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Unveiling the Swiss Microalgae Sector

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Abstract

To boost the local microalgae sector, Switzerland needs to better understand the current state of the industry, which is not fully represented in the existing literature. Only by identifying the strengths and weaknesses of the Swiss microalgae industry, will the country be able to develop strategies toward a strong and sustainable sector in the future. This work provides the first structured assessment of Switzerland's fragmented and poorly documented microalgae sector through desktop research and an online survey of the country's microalgae stakeholders. First, research articles with Swiss authors and patents with Swiss applicants were mapped. Then, a survey consisting of 8 questions was designed to gather information about the location, purpose, employees, production capacity, activities, and installations of 42 organizations with a research and/or commercial focus. The growing number of organizations working with microalgae in Switzerland is dominated by small companies (<50 employees) that provide services rather than biomass or bioproducts. Microalgae biomass production is about 2 tons DW per year and is also dominated by small-scale producers (<100 kg DW per year). One third of Swiss companies that sell microalgae-based products produce their own biomass abroad or purchase from abroad. Our findings highlight the growth potential of the Swiss microalgae sector. This systematic summary of research interests, technological innovations, and current market parameters is the first step toward future improvements in the sector.

Keywords: Europe; Switzerland; microalgae industry; microalgae research; biomass production; online survey

1. Introduction

By enabling carbon capture, sustainable biomass production, and bioremediation, microalgae biotechnology can help address global challenges such as climate change, food insecurity, and environmental pollution [1]. It is estimated that approximately 150,000 tons of dry microalgae are produced worldwide each year, creating a billion-dollar market and around 25,000 jobs. Asia, especially China, is the main driver of this market. Europe contributes to around 1% of the global production and market value [2–4]. Today, microalgal biotechnology is a central part of recent European strategic policies toward a more sustainable bioeconomy [5,6] and the United Nations' Sustainable Development Goals (SDGs) [7]. For these reasons, the European microalgae sector has grown rapidly in recent years, both in the research and industrial sectors. From 2022 to 2025, the European market for well-established microalgae biomass (e.g., Spirulina, and *Chlorella*) had a compound annual growth rate of about 10%, which is expected to continue increasing in the future [8]. Recent comprehensive reviews have identified about 70 microalgae producers, with more than 140 microalgae-based products available on the European market [2,4]. However, the

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Swiss microalgae sector has been misrepresented in the literature, with its market and production values frequently underestimated. For example, a recent comprehensive mapping and characterization of the European algae sector incorrectly indicated that Switzerland has only one microalgae company that produces Spirulina [4].

Historically, Swiss research on microalgae emerged from public concern about the eutrophication of lakes during a period when waste was indiscriminately disposed in rivers. This concern led to the creation of the ETH Advisory Center for Wastewater Treatment and Drinking Water Supply (today, Swiss Federal Institute of Aquatic Science and Technology–EAWAG) in 1936 and the Limnological Station in Kilchberg (now part of the Institute of Plant Biology at the University of Zurich) in 1977 [9]. The research carried out in these institutes has provided new and relevant information on wastewater management and aquatic ecology in Switzerland and many other countries. For example, they identified the toxic bloom-forming cyanobacterium *Planktothrix rubescens*, popularly called "burgundy blood alga" due to its red color, which was associated with the blood of fallen Burgundian soldiers from the Battle of Murten in 1476 [10]. Researchers also revealed the crucial role that phosphates play in eutrophication, which led to a ban on phosphates addition to dishwashing detergents in 1985 [11]. Today, these institutions and others still conduct excellent research on aquatic management and ecology. For example, The ALGA project (2024–2027), conducted by the University of Geneva, aims to investigate the effects of algal blooms on the water quality of Lake Geneva and the various services it provides, such as drinking water supply, fishing, and recreation. However, scientific and industrial interests and investments have shifted toward large-scale microalgal cultivation and commercial biomass application. It is unclear whether the long-lasting ecological expertise translates to more recent industrial applications.

Switzerland is a wealthy and industrially mature country, particularly known for its livestock, dairy, and pharmaceutical industries. Due to its small territory and geoclimatic conditions, the country depends on external resources from the primary sector. Microalgae biotechnology can play an important role in the future of Swiss industries as a locally produced noble resource for sectors such as agriculture, food, feed, energy, and pharmaceutical [12]. Compared to European countries with well-established microalgae sectors, such as France, Spain, and Portugal, Switzerland has considerably less territory and less favorable weather for outdoor microalgae cultivation. However, these limitations can be overcome with state-of-the-art facilities that maximize productivity and control environmental parameters. It is unclear whether such technological solutions could make the Swiss microalgae sector competitive. First, the fragmented and relatively unknown Swiss microalgae sector must be better understood in order to correctly assess the national potential of microalgae production [8].

