compatibility”, defined as the consistency of the product with a consumer’s values, needs, and past experience; “complexity”, the extent to which it is difficult for consumers to understand and use the product; “trialability”, the accessibility of the product (price and shelf presentation) for consumers; and “observability”, the benefits observed during its use.

To our knowledge, there are no existing studies that examine the representations and perceptions of consumers towards dried spirulina (in powder or flake form) that might help clarify its potential for widespread adoption. Consequently, this study was designed to explore the factors that influence the adoption of dried spirulina by consumers of organic products. Our aim was to describe the tradeoffs between the sensory and health aspects of this alga, and to determine if familiarity due to prior knowledge and experience with spirulina had an effect on adoption. We hypothesized that (1) prior consumer knowledge and experience with dried spirulina would promote adoption, and (2) the perceived health benefits would be the main reason for adoption, while its peculiar sensory characteristics would be the main factor limiting adoption.

## **Materials and methods**

In food and nutrition science, qualitative research is progressively becoming a way to obtain deeper insights about interviewees than surveys, in a short period of time, and with a greater flexibility of preparation (31). To understand consumers' views, the focus group method has been used in order to fully capture nuances in consumer opinion. Because we were primarily interested here in exploring the differing images that consumers may have of spirulina, we designed the present study to focus on the results of qualitative analyses.

### **Subjects**

From organic food stores around Angers (France), we recruited 28 regular consumers of organic products: 23 women, 5 men. They all declared that they bought organic food products at least once a month ( $n = 11$ ) or more often ( $n = 17$ ). Subjects were also classified by age, with 9 subjects aged 56-75, 14 subjects aged 36-55, and 5 subjects aged 20-35. Age and gender were balanced among focus groups. All subjects received a gift coupon for their participation. Because the existing market for spirulina is still a niche, the opinions of non-consumers were important to understand its potential for development. The study therefore also considered subjects with regard to their experience with spirulina: 14 subjects had previously consumed dried spirulina and 14 had not.

### **Focus groups**

Consumers of spirulina (C subjects) and non-consumers of spirulina (NC subjects) were invited to separate focus groups. As at least 80% of the relevant information about a topic is

typically covered by two focus groups (32), two groups of each type of consumers were constituted. Each group was composed of 6 to 8 participants. Each of the four focus groups was held in the same dedicated room, lasted 2.5 hours, and was led by the same moderator. The groups were all video-recorded. During transcription, subjects were individually identified using a 3-item code (e.g., MV-W50-NC): first and last initials, gender (W for women, M for men) and age, and consumer group (C or NC). A six-part moderator’s guide was used to conduct discussions (Table 1). In parts 2 and 3, spontaneous and unbiased responses were collected from participants. After the spontaneous comments dried up, the moderator explained what is spirulina and how it is produced in parts 3 and 4 (

Table 2). At this time, spirulina flakes and powder were shown to the groups but not tasted. The aim of parts 4 to 6 was then to provoke reactions about previously implicit or unstated responses. In addition, this allowed the groups of NC to understand broadly what spirulina is in order to then discuss its potential interest as a functional food ingredient.

**Table 1. Summary of six-part moderator’s guide for focus groups**

<b>Part 1</b>	Introduction, rules in focus group discussions, short individual presentation.
<b>Part 2</b>	Motives for buying organic products: “What does ‘organic product’ mean to you?”
<b>Part 3</b>	Spontaneous responses to spirulina: “What does the word ‘spirulina’ mean to you?”
<b>Part 4</b>	Additional comments elicited by the description of spirulina and its method of production.
<b>Part 5</b>	Reasons why people would or would not consume spirulina.
<b>Part 6</b>	What are the known and/or assumed uses of spirulina in food?

**Table 2. Description of spirulina that was given to subjects to elicit implicit perceptions and to allow non-consumers of spirulina to discuss its potential benefits and uses**

Spirulina is a freshwater microalga, also called “blue alga” (in French). It contains antioxidant phytonutrients, such as chlorophyll, which provide its typical color. It is well known as a nutritionally complete food source for its high protein content, vitamins (including B<sub>12</sub>), and minerals (including iron). Spirulina grows naturally in lakes in Africa and Central America. It can also grow in clean freshwater pools warmed by sunlight. In France it is produced without

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pesticides, is organically grown, and is often Ecocert-certified. European agreements are being developed to obtain a European organic label for spirulina-containing food products.

