

## Article

# Barriers and Opportunities: Specialty Cultivated Mushroom Production in the United States

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**Abstract:** Producing and consuming specialty cultivated mushrooms (SCMs), cultivated mushrooms outside of the *Agaricus* genus, has the potential to positively impact sustainable food systems. Few studies have examined consumer perceptions of SCMs and industry-wide trends of SCM production in the United States (US), despite the USD 66.1 million in SCM sales in the US during 2020. This study looked at the barriers to and opportunities for cultivating, marketing, and consuming SCMs in the US by conducting a producer survey with SCM facilities in the US ( $n = 63$ ). Survey results found diversification across products and practices within the SCM industry and on an individual business level. The most common place SCM growers sold their products was farmers' markets ( $n = 63$ ). The majority (53%) of growers ( $n = 60$ ) used diverse (four or more) approaches to advertise their products. The majority of SCM growers (57%) indicated they had participated in a community outreach event in the past five years to help promote their SCM products ( $n = 63$ ). Findings indicate there are opportunities for greater SCM business owner diversity. Our results indicate that production of SCMs may support economic, environmentally, and socio-culturally sustainable food systems and that there is further room for increased sustainability across the industry.

**Keywords:** sustainability; diversification; food marketing; mushroom cultivation; consumer perceptions; farming practices; specialty crops; value-added; food system resilience



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## 1. Introduction

Around the world, food systems face substantial sustainability challenges with an estimated 19–30% of total greenhouse gas (GHG) emissions linked to the global food system overall, depending on which subsystems are included [1–3]. Food systems represent the processes involved in growing, processing, distributing, consuming, and disposing of foods [2]. Examples of food subsystems include production and processing systems, economic systems, institutional activities, social and cultural interactions, and the environment [4]. Sustainability is briefly defined as the ability to meet the needs of the present without compromising the ability of future generations to meet their needs [5]. A sustainable food system, accordingly, is one that meets the current needs for nutritious, healthy, and culturally appropriate food without negatively impacting the needs of future populations [6]. Food systems are negatively impacted by climate change, while also contributing to it, resulting in decreased food security and food safety [7–9]. While there is not one singular approach that will remedy the multi-dimensional challenges of a given food system, producers, businesses, and consumers can influence food system dynamics.

Businesses and producers may support socio-culturally sustainable systems by providing their employees a living wage, participating in equal opportunity best practices, and

providing a safe and fair workplace [10,11]. Business planning, financial literacy, and diversified income streams can increase economic sustainability [12,13]. Consumers can choose to financially support businesses and producers that implement sustainable practices.

There is increased recognition that adopting more sustainable food consumption practices, including sustainable diets, can help mitigate the economic, environmental, and socio-cultural challenges that stem from the food system [2]. The types of foods that individuals choose to consume can notably influence sustainability including the GHG emissions linked to food consumption and production [14]. Diet change that incorporates more produce, grains, and locally sourced foods, and less ultra-processed foods and industrially raised meat, has the potential to positively impact food system sustainability [2].

Mushrooms are an underutilized, nutrient-dense, high-value crop and are recognized as an acceptable meat extender [15–17]. Growing and/or consuming specialty cultivated mushrooms (SCMs) can support the advancement of a more sustainable food system by positively impacting the economic, environmental, and socio-cultural dimensions of sustainability [18]. Royse [19] defines SCMs as any cultivated mushrooms outside of the *Agaricus* genus including the commonly consumed varieties white button, cremini, and Portobello mushrooms. While some individuals colloquially interchange the words “fungus” and “mushroom”, a “fungus” is the entire organism including the mycelium and fruiting body (when present), while a “mushroom” is exclusively the fruiting body. Most SCMs are saprophytes meaning that they live on dead or decaying organic matter. Many popular edible and medicinal varieties of mushrooms, such as mushrooms of the genera *Cantharellus* (chanterelles) and *Boletus* (boletes), are mycorrhizal, growing symbiotically with the roots of particular plants [20]. In many cases, the cultivation of mycorrhizal fungi has been slow to develop due to challenges surrounding the re-creation of proper growing conditions [20–22].

Previous research has highlighted overall mushroom market trends and consumption patterns in the US, with little research specifically focused on SCMs [23,24]. As one SCM grower in our study noted, “Academia focuses almost exclusively on buttons (*Agaricus*) and the ‘homebrew’ side focuses almost exclusively on psychedelic. There is very little in between.” In addition, previous studies have characterized perceptions related to mushrooms in various cultures outside the US [25–27]. Researchers have noted that there is a gap in the literature regarding human attitudes toward fungi across different cultures throughout history [28]. Perception-related information in the US could provide SCM growers with a relevant outlook on their consumer base. Research is needed regarding barriers to and opportunities for SCM production to inform growers as well as policymakers about current trends in SCM production and consumption in the US. This study seeks to address these research needs by examining the following research question: *What are the barriers to and opportunities for cultivating, marketing, and consuming specialty cultivated mushrooms in the United States?* We hypothesized that highlighting industry-wide trends may lower barriers to on-farm diversification with SCMs while advancing associated sustainability practices to support both human and environmental health.

## 2. Background

### 2.1. History of Mushroom Production

Understanding the basic history of mushroom cultivation provides context for SCM in the US today. The first recorded example of mushroom cultivation is believed to have occurred around 600 CE in China with wood ear mushrooms [29]. In the 1600s, the French started cultivating *Agaricus bisporus* mushrooms in abandoned quarries and caves [29]. In the 1870s, Asian and European mushroom cultivation practices were first introduced in the US, and by 1914, an estimated 2,041,165 kg of *A. bisporus* were produced annually in the US [30]. William Falconer published a book on mushroom cultivation in 1903 in which he suggested that mushroom farming would be a profitable business venture for farmers or ranchers looking to increase income and use farm byproducts [31]. By 1930, Pennsylvania emerged as a leader in *A. bisporus* production in the US, due to the consistent supply of

horse manure in the area and remains a major hub for *A. bisporus* production today [32]. While little evidence suggests that Indigenous peoples in the Americas cultivated SCMs, many used wild mushrooms for food, medicine, art, ritual practice, and ceremony [33,34]. Although production of SCMs was not common in the US until the 1980s, by the early 2000s several small-scale SCM facilities were operating throughout the US [35].

## 2.2. Mushrooms and Sustainability

Introducing or expanding specialty mushroom cultivation has the potential to positively impact three sustainable food system pillars: economic, environmental, and social considerations [12,36,37]. In the context of food systems, diversification is the incorporation of variety; this can be in reference to crops grown, products sold, and sales channels, along with other components [38].

### 2.2.1. Economic Dimensions of SCM Production

Specialty cultivated mushroom production may be an economically viable option for producers who wish to focus solely on mushroom cultivation. Increased urbanization throughout the US is resulting in substantial loss of agricultural land [39]. In urban areas, SCM production may provide an opportunity for income through non-traditional indoor farming in areas with limited access to agricultural land [40,41]. As compared to other produce, mushrooms have high output rates of edible biomass produced per area [35]. One report from 2013 estimated that an indoor SCM operation might expect to make USD 10.76 to USD 32.29/m<sup>2</sup> in net income annually [35]. According to the 2020–2021 USDA Mushrooms Report, the volume of sales of SCMs in the US was 9,332,209 kg resulting in USD 66.1 million in sales [42]. In the US, SCMs sold for an average of USD 7.08/kg in the 2020–2021 season, while *A. bisporus* sold for an average of USD 2.98/kg [42]. In comparison during 2021, other specialty crops sold for lower prices/kg, such as eggplant which sold at an average price of USD 3.48/kg and cauliflower which sold at an average price of USD 2.53/kg [43]. While demand for SCMs is increasing in the US, the production output has lagged and, in many cases, demand is outpacing supply [44]. The US supplements its demand for SCMs by importing from major mushroom producers such as China [45]. Global emergencies and pandemics have highlighted the importance of supporting and promoting more localized food systems due to the vulnerability of global supply chains [46].

Current producers may introduce SCM production into their farming system to increase crop diversification, thereby reducing crop-related climate change risk and increasing economic stability [12]. Traditional farmers' income and economic stability are often determined by factors outside of their control such as annual rainfall and temperature. Farmers can mitigate their economic risk by diversifying their methods of crop production and the types of products grown [12]. Farm diversification may lead to a higher and more stable income for producers and may provide a financial buffer in the event of crop failure [47–49]. Climate change has been linked to an increase in extreme weather events resulting in an increase in crop failure [50]. Since many SCM growers produce their products in indoor facilities, cultivating mushrooms can provide a more stable revenue stream when growers experience crop failure due to environmental factors [42,51]. Overall, the economic aspects of sustainability are a dominant factor in the adoption of diversified practices by farmers [52]. In a study by Nickerson et al. [52], 61% of farmers reported economic reasons as the main driving force behind farm diversification. The inclusion of high-value specialty crops, such as SCMs, in farming systems has the potential to provide producers with a more stable, supplemental diversified stream of income [12]. Adding SCM production as a crop diversification strategy may mitigate economic instability for farmers, especially as climate change increases traditional cultivation challenges.

