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Birgit A. Rumpold *, Kerstin Damerau, Melanie Klein, Nina Langen

Posted Date: 19 May 2026

doi: 10.20944/preprints202605.1260.v1

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 doi:10.20944/preprints202605.1260.v1

Article

Culinary Education for Sustainable Development in Germany—The Example of Sous Vide Cooking

Birgit A. Rumpold [1,*], Kerstin Damerau [1,2], Melanie Klein [1] and Nina Langen [1]

[1] Department Education for Sustainable Nutrition and Food Science, Technische Universität Berlin, Berlin, Germany

[2] Department of Global Development, Cornell University, Ithaca, NY, USA

* Correspondence: rumpold@tu-berlin.de; Tel.: +49-30-314-73235

Abstract

Within modern culinary education, education for sustainable development is essential for vocational students. Using the example of sous vide, its suitability for addressing sustainability in culinary education was investigated as well as to which extent it is currently implemented in Germany. Therefore, literature on potential environmental, social, economic and health impacts of sous vide cooking was reviewed and its current implementation in German culinary educational materials was analyzed. The analysis revealed a number of sustainability aspects of sous vide. Despite being covered in textbooks, it is not brought into a sustainability context. Moreover, existing sustainability concepts for the gastronomy sector neither identify environmental conditions as a basic requirement for any socio-economic activity nor illustrate interdependencies and trade-offs between different sustainability dimensions. Hence, currently in Germany available sustainability concepts and culinary teaching and training materials do not support the development of a systemic understanding and multi-dimensional engagement when training future chefs.

Keywords: culinary education; sous vide cooking; Sustainable Development Goals; vocational education and training; vocational education for sustainable development

1. Introduction

With global challenges such as climate change and food security, a transformation towards sustainability is imperative. Accomplishing global sustainability according to the UN's Sustainable Development Goals (SDG) [1] depends on the knowledge, skills, values and attitudes of current and future generations. For example, the twelfth SDG focusses on responsible consumption and production by aiming to make relevant information and awareness for lifestyles in harmony with nature available to all people by 2030. In order to reach all SDGs, an understanding of the complexity of environmentally and socially responsible behaviors together with the need for a profound transformation of our economic systems but also everyday lives and practises is required. Thus, from a local to a global scale – education for sustainable development plays a pivotal role for equipping students with the knowledge and skills to pioneer innovative and creative responses to transforming society and working processes and achieving wider economic, social and environmental well-being [2,3].

Following the UN's ambitions in regard to education for sustainable development [4], Germany released a strategy report in 2002, outlining its plans for implementing education for sustainable development in primary, secondary and tertiary education [5]. With respect to vocational education and training (VET) in particular, this agenda is supposed to be advanced and implemented through a specific national initiative, vocational education and training for a sustainable development [6]. With seventeen and more years having passed since these declarations have been issued, we set the focus of this study on German culinary education for future chefs. Here, two major German national sustainability goals congruent with the SDGs – education for sustainable development and

 doi:10.20944/preprints202605.1260.v1

sustainable nutrition and food security [1] – coincide. Beside the apparent theoretical overlap between these two goals and their crucial importance for creating sustainable food systems, those principles also need to be implemented in training of practical skills and in operational processes, including food preparation and cooking itself, during VET in order to equip future chefs with the necessary skill set for fostering sustainable development [7,8]. Understanding the characteristics of restaurant products and their preparation processes is essential for a sustainable catering industry [9]. The range of skills and competences (professional, methodical and social competencies) to "impart the vocational skills, knowledge and abilities (occupational competence) necessary to engage in a form of skilled occupational activity in a changing working world" [10] are outlined in German VET curricula. Teaching and learning contents that support teaching these competences remain optional due to open curricula [11]. Based on these national standards, educational researchers and textbook authors are free to decide on how to design particular teaching contents in order to reach these overarching educational goals. This includes adequate educational materials for sustainable development such as school books, work books and digital educational materials for culinary education.

At the same time, consumer preferences and expectations are changing. Due to an increasing awareness of relationships between food production and consumption, the environment as well as human and planetary health are gaining more and more perceived importance [14]. Simultaneously, novel trends in food preparation and cooking such as sous-vide cooking are receiving public as well as professional interest [15]. This should be reflected in an up-to-date culinary education.

1.1. Sustainability Concept for the Catering Sector

Applying the three main interdependent pillars of sustainability – the environmental, economic, and social pillar – to nutrition-related and culinary professions and more specifically to the catering business, these three pillars are complemented by a fourth dimension, health. Embedded in fundamentally required environmental sustainability of food systems, economic viability, social conditions and health outcomes constitute major, interdependent sustainability dimensions for a catering business (see Figure 1). The term economic viability was chosen to emphasize the need for shifting prevailing economic targets from direct growth to individual wellbeing, which requires the inclusion of external environmental, health and social costs of food systems. Globally, these have been estimated to exceed the food system's annual market value by $2 trillion [16].