To produce spirulina, freshwater ponds are warmed by sunlight and slightly agitated to aerate the water. Like plants, spirulina feeds on minerals in the water and on carbon dioxide. Spirulina is filtered into an edible paste. Then, producers usually dry spirulina paste at a low temperature to obtain flakes, or grind it into a powder.

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## **Product**

Samples of powder and flake forms of spirulina were presented as a functional food product. The participants did not taste or smell the samples as the goal was only to provoke responses about spirulina.

## **Data analysis**

Before analysis, the recorded discussions were completely transcribed. Transcripts were initially analyzed by a single person, who performed a qualitative thematic content analysis following Krueger's guidelines (33). For each question, topics were identified, and comments were grouped in each topic. Results were checked by another person of the team. Second, a lexical analysis of transcripts was performed using IRaMuTeQ<sup>®</sup> software (34) on a total of 24,128 occurrences and 1,666 forms from group discussions to highlight lexical fields grouped in classes. To do this, Reinert's Descending Hierarchical Classification (35) was performed within IRaMuTeQ<sup>®</sup> using default settings and the lemmatized wording option. The thematic analysis and lexical analysis were qualitatively triangulated. Quotes from participants were translated from French into English as close to the original meaning as possible.

## **Results and discussion**

### **Spontaneous responses to spirulina were related to familiarity: emergence of three consumer types**

Three types of subjects were identified from their knowledge of and experience with spirulina, according to the freely elicited answers to the question “What does ‘spirulina’ mean to you?” (Table 1 part 3).

#### **Naïve type**

A subset of NC subjects (n=7) had never consumed spirulina and some had never heard of it; these subjects were classified as “naïve”. “Naïves” tried to find the meaning of “spirulina” from its etymology. To them, “spir-” brought a spiral shape to mind, while “-ine” (from the French word “spiruline”) alluded to pharmaceuticals, chemical products, sugar, and food additives.

#### **Novice type**

The other type of NC had never consumed spirulina, but had basic knowledge about it. They were classified as “novices”. “Novice” consumers knew of spirulina’s blue-green color. Three of them declared that spirulina was seaweed. Some general benefits were mentioned, from the general “*health virtue*” (MV-W50-NC) to more specific features such as “*high in protein*” (RP-M20-NC). The use of spirulina as a food supplement was known: “*a food that serves as a dietary supplement*” (RP-M20-NC). For them spirulina was a trendy product. In Figure 1, Reinert’s Descending Hierarchical Classification of the discussions of NC (1439 forms, 327 segments of text, 84.10% retention) distinguished five classes ordered by the frequency of forms spoken by NC during focus groups. The predominant class (class 3, 28.7% of forms) highlighted the lack of knowledge about spirulina in the combined group of naive and novice consumers. Indeed, the most frequent forms in this class were words conveying unclear and fuzzy concepts: “think”, “worth”, “product”, “thing”, “stuff”. NC subjects had either never received information about spirulina (“naive”) or had received some only incidentally (“novices”). Their descriptions of spirulina were vague and/or based on assumptions.

#### **Experienced type**

All C subjects (n=14) were classified as “experienced” for their familiarity (knowledge and experience) with spirulina, which they identified as a “seaweed”. The health benefits mentioned were features such as “*booster*”, “*energizing*”, “*anti-fatigue*”, and “*fortifying*” (n = 6); “*control of appetite*” (n = 1); and “*useful for sports*” (n = 1) as a food supplement. “Experienced” subjects consumed spirulina for these reasons, even though these consumers readily admitted that the experience itself was disagreeable due to its unpleasant flavor and odor. One subject even shared a strategy for mitigating the distasteful sensory experience: “*they [tablets] help disguise the bad taste [of powder]*” (FR-W67-C). Consumers of spirulina were able to describe it in terms of its available forms (flakes and powder), origin (French, South American, and African production), dose (one tablespoon per day), and the presence of good-quality proteins. Nevertheless, even the “experienced” consumers did not demonstrate knowledge about micronutrients in spirulina.