### 2.2.2. Environmental Dimension of SCMs

Human behavior has the potential to limit and potentially reverse the impacts of climate change [53]. A transition to a diet that incorporates more vegetables, grains, and

mushrooms could decrease the demand for industrially raised livestock, thus decreasing the GHG emissions linked to meat production and consumption [2,54]. Recent studies demonstrate that consumers widely accept mushrooms as an alternative or supplement to consuming meat [16,23,55–58]. In addition, meat-mushroom blended products are experiencing a rise in popularity and represent an opportunity for consumers to decrease consumption of industrially raised meat [59].

The cultivation of mushrooms further supports sustainable agriculture through its utilization of agricultural and food byproducts as growing substrates and limited space/resource requirements [37]. Growers can use food waste, coffee grounds, the seeds and peels of vegetables and fruits, manure, and tea waste, among other byproducts, as substrates for growing mushrooms [60–68]. Spent mushroom substrate (SMS), the main waste output from mushroom cultivation, can be used as a carbon-rich soil amendment and as food for livestock [35,69]. The use of SMS can decrease the cost of inputs for producers while increasing soil fertility and animal health [70,71]. Several studies have shown that SMS can also be used in treating wastewater and as an input for biofuel and biochar [69,72,73]. Since mushroom cultivation requires little land usage, the risk of clearcutting and destruction of wild spaces tied to facility construction remains low [37]. Increasing local mushroom production may help shorten food supply chains thus decreasing the GHG emissions related to food transportation [74].

Conducting life cycle assessments (LCAs) is a method of measuring the climate impacts of food production, but due to the varying growing processes globally, these have a high variation in results across countries [40]. A LCA was conducted in France to quantify the climate impact of producing one kg of fresh oyster mushrooms (*Pleurotus ostreatus*) [40]. This study found that the product system emitted 2.99–3.18 kg CO<sub>2</sub>-eq./kg mushroom produced, with the highest CO<sub>2</sub> contributions linked to on-farm energy use and transport of mushrooms and substrate materials throughout the supply chain [40]. More specifically, natural gas consumption for pasteurization when using an autoclave accounted for 43% of the climate change impact [40]. Another LCA of oyster mushroom (*Pleurotus sajor-caju*) production was conducted based on information from growers in Thailand [75]. This study showed that production and acquisition of raw substrate materials and burning firewood and fuel to sterilize growing substrate were the top contributors to CO<sub>2</sub> emissions [75]. Studies noted that climate impact would change based on farm location, particularly based on energy grid inputs [40,76]. Dorr et al. [40] noted the difficulty in comparing LCAs between *A. bisporus* and SCM production because the processes and inputs are significantly different.

Since studies indicate that consumers readily accept mushrooms as a meat alternative, it is useful to compare LCAs of mushroom production with meat production [15–17,55–58]. For example, an LCA of a conventionally grown beef production system showed that the product system emitted 33 kg CO<sub>2</sub>-eq./kg carcass weight [77]. Other LCA studies that analyzed beef production systems showed varying levels of CO<sub>2</sub> emissions as these results are dependent on location and ranching practices, among other variables [78]. Little to no research has been conducted to assess the environmental impacts of producing SCMs in the US.

### 2.2.3. Socio-Cultural Dimension of SCMs

Socio-cultural dimensions influence how and why people make sustainability decisions surrounding food consumption and production [2]. Social sustainability involves improving well-being and quality of life independent of race, class, or gender, while cultural sustainability is related to the continuation of tradition and history specific to the geographical elements of a territory [79,80]. Two components of social sustainability are social constraints limiting development and maintenance or improvement of the well-being of people within and over generations [81]. Exploring past and current socio-cultural dimensions of SCM production and consumption may help illuminate ways to further support socio-cultural sustainability for the SCM industry in the future [2,28].

The types of foods that are commonly consumed in any given community are influenced by community members' food cultures and social norms [82]. Specific cultures have been recognized as being mycophobic, having a fear of mushrooms, while others are mycophilic, having a love of mushrooms [36,83]. Research indicates that some of the factors influencing acceptance of mushrooms include geographic location, language, ecology, and culture [36,84]. Historically, Anglo-Saxon peoples have expressed mycophobic tendencies and have associated mushrooms with witchcraft, disease, and death [83,85]. This mycophobic viewpoint in the US, a constraint linked to social and cultural norms, has led to slow development of the SCM industry in the US [31,86]. That said, cultural attitudes regarding mushrooms are nuanced [87].

It is important to note that many Indigenous cultures throughout North America have a rich history of using mushrooms and continue these practices today [33]. On a global scale, much of what colonizing cultures know about mushrooms as food and medicine comes from Indigenous knowledge [88–90]. Part of cultural sustainability involves acknowledging history and providing Native communities with tools and support to help conserve their cultural heritage [81]. Currently, the Fungi Foundation is working closely with Indigenous peoples on a project to bring together both oral history and scientific publications to help illuminate how Indigenous peoples from around the world have used mushrooms for generations [91]. Ethnomycology, the study of how different cultures perceive, use, and connect with fungi and mushrooms, is a field that has the potential to support socio-cultural sustainability surrounding specialty mushrooms [28].

While historically, many White residents in the US have been wary of mushrooms, many immigrants moving to the US, particularly of Asian descent, bring with them food cultures that incorporate a wide variety of mushrooms in their cooking [24,85,92]. With the rise of specialty mushroom cultivation, increased inclusion of mushrooms in popular media, and use of mushrooms among chefs, the demand for both *A. bisporus* and SCMs is on the rise in the US [32,42,93]. As the SCM industry evolves in the US, it will be important to make sure the industry is open and inclusive to people of varying cultures and backgrounds.

Outputs of food systems may contribute to improvement of well-being, a criterion of socio-culturally sustainable food systems, through consumption of nutritious and medicinal foods [80,94]. Evidence supports the contribution of human SCM consumption to a wide range of health benefits, including improved cognitive function, decreased risk of cancer, strengthening of the immune system, and decreased sodium intake [15,55,58,95–97]. Many of the medicinal benefits linked to SCM consumption are not associated with *A. bisporus* consumption [98]. Each species of SCM has a different nutritional profile, but in general, mushrooms are low in fat, high in fiber and carbohydrates, and contain essential amino acids [99,100]. Mushrooms also provide nutritionally significant amounts of vitamins B1, B2, B12, C, and D [101].

Another tenet of socio-cultural food sustainability is producing food that is accessible regardless of socio-economic status [2]. While wild mushrooms have long been used as survival food for the rural poor, access to SCMs may be limited due to their relatively high price point [28,42]. However, a report published by the United States Department of Agriculture (USDA) showed that as SCM production has increased in the US, the price/kg has decreased [42]. One SCM grower from our survey stated "My goal is to bring specialty mushrooms down in cost similar to button mushrooms (*A. bisporus*) so people can fully experience the taste and health benefits that mushrooms can actually offer." Diversifying farm offerings helps increase the availability of affordable, nutrient-dense, locally grown food options in communities [42,102].

### 3. Materials and Methods

#### 3.1. Study Design

This study uses an exploratory mixed methods research design including structured surveys and qualitative interviews [103]. Between October 2020 and February 2021, pro-

ducer surveys were distributed throughout the US. Consumer interviews were conducted with participants living across the US to mirror the geographic distribution region of the producer surveys.

### 3.2. Producer Surveys

The producer survey questionnaire was informed by the Warne et al. lentil producer survey [104] and a SCM survey developed by Cornell University researchers [105]. The survey instrument integrated multiple choice, ranking (Likert-Scale), fill-in-the-blank, and open-ended response questions. In July 2020, the survey draft was sent out for review to a panel of experts in sustainable food systems, mycology, marketing, and human and planetary health, and respective feedback was integrated. A pilot test of the survey was run with three SCM growers in Montana and Georgia. The producer survey questionnaire was approved by the Montana State University Institutional Review Board (AM081420-EX) for the protection of human subjects. The survey elicited information about industry-wide growing practices, challenges and opportunities, inputs, outputs, sales, and marketing. In the context of this study, a sales outlet is defined as any place where food or produce is sold [106]. The survey (Appendix A) consisted of 36 questions divided into four sections:

1. Farm background
2. Mushroom cultivation practices
3. Sales, distribution, and advertising of mushrooms
4. Producer background

Survey participants were initially identified using an online list of SCM growers [107]. This list was edited, removing SCM growers no longer in production and adding many additional growers identified through online searches and social media. In October 2020, the survey was initially released to SCM growers in the Western region of the US ( $n = 121$ ), and in January 2021, the survey was sent to all remaining SCM growers in the US ( $n = 452$ ). Growers were informed about the survey via email and phone. The questionnaire was distributed using Qualtrics (Provo, UT, USA). Data were processed only after growers provided informed consent and acknowledged that they were over the age of 18 before completing the survey. Survey completion was rewarded with a USD 15 gift card. If growers did not answer at least 60% of questions, their survey was considered incomplete. Incomplete survey responses were excluded from data summaries and visualizations.