In literature, while there are a number of concepts for a sustainable food system framework [17,18], there are few sustainability concepts, which have already been applied specifically to the catering sector or hospitality sector. A rather simplified concept is depicted by the 'a'verdis house' by Roehl and Strassner [19]. The "house" is constructed by putting economic viability at its foundation; "supporting walls" are made up by health and desirability; the "protective roof" comprises social and environmental aspects. The authors, however, do not explain how economic viability of a business can form the basis of their conceptualization when environmental and social conditions are effectively a prerequisite for any economic activity. Furthermore, interdependencies and trade-offs between sustainability dimensions are not included.

In Figure 1, a sustainability concept for the catering sector is displayed, which was developed for this study. The overlapping circles model of sustainable development was adapted to illustrate any interdimensional overlaps without hierachichal elements. The concept deviates decisively from the a'verdis approach as it identifies environmental conditions as a basic requirement for any socio-economic activity, and then depicts social equity, human health and economic viability as subsequent interdependent dimensions. At their intersections, we find sub-dimensions such as food safety, nutritional value of foods, and occupational health and safety; labor conditions including wages, benefits and social security; and desirability of products assessed in the form of taste, affordability, popularity and (perceived) health-promoting properties. Applying this sustainability concept to culinary VET for sustainable development in general and teaching of sous vide cooking in particular,

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its impacts have therefore to be analyzed from a variety of different, interdependent sustainability perspectives.

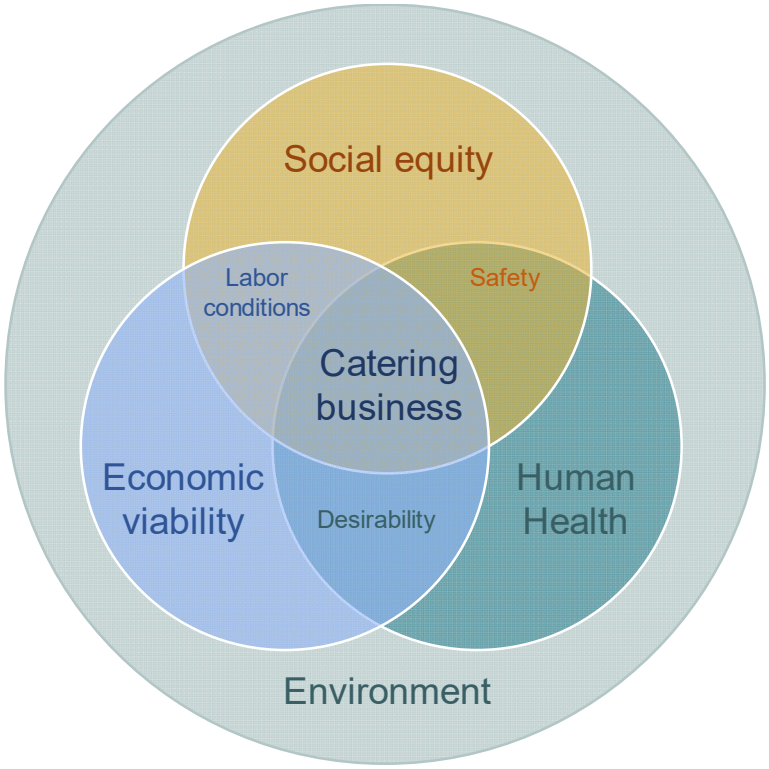

Figure 1. A sustainability concept for the culinary sector. Embedded in environmental sustainability as the fundamental prerequisite to achieving sustainability in all dimensions, social equity, economic viability and human health as well as their correlating scopes, such as labor conditions, safety and desirability, are of crucial importance for a business's overall sustainability (own design).