In this study, we hypothesized that the Swiss microalgae sector is growing alongside European initiatives in this field. This study is the first systematic effort to describe the microalgae sector in Switzerland. To accomplish this, we mapped research articles from Swiss authors and patents from Swiss applicants. Additionally, a survey developed by Swiss researchers and industrial representatives was sent to a list of algae stakeholders. Although the limited availability of data highlights the nascent state of the microalgae sector in a country not traditionally known for this industry, the results offer valuable baseline insights to guide current efforts, inform strategic planning, and encourage the integration of microalgae into circular and sustainable development pathways in Switzerland.

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2. Materials and Methods

2.1. Desktop Research–Scientific and Technological Mapping

A study of scientific publications related to microalgae, published by Swiss institutions, was conducted using the Clarivate Web of Science platform. The query included the keywords "Microalgae" (topic) and "Switzerland" (address), covering the period from 2012 to 2025. Similarly, a search of deposited patents was conducted in Espacenet using the keyword "Microalgae" (title, abstract, or names), and filtering by Swiss applicants during the period from 2012 to 2024, the last year with information from the earliest publication date of a document family. In both cases, the retrieved documents underwent manual screening for redundancy, and duplicates were removed. No further pretreatment was conducted on the resulting data.

The parameters analyzed from the list of research papers were: (i) number of publications per year, (ii) author affiliation institution, (iii) research areas, and (iv) Swiss or European funding agencies involved. From the retrieved list of patents, the parameters were: (i) number of publications per year, (ii) applicant institution, and (iii) international patent classification (IPC) main groups.

2.2. Stakeholders Survey

To describe the Swiss microalgae sector, an initial list of Swiss algae stakeholders was built based on the participants of the DACH Algen Summit, held at Agroscope (Bern, Switzerland) in May 2024. The event had 28 speakers and more than 100 participants among microalgae researchers, entrepreneurs, and enthusiasts mostly from the DACH region (Germany, Austria, and Switzerland). Shortly after the event, an online survey was sent to the identified players in the Swiss microalgae industry (Table 1). The final list of survey participants was augmented through participant referrals (see Question 8 in Table 1), with further desktop research used to complement and validate the sampling process. All reported data was disclosed either with authorization from the participants or was retrieved from publicly available platforms.

Table 1. Questions and answer options presented in the online survey completed by selected Swiss microalgae stakeholders.

Questions	Answer Options
1. General information about the organization Name Starting year Address Responsible	Open answer
2. Organization purpose	- Research institute - Non-profit organization - Startup - Foundation - University - Company - Club/Society - Other

Table 1. *Cont.*

Questions	Answer Options
3. Number of employees	- Less than 10 employees - 10–50 employees - 51–200 employees - 201–500 employees - More than 500 employees
4. Annual production capacity	- Less than 100 kg - 100–500 kg - More than 500 kg - The organization is not a biomass producer (e.g., only R&D) - Biomass originates (own production or purchase) from outside Switzerland
5. Short presentation of the organization Website, if available	Open answer
6. Portfolio/main activities in the algae sector Mention biomass application(s) and product(s), if applicable	Open answer
7. Reference projects/Reference installations Mention the cultivates algae species and the cultivation technology used	Open answer
8. Do you recommend other organizations in the algae sector to which we should send this questionnaire?	Open answer

3. Results and Discussion

3.1. Scientific and Technological Productivity Related to Microalgae in Switzerland

An oriented search using the selected keyword combination and relevant filters retrieved 300 research articles and 18 patents, which were used for the data reported in this study. This prospective study aims to identify main trends across the Swiss microalgae sector, pinpoint promising areas, and highlight viable investment opportunities [13]. From a commercial point of view, this information may provide a competitive advantage to entrepreneurs and organizations. From a scientific perspective, up to 80% of the information in patents is not available elsewhere and frequently missing in the scientific literature [14].

The number of scientific publications related to microalgae in Switzerland increased sharply over the last years (Figure 1A). ETH Zurich (the Swiss Federal Institute of Technology) is the leading institution for scientific research on microalgae, having authored approximately 30% of the research articles in this period (Figure 1B). This institution is a pioneer in Switzerland for microalgae industrial applications. For over a decade, ETH Zurich has been working to develop sustainable protein from microalgae to offer viable alternatives to meat and seafood. They have developed innovative methods to cultivate, process, and structure microalgae to improve taste, texture, and nutritional value. Another key goal is to make production systems more efficient and scalable to enable large-scale deployment with low environmental impact [15].