There were clear differences in knowledge between these groups, and C participants clearly relied on their product experience. Two common representations of spirulina arose from the initial discussions of focus groups. The first was “dietary supplement”, which was identified by “novice” subjects, and the second was “seaweed”, mentioned by “experienced” and “novice” subjects; this latter identification confirmed the categorization of spirulina as a seaweed that was observed by Le Bras et al. (5) in a national study of French consumers. It has been shown that representations of a product play an important role in behavior (21), as they affect the formation of an opinion during the second stage (persuasion) of the innovation-decision process (30), which precedes the decision to purchase. Here, we observed that some people, the NC, were barely past the first stage of the innovation-decision process, i.e. they had little or no knowledge of the innovation. Conversely, the C had reached the last stage of the innovation-decision process, the confirmation of their decision to adopt or reject the innovation.

Familiarity with spirulina did not guarantee adoption, but did facilitate it. Of the 14 S-consumers, 11 regularly incorporated spirulina in their diet (adoption), while 3 demonstrated a lack of interest because they had observed no visible health effects (rejection). These three C participants represent a case of rejection of a novel product due to a negative previous experience (36,37). Instead, individuals unfamiliar with a product form perceptions of its benefits and risks based only on information they receive (36). The perceived performance of the product should in theory be closer to the expectations formed by consumers as a result of this information, a phenomenon known as the assimilation effect; for this reason, “novice” subjects may adopt a novel

product more easily than “naïve” subjects (6). Other factors that might influence adoption, such as individual psychosocial influences and bodily states (6), were not investigated in this study, so their impact with respect to spirulina remain unknown.

## **Motives for consuming spirulina**

To further explore actual or potential motives for and obstacles to the consumption of spirulina, all groups were given information about spirulina (Table 2) in parts 4-6 of the focus group discussions. Nutritional and health benefits were respectively identified by C- and NC participants as effective and potential key motives for the consumption of spirulina. The overall benefits were very interesting to NC: *“It has a large beneficial effect, it is full of vitamins [...], proteins and minerals that prevent dietary deficiencies”* (RP-M20-NC). They also saw the potential benefits of proteins that could replace meat: *“It could be an alternative; many young people don’t want to eat meat anymore!”* (LN-W51-NC).

“Experienced” subjects valued that spirulina is a natural product, and individuals mentioned feeling an increase in energy from spirulina: *“It is an energy booster, that’s the advantage of a natural food supplement compared to chemical tablets”* (BL-W50-C). Subjects highlighted other health benefits such as fighting fatigue (*“I used it for fatigue before my exams”*, BH-W29-C), treating anemia (*“I consumed it because I got anemia and I am tired of iron supplements”*, BA-W40-C) and helping physical recovery from endurance sports (*“A lot of people perform long-distance races [...] and spirulina helps in recovery”*, HP-M40-C; *“It’s good against cramps.”*, PC-W59-C). When we carried out Reinert’s Descending Hierarchical Classification on the C discussions (1576 forms, 350 segments of text, text segment retention of 78.57%; Figure 2), five classes were formed. Classes 1, 2, and 5 referred to qualities of spirulina itself, while classes 3 and 4 mainly referred to discussions of its production. Class 1 (21.1% of forms) included terms related to the benefits of spirulina as a treatment for tiredness, as an energy provider, and as a source of vitamins and iron. Few C were aware, though, that spirulina contained vitamin B<sub>12</sub> in particular, which is deficient in vegetarian and vegan diets. The subject was discussed further, explaining the presence of “B<sub>12</sub>” in class 1.

“Naïve” and “novice” subjects did not mention many specific motives for consumption. The comments that these subjects made are illustrated in class 5 in Figure 1; “food supplement”, “effect”, and “intake” were the main statements made regarding motives for the actual use of spirulina as a functional food in Western countries. Because these subjects lacked experience, the

lexical fields for these groups were not as precise as those of C groups. However, two NC believed spirulina could be an alternative source of protein, information that is often put forward by spirulina producers, vendors, and the media.