1.2. Sous Vide Cooking

Sous vide cooking is a gentle cooking method that allows to conserve flavors and nutrients. An increasing number of restaurants and caterers integrate sous vide cooking in their menus [20–22]. It was first developed by French chefs in the 1970s [23] and has gained popularity beyond high-end gourmet restaurants since 2010. Sous vide cooking is now increasingly used in the catering sector (including hospitals and nursing homes), the food industry and even private households [15,20,24–27]. The term "sous vide'' means "under vacuum", i.e., foods are vacuum-sealed in impermeable, heat-resistant plastic bags using a vacuum sealer, and then slowly cooked at tightly controlled, low temperatures in warm water (or sometimes steam) [28]. Water temperatures range between 55 and 85 °C, with the lower end typically used for cooking fish, seafood and meats, taking several hours, and the upper end used for cooking vegetables for a few minutes to hours [25,29]. Sous vide cooking allows for controlling optimal cooking times and desired texture as well as greater reproducibility and thus consistent quality [20,28,30,31]. Sous vide cooked foods can also be cooled down quickly and, if necessary, frozen, stored, and when needed regenerated at any time [32,33]. They can be marinated and seasoned before and/or shortly roasted after sous vide cooking to generate roasting flavors and colors [20,28,32]. However, not all foods are suitable for sous vide cooking methods - for example certain cabbage varieties and beans are inapplicable for this cooking method [20,28,34].

It is proposed that this cooking method offers an opportunity for culinary educators to not only technically train apprentices how to cook sous vide but also to integrate sustainability dimensions, such as environmental, economic, social and health impacts, into their teaching and training. This enables active and critical engagement with these topics and the development of cohesive, forward-thinking and problem-solving competencies of apprentices. However, this requires also an

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integration of sustainable approaches into educational materials such as textbooks since it was suggested that they directly influence content and way of teaching [35]. Using sous vide cooking as an example, the goal of this study was to assess and discuss to what degree national guidelines for vocational education and training for sustainable development have been formally and practically implemented in German culinary education to date. We start by reviewing and summarizing the current available literature on potential environmental, economic, social and health-related sustainability issues of sous vide cooking. Subsequently, its general coverage in current German culinary educational materials and how well sous vide was put in a sustainability context as part of practical educational approaches was analyzed. Finally, results of the analysis were discussed with regard to existing teaching approaches and materials as well as German culinary curricula.

2. Materials and Methods

2.1. Literature Review

An extensive, integrative literature review – including grey literature – of English and German literature was conducted to collect and synthesize existing information on potential sustainability aspects of sous vide cooking. It was aimed to provide an overview of sustainability-related aspects of sous vide cooking.

2.2. Textbook Analysis

The integration of sous vide in general as well as with respect to its sustainability-related aspects was analyzed in currently available textbooks, which are designed for culinary education in German speaking countries and are commonly used in national culinary schools. We analyzed seven German culinary textbooks and two exemplary workbooks (see Table 1). While five of these textbooks were designed to cover all topics of a cook apprenticeship, two of the books belonged together (part 1 and 2) with one book covering the first year of the apprenticeship (Experience kitchen 1) and the second book (Experience kitchen 2) covering year 2 and 3. It was investigated in all textbooks how sous vide cooking methods are covered in general as well as in regard to various sustainability criteria. We searched the tables of contents for the terms sous vide, sous-vide and the German synonym "Vakuumgaren" as well as additional mentioning of these terms throughout all books. In all parts of the respective books covering sous vide, hits for health aspects, environmental aspects, economic aspects, social aspects and desirability aspects were counted. The aspect "desirability/ attractiveness" was included in the textbook analysis based on the a'verdis house [19] as it plays a central role in the out-of-home sector (see also Figure 1). This includes factors such as taste, texture and color. In addition, it was checked for the presence of exercises on the subject of sous vide cooking. If present, it was also checked whether the exercises contain aspects of sustainability or encourage students to deal with aspects of sustainability. This comprehensive approach allowed to gather all provided information on sustainability aspects of sous vide cooking in the textbooks and workbooks.

Table 1. Overview of analyzed German culinary textbooks (1-7) and workbooks (8-9) and their hits regarding sustainability aspects.

	Included German culinary textbooks and workbooks	No. of pages covering sous vide cooking		No. of references to sustainability aspects (accompanying exercises)	
		Main text	Further references	direct	indirect
	Textbooks				
1	Pauli Lehrbuch der Küche (Pauli textbook of the kitchen) [101]	4	15	0 (0)	35 (0)
2	Der junge Koch. Die junge Köchin (The young cook) [105]	4	10	0 (0)	28 (0)

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3	Die Lehrküche (The teaching kitchen) [99]	2	3	0 (0)	15 (1)
4	Gastronomie: Grundstufe (Gastronomy basics) [100]	2	2	0 (0)	15 (1)
5	Erlebnis Küche 1 Koch/Köchin (Experience kitchen 1) [104]	1	3	0 (0)	3 (0)
6	Erlebnis Küche 2 Koch/Köchin (Experience kitchen 2) [102]	1	2	2 (0)	15 (0)
7	Der Gast & ich – Koch/Köchin (The guest & me) [106]	1	0	0 (0)	5 (0)
	Workbooks				
8	Arbeitsheft Koch/Köchin – Schülerausgabe (Workbook cook – student edition) [103]	-	-	- (0)	- (1)
9	Arbeitsheft Gastronomie: Grundstufe (Workbook gastronomy basics) [107]	-	-	- (0)	- (0)

3. Results

3.1. Literature Analysis of Sustainable Aspects of Sous Vide Cooking

In Figure 2, an overview of all identified sustainability aspects in this study and their potential interdimensional overlap between the dimensions environmental impact, health impact, economic impact and social impact is shown. The aspects are described in more detail in the following subchapters.