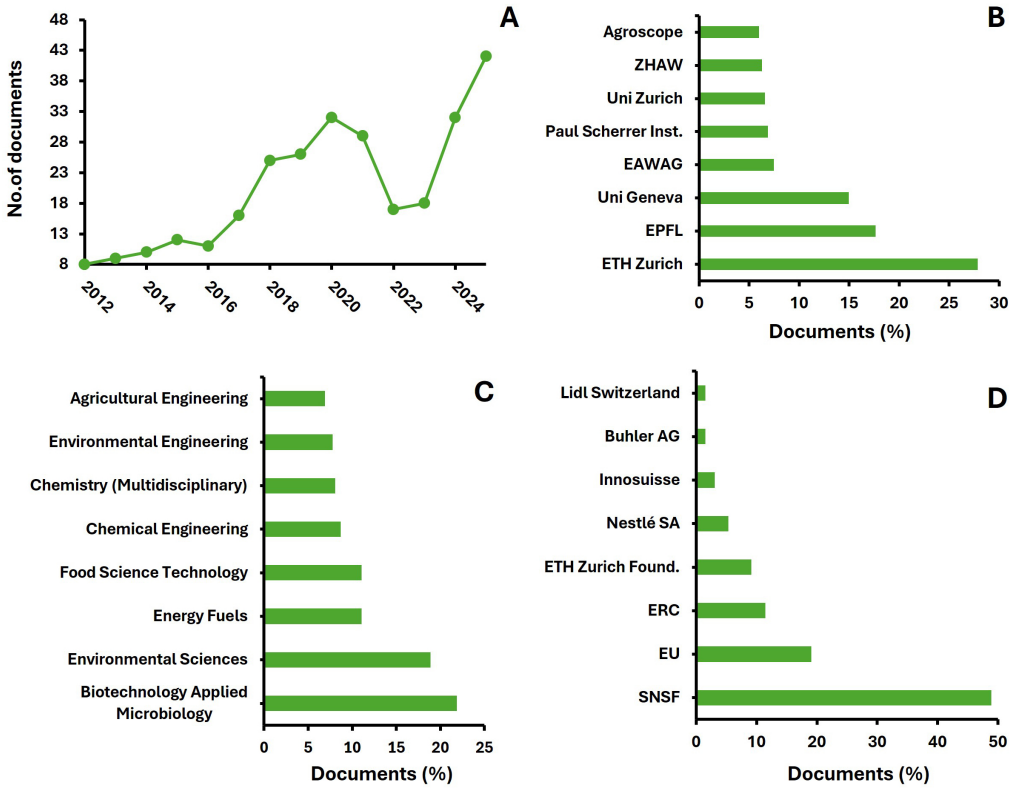

Figure 1. Number of documents (**A**), authors affiliations (**B**), main research areas (**C**), and funding agencies (**D**) of research articles related to microalgae published from 2012 to 2025 by Swiss authors. Source: Clarivate Web of Science. Abbreviations: EAWAG = Swiss Federal Institute of Aquatic Science and Technology; EPFL = Federal Polytechnic School of Lausanne; ERC = European Research Council; EU = European Union; ZHAW = Zurich University of Applied Sciences.

Reasonably, the most widely researched areas were biotechnology and applied microbiology, accounting for 24% of the documents (Figure 1C). Environmental sciences accounted for 21% of the publications, highlighting the historical importance of Swiss research on aquatic ecology. Taken together, these findings suggest that the industrial application of microalgae is a currently relevant topic, reflecting a global trend in phycological research [1]. Furthermore, the Swiss National Science Foundation (SNSF) funded 49% of the retrieved research papers (Figure 1D). Interestingly, European funding agencies (e.g., the European Union (EU), and the European Research Council (ERC)) were the second most-cited funding agencies in our search. Combined, they funded approximately 30% of the microalgae research involving Swiss institutions. Despite a long history of partnership between Switzerland and the EU member states, Swiss researchers and organizations were limited in their participation in European research programs until recently. Only in November 2025, Switzerland and the EU signed an agreement that places Swiss researchers and institutions on the same footing as those in EU member states. They can now lead consortia, receive direct EU funding, and have full access to the program instruments [16]. In contrast, private funding accounted for less than 10% of total research funding for microalgae in Switzerland. One might expect more private funding for research. However, this finding shows that major industrial players, such as Nestlé SA, Bühler AG, and Lidl Switzerland, are interested in microalgae scientific innovations.

Like the behavior observed in published research articles, there was a sharp increase in the number of patents filed in 2022–2023, followed by a decrease in 2024. However, the numbers remained considerably higher than before 2022 (Figure 2A). These findings demonstrate that the industrial application of microalgae has become increasingly relevant

in Switzerland over the last few years. However, the youth and volatility of the microalgae sector may lead to negative outcomes, such as companies with patents found in this study moving abroad or ceasing operations [17]. For example, the food tech company Alver World SA was founded in Switzerland but relocated its core business and headquarters to the Netherlands, closer to the Dutch expertise in microalgae production. The cleantech company Algues Energy Systems AG, known for developing patented photobioreactors and microalgae-to-biogas technologies, ceased operations amid a general downturn in the algal biofuel industry [18].