### 3.3. Consumer Interviews

Two different structured consumer interview guides were developed based on the framework used in *Learning From Strangers* [103]. One guide was developed for people who had consumed some form of SCMs in the past six months (Appendix B) and the second guide was designed for consumers who had not consumed some form of SCMs in the past six months (Appendix C). The interviewer asked consumers questions about SCM consumption, access, perceptions, and knowledge. The interview guides included binary and open-ended questions based on input from an expert panel. Both interview guides were pilot tested with consumers ( $n = 3$ ) before dissemination.

The questionnaire for people who had recently consumed SCMs consisted of 22 questions respectively; the questionnaire for persons who had not recently consumed SCMs included 20 questions respectively. The number of questions asked depended on the responses provided [108]. Both questionnaires were divided into the same five sections:

1. Introduction
2. Consumption and purchasing patterns
3. Barriers and opportunities for mushroom consumption
4. Consumer knowledge
5. Consumer background

Consumer interviews were open to residents across the US over the age of 18. Convenience sampling and snowball sampling were used to recruit 40 consumers from 18 different

US states. The interviews were conducted and recorded January 2021 through March 2021 online using Zoom with ( $n = 40$ ) participants. Interviews were then transcribed using NVivo 1.6.1 (1137) (QSR International, Doncaster, Australia). The transcriptions were compared to the recordings and edited for accuracy. All interview participants provided informed consent and acknowledgment that they were over the age of 18 prior to the interview. Consumer interviews took 15–20 min, and each participant received a USD 15 gift card for their participation.

### 3.4. Participant Characteristics

#### 3.4.1. Producers

The target response rate for the producer survey was 10% of contacted individuals. We received a 14% response rate. Sixty-three respondents completed at least 60% of the survey, therefore all analyses and visualizations include those 63 observations unless otherwise stated. The online producer survey received valid responses from 23 states. We received multiple responses from New York ( $n = 2$ ) and California ( $n = 2$ ), the states that we found had the largest number of SCM farms [107] (Appendix D). This finding was based on self-reported zip code data. Thirty-six percent of growers ( $n = 63$ ) chose not to report the zip code affiliated with their farm location. The vast majority (77%) of SCM growers ( $n = 63$ ) surveyed were under the age of 45, and 75% had produced SCMs for less than nine years. Forty-four percent of SCM growers ( $n = 61$ ) were growing/producing other crops/products on their farm with the most common types being vegetables (23%), herbs/medicinal plants (11%), livestock (11%), and field crops (10%). Fifty-four percent of growers ( $n = 63$ ) produced mushrooms indoors only, while 37% grew both indoors and outdoors. All producer survey sample characteristics are presented in Appendix E.

#### 3.4.2. Consumers

The consumer interviews were conducted with participants ( $n = 40$ ) living in 18 different states (Appendix D). The sample size was determined a posteriori when no new information was forthcoming during consumer interviews, i.e., we achieved data saturation [109]. Thirty participants had consumed some variety of SCM within six months before the interview date. Of the participants who had consumed SCMs within six months ( $n = 30$ ), 37% consumed them at least once a week, and 57% one to three times per month. No demographic information was collected from consumers. All consumer interview sample characteristics are presented in Appendix E.

### 3.5. Data Analysis

All quantitative data from producer surveys are presented as descriptive statistics. Frequency distributions were plotted using ggplot in R. Regarding qualitative data from consumer interviews, coding involved conducting inductive content analysis and creating a codebook based on common themes [110]. Open-ended questions from the producer surveys and qualitative consumer interviews were coded in NVivo. The codebook was then updated to reflect NVivo results. All meaning units were calculated for frequency [111].

## 4. Results

### 4.1. Products

There was variety in income sources for SCM growers (Table 1). Seventy-two percent of respondents ( $n = 63$ ) were producing four or more varieties of SCMs (Table 1) with the highest percentage of growers producing oysters (87%), lion's mane (81%), shiitake (79%), chestnuts (59%), piopinno (44%), and reishi (48%). Sixty-seven percent of growers ( $n = 63$ ) were selling mushrooms in some additional form other than fresh. The most common processed forms were dried (whole) (41%), tincture/supplement (33%), dried (powdered) (32%), and mushroom food products (24%) ( $n = 63$ ). There was diversification in the types of products sold, with 80% of SCM growers ( $n = 61$ ) indicating that they sold cultivation-related equipment or foraged wild mushrooms as additional income streams. The most

sold items, other than cultivated mushrooms, were grow kits (62%), grain/sawdust/plug spawn (43%), and foraged wild mushrooms (31%) ( $n = 61$ ).

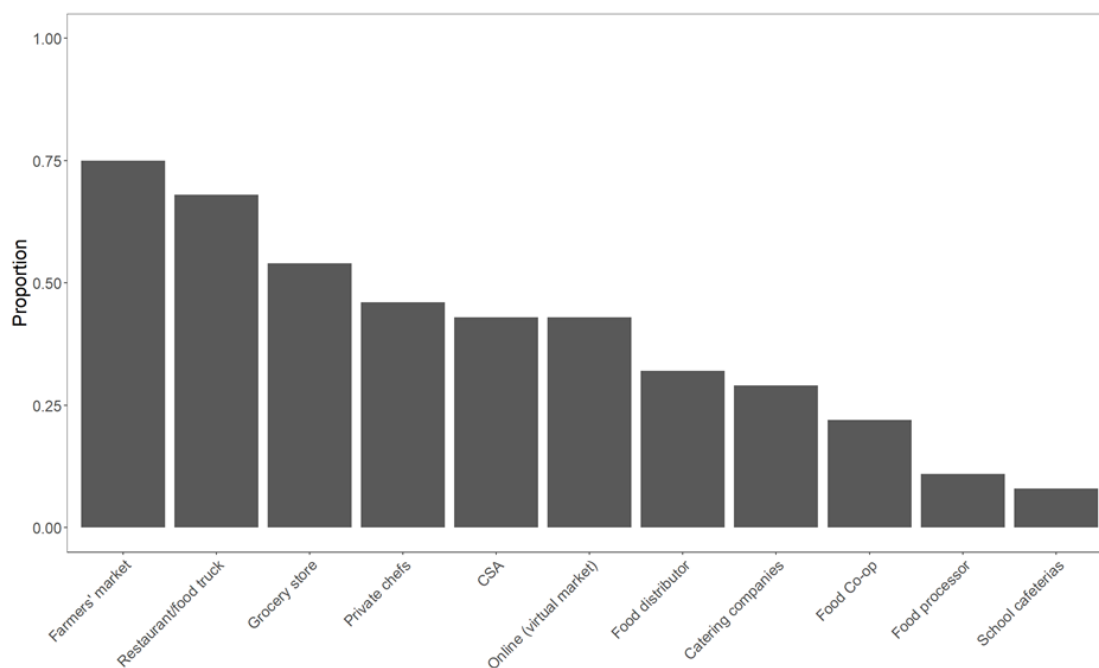
**Table 1.** Diversification of products grown, sales outlets, and advertising methods.

| Measure   | 0   | 1–3 | 4–6 | 7+  |
|---|-----|-----|-----|-----|
| Number of SCM varieties grown ( $n = 63$ )            | N/A | 29% | 40% | 32% |
| Number of distinct outlets for SCM sales ( $n = 63$ ) | 0%  | 43% | 37% | 21% |
| Number of advertising methods used ( $n = 60$ )       | 2%  | 45% | 50% | 3%  |

On the consumer side, half of individuals who chose to consume SCMs, also consumed mushroom products ( $n = 30$ ), particularly supplements (40%), beverages such as mushroom coffee (40%), and seasoning (33%). The most consumed varieties of SCMs were shiitake (70%), oysters (47%), and lion's mane (37%) ( $n = 30$ ).

#### 4.2. Markets

More than half (57%) of SCM growers ( $n = 63$ ) sold their products through four or more sales outlets (Table 1). The most common outlets for selling SCMs were farmers' markets (75%), restaurant/food trucks (68%), and grocery stores (54%) ( $n = 63$ ) (Figure 1). Seventy-three percent of growers ( $n = 62$ ) reported they had adequate access to consumers. This was supported by the findings that 75% of SCM growers ( $n = 63$ ) sold 81–100% of their fresh mushrooms, while 14% sold 61–80% respectively. Most growers who did not sell all their SCMs ( $n = 51$ ) processed them (68%) or gave them away to family/friends/employees (48%) (Figure 2). The most common sales outlets for consumers to purchase their SCMs were grocery stores (87%), farmers' markets (30%), and restaurants/food trucks (27%) ( $n = 30$ ).