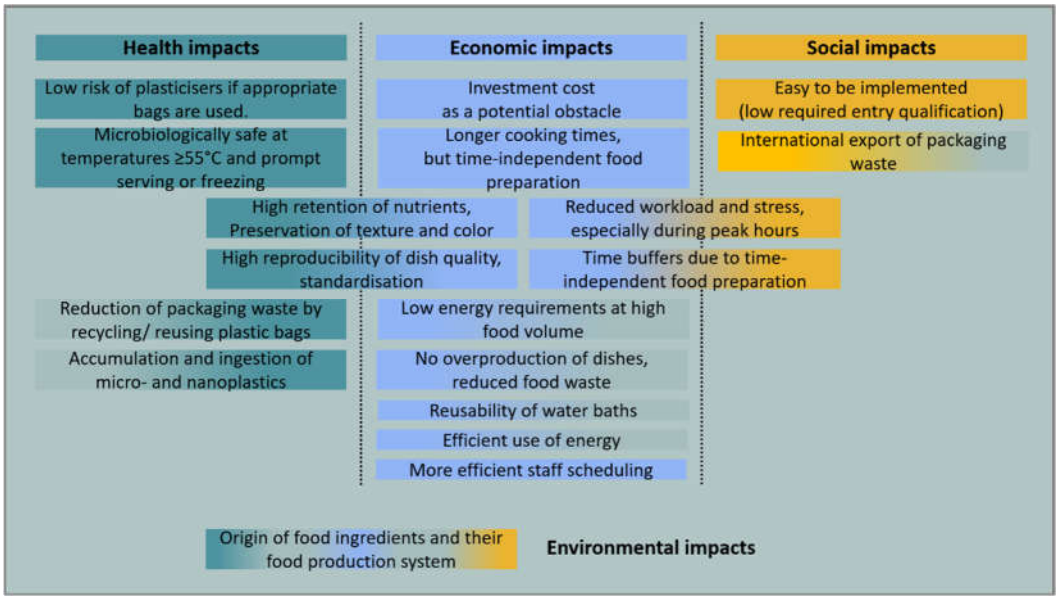

Figure 2. An Overview of all assessed sustainability aspects concerning sous vide cooking and their potential interdimensional overlap, as indicated by their gradient color fills.

3.1.1. Environmental Impact

Natural resource use as well as waste recycling or disposal play an important role for overall food system sustainability [36]. It was shown that the total life cycle of a food product had a lower global warming potential using sous vide technique (2.664 ng) in comparison to traditional cooking techniques such as cooking or frying (4.702 ng) [9]. The carbon footprint of sous vide cooked food

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products depends on the electricity consumption (cooking temperature, treatment time), water usage, and the carbon footprint of the bag and product itself (production, transport) [37]. Besides the purchase of organic, seasonal and regional products, the overall environmental sustainability of sous vide cooking can be improved through efficient waste management, material, water and energy use.

- Origin of ingredients

Depending on the type of food chosen for sous vide cooking (often fish or meat) and its particular production system, the environmental impacts (e.g., water and land use, fertiliser and pesticide application, greenhouse gas emissions both from production and transport, biodiversity) can drastically vary and accelerate environmental degradation and exploitation of land [38,39]. Also, opportunities to obtain locally or regionally produced foods directly from regenerative farms or from well-managed pasture-raised animals can have a significant impact not only on the environmental sustainability of chosen foods but also on their nutritional value and safety [40–42]. Labels such as those indicating organic or fair-trade production facilitate the purchase of more environmentally and socially friendly ingredients [43,44]. Most consumers, however, would prefer to search for only one sustainability label, which addresses multiple dimensions of sustainability [45].