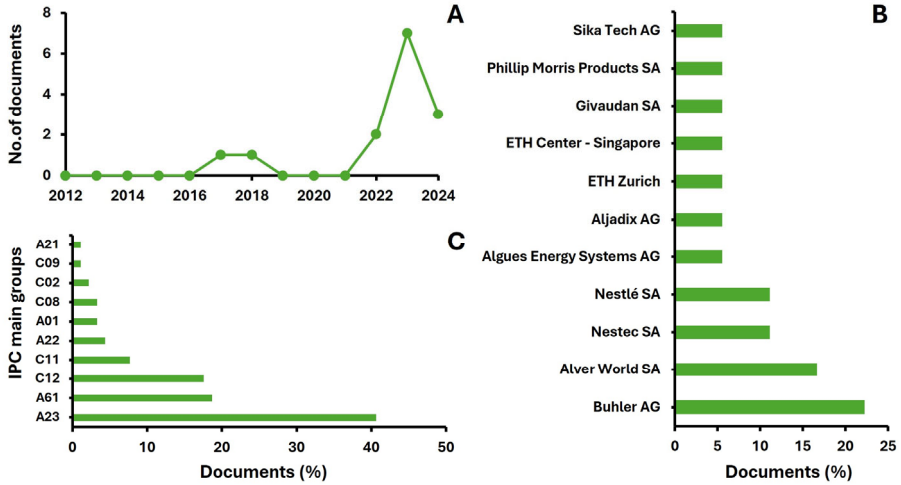

Figure 2. Number of documents (**A**), applicants (**B**), and International Patent Classification (IPC) main groups (**C**) of patents on microalgae technologies published by Swiss applicants from 2012 to 2014. IPC main group codes: A01 = agriculture, forestry, animal husbandry, trapping, fishing; A21 = baking, equipment for making or processing dough, doughs for baking; A22 = butchering, meat treatment, processing poultry or fish; A23 = foods, foodstuffs or non-alcoholic beverages, preparation, treatment, or preservation thereof; A61 = medical or veterinary science, hygiene; C02 = treatment of water, wastewater, sewage, or sludge; C08 = organic molecular compounds, their preparation or chemical working-up, compositions based thereon; C09 = dyes, paints, polishes, natural resins, adhesives, compositions not otherwise provided for; C11 = animal or vegetable oils, fats, fatty substances or waxes, fatty acids therefrom, detergents, candles; C12 = biochemistry, beer, spirits, wine, vinegar, microbiology, enzymology, mutation, or genetic engineering.

Big multinational corporations are at the forefront of technological advancements in microalgae processes. Bühler AG and Nestlé SA combined hold 33% of Swiss patents regarding microalgae (Figure 2B). Interestingly, research institutions filed very few patents compared to the private sector. This contrasts with other studies that analyzed two specific topics within the microalgae sector. Most patents on microalgae-based wastewater treatment (65%) were filed by universities [19]. Universities also made a significant contribution (26%) to patents on phycocyanin production from microalgae [20].

According to the IPC group classification, the most frequently addressed topic in Swiss microalgae patents were applications in the food sector. Together the IPC main groups related to food and beverages (i.e., A21, A22, A23, and C12) account for over 60% of the patents filed during the analyzed period (Figure 2C). Interestingly, a recent study showed that Swiss consumers had positive attitudes and perceptions toward microalgae-based food [21], which seems to be a global trend reinforced by health and environmental awareness [8]. These findings suggest that the most promising use of microalgal biomass in Switzerland may be in food applications. In Europe, 11 microalgae-based foods have commercial authorization as novel foods. According to European legislation, Spirulina and *Chlorella* spp. are classified as conventional foods due to their history of safe and

significant consumption before 15 May 1997 (EU 2015/2283 Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32015R2283). Still, the complex process of recognizing microalgae as novel foods can hinder the exploitation of new, promising species [22].

3.2. The Current Swiss Microalgae Sector According to Stakeholders

Invitation to participate in the survey was sent to 42 identified stakeholders (22 from research and 20 from commercial institutions). Among these, 18 complete responses and 20 incomplete responses were obtained. The incomplete responses were very heterogeneous, ranging from very few unanswered questions to no relevant information. Since the amount of data was not too large, all possible information from incomplete responses was extracted manually, resulting in a range of 20 to 34 outputs for each question. All the information from the complete responses is summarized in a report (Supplementary Materials). Due to the small sample size, our discussion focuses on a descriptive analysis of the data rather than a statistical one, since non-parametric tests lose significant power with small samples.

A map showing the location of Swiss institutions working with microalgae biomass or related services showed that, interestingly, these institutions are mainly concentrated in the western part of Switzerland (Figure 3A). This could be related to the proximity to France, one of the largest producers of macro- and microalgae in Europe [4]. In fact, some Swiss biomass producers are located very close to the French border and have reportedly obtained their know-how and inoculum from French companies. Over time, the number of research and commercial Swiss institutions working with microalgae has increased at a similar rate (Figure 3B). The numbers contradict a recent comprehensive review of the European algae sector which found only one microalga (Spirulina) producing company in Switzerland [4]. We found that four Spirulina producing companies were operating during the same period. Araújo et al. [4] initially based their review on companies registered with the European Algal Biomass Association (EABA). The discrepancies between the two studies primarily highlight the limitations of relying on different data sources to characterize a rapidly evolving sector. Although Switzerland is not a member of the EU, bilateral agreements facilitate its participation in many European programs. In this context, the Swiss microalgae sector would benefit from continued engagement with organizations such as EABA [23] and EU4Algae [24], and it is recommended to take advantage of these thriving initiatives.