## **Obstacles to the consumption of spirulina**

### **Cognitive dissonance**

Many subjects were surprised to learn that spirulina is not a seaweed but is in fact a microalga; the discordance between this new knowledge and the common representation “seaweed” seemed to arouse suspicion: *“I thought that it was seaweed!”* (LGA-W67-C). The word “seaweed” appears in class 4 of the C groups’ lexical analysis in Figure 2, and class 2 of the NC groups’ analysis in Figure 1. Even the incorrect perception of spirulina as a seaweed induced mistrust: *“it’s too strange to eat seaweeds”* (BL-W50-C); *“it goes against our current culture”* (DN-M52-C); *“when it isn’t well known, there’s always a slight distrust”* (BV-M24-NC). This mistrust and lack of familiarity gave rise to discussions of fears of digestive disorders, such as allergic reactions or gastric problems. As in the United States and Canada, Europe has not traditionally used seaweeds as food (3). A strong degree of reluctance to spirulina was therefore not surprising; it is a novel product that represents a departure from traditional cooking habits (38,39). From this perspective, it may be useful to consider Robertson’s research (40), which classified innovations by their degree of impact on consumption patterns: a brand-new product that challenges consumers’ references and modifies behaviors can be described as “discontinuous”, while an innovation that does not is “continuous” or “incremental”. Individuals may have difficulties in associating a discontinuous innovation with an existing category (41). If we view spirulina as a discontinuous food innovation, we can imagine it is likely to have lower immediate purchasing appeal than an incremental food innovation (42), with higher risks of market failure (43).

### **Sensory problems and lack of culinary interest**

Unlike NC, C participants consumed spirulina, but were likely to criticize its sensory aspects, of which flavor and odor were the two most-disliked. All C felt neither culinary interest nor pleasure in consuming spirulina. Classes 2 and 5 from Figure 2 link spirulina with consumers’ different strategies of consumption, e.g., “powder” and “flakes” with “yogurt”. However, the group discussions revealed that *“taste and cooking pleasure should not be forgotten”* (DN-W52-C). Even

a C participant felt that spirulina would not be good: *“spirulina seems not an ingredient we would enjoy eating”* (OC-W27-NC). To get around these issues, four C participants suggested mixing spirulina into a strongly flavored food *“to mask its taste”* (CM-W50-C). But two subjects feared that spirulina’s nutrients would be lost if cooked, as was shown to be true with vitamins (44). After flavor, the smell of spirulina was also greatly disliked by five participants: *“It smells like fish food”* (MC-W32-C). To a lesser extent, color and texture were also criticized. A few participants found the dark green color of spirulina to be repulsive: *“Its color is extraterrestrial, [...] it is quite disgusting, [...] not like a beautiful lettuce”* (HP-M40-C). The texture was found to be *“very viscous when mixing with oatmeal”* (MC-W32-C), and unpleasant in the morning because of its stickiness in the mouth. Despite these sensory issues, nine C subjects confirmed that they regularly consumed spirulina for its health benefits. It was interesting to note that NC projected similar uses as C did during part 6 of the discussions, which showed the overall interest in incorporating dried spirulina into a known product. Class 4 in Figure 1 illustrates the combined C and NC groups thoughts on the potential uses of dried spirulina: to add “texture” with crunchy flakes or an interesting “color”, in “pasta”, in “soup”, with “vegetables”, but always with a need for “pleasure” at meals. Their condition for acceptability was to *“have something with a good taste”* (RJ-W43-NC).

### **Risks of excess micronutrients**

Three NC felt they consume enough nutrients with their existing diet, and that the addition of spirulina would therefore not be necessary. One subject particularly mentioned the risk of iron overdose for people with hemochromatosis. In addition, three C participants had not seen any clear health benefits from their experiences of consuming spirulina.

### **High price and low shelf visibility**

Three C found spirulina powder or flakes to be very expensive. As price is an extrinsic driver of appeal, and willingness-to-pay affects repeated purchasing (45), a high price could limit the adoption of spirulina. Also, most NC participants had never seen spirulina in their local organic store.

### **Mistrust in spirulina production**

Two NC subjects and two C subjects did not trust the nutrients provided to the spirulina for its production: *“they add crap in the water?”* (QG-W66-NC); *“by feeding it with those products,*

*it's not natural anymore*” (FR-W67-C). However, these same NC conceded that spirulina would probably not be as effective without a supply of nutrients: *“If we don't feed it, maybe it doesn't have any natural benefits”* (MV-W50-NC). Three NC subjects were also worried about how the industrial production of spirulina might influence its quality compared to the parent strain from Africa: *“Will they have the same nutrient content as those found naturally in lakes in Africa?”* (MV-W50-NC).