- Food waste and associated natural resource use

The application of sous vide cooking can contribute to food waste reduction by decreasing cooking waste, perishing of fresh ingredients as well as overproduction [46]. For example. Meat loss can be reduced from 20% to 8% and potato loss from 5% to 2% when sous vide is applied instead of traditional cooking methods such as cooking or frying [9]. With approximately 5.5 million tonnes of avoidable food waste being generated in Germany each year [47], food waste reduction could also play a major role for efforts to decrease natural resource inputs such as irrigation water and land use in the agricultural sector [36]. Furthermore, in contrast to boiling foods, freshwater resources needed for sous vide water baths can potentially be reused multiple times before the cleaning of equipment becomes necessary [48].

- Plastic waste

Every year, Germany exports approximately one million tonnes of plastic waste, particularly plastic packaging made from polyethylene, polypropylene (both also used for vacuum bags) or polystyrene. Making up one sixth of national annual plastic waste, proper recycling cannot be guaranteed in importing countries such as Malaysia or Turkey and are posing a threat to the local environment but also human health [49]. Having to use and dispose of a plastic bag after preparing any single food stands in stark contrast to sustainability goals, even if theoretically the bag's chemical composition allows for recycling [50]. If they are not recycled, however, plastic bags can create a significant risk to environmental health [51]. Reusable plastic bags with zip fasting and air-valves can be reused for up to 50 times [52] Suitable alternatives might be reusable, heat-resistant silicone bags free of plasticisers [53] as well as stainless steel containers with lids equipped with air-valves [54]. Mason jars with vacuum caps, however, show lower heat conductivity, and hence lengthen cooking times and reduce microbiological safety [53].

- Energy

Głuchowski et al. [46] found that sous vide cooking, including vacuum sealing, requires five to ten times more energy than traditional cooking or steaming methods. Therefore, this technique only becomes energetically efficient when used in larger, commercial kitchens [55]. Well insulated and tempered water containers can keep total energy use relatively low [55–57]. Regardless of the steps taken to minimise overall energy use, using renewable energies is the most viable measure to reduce global greenhouse gas emissions.

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3.1.2. Health Impacts

- Nutrition and sensory aspects

Because sous vide foods do not get in direct contact with any cooking liquids and are processed at lower cooking temperatures, minerals and vitamins are contained better than by other cooking methods [34,58–61]. This is due to both protecting nutrients prone to oxidation and heat degradation [20] but also the preservation of cell membranes of plants acting as a physical barrier for nutrient leaching [62–64]. As a gentler cooking method, sous vide also preserves colour [58,64–66], texture [67,68], as well as juiciness and tenderness with respect to meats [69,70] better than other cooking methods. It was shown that sous vide processing of meat has beneficial effects on meat quality including sensory and nutritional properties [71]. And for vegetables, improved bioavailability and bioaccessibility of phytonutrients were found [72]. Moreover, the antioxidant activity and total phenolic, carotenoid, glucosinolate and chlorophyll contents of broccoli were improved upon sous vide [73]. On the other hand, for some meat products a two-step cooking method is required such as sous vide and then grilling or searing in a pan before sous vide cooking to generate roasting flavours and colours [15,20]. In addition, it was determined that a higher palatability of meat is achieved at higher temperatures (> 70 °C), presumably due to the development of umami flavor [74].

- Plasticisers

Vacuum bags typically used for sous vide cooking are primarily made up of polyethylene or polypropylene [75,76], both of which are associated with low health risks [75]. Oz and Seyvar [77] assessed the migration of bisphenol A (BPA) during sous vide cooking and found very low concentrations of 0.005-0.025 mg/kg in the studied foods, thus lying under the current European Union's threshold of 0.6 mg/kg of food [78] but being partly above the upcoming threshold of not being detectable with a limit of detection of 0.01 mg/kg of food [79]. In an opinion paper in 2023, the European Food Safety Authority (EFSA) concluded that there was a health concern for dietary exposure to BPA and recommended a tolerable daily intake (TDI) 20,000 times lower than before (0.2 ng/ kg of bodyweight and d instead of 4 µg/kg of bodyweight and d) [80]. Due to this EFSA opinion, an initiative is underway to "impose a ban on the use of BPA in food contact materials (FCMs), including plastic and coated packaging" [81]. However, vacuum bag producers often do not list precise chemical compositions, so at this point customers have to fully rely on producer information on BPA and other plasticisers. By sampling over 300 products, Yang et al. [82] found that almost all commercially available plastic products leached detectable amounts of estrogenic chemicals, including those advertised as BPA-free, some of which at higher rates than products with declared BPA contents.

- Micro- and nanoplastics

Conservative per capita estimates on regular micro- and nanoplastic ingestion through food amounts to 39,000 to 52,000 particles annually. Food overconsumption, inhalation, and consumption of bottled water more than double these estimates [83]. While all foods containing such particles pose a threat to human and environmental health, an ongoing use of plastic products such as vacuum bags used for sous vide cooking further contributes to an accumulation of micro- and nanoplastics in our food systems. Thus, while direct health impacts of plasticisers stemming from sous vide might be small, indirect impacts through plastic use might add an additional health and environmental burden [84].