Based on the total number of organizations analyzed in this study, a ratio very close to 1:1 was found between research (universities and research centers) and commercial (companies and startups) institutions (Figure 4). Most of the companies and startups involved with microalgae (37.5%) provided services to the field, such as photobioreactor design and construction, downstream processing equipment, and consultancy for various purposes. The second most common commercial use of microalgae in Switzerland is the production and sale of biomass (31.2%). Food (18.8%) and pharmaceutical (12.5%) products based on microalgae completed the Swiss panorama of applications (Figure 4). Interestingly, these results contradict those observed in patent classifications (Figure 2C), in which food and pharmaceutical applications were the most frequently covered topics. This suggests that the food and pharma companies produce most of the technological innovations as represented in patents, despite being fewer in number. No commercial endeavors focused on microalgae-based animal feed were found, although this is a major concern of the Swiss government today [25]. With relatively small territory and limited arable land, the country can produce about 75% of the protein needed for its livestock, relying heavily on soybean exports, which cost around CHF 200 million per year [26]. Researchers have proposed that

domestic microalgae production could address this issue in a more sustainable and circular manner [25,27].

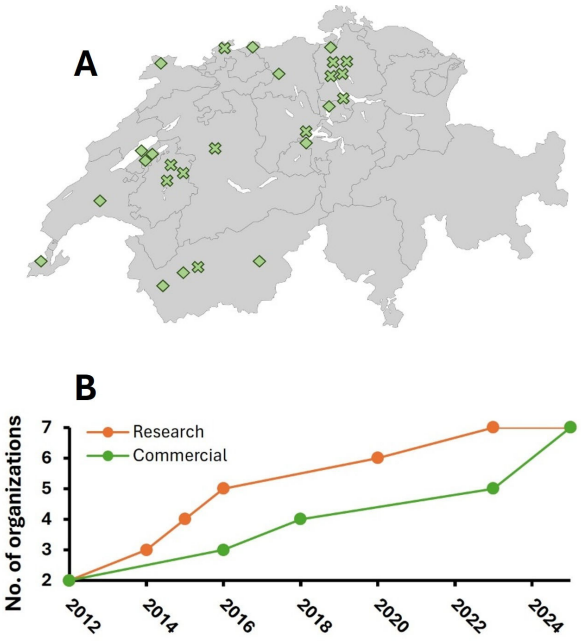

Figure 3. Location (**A**) and total number as a function of time (**B**) of microalgae-related Swiss organizations. Universities and research institutes (green crosses) and commercial companies and startups (green diamonds) are compared in panel (**A**).

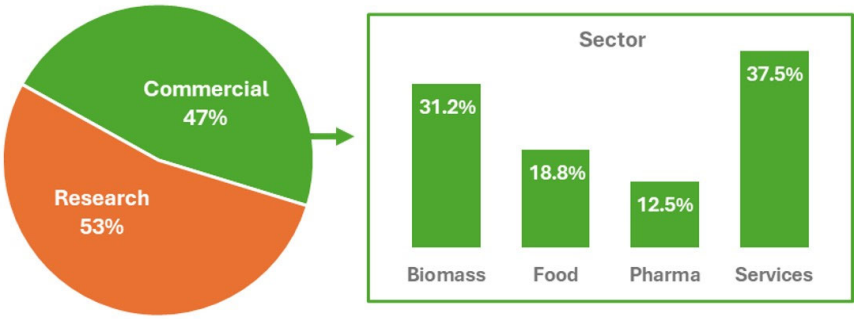

Figure 4. Proportion of commercial and research organizations involved in the Swiss microalgae sector. Displayed are the main sectors to which the commercial organizations surveyed are dedicated. "Biomass" refers to companies that produce and sell raw biomass; "Food and "Pharma" refer to companies using microalgal biomass for food or pharmaceutical formulations, respectively; and "Services" refers to companies offering services such as photobioreactors, up- and downstream machinery, and consultancy. The same institution could fit more than one category. These percentages are based on the number of institutions. Companies and startups are labeled "commercial", whereas universities and research centers are labeled "research".

The relative size and potential market coverage of Swiss microalgae-related institutions were assessed based on the number of employees (Figure 5). Despite the relatively high and growing number of microalgae-related organizations in Switzerland, all commercially directed institutions had less than 50 employees, indicating limited industrial capacity, dominated by startups and SMEs. Larger organizations were exclusively research-directed institutions. Due to a limitation on the survey design, the responses from universities and research centers sometimes only considered a specific laboratory or department conducting research on microalgae, rather than the entire institution. Similarly, desktop research

on large companies known to be involved with microalgae (e.g., Nestlé SA and Buhler AG) could not estimate the number of employees in departments directly involved with microalgae. Therefore, our approach likely could not accurately represent the number of jobs created by the microalgae sector, which is expected to grow alongside a thriving EU algae industry [8]. Further directed research is needed to better determine the number of jobs created by the microalgae sector in Switzerland.