**Figure 1.** SCM sales outlets (multiple mentions possible) ( $n = 63$ ).



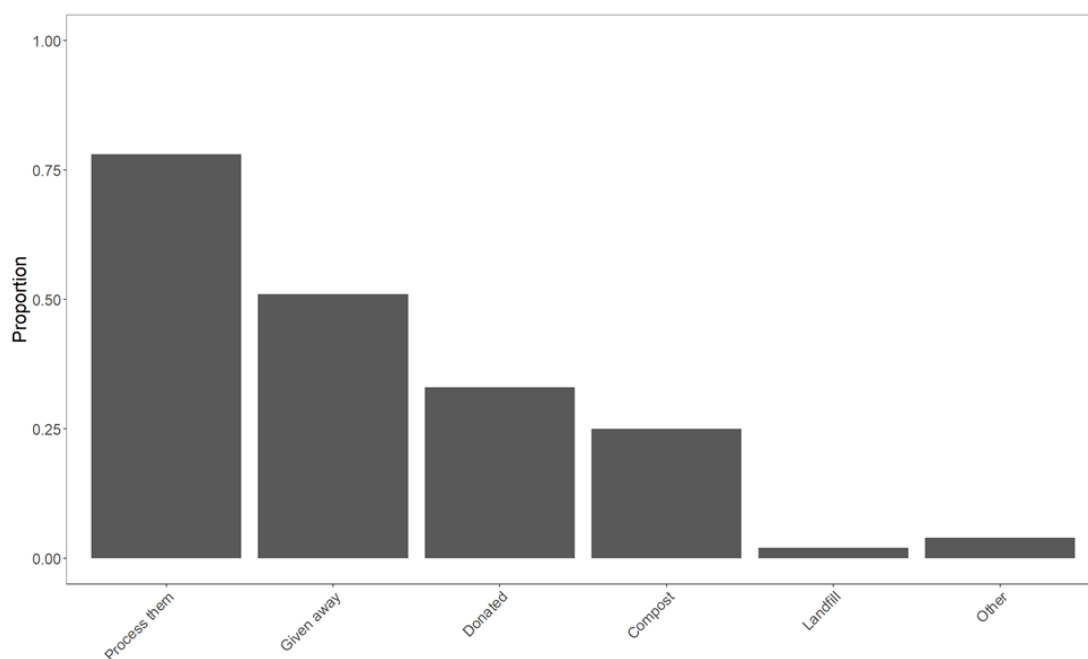


Figure 2. Use of unsold SCMs ( $n = 51$ ).

### 4.3. Marketing

The majority (53%) of growers ( $n = 60$ ) used diverse (four or more) approaches to advertise their products (Table 1). The most common advertising methods used were social media sites, specifically Facebook (83%) and Instagram (75%), as well as a farm website/blog (68%) ( $n = 60$ ) (Figure 3). Twenty-four percent of growers ( $n = 62$ ) indicated that they did not have an adequate understanding of the demand for their products, while 31% expressed difficulties with advertising their products in general. Some of the most common marketing messaging SCM growers ( $n = 59$ ) used to promote their products included supporting local food systems (86%), health/nutritional benefits (84%), and growing practices (84%) (Table 2).

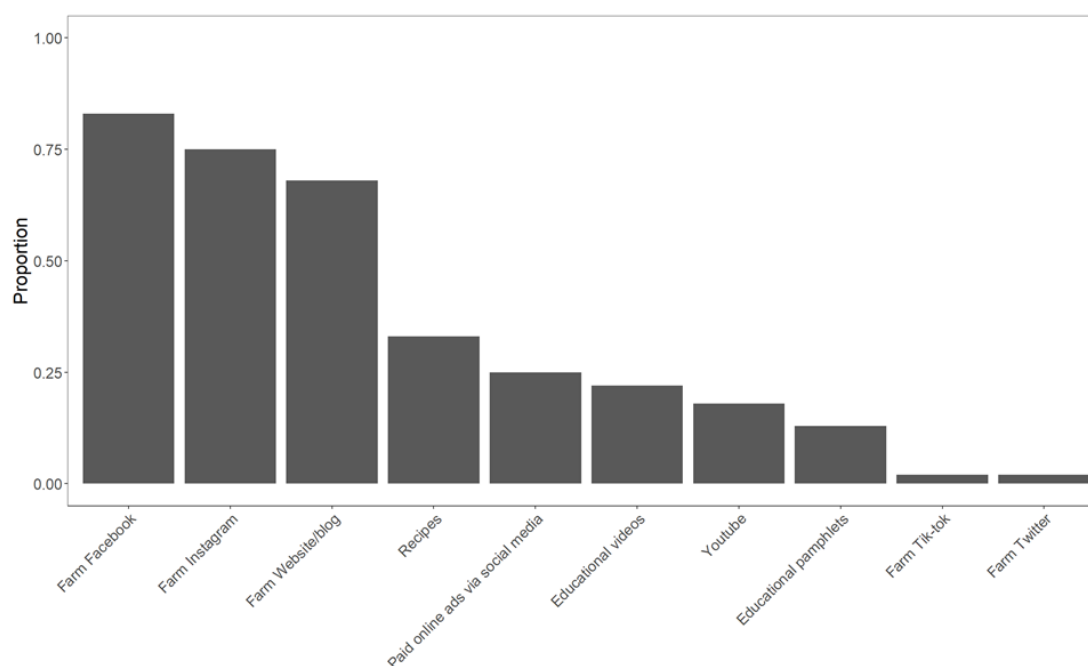


Figure 3. Advertising methods used by SCM growers ( $n = 60$ ).

**Table 2.** Messaging used for SCM sales ( $n = 59$ ).

| Attribute                                | Yes | No  |
|--|-----|-----|
| Support local food system                | 86% | 14% |
| Growing practices                        | 84% | 16% |
| Nutritional/ health benefits             | 84% | 16% |
| Vegetarian/ vegan friendly               | 79% | 21% |
| Flavor profile                           | 77% | 23% |
| Medicinal benefits                       | 72% | 28% |
| Environmental benefits                   | 49% | 51% |
| Savings associated with meat replacement | 32% | 68% |

#### 4.4. Consumer Preferences

The vast majority (93%) of consumers ( $n = 40$ ) stated that they valued sustainability, medicinal, or nutritional value when making food purchasing decisions. Of consumers that held these values ( $n = 37$ ), 38% stated that sustainability was the most important value, and for 27%, nutrition was most important. Instead, 19% valued nutrition and sustainability equally ( $n = 37$ ), with one consumer pointing out that “sustainability and the nutritional value go hand in hand so that the more you grow it in a sustainable manner, the inherently more nutritious it’s going to be for you.”

The majority of consumers ( $n = 40$ ) felt there were nutritional (85%) and medicinal (83%), benefits related to consuming SCMs, while 63% of consumers felt there was a link between sustainability and SCM consumption and production. Of the consumers who stated they felt there were nutritional benefits related to consuming SCMs ( $n = 34$ ), 77% could not provide a specific example of benefits. Fifty-three percent of consumers ( $n = 40$ ) could not identify any specific medicinal benefits related to consuming SCMs and 50% could not state a specific example of how sustainability is related to SCM production/consumption.

The most commonly stated nutritional benefits of SCMs were fiber (9%), protein (9%), and vitamins and minerals (9%) ( $n = 34$ ). Brain health was the most commonly stated medicinal benefit (33%) ( $n = 25$ ). For consumers ( $n = 29$ ), the most relevant link made between sustainability and SCM consumption and production, respectively, was that mushrooms act as nutrient recyclers (28%) and that consuming SCMs is environmentally more sustainable than consuming meat (28%). Of regular SCM consumers ( $n = 30$ ), the most common motives for consuming SCMs were taste (40%), adding diversity to their diet (30%), and nutritional value (15%). Non-regular SCM consumers ( $n = 10$ ) articulated lack of exposure (30%) and access (20%), taste (20%), and texture (20%) as reasons for not eating SCMs.

#### 4.5. Economic Challenges and Opportunities

More than half (58%) of consumers ( $n = 40$ ) indicated that their consumption of SCMs increased in the last five years, while 35% said it stayed the same, and only 8% stated their consumption had decreased. A large percentage (43%) of regular SCM consumers ( $n = 30$ ) stated that they did not have access to all varieties of SCMs they would like to be consuming, and most (77%) of consumers in this category wanted more variety generally without providing specific examples of varieties they did not have access to. Half (50%) of consumers who had not consumed SCMs in the past six months ( $n = 10$ ) indicated they would eat SCMs if they were available locally.