We identified that the health benefits of spirulina were the most significant reason why it might be adopted as a functional food ingredient. However, spirulina received more negative than positive feedback due to consumers' conflicted representations and psychological obstacles to consumption, which could increase resistance (46) and make consumers unlikely to purchase it again. To better understand spirulina's potential, we next analyzed our results through the lens of the five characteristics that influence adoption (30): relative advantage, compatibility, complexity, trialability, and observability. The natural nutrient composition of spirulina would seem to confer upon it a positive relative advantage. However, we observed here that spirulina was not consistent with consumers' values and norms due to their representations of it as a seaweed, and, furthermore, that spirulina was incompatible with these consumers' typical cooking habits. Our results revealed the difficulty of using spirulina flakes and powder as ingredients in other foods because of its sensory qualities: its color and flavor were generally disliked, which accentuated the perceived complexity of spirulina products. A food's color is known to influence sensory and hedonic expectations (47,48), and Martins et al. (49) highlighted that color particularly affected food acceptance. In addition, a bad flavor can lead to aversion (50). People may taste an unfamiliar product out of curiosity but never buy it (again) if they consider it unsuitable to eat (51). Therefore, the sensory appeal and convenience of a discontinuous food innovation is crucial (52,53). With respect to Rogers' final two characteristics, spirulina's high price and limited shelf visibility would appear to decrease its trialability, but its observability remained moderate, as only 3 of the 14 C subjects complained about not seeing real health effects.

## **Environmental dilemma**

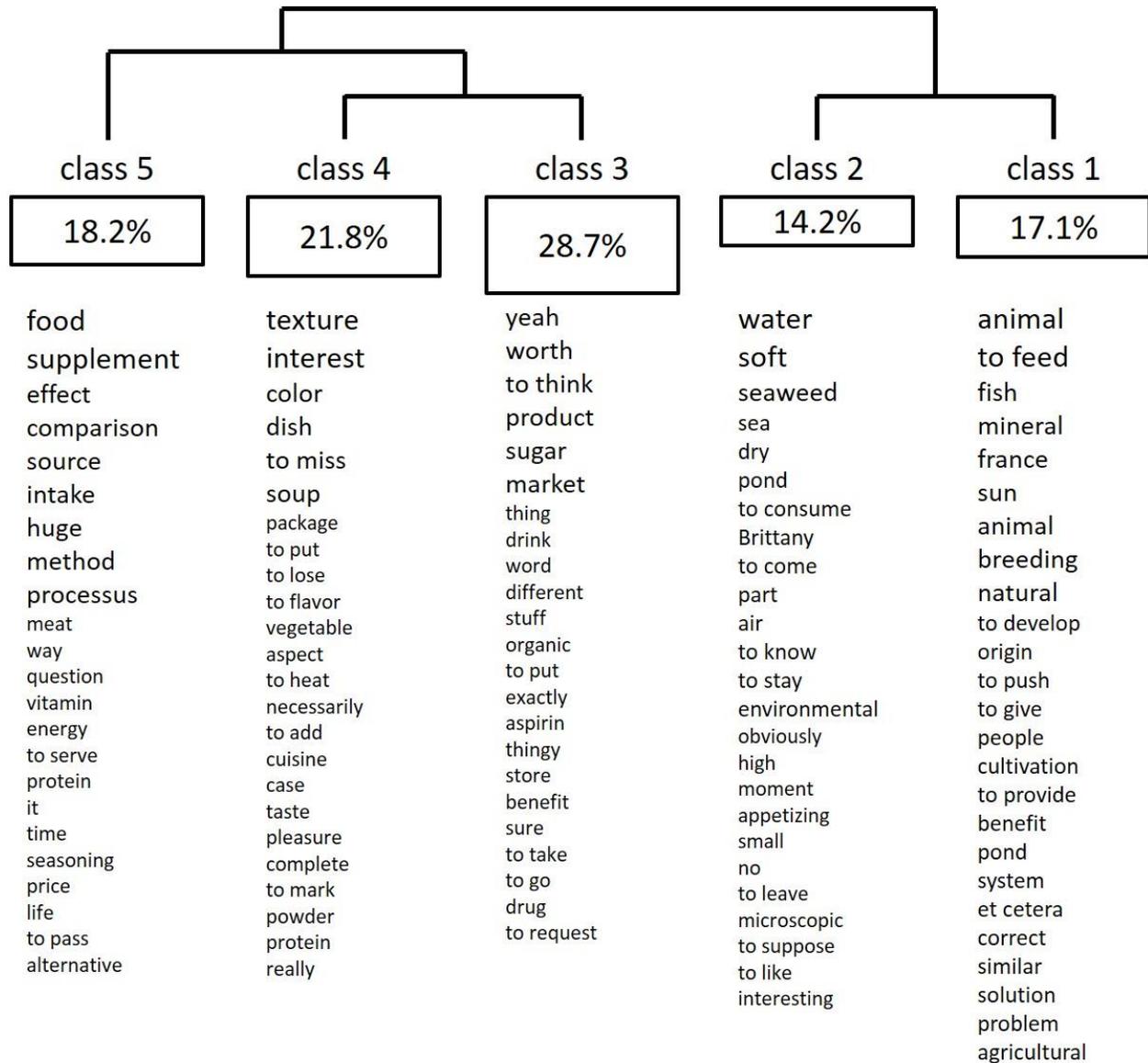
In addition to the discussions focused on the characteristics of spirulina itself, some unsolicited comments focused on the environmental impacts of spirulina products and production, both positively and negatively. Classes 3 and 4 in the C subjects' lexical analysis (Figure 2) contained almost a quarter of the forms, and referred to production conditions (“water”, “sun”,