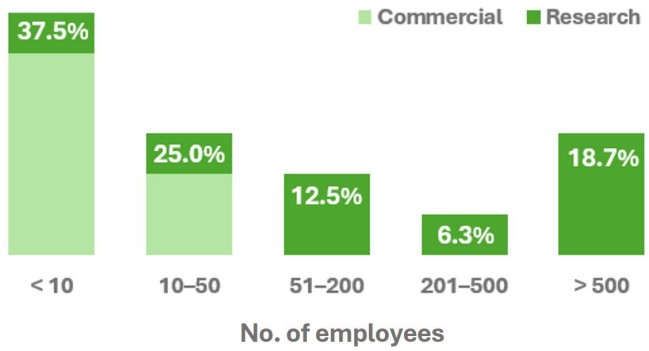

Figure 5. Number of employees of Swiss organizations related to microalgae. These percentages are based on the number of institutions. Companies and startups are labeled "commercial", whereas universities and research centers are labeled "research".

Of the Swiss institutions that produce and/or commercialize microalgae biomass, 66.7% produced it in Switzerland, while 33.3% either purchased it from abroad or have their production sites outside Switzerland (Figure 6). The total production of microalgae biomass in Swiss territory was around 2 tons DW per year, based on range values and not on exact production data (see Question 4 in Table 1). The typical Swiss microalgae producer is characterized by a small-scale family production (<100 kg DW per year), often combined with equally small-scale cultivation of other crops and animal husbandry. Frequently, the cultivation system lacked a high-tech and expensive structure, and production stopped during the cold season due to low temperature and light availability. In northern Italy, a recent study showed that a greenhouse heated by the excess thermal energy of a biogas plant, a relatively inexpensive solution, supported the cultivation of Spirulina throughout the year [28]. A similar strategy was observed in only one Swiss producer, allowing year-round microalgae exploitation [29].

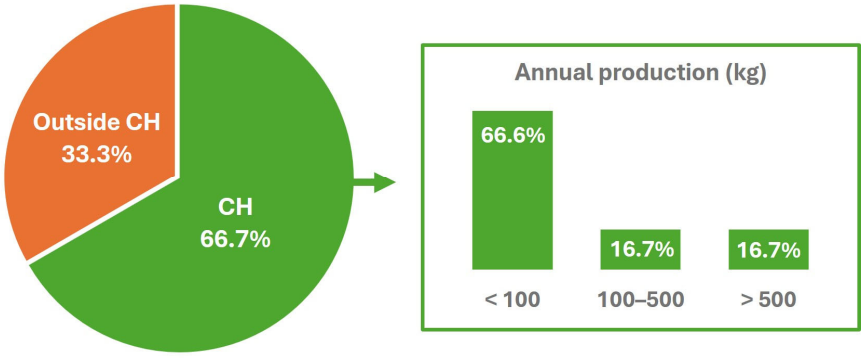

Figure 6. Microalgae biomass production in Switzerland. The annual production capacity of institutions whose main activities involve biomass production is shown. These percentages are based on the number of institutions. The label "outside CH" represents institutions whose biomass originated (own production or purchase) from outside Switzerland (see Question 4 in Table 1).

3.3. The Future of the Swiss Algae Sector

The European Commission has been promoting the use of (micro- and macro-) algae as renewable resources in Europe. The Farm to Fork Strategy, for example, highlights the role of algae as important sources of alternative proteins for a sustainable food system and global food security [30]. Furthermore, algae biotechnology may contribute to achieving several goals of the European Green Deal [5] and Blue Bioeconomy [31] in terms of decarbonization, zero pollution, circularity, biodiversity preservation and restoration, ecosystem protection, and the development of environmentally friendly services. Europe harbors a number of funding opportunities for microalgae endeavors (e.g., Horizon Europe, the European Maritime, Fisheries, and Aquaculture Fund, and the Circular Bio-based Joint Undertaking); as well as support mechanisms for algae-related businesses, such as BlueInvest [32], and the Aquaculture Assistance Mechanism [33]. The European algae market is expected to grow 6–10% annually, reaching up to 9 billion euros by 2030 [8]. In contrast, European algal biomass production remains limited compared to market demand. The main bottlenecks for European algal biomass production have been identified as (i) high production costs, (ii) small-scale production, (iii) limited markets and consumer knowledge, and (iv) a fragmented governance framework [8]. In this sense, the results and perspectives presented here contribute to strengthening area (iii) and promoting the development of European algal biotechnology.

In line with the European Commission's vision for a robust and sustainable algae sector, Switzerland has been promoting research and development in microalgal biotechnology, which will in a near future pave the way for industrial opportunities. Agroscope, the Swiss center of excellence for agricultural research, has research lines addressing the main bottlenecks of the algae sector in Switzerland and Europe (Figure 7). For example, AlgoScope, the first public collection of native Swiss microalgae strains, aims to reduce the seasonality and potential environmental risks of the Swiss microalgae production [27]. Additionally, the Swiss Federal Office for the Environment recently funded a project to assess the sustainability of upcycling agri-food byproducts into microalgal biomass using a crop rotation system with strains adapted to the warm and cold seasons for year-round production [34]. Agroscope envisions a future where Swiss algaculture is decentralized, with microalgal biomass produced and applied locally to agricultural processes in Swiss farms (e.g., as a feed ingredient, or a biofertilizer) [25]. In this sense, the application of diluted microalgal suspensions that requires minimal downstream processing is being thoroughly investigated (unpublished data), and a remote-assisted modular production system will be made available to Swiss farmers for testing and prototyping by 2030.