Our results provided insight into several challenges SCM businesses might face. Sixty-one growers provided 75 responses to what they believed the three biggest barriers to entry for cultivating mushrooms were. The most common barriers to entry were cost of equipment/training employees/startup/overhead (53%), a lack of knowledge/available information for new growers (28%), and a lack of adequate growing space (19%). One

grower noted that, “The hardest part of mushroom growing is funding—it is not a common commodity so funding from lenders both local and federal is tough.” The largest challenges SCM growers ( $n = 62$ ) faced were production costs (26%) and storage/transportation (19%).

In lieu of these challenges, SCM producers reported making an annual average of USD 20.40 m<sup>-2</sup> of production space and an annual median of USD 9.58 per square meter of production space. The average number of kilograms of SCMs produced per square meter of production space was approximately 48.9 kg m<sup>-2</sup> and the median were 16.7 kg m<sup>-2</sup>. These numbers were based on total reported income, total production space, and total annual kilograms of SCMs produced. Based exclusively on the number of mushroom farms per capita (Appendix D), the states with the greatest potential for supporting additional SCM businesses include Texas, New Jersey, Nebraska, and Florida.

#### 4.6. Environmental Factors

Based on our sample, the most used substrates for growing SCMs were wood chips or sawdust (84%), soybean hulls or meal (55%), wooden logs (29%), and wheat straw (23%) ( $n = 62$ ). Over half (57%) of growers ( $n = 56$ ) purchased their substrate locally, while 86% of logs ( $n = 21$ ) and 87% of spawn were purchased locally ( $n = 50$ ). The majority (79%) of growers ( $n = 62$ ) left most of their spent substrate on their farm to be composted, while about one-third (31%) sold their spent substrate. Most growers ( $n = 62$ ) produced SCMs free of synthetic products (60%), followed by certified organic (24%). Seventy-seven percent of SCM growers ( $n = 62$ ) did not use geothermal, hydroelectric, wind, or solar energy sources for mushroom production. When growers were asked why they chose to grow SCMs the most common responses they provided related to passion (26%), wanting to produce SCMs they enjoyed consuming (26%), a desire to participate in an environmentally sustainable business (23%), and profitability (23%) ( $n = 62$ ).

Half of SCM consumers ( $n = 30$ ) indicated that they prioritized purchasing organically or locally grown SCMs, while 13% of participants indicated they did not have the option to do so. Seventy percent of consumers ( $n = 40$ ) indicated that they consciously use *A. bisporus* or SCMs as a meat replacement, meat substitute, or meat extender with the most common examples being as a meat replacement in sandwiches (50%).

#### 4.7. Socio-Cultural Factors

When consumers ( $n = 40$ ) were asked about what they associated with mushrooms, two trends emerged: The most common associations were food or food-related (53%), followed by psychedelic-related (33%). Consumers were also asked to describe a memory they had attached to mushrooms. Common memories included cooking/eating culinary mushrooms (48%), foraging (43%), and consuming psychedelic mushrooms (35%) ( $n = 40$ ). Memories were classified as “cooking/eating culinary mushrooms” when participants explicitly discussed cooking and/or eating mushrooms but could be coded in multiple themes. An example of this was when a participant stated, “When I was a young boy, I got myself a giant king bolete in the Sierras, bigger than my head. Furthermore, no one else in the family wanted mushrooms, so I ate the whole thing even though it had five hundred worms in it, and I ate the worms.”

The majority of SCM growers (57%) indicated they had participated in a community outreach event in the past five years to help promote their SCM product(s) ( $n = 63$ ). Forty percent hosted at least one educational workshop, 27% participated in or hosted a community dinner/potluck, and 27% participated in a community fundraiser ( $n = 63$ ). Twenty-six growers indicated in an open-ended response that they put on 38 different workshops in in the last five years with the most common workshop topics being cultivation-related (65.8%) and medicinal education (13.2%) ( $n = 38$ ). Of the 63 SCM facilities surveyed, 11 indicated that one of more of their business owners identified as American Indian or Alaska Native, Asian, Hispanic or Latino, or Native Hawaiian or Pacific Islander ( $n = 63$ ). Zero mushroom facility owners identified as Black or African American ( $n = 63$ ).

One quarter (25%) of consumers ( $n = 40$ ) perceived a cultural link to mushrooms. Most (60%) consumers with such a cultural link ( $n = 10$ ) stated that their tie was with the outdoor foraging community. An example of this was, “You know, I think it goes back to that memory. My fondest memory of mushroom hunting, we didn’t do a lot of gathering as kids, but my parents certainly did. We were farmers. My grandparents, my great-grandparents were farmers. And, you know, the sustainability of finding food, nutritious food, and food in general, is just something that we’ve always done. So certainly, cultural for my family, there’s a strong link.”

## 5. Discussion

### 5.1. Economic Dimensions of SCM Production

Increasing farm resilience has been shown to increase economic sustainability [4]. Farm resilience can be defined as the ability of a farm system to withstand disturbances while still providing stable and consistent levels of nutritious food to consumers [95]. Increasing diversification is a core strategy used to increase farm system resilience [112]. There was notable diversification surrounding additional crops grown, varieties of cultivated SCMs, form in which SCMs were sold, and income streams related to SCMs. These categories had diversification across the industry and on an individual business level. Most (57%) growers sold their SCMs at four or more outlet types ( $n = 63$ ). Research shows that producers who sell their goods through different types of sales outlets are more resilient when facing shocks to the food system, such as a pandemic [113]. While consumer interviews indicated that the most common place for people to purchase SCMs was the grocery store, the most common place for growers to sell SCMs were farmers’ markets. This may be because most growers can sell produce at a higher price point when it is sold directly to consumers [114]. Selling products to grocery stores may increase sales volume and brand recognition, which may be helpful to the 27% of SCM growers who indicated that they did not have adequate access to consumers ( $n = 62$ ) [115]. Our results also indicated that SCM growers engage in a variety of marketing channels, which has been linked to greater resilience [113]. However, 24% percent of growers ( $n = 62$ ) indicated that they did not have an adequate understanding of the demand for their products and 31% expressed difficulties with advertising their products in general. This indicates there is room to help educate SCM growers about product demand and marketing techniques.

SCM producers also have some room for improvement surrounding economic sustainability. While there are around 100 species of mushrooms cultivated around the world, our results showed that 68.3% of SCM growers are producing six or less varieties [35]. These findings indicate potential for an increase of diversification of varieties cultivated by producers. Growers indicated that the most common barrier to entry in the SCM industry was cost-related (53%). There is room to help connect SCM growers with lenders and grant opportunities, particularly grants available through the United States Department of Agriculture and state level departments of agriculture, since SCMs are recognized as a specialty crop.

Consumer interviews provided a glimpse into future opportunities for SCM growers. Of the three listed values (sustainability, nutritional, and medicinal), consumers stated that they valued sustainability most when making food purchasing decisions. However, there was a consumer knowledge gap surrounding the sustainability, nutritional, and medicinal value of SCMs. The top reason that non-regular SCM consumers ( $n = 10$ ) chose not to eat SCMs was lack of exposure. Research supports that greater consumer education surrounding use and value of SCMs may result in increased demand [116]. Both consumers who regularly consumed SCMs and those who did not, indicated that they would like greater access to a wider variety of SCMs. In general, the demand for SCMs in the US is growing and there appears to be room for growth across the industry [23,42,43]. Many of the individuals we interviewed consume SCMs mushroom food products (50%), while the list of SCM products consumed was limited. A random sample of mushroom consumers in the US may show there is sufficient demand for further SCM product development.

### 5.2. Environmental Dimensions of SCMs

Our findings showed several ways that the SCM industry is supporting environmental sustainability. When SMS is added to compost it strengthens the biodiversity in soil and SMS can be sold by mushroom growers to further diversify their income streams [117]. Our results indicated that 31% of growers sold their SMS and the majority of growers composted them, either on or off the farm. The most commonly used substrates for growing mushrooms were agricultural byproducts, but 43% of substrates were not purchased locally ( $n = 56$ ). Our results, along with previous research, highlight the possibility of increased purchase of locally produced substrates as mushrooms have been shown to successfully grow on a wide variety of byproducts, and acquisition of substrates can be resource-intensive [40,60,62,63,75,118]. Use and sale of agricultural byproducts have the potential to increase producer income and total resource use efficiency [119]. The vast majority (77%) of SCM growers ( $n = 62$ ) did not use any form of renewable energy as inputs in their operation. This finding aligns with the general energy market in the US with around 20% of total electricity generation coming from renewable energy [120]. Renewable energy usage in the US might be increased through the promotion of democratic institutions, municipal support, and financial incentives [121,122].