“pond”, “quality”), packaging, and production areas. NC subjects discussed production conditions in less detail (Class 2 in Figure 1).

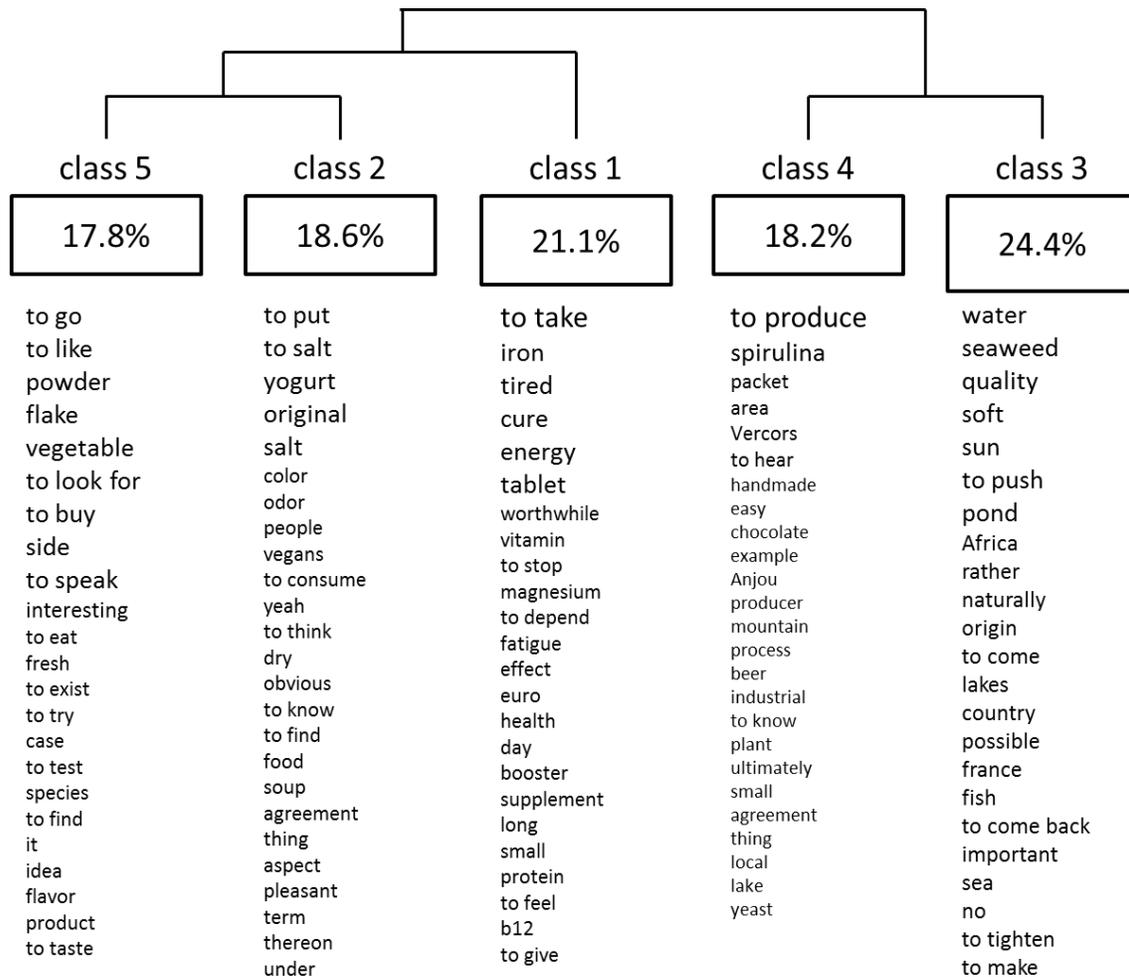
We should first note that these discussions were conducted by buyers of organic products. According to the associations of the word “organic” (part 2 in Table 1) from all subjects, environmental stewardship appeared to be the second-most important factor motivating the purchase of organic products, after health: “*healthy*” was mentioned 22 times (79% of all subjects), “*respect for the environment*” 16 times (57%), “*natural*” 13 times (46%), “*quality*” 12 times (43%), and “*good flavor*” 5 times (18%). These results were in line with those of a quantitative survey (54) which showed that 66% of respondents considered health to be the main reason for buying organic products, followed by 58% for environmental reasons and 56% for quality and flavor. Thus, these consumers expected that these types of products would be manufactured in a way that demonstrates respect for the environment, and trusted in the process because they believed that “*these practices [environment friendly] are already carried out in organic farming, thanks to the organic specifications*” (BA-W40-C). This observation was consistent with those of Massey et al. (55). Likewise, Hauser et al. (56) and Lazzarini et al. (57) also showed that consumers rarely referred to “sustainability” to explain their purchasing behavior. A potential organic certification for spirulina in Europe would lead to greater security and nutritional quality, because “*that ensures quality*” (HP-M43-C).