Other algae-related research efforts in Switzerland have several different objectives. For example, the University of Applied Sciences and Arts of Western Switzerland (HES-SO) focuses on EPS production, downstream processes, and food applications. Meanwhile, the Bern University of Applied Sciences (BFH) conducts extensive research on algal biofilms. The School of Engineering and Architecture of Fribourg (HEIA-FR), in turn, conducts bioremediation experiments to valorize lactoserum permeate using microalgae alongside with photobioreactor design and development. The Zurich University of Applied Sciences (ZHAW) investigates methods for increasing biomass production sustainability. The University of Zurich maintains a cyanobacterial culture collection for novel drug discovery research. Despite our extensive efforts to characterize the sector as accurately as possible, some research groups and/or institutions may not have responded to our inquiry and gone further overlooked in our desktop research. Not all information required to fill in gaps in the survey was available online. Nevertheless, Switzerland possesses excellent research infrastructure that is shaping the future of the algae sector, regardless of the fundamental or applied nature of research.

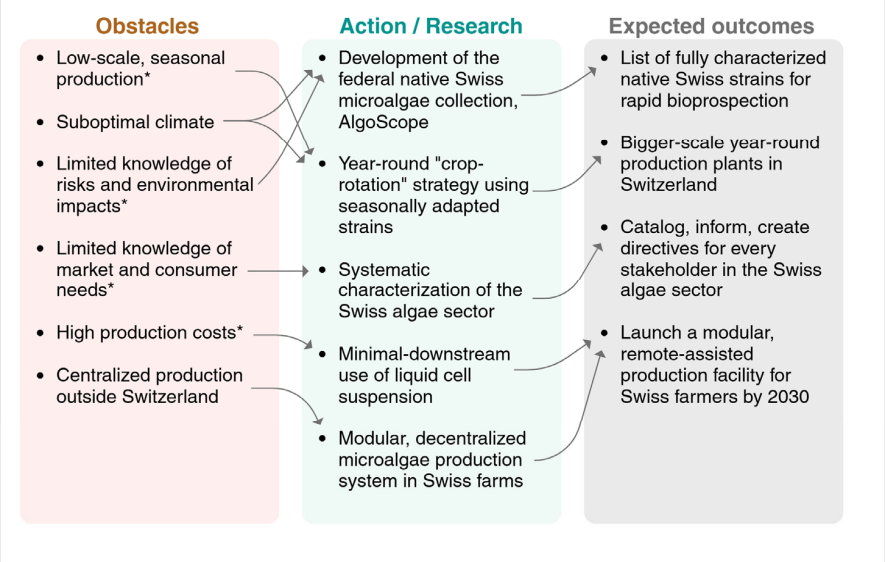

Figure 7. The main research lines for the development of the Swiss algae production sector carried out by Agroscope, the Swiss center of excellence for agricultural research, the obstacles they address, and their expected outcomes. The gray arrows indicate direct or indirect association between obstacles, actions, and outcomes. * Obstacles previously identified by the European Commission for algae-related initiatives in Europe [8].

This study identified the main examples of successful algae-related initiatives in Switzerland. These initiatives focus on research and/or services, such as consultancy, equipment supply, and reactor design. In terms of commercialized algae-based products, the Swiss market is dominated primarily by Spirulina raw biomass, which is often produced or purchased outside of Switzerland (see Supplementary Materials). This suggests that some companies may be unaware of local producers, underlining the fragmented current scenario and the importance of studies like this one. A successful strategy for standing out in the raw biomass market is developing products such as food formulations and/or cosmetics instead of commercializing raw biomass. Bioactive extracts, such as phycocyanin, are also an option for market diversification. However, these strategies are scarce in Switzerland. Interest in microalgae is increasing in the cosmetics, food, feed, pharmaceutical, and fine chemical sectors, encouraging product and strain diversification [35]. Clearly, the Swiss microbial diversity is undervalued in the current Swiss algae industry. For example, theoretically, strains from colder environments accumulate more polyunsaturated fatty acids (PUFAs), which are highly valued in the algae-related market [36]. Bigger Swiss companies, such as Veramaris® (https://www.veramaris.com) and Mibelle AG (https://www.snow-algae.com), already exploit microalgal bioactive molecules for the nutraceutical and cosmetic market, respectively. However, it is unclear whether they use domestically produced or imported biomass. Links with well-established sectors of the Swiss industry are perhaps the most promising way to expand the algae industry. For example, the animal husbandry sector's interest drives significant research efforts to develop cost-, energy-, and environmentally effective algae-based feed ingredients [37–39]. Similarly, the dairy industry has turned to microalgae biotechnology to find more sustainable and circular ways to treat and upcycle its nutrient-rich side streams [40].