The majority (60%) of growers ( $n = 62$ ) were producing SCMs free of synthetic products, while half (50%) of applicable consumers ( $n = 30$ ) indicated that they prioritized purchasing organically or locally grown SCMs. Producing food free of synthetic inputs and shortening the food supply chain helps mitigate the negative climate impacts tied to the food system [74,123]. Research suggests that many mushrooms, including SCMs, absorb heavy metals found in conventional fertilizers, pesticides, and agricultural byproducts [124,125]. While this is helpful in the context of water remediation, heavy metal accumulation results in mushrooms unfit for human consumption [124]. Consuming SCMs produced free of synthetic inputs can eliminate the risk of heavy metal consumption [124].

From the consumer perspective, our findings highlighted the potential of SCM consumption/production to decrease the consumption level of industrially raised meat. Accordingly, 70% of consumers ( $n = 40$ ) indicated that they consciously used mushrooms as a meat replacement, meat substitute, or meat extender. This finding is supported by previous research that indicates consumer acceptance of mushrooms as a meat replacement [15–17]. There may be room in the market for additional mushroom products targeted at consumers looking to reduce their meat consumption.

### 5.3. Socio-Cultural Dimensions of SCMs

Age, culture, local collaboration, and ethnic diversity of growers are factors that influence SCM production and differ from traditional agricultural stereotypes. Data shows that the average age of the US farmer is 58 years, and that as farmers age, they become less productive [126]. If younger people do not have the desire or access to pursue farming, the food system in the US will have a severe lack of producers within the next 50 years. Results from our study show that 77% of SCM growers in the US fall between the ages of 26–45 and many (75%) are new SCM growers. This indicates that growing SCMs is attracting young producers at much higher rates than traditional farming.

Collaboration between community, authorities, and the civil society is an identified cultural indicator of socio-culturally sustainable food systems [80]. Our research indicated that SCM growers are involved in their communities through farmers' market engagement, community events, educational workshops, community dinners, and fundraisers. Twenty-seven percent of growers ( $n = 63$ ) indicated that they donated unsold mushrooms, while 21% indicated that their unsold mushrooms were composted. Helping SCM growers connect to their local food banks may be a viable option for decreasing food waste and food insecurity, while increasing access to nutrient-dense food to a wider group of people.

Two potential areas for increased socio-cultural sustainability in the SCM industry include increased racial diversity and collaboration. Little racial/ethnic diversity existed among surveyed SCM business owners, and this group reportedly lacked Black or African

Americans altogether. This lack of diversity in farming can be linked to structural historic and current racism, loss of agricultural land, lack of access to credit, natural disasters, and organized opposition to black land ownership [127]. Reports from 2012–2014 showed that White people owned 98% and operated 94% of all farmlands in the US [128]. Free and formally enslaved Black and African Americans have farmed and produced food in the US for almost four centuries [127]. Seventy-five percent of agricultural workers in the US were born in Mexico or Central American countries [129]. Despite the representations of minorities in farming practices, farmland is owned and operated disproportionately by White people [128]. For SCM farming to be truly socially sustainable, communities, institutions, agencies, and government systems should support and prioritize food producers of color.

In the open-ended SCM grower responses, several growers indicated they desired more connection with other growers. For example, one grower stated that “... I feel like more dialogue needs to be had between all the producers so we can all help shape the developing rules and regulations that we will start to see in everyday operations pretty soon,” while another indicated that what would be most valuable for their business was networking with other growers. Based on extensive internet research and conversations with SCM growers, there are currently no central organization or network in the United States specifically for SCM growers. The industry as a whole and the communities they reside in would likely benefit from greater communication between SCM growers.

Looking towards the future of SCM production, there are ways the industry might choose to expand that relate to peoples’ cultural backgrounds. Culture has been shown to affect the types of associations people make with food [130]. The most common associations and memories consumers expressed surrounding mushrooms related to food/cooking, foraging, and psychedelic mushrooms. Of the 14 interviewees that discussed a memory involving psychedelic mushrooms, two expressed an openly negative memory, seven explicitly stated their experience was positive, while five used neutral language. Marketing research shows that previous memories may influence sales of a good [131]. There are few places in the US, such as Oregon, that have legalized therapeutic psilocybin, a hallucinogenic alkaloid found in psychedelic mushrooms [132]. As the legalization of psychedelic mushrooms becomes more commonplace throughout the US, there may be room to integrate SCM sales, marketing, and products with psychedelic mushroom products.

#### 5.4. Limitations

Based on the location data collected, responses were received from SCM farms in all major geographic areas of the US. Since the total population of SCM growers in the US was relatively small [133], our results do not reflect all regional differences in farming practices. It is important to note that the number of mushroom growers reported by USDA Agricultural Marketing Service has historically been much lower than in research findings [35,133]. Hence, dissemination outside established databases would have increased the sample size. We acknowledge that numerous mushroom growers were not contacted due to their lack of online presence. Since the producer survey data was self-reported, there was potential response bias.

Limitations of the consumer interviews included sampling methodology. Snowball sampling of peer references was used for the interviews. Our results cannot be extrapolated to all consumers in the US. In addition, nonprobability sampling typically has inherent biases [134]. In our case, the interviewer personally knew some of the interviewees.

#### 6. Conclusions

This study highlights barriers to and opportunities for SCM growers in the United States. Findings explored how SCM production and consumption might contribute to sustainable food systems from economic, environmental, and socio-cultural perspectives. While most SCMs are grown using agricultural byproducts, there is room for more SCM producers to utilize locally produced substrates as mushrooms have been shown to successfully grow on a wide variety of byproducts [40,75,118]. Our results found a lack of racial

representation among SCM business owners, and minority SCM growers would benefit from additional support. We recommend conducting similar future studies focusing on SCM growing practices based on region, sustainability factors, and varieties of SCM grown.

Our consumer data provides an introductory look into consumer perceptions surrounding SCMs. More research is needed to better understand current and future consumer demand for SCMs. Consumer knowledge and understanding of nutritional and medicinal benefits of SCMs was low among those interviewed. Marketing SCMs in culturally appropriate ways that speak to people's associations and memories may lead to increased sales [131]. This could entail offering recipes and food samples that align with consumers' food cultures when selling SCMs at farmers' markets. Future studies looking at consumer perceptions and consumption of SCMs should be conducted. This study identifies current trends, challenges, and opportunities in the US SCM industry. Study findings can be used as a baseline for stakeholders to develop strategies for lowering barriers to entry for current and future SCM producers.

**Author Contributions:** A.M. headed the study conceptualization, design, dissemination, qualitative data analysis, and manuscript authorship. C.L.C. and C.G.A. contributed to the study design. M.W. conducted quantitative data analysis and figure creation. A.M., R.E., C.L.C., C.G.A., M.S. and M.W. contributed to manuscript revision and approved the submitted version. All authors have read and agreed to the published version of the manuscript.

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**Institutional Review Board Statement:** The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of Montana State University, under Application No. AM081420-EX on 14 August 2020, for studies involving humans. A request for minor modification was approved by the Institutional Review Board of Montana State University on 18 November 2020.

**Informed Consent Statement:** Written informed consent has been obtained from the participants to publish this paper.

**Data Availability Statement:** The datasets generated for this study are available upon request from the corresponding author.

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## Appendix A

Survey Title: Barriers and Opportunities for Specialty Mushroom Production in the United States

Greetings! We are a team of researchers at Montana State University interested in understanding the production of specialty cultivated mushrooms in the United States including growing, marketing, and communication practices. In particular, we are interested in understanding barriers and opportunities for specialty cultivated mushroom production in order to provide recommendations for strengthening this sector and enhancing sustainability and reliance. Thus, we are carrying out an online survey with producers of specialty cultivated mushrooms in the United States.

We define **specialty cultivated mushrooms** here as any cultivated mushroom intended for human consumption besides white button mushrooms (*Agaricus bisporus*; also known as cremini or Portobello).

If you choose to participate in this voluntary and confidential survey, you will be presented with **36 questions** grouped into the follow 4 parts:

- **Part 1: Farm background**
- **Part 2: Mushroom cultivation practices**
- **Part 3: Sales, distribution, and advertising of mushrooms**
- **Part 4: Producer background**

We expect this survey to take about 15–25 min to complete. All responses will remain anonymous, meaning your responses will not be traceable to you. We are offering a \$15 Amazon gift card for all producers that complete this survey.

Responses from this survey will be compiled and analyzed to understand production practices of specialty cultivated mushroom producers. Survey findings will be used to prepare educational and scientific outreach materials. We will share our findings with the specialty cultivated mushroom community by presenting at conferences and sharing our outreach material.