- Microbiological safety

To preclude any microbiological hazard, a food's core temperature has to be held at 72 °C for two minutes [85,86], which corresponds to pasteurisation processes. Regular sous vide cooking temperatures lie under this specific threshold, which is compensated by the increased length of the cooking process [28,34,65] at a minimal cooking temperature of generally 60 °C, which is necessary to ensure microbiological safety [87]. Although this is sufficient for food preparation, the effectiveness of these conditions in eliminating microbial pathogens, including viruses, parasites, vegetative and

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spore forms of bacteria, is limited [88] and needs to be kept in mind when handling food using sous vide. To ensure food safety, the addition of natural antimicrobials such as essential oils have been shown to be effective [89]. Additionally, recontamination of foods with microorganisms is prevented as long as foods stay within vacuum bags [22,25,30]. Adhering to the cold chain allows frozen storage of sous vide foods safely for up to 21 days [54,90,91], also suppressing the growth of particular resistant microorganisms such as Listeria monocytogenes, Bacillus cereus and Clostridium botulinum [25,29]. In compliance with general food safety rules, sous vide cooking so far has been safely in practice over the last years [92,93].

3.1.3. Social Impacts

Besides fair wages, continued training, and additional benefits, also any efforts ensuring continued mental and physical health and resilience of workers is critical for the social sustainability of (catering) businesses [94]. Employment in the catering sector is often characterized by low required entry qualification and labour under high time pressure. Although the preparation time is longer in comparison to conventional cooking techniques, sous vide cooking allows time-independent food preparation and shortens preparation time before serving, thus creating a temporal buffer, which can facilitate kitchen management and take workload off of kitchen personnel, especially during peak hours [32]. It also requires less preparation such as readjusting cooking temperature or rotation, freeing time for other tasks [95]. As regenerating sous vide food also does not require specific professional qualification, kitchen chefs do not need to be present when foods are being ordered [91]. However, the necessity for training of the operating personnel remains [96].

3.1.4. Economic Impacts

Sous vide has the potential to reduce costs of labor, materials and storage [71]. Since it allows better planning and management in the kitchen, sous vide cooking can contribute to more efficient personnel schedules, which can lead to lower labor cost [32,91,95]. Moreover, it can help to reduce/avoid food waste due to overproduction as dishes can be frozen and regenerated as needed without loss of sensory qualities, increasing the caterer's ability to offer a reproducible and varied yet high-quality menu. When done on a larger scale, reduced electricity needs might add another economic advantage [91]. For example, it was shown that sous vide had a lower energy use than oven cooking using low heat [97]. Additionally, lower amounts of food waste occurring during cooking along with decreased requirements for seasoning can also lower the overall demand for commodities, and thus cost but also environmental impacts of food production [22,46,95]. Relatively high investment cost, however, might create a potential obstacle for businesses. Although many caterers might, at least partially, already be equipped with appliances such as bain-maries [91,95]. As sous vide cooking might not offer nutritional, sensory and economic advantages for all dishes, businesses have to weigh the cost and benefits for individual dishes [98].

3.2. Sous Vide in Textbooks for Culinary Students

Simultaneously with the growing interest in sous vide cooking methods, culinary textbooks started including procedures and providing guidance for the practical training of sous vide methods to trainees and their apprenticeship employers. An overview of hits regarding sustainability aspects upon a text and keyword analysis in seven German culinary textbooks and two exemplary workbooks is shown in Table 1. Though specific foci varied between textbooks, all seven German culinary textbooks analyzed cover basic technical procedures of sous vide cooking, focusing primary on developing students' professional competencies. Both "Die Lehrküche" (the teaching kitchen) [99] and "Gastronomie Grundstufe" (gastronomy basics) [100], however, include some technical inconsistencies and errors, e.g., grouping sous vide with cook and hold methods. With 19 pages total (4 pages main text and references on 15 additional pages), the textbook "Pauli Lehrbuch der Küche" (Pauli textbook of the kitchen) [101] covers sous vide cooking most extensively, even including a

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short video on DVD additional learning material. None of the textbooks offer accompanying exercises for students, with the exception of one open assessment task, being identical in two out of the five books (in the textbooks by Herrmann and colleagues [99,100]) and an exercise to translate the French term sous vide in the textbook by Bartl and colleagues [102]. An additional exercise can be found in one of the two workbooks by Brandes et al. [103]. Thus, the educational scope in all seven analyzed educational materials lies mainly on the technical knowledge on sous vide cooking itself.