This work reports unavoidably limited information about a nascent and fragmented sector in a country not traditionally known for this industry. Nevertheless, the results offer valuable insights to guide current efforts, inform strategic planning, and encourage the integration of microalgae into circular and sustainable development pathways in Switzerland. Such integration has been strongly encouraged by Agroscope into the Swiss agri-industrial

sectors. Given the growing interest among research institutions in microalgae production, it is highly likely that industrial and technological development will focus on microalgae in the coming years. Promising areas include improving energy efficiency, optimizing processes, and achieving economic viability, which will enable large-scale industrialization of microalgal production. Still, significant research and governance efforts are necessary to improve and establish a solid Swiss algae sector (Figure 8).

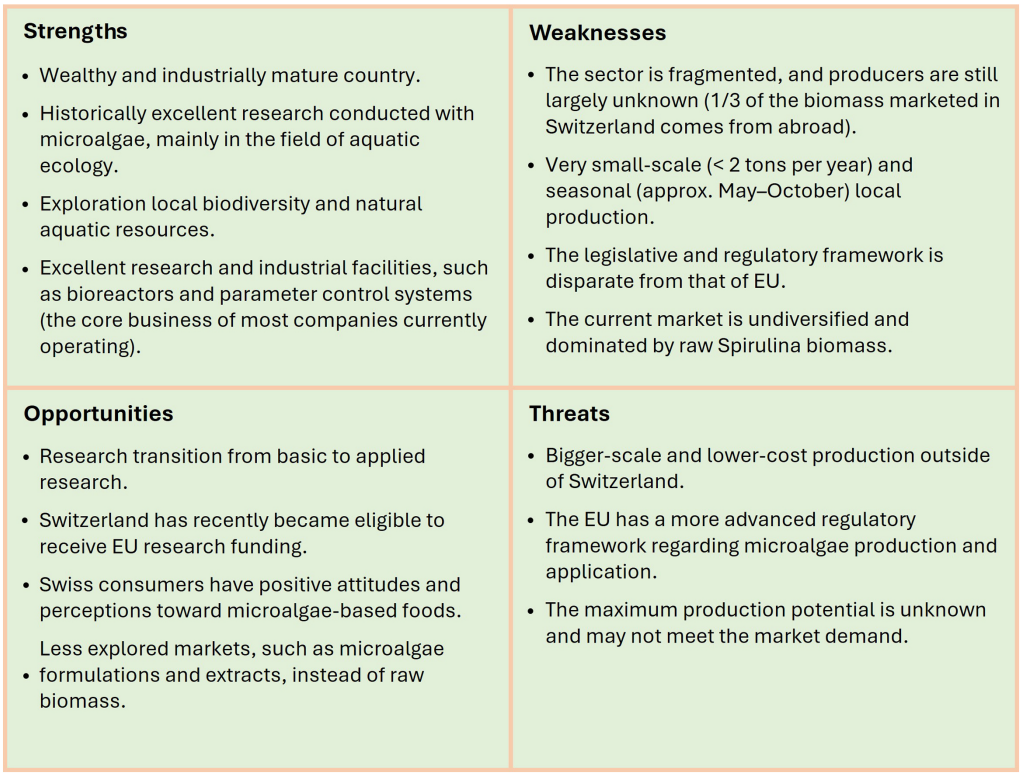

Figure 8. SWOT matrix for the Swiss microalgae sector. Internal and external strengths, weaknesses, opportunities, and threats are mapped to identify competitive advantages and potential vulnerabilities.

4. Conclusions

This work systematically mapped the young and not fully characterized Swiss microalgae sector. The hypothesis that the Swiss microalgae sector is growing alongside European initiatives was confirmed by the increasing number of research articles, filed patents, and institutions working in the field. According to our results, Swiss microalgae stakeholders should (i) transition from historically excellent basic research to applied research, (ii) take advantage of the recently fully available EU research funding, (iii) translate the extensive technological innovation in the food sector—as shown by patents—to their open-minded consumers, (iv) acknowledge and support its local producers, and (v) explore unexplored markets, such as using microalgae formulations or extracts instead of raw biomass.

Despite limitations, such as the small number of participants in the survey and the lack of prior information, the findings highlight a young and promising scenario for the commercial exploitation of microalgae in Switzerland. All companies and startups were small (<50 employees) and mainly focused on providing services for microalgae cultivation (e.g., bioreactor design, downstream processing, consultancy). A significant part of the microalgae biomass sold by Swiss companies was produced abroad or purchased from abroad, as the biomass produced on Swiss territory was dominated by small-scale producers (<100 kg DW per year). These findings suggest the need for further research into cost-effective strategies for large-scale, year-round production in Switzerland to promote this innovative sector.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/phycology6030068/s1: List of Swiss algae stakeholders.

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