However, during part 4 of the discussions, subjects of all experience levels questioned the environmental effects of spirulina production in France. On one hand, spirulina was perceived by four NC as environmentally friendly compared to meat products: “*Meat production has negative environmental impacts, while spirulina has obviously little environmental impact*” (LA-W47-NC). Comparisons to “animal production” are illustrated in class 1 of Figure 1. Environmental friendliness has been demonstrated to be an important factor in the decision to adopt meat alternatives (58). However, the C groups never mentioned any comparison to meat; this group was mainly interested in spirulina as a functional food that provides complementary micronutrients, and not as a protein substitute. Indeed, a comparison of the environmental impact of protein from spirulina to that of meat protein is not straightforward, and must take into account the functional units of the different product categories in question (59). On the other hand, most subjects were concerned about the unknown effects of introducing into Europe what they considered an exotic species of seaweed. For instance, C subjects questioned the quality of water used in ponds to

produce spirulina, and one subject even thought that tap water contained “bad things”. “Naïve” and “novice” subjects in particular worried about the risk of groundwater pollution from spirulina leaking out: “*The ponds for producing spirulina, are they really well separated from groundwater?*” (RA-W37-NC). But one NC subject said spirulina production was less dangerous for the environment than “disastrous” fisheries. Another subject mentioned a fear of a decrease in biodiversity near production sites because of the introduction of a foreign species. Finally, one “novice” was extremely concerned about land use; he feared that the “huge infrastructure” for producing spirulina could replace livestock farming when “*the interest only lies in having a dietary supplement*” (RP-M20-NC). Overall, C and NC participants were no different on this subject; the concerns expressed were similar regardless of subjects’ product experience.