In order to participate in this survey, you must be 18 years of age or older.

Our project has received human subject approval to administer this survey from the Montana State University Institutional Review Board, which serves to oversee ethics in research at our institution.

If you have any questions, concerns, or suggestions please reach out to our research team (contact information below) or the Chair of the Montana State University Institutional Review Board, Mark Quinn (406) 994-4707 (mquinn@montana.edu).

Thank you for consideration of participating in this study,

Ali Moxley—Lead Graduate Researcher

Roland Ebel—Faculty Advisor

Cathy Cripps—Committee Member

Mary Stein—Committee Member

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**By clicking “Next”** I agree that I am willing to voluntarily participate in the study outlined above by responding to the following survey questions. I give permission for you to include my survey responses in your research analysis and publication material, while upholding confidentiality. I understand that in order to participate in this survey, I must currently be a specialty cultivated mushroom grower over the age of 18 living in the US.

**Part 1: Farm background**

- (1) What is the zip code associated with your mushroom farm? Fill in the blank
- (2) How many years has your farm been producing specialty cultivated mushrooms?
  - Under a year
  - 1–4 years
  - 5–8 years
  - 9–12 years
  - Over 12 years
- (3) What other crops/products do you commercially grow on your farm? Check all that apply.
  - Bees



- Dairy
  - Field Crops
  - Flowers
  - Fruit
  - Herbs/medicinal plants
  - Hops & Brewing
  - Hemp/Cannabis
  - Livestock
  - Vegetables
  - Other (please specify)
  - I do not commercially grow other crops/products for sale on my farm
- (4) Which varieties of mushrooms do you grow? Check all that apply.
- Cauliflower fungus
  - Chestnut
  - Cordyceps
  - Enokitake (winter mushroom)
  - Lion's mane/bear's head tooth
  - Maitake
  - Oyster
  - Piopinno
  - Reishi
  - Shiitake
  - Straw
  - White button mushroom (*Agaricus bisporus*; also known as cremini or Portobello)
  - Wine Cap
  - Other (please specify)
- (5) In what form do you sell the mushrooms you cultivate? Check all that apply.
- Canned
  - Dried (powdered)
  - Dried (whole)
  - Fresh
  - Frozen
  - Mushroom food product (jerky, coffee)
  - Tincture/Supplement
  - Other (please specify)
- (6) Does your farm sell any of the following? Check all that apply.
- Cultivation equipment
  - Foraged wild mushrooms, please specify which types:
  - Grain/sawdust/plug spawn
  - Grow kits
  - Logs
  - Liquid cultures/spore syringes/agar
  - Substrates
  - My farm does not sell any of these products
- Part 2: Mushroom cultivation practices**
- (7) Why do you choose to grow mushrooms? Fill in the blank
- (8) Where do you grow mushrooms?
- Both indoors and outdoors
  - Indoors only
  - Outdoors only

(9) Do you feel that you have adequate access to the following with regards to mushroom cultivation?

|  | No | Yes |
|--|----|-----|
| Access to alternative energy                         |    |     |
| Access to energy sources                             |    |     |
| Access to information on production                  |    |     |
| Access to information on sustainable production      |    |     |
| Access to substrate/grain spawn                      |    |     |
| Access to recycling and composting of waste products |    |     |
| Space to cultivate mushrooms                         |    |     |

(10) Which substrates do you use for growing mushrooms? Check all that apply.

- Almond husks
- Ammonium nitrate
- Brewers’ grain
- Cocoa bean hulls
- Coffee pulp or grounds
- Corncobs
- Cottonseed hulls or meal
- Mulched straw
- Nut and seed hulls
- Soybean hulls or meal
- Strawbedded horse or poultry manure
- Urea
- Waste or recycled paper
- Wheat straw
- Wood chips or sawdust
- Wooden logs
- Other (please specify)

(11) Where do you source the key inputs, your farm uses for mushroom cultivation? Check all that apply. Please note, if they are purchased locally, but produced outside the US, mark them as “outside the US.”

|   | Locally (sourced from within your state) | Regionally (sourced from any neighboring states) | Within the US, but not locally or regionally | Outside the US | I do not know | I do not purchase this item |
|---|--|--|--|----------------|---------------|-----------------------------|
| Bags for growing mushrooms              |  |  |  |                |               |                             |
| Bags/containers for packaging mushrooms |  |  |  |                |               |                             |
| Logs                                    |  |  |  |                |               |                             |
| Spawn (sawdust or grain)                |  |  |  |                |               |                             |
| Spores/agar                             |  |  |  |                |               |                             |
| Substrates                              |  |  |  |                |               |                             |

(12) What does your farm do with the majority of the spent substrate material involved in mushroom production (fruiting blocks, logs, etc.)? Check all that apply.

- It ends up in a landfill
- It ends up in a municipal compost

- It is sold
  - It stays on the farm and get composted
  - Other (please specify)
- (13) How do you dispose of the waste from the following inputs for mushroom cultivation the majority of the time?

|   | Composted | Recycled | Sent to a landfill | This is not a waste product related to our mushroom cultivation |
|---|-----------|----------|--------------------|---|
| Bags for growing mushrooms                  |           |          |                    |   |
| Disinfectant bottles                        |           |          |                    |   |
| Filters                                     |           |          |                    |   |
| Gloves                                      |           |          |                    |   |
| Jar lids                                    |           |          |                    |   |
| Lab plastics (syringes, petri dishes, etc.) |           |          |                    |   |
| Other: please specify                       |           |          |                    |   |

- (14) What types of mushrooms do you sell?
- Certified organic
  - Conventionally grown
  - Pesticide/chemical free, but not certified organic
  - Multiple types
- (15) Does your farm use any of the following energy sources for mushroom production: geothermal, hydroelectric, wind, or solar energy?
- No
  - Yes (Please indicate what percentage of your energy input comes from geothermal, hydroelectric, wind, or solar energy.)
- (16) Optional: Attach a document that has up to 5 photos of the packaging you use for your mushrooms and please add a brief photo caption.

### Part 3: Sales, distribution, and advertising of mushrooms

- (17) Where do you sell your mushrooms/mushroom products? Check all that apply.
- Catering companies
  - Community Supported Agriculture (CSA) share
  - Farmers' market
  - Food Co-op
  - Food distributor
  - Food processor
  - Grocery store
  - Online (virtual market)
  - Restaurant/food truck
  - Private chefs
  - University/elementary/middle/high school cafeterias
  - Other (please specify)
- (18) On average, what percentage of your fresh mushrooms sell?
- 0–20%
  - 21–40%
  - 41–60%
  - 61–80%
  - 80–100%
  - We do not sell fresh mushrooms

(19) What happens to fresh mushrooms your farm is unable to sell? Check all that apply.

- They are donated to a food bank/pantry
- They are given away to family/friends/employees
- They are sold to a food processor
- They end up in a compost
- They end up in a landfill
- We are always able to sell all of the mushrooms we grow
- We do not sell fresh mushrooms
- We process them (drying, freezing, canning)
- Other (please specify)

(20) Do you feel that you have adequate access to the following with regards to mushroom sales and knowledge surrounding marketing communications?

|   | No | Yes |
|---|----|-----|
| Adequate number of consumers  |    |     |
| Understanding of consumer demand  |    |     |
| Understanding of how to advertise specialty mushrooms   |    |     |
| Understanding of the attributes of specialty mushrooms (i.e, health, environmental, cultural) |    |     |

(21) Please indicate approximately what percentage of your sales come from the following sources.

|   | 0% | 1–20% | 21–40% | 41–60% | 61–80% | 81–100% |
|---|----|-------|--------|--------|--------|---------|
| Selling direct-to-consumers (CSA, online virtual market, farmers' market, etc.) |    |       |        |        |        |         |
| Selling to restaurants, food trucks, catering companies, private chefs          |    |       |        |        |        |         |
| Selling to grocery stores/food co-ops   |    |       |        |        |        |         |

(22) Do you advertise your mushrooms using any of the following approaches? Check all that apply.

- Educational pamphlets
- Educational videos
- Farm Instagram
- Farm Facebook
- Farm Tik-tok
- Farm Twitter
- Farm Website/blog
- Radio advertisements
- Recipes
- Paid online ads via social media
- Television advertisements
- Youtube
- Other (please specify)

(23) Have you participated in any of the following community outreach events in the past 5 years to promote your mushrooms?

- Community dinner/potlucks
- Community fundraisers
- Educational workshops
- Other community events (please specify)

(24) If you have hosted any workshops in the last 5 years, what was the topic of the workshop(s)?