Every textbook contains a specific chapter on sustainability within catering businesses. Environmental and social dimensions of sustainability, however, are barely acknowledged in the majority of the analyzed books. Only the two newest textbooks "Erlebnis Küche Band 1 und 2" (Experience kitchen 1 and 2) briefly cover environmental aspects such as energy consumption, food waste, regionality, seasonality and carbon footprint on one page [104] and packaging and food waste, degree of processing, regionality, seasonality, utilization of leftovers, nose-to-tail, and waste separation on two pages [102]. However, the information provided on sous vide cooking in all of the textbooks lists a number of aspects that could be put into a sustainability context, even if not explicitly done so.

"Pauli Lehrbuch der Küche" (Pauli textbook of the kitchen) [101] lists with 35 hits the most sustainability aspects of sous vide by referring to desirability seven, health 13, environmental and social aspects each two, and economic aspects eleven times. Sous vide contents in "Der junge Koch Die junge Köchin" (the young cook) [105] amounts to sustainability-related hits 28 hits and refer to desirability aspects ten, health aspects three, environmental two times, economic aspects each twelve times, and social aspects one time. In comparison, "Die Lehrküche" (the teaching kitchen) [99] and "Gastronomie Grundstufe" (gastronomy basics) [100] refer to desirability aspects six, health aspects two, social aspects one, and economic aspects six times (15 hits altogether each). The textbooks "Erlebnis Küche 1" and "Erlebnis Küche 2" (Experience kitchen 1 and 2) together contain 20 sustainability-related aspects including seven aspects concerning attractiveness, seven economic aspects, four health aspects and one environmental and social aspect each. In the first part of "Erlebnis Küche 2" (Experience kitchen), only three aspects in relation to sustainability were counted. One aspect mentioned in "Erlebnis Küche 2" (Experience kitchen 2) is explicitly put into a sustainability context (via an icon that represents sustainability) and refers to the energy consumption of sous vide cooking (both environmental and economic aspect). This is the only explicitly drawn connection between sous vide and sustainability in all seven textbooks analyzed. In the textbook "Der Gast & ich" (the guest and me) [106] only five aspects concerning the sustainability of sous vide are mentioned (desirability aspects four times and economic aspect once). Potential issues stemming from for example plastic waste and plasticizers are not discussed in all educational materials included in the analysis. Likely also due to lack of scientific evidence, energy use of sous vide is generally described as low.

Concludingly, all textbooks cover sustainability issues as well as sous vide cooking methods. A general lack of information on environmental and social sustainability dimensions together with missing direct links to sous cooking and accompanying exercises, however, do not allow students to establish a conscious relationship and active, comprehensive engagement between the two topics.

4. Discussion

The literature review revealed a number of sustainability-related aspects concerning sous vide. This showed that sous vide provides an appropriate topic to integrate sustainability dimensions in culinary schools – especially in comparison to other cooking methods. Although each of the analysed textbooks cover sustainability to some degree within a separate chapter and list a number of aspects (e.g., desirability, economic) with regard to sous vide, which theoretically could be put into a sustainability context, only one does so directly for one aspect (energy consumption) and none do so indirectly in the form of accompanying learning materials. Based on the textbooks' current outline, students might hence struggle establishing a conscious relationship and active engagement between the limited and incomplete information provided in each textbook's sustainability chapter and those