**Figure 1. Reinert Descending Hierarchical Classification of word forms from non-consumers of spirulina (NC subjects) listed in descending order of frequency**



**Figure 2: Reinert Descending Hierarchical Classification of word forms from consumers of spirulina (C subjects) listed in descending order of frequency**

## **Tradeoffs between health, sensory quality, and respect for the environment**

Health and sensory quality were spontaneously mentioned by consumers as the main factors behind their decision to consume spirulina as a functional food in powder or flake forms. Similarly, Brunsø et al. (60) and Grunert (61) observed that the perceived health performance and convenience of functional foods greatly influenced purchase decisions. Belief of health benefits also is determinant of acceptance (62). Consumers also balance trade-offs between nutrition and flavor. In the present study, 11 out of 14 C subjects seemed to favor spirulina's positive health benefits over its negative sensory qualities: they consumed spirulina even if it was not pleasant. This echoed the finding of another recent study which reported that spirulina's perceived distasteful

flavor may not influence its use as long as consumers are more concerned about health benefits (63). In the present study, the environmental impact of spirulina was important to the participants, in particular in the context of organic food, but was less crucial than its effects on health. The participants appeared to hold conflicting views on the environmental impact of spirulina, particularly with respect to its health properties. Participants expressed beliefs that some environmental aspects of spirulina could affect health in a positive way compared to meat (“*spirulina is clean compared to meat production*”, “*meat scandals*”), but were also concerned about perceived negative aspects of production (“*We must be sure of the quality of the water used to produce spirulina*” (DA-W38-C)). These results were consistent with those of Pappalardo and Lusk (64), who examined the role of beliefs in purchasing decisions on functional foods and found that environmental friendliness was less important to consumers than health. The same observation was done by Moons et al. (65) on early adopters of spirulina-enhanced food from vegetarian and sportive target consumers.

## **Limitations of this study**

This qualitative study has two limitations: it was conducted on a small population of consumers, and our sample group was composed of a majority of women due to the difficulty of recruiting men in stores. Therefore, these results may not be generalizable to all French consumers of organic products. However, our focus groups provided interesting detailed insights on popular representations and perceptions of spirulina. In future work, it would be interesting to investigate the perceptions of consumers from other countries in order to investigate the effect of food culture and additional population-specific insights.

## **Conclusion**

This study represents a first step to understand the images and perceptions of spirulina as a nutritional food. Our results explored the opinions and beliefs of consumers in the market of organic products. Three types of consumer profiles were considered, based on familiarity with spirulina (product knowledge and experience): “naïve”, “novice”, and “experienced” consumers. However, greater levels of knowledge of and experience with spirulina did not necessarily lead to adoption, due to its lack of fit with the traditional food culture, its negative sensory properties (green color and taste), mistrust in spirulina production methods, and its high price. The first obstacle to consumption was the cognitive dissonance between the two major representations of

spirulina—as a functional food and a seaweed. Furthermore, each of these concepts is inconsistent with current French cooking norms. The second major obstacle mentioned by experienced consumers was the microalga’s distasteful sensory qualities. The main motives expressed for consuming spirulina were the nutritional benefits related to its vitamin and mineral content, and health benefits related to sensations such as “energizing”. The consumers in this study considered different aspects of spirulina’s environmental impact (e.g., participants believed the environment is less affected by spirulina production than meat production, but doubts were expressed about the quality of production water and the impact on local biodiversity), but overall, the concerns expressed by subjects seemed to focus more on health and sensory aspects than environmental aspects.

Based on the results of this study, some recommendations can be made to promote the adoption of spirulina-containing products. First, the use of recognizable taste markers from familiar products in a recipe could encourage acceptance of a discontinuous food innovation like spirulina. Second, product development should include communication to consumers to improve expectations and reduce dissonance with the predominant cooking culture. Finally, given the consumers' expressed interest in spirulina, it could be useful to consider the use of forms of spirulina whose sensory qualities are more broadly acceptable, such as fresh spirulina.

Qualitative research on consumer opinions, as we present here, is a powerful tool in evaluating common perceptions of foods from aquaculture and provides indispensable information to aquaculture producers and food-product manufacturers.

## **Acknowledgments**

This study was part of the “Spilife” project, supported by the region of Bretagne (France) and Valorial, in collaboration with the French SME GlobeXplore. We thank them for providing spirulina samples and giving us the opportunity to publish the results. We thank the staff of the USC GRAPPE, in particular Flore Lourtoux, for their help in the organization of the focus groups.

# Compliance with ethical standards

**Funding :** This study was funded by the region of Bretagne (France).

**Conflict of interest :** The authors declare that they have no conflict of interest.

**Ethical approval :** All participants of focus groups consented to participate in the research and to be video recorded.

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