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covering sous vide methods. During their career, future chefs will likely encounter sous vide cooking methods since its utilization in the catering sector keeps increasing [22]. Despite being technically outlined in current textbooks, this cooking method is currently not part of standardized professional training programs in Germany. Among teaching materials that are available online, sous vide was mentioned only in one wall chart on cooking methods from the Federal Office for Agriculture and Food (BLE) [108]. Adding the growing interest of customers for sustainably produced meals and services [109], the discovered lack of sous vide training materials for apprentices highlights four shortcomings of current German culinary education: One, current training standards have just been updated in 2022 but have yet to explicitly include technical skills for increasingly popular cooking methods such as sous vide. However, it has been recommended that sous vide be taught as part of the in-company-training in the context of topic '9. Processing meat and offal' [110]. Two, with less than ten years remaining to reach the national and international goal of implementing education for sustainable development, in summer 2021 this goal was finally embedded legally in the VET curricula. A new so-called standard occupational profile was adopted that dictates teaching general skills in the areas of sustainability in every VET [111]. Until now, it received little consideration on a national political level [112]. Three, comprehensive sustainability issues, which go beyond the direct economic sustainability of a catering company, are inadequately covered. Other dimensions need to be integrated and/or set in a direct sustainability context when for example environmental issues such as packaging waste are mentioned in textbooks. And four, achieving a widespread implementation of education for sustainable development requires exposing students to the practical implications of reaching generally defined sustainability goals by creating teaching and training materials that allow for an active engagement and application during the practical learning process as well as everyday working life (compare [113]) – one example being sous vide cooking methods and their numerous implications for environmental, social, health and economic sustainability. While sous vide cooking appears favourably in comparison to other cooking methods given the current available information, further research is required on full life cycle impacts or the safety and recyclability of vacuum bags. By preparing millions of meals every day, restaurants and cafeterias have an impact on both our food system and general food culture. Present day culinary education should aim at enabling future chefs to make informed decisions and create healthy, nutritious and (more) sustainable dishes by equipping them with the necessary knowledge and skills. However, education for sustainable development has yet to become fully and comprehensively implemented in VET of future chefs in Germany. While environmental protection is and has been part of current curricula for the last few decades, a practical multi-dimensional implementation of sustainability has not been achieved yet [114]. Nevertheless, even before the revised national Vocational Education and Training Act [10] was passed in 2020, multiple efforts have been made to advance culinary curricula by developing new frameworks [115–117], extending the current national teaching standards and issuing various teaching and training materials that can support teachers and students when integrating sustainability themes during class [118–121]. These cover topics such as seasonal and regional sourcing of fruit and vegetables, sustainable fisheries, food waste and organic and/or climate-friendly meat sources.

But as the example of sous vide cooking in particular and the exploration of the current educational literature in general revealed, there is still a lack of practical approaches and materials that allow future chefs to develop a comprehensive and interdependent understanding of various sustainability issues across time and spatial scales during entire work processes such as food preparation and cooking (compare [120]). While materials for a variety of environmental, social, economic and health issues exist, they still generally discuss these issues in isolation from overall work process stages or food supplies. For example, although various environmental issues of fisheries are outlined in a number of available resources, their associated social, economic and health aspects are entirely omitted [119]. Another example would be the available educational materials for planning a sustainable breakfast buffet or sustainable convenience food [118]. Here again, the only sustainability dimension discussed is the environmental sustainability of ingredients. Despite the

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comprehensiveness of our literature reviews both in English and German within the narrow scope of the culinary education in Germany, potential limitations to these findings might lie in the exclusion of research and grey literature on the sustainability of sous vide published in other languages and potential German training materials subject to change, which might be available complementary to those from the range of major text- and workbook publishers that we assessed as well as the additional (online) resources we discussed above.

5. Conclusions

The literature review revealed that the topic of sous vide cooking provides ample opportunities to implement sustainability and its interdimensional trade-offs in culinary education. However, our findings on available teaching and learning materials in Germany stand in stark contrast to the concept of truly transformative vocational education and training, which combines economic development, social equity and environmental sustainability concerns [122]. This bears the risk of culinary students not being able to develop and practice a complex, systemic understanding and application of sustainability principles. A successful nationwide implementation through integrated instead of still prevailing compartmentalized teaching approaches and materials is urgently needed to transform current culinary education towards culinary education for sustainable development and thus pave the way not only for national but also global socio-ecological transformations needed for creating sustainable food systems. Future research might focus on developing and testing the effectiveness of practical applications of adaptable and transferable teaching approaches such as learning stations, which allow combining various self-selected teaching modules on a set of sustainability issues. While integrating already existing materials, these might be advanced to cover new culinary trends like for example sous vide, air or vacuum frying, for which a set of various sustainability issues can be presented to and discussed by students simultaneously and complementary.

Author Contributions: F MK, NL and BR designed the analysis. MK conducted the literature review and analysis. KD, NL and BR conceptualized the paper. BR and KD wrote the first draft, complemented the literature review and designed the graphs. BR wrote the second draft and conducted a complementary analysis. KD, NL and BR contributed to the writing of the paper. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the German Federal Ministry of Education and Research under grant number 01JA1928 (project TUB Teaching 2.0 in the framework of the „Qualitätsoffensive Lehrerbildung") and by the German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection under grant agreement EURENI_23_D_026 (project CulSus). (This manuscript only reflects the author's view and the ministries are not responsible for any use that may be made of any information it contains.).

Acknowledgments: Part of this study is based on the master thesis "Das Sous-Vide-Garverfahren - Unterrichtsmaterial fuer den Ausbildungsberuf Koech*innen unter Beruecksichtigung von Nachhaltigkeitsaspekten" (2020).

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

Abbreviations

The following abbreviations are used in this manuscript:

VET	Vocational education and training

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