Fill in the blank

|   | In most advertising material | In about half of advertising material | In some advertising material | We do not use this in any advertising material |
|---|------------------------------|---------------------------------------|------------------------------|--|
| Cost savings associated with meat replacement |                              |                                       |                              |  |
| Environmental benefits                        |                              |                                       |                              |  |
| Flavor profile                                |                              |                                       |                              |  |
| Growing practices                             |                              |                                       |                              |  |
| Health/nutritional benefits                   |                              |                                       |                              |  |
| Medicinal benefits                            |                              |                                       |                              |  |
| Supporting local food systems/economy         |                              |                                       |                              |  |
| Vegetarian/vegan friendly                     |                              |                                       |                              |  |

(25) Please indicate how frequently you use the following attributes to help advertise your products.

(26) How would you like to see the production level of your business/farm change in the next 5 years?

- Grow
- Remain unchanged
- Shrink

(27) How has COVID-19 (the novel coronavirus) affected your mushroom sales or production?

|                            | Effect on sales | Effect on production |
|----------------------------|-----------------|----------------------|
| My sales decreased         |                 |                      |
| My sales increased         |                 |                      |
| My sales were not affected |                 |                      |

(28) What do you think are the three biggest barriers to entry for cultivating mushrooms?

- Item 1 (fill in the blank)
- Item 2 (fill in the blank)
- Item 3 (fill in the blank)

(29) What is your biggest challenge as a mushroom farmer?

- Contamination
- Markets
- Production costs
- Storage/transportation
- Other (please specify)

(30) Overall, what information would be valuable for you to have as a mushroom farmer (including research on mushroom genetics, marketing communications, growing practices, etc.)?

- Item 1 (fill in the blank)
- Item 2 (fill in the blank)
- Item 3 (fill in the blank)

(31) As a mushroom producer, what would you like to know from consumers to help with your marketing communications and outreach efforts?

- Item 1 (fill in the blank)
- Item 2 (fill in the blank)
- Item 3 (fill in the blank)

- (32) Is there anything else you would like to share about your mushroom operation or cultivation experience? Fill in the blank
- (33) Please estimate your production quantity, net sales, and production space based on your farm from last year (2019).

|  | Actual, I kept records | Estimate | I do not know |
|--|------------------------|----------|---------------|
| Pounds of mushrooms produced annually                                |                        |          |               |
| Total annual net income from sales of fresh mushrooms                |                        |          |               |
| Total annual net income from entire mushroom operation               |                        |          |               |
| Total space where you prepare and grow your mushrooms in square feet |                        |          |               |

- (34) Optional: Attach up to 5 screenshots and/or photos of advertising/marketing examples your company/farm uses and include caption.

#### Part 4: Producer background

- (35) Do you or any of mushroom farm owners identify as the following? Check all that apply.

- American Indian or Alaska Native (Tribal affiliation: \_\_\_\_\_)
- Asian
- Black or African American
- Hispanic or Latino
- Native Hawaiian or Pacific Islander

- (36) What is your age in years?

- 18–25
- 26–35
- 36–45
- 46–55
- 56–65
- 65–75
- 76+

#### As an incentive for participating in this survey, would you like to receive a \$15 Amazon gift card?

Please note, the gift cards will be mailed to participants after the survey closes.

- No
- Yes

To receive a \$15 Amazon gift card, please fill out your contact information below. (Your name and contact information will remain confidential)

Name:

Complete mailing address:

City:

State:

Zip Code:

#### Appendix B

Interview questionnaire for people who have consumed specialty cultivated mushrooms in the last six months.

##### Part 1: Introduction

[MSU Researcher]:

“Hello, my name is Ali, and I am a master’s student at Montana State University studying Sustainable Food Systems. Today I am going to ask you a series of questions regarding your perceptions of and knowledge surrounding specialty cultivated mushrooms.”

“Before we begin, I would like to remind you that in order to participate in this study I need to receive your consent to record this session. Recording is required for participation in this study but will remain confidential. The recording may be used to make educational materials and research articles.

“Do I have your permission to record this interview?”

[Informant]: Yes.

*If permission is not granted to record the session, extend thanks for their time, and end the remote meeting.*

[MSU Researcher]:

“I want to start out by explaining how mushrooms are categorized for the sake of this study. For this study, mushrooms are grouped into four categories. These include: *Agaricus bisporus*, specialty cultivated, edible wild, and psychedelic mushrooms.

*Agaricus bisporus* includes white buttons, Portobello, and cremini mushrooms. These are all actually the same mushroom just in different stages of growth!

Specialty cultivated includes mushrooms grown by farmers such as oysters and shitakes. They also included medicinal mushrooms such as reishi and cordyceps. This is the group of mushrooms most of our questions today will focus on today.

Edible wild includes mushrooms such as boletes, morels, and chanterelles.

Psychedelic includes any mushrooms with psychoactive agents.

Do you have any questions regarding the distinction between these categories?”

[Informant]:

Screening question: “Have you consumed **specialty cultivated mushrooms** within the last 6 months?”

[Informant]:

## Part 2: Consumption and purchasing patterns

Q1: [MSU Researcher]: “Do you consume any mushroom food products?”

[Informant]:

Q2: [MSU Researcher]: If they say yes . . . “What kind of food products? For example, mushroom coffee, seasonings, or chips.”

[Informant]:

Q3: [MSU Researcher]: “Where do you typically purchase your specialty cultivated mushrooms or specialty cultivated mushroom products?”

[Informant]:

Q4: [MSU Researcher]: “Which varieties of specialty cultivated mushrooms do you consume?”

[Informant]:

Q5: [MSU Researcher]: “On average, how many times a week, or if more appropriately a month, do you choose to consume some form of specialty cultivated mushrooms?”

[Informant]:

Q6: [MSU Researcher]: “Do you prioritize purchasing organically or locally grown specialty cultivated mushrooms?”

[Informant]:

Q7: [MSU Researcher]: “Has your consumption level of specialty cultivated mushrooms changed in the past 5 years? Has it increased, decreased, or stayed the same?”

[Informant]:

Q8: [MSU Researcher]: “Has COVID-19 changed your consumption of specialty cultivated mushrooms or wild edible mushrooms?”

[Informant]:

Q9: [MSU Researcher]: If they say yes . . . . “In what ways?”

[Informant]:

Q10: [MSU Researcher]: “Do you ever consciously use **any type** of mushroom as a meat replacement, meat substitute, or meat extender? This includes Portobello, cremini, or white button.

[Informant]:

Q11: [MSU Researcher]: If they say yes . . . “What does that look like for you?”

[Informant]:

### Part 3: Barriers and opportunities for mushroom consumption

Q12: [MSU Researcher]: “Do you have access to all the types of specialty cultivated mushrooms you would like to be consuming in your community?”

[Informant]:

Q13: [MSU Researcher]: If they say no . . . “What additional varieties would you like to have available locally?”

[Informant]:

Q14: [MSU Researcher]: “When you think of mushrooms in general, what do you most associate them with? For example, mold, sustainability, drugs, spirituality, etc. When you hear the word mushroom what comes to mind?”

[Informant]:

Q15: [MSU Researcher]: “Can you describe a memory you have attached to mushrooms? This can be positive or negative, mushrooms of any kind.”

[Informant]:

Q16: [MSU Researcher]: “Why do you choose to consume specialty cultivated mushrooms? What do you like about them?”

[Informant]:

### Part 4: Consumer knowledge

Q17: [MSU Researcher]: “Do you feel like there are medicinal benefits related to consuming specialty cultivated mushrooms?”

[Informant]:

Q18: [MSU Researcher]: If they say yes . . . “What do you think some of those benefits are?”

[Informant]:

Q19: [MSU Researcher]: “Do you feel like there are nutritional benefits related to consuming specialty cultivated mushrooms?”

[Informant]:

Q20: [MSU Researcher]: If they say yes . . . “What do you think some of those benefits are?”

[Informant]:

Q21: [MSU Researcher]: “Do you feel like there is a link between sustainability and specialty cultivated mushrooms consumption and production?”

[Informant]:

Q22: [MSU Researcher]: If they say yes . . . “How do you feel like sustainability is related to specialty cultivated mushrooms?”

[Informant]:

### Part 5: Consumer background

Q23: [MSU Researcher]: “Do you value sustainability, medicinal, or nutritional value when making food purchasing decisions?”

[Informant]:

Q24: [MSU Researcher]: If they say yes . . . “Do you value them fairly equally or is there one that is the most important to you.”

[Informant]:

Q25: [MSU Researcher]: “Do you feel like you have a cultural link to mushrooms of any kind?”

[Informant]:

Q26: [MSU Researcher]: If they say yes . . . “Would you be willing to speak to that?”

[Informant]:

[MSU Researcher]: “Would you like to receive a \$15 Amazon gift card? Please note, the gift cards will be mailed to participants within a week after the survey closes on December 30th, 2020.”

[Informant]:

- Yes- ask for mailing address, record in excel



- No- continue on with script

[MSU Researcher]: “That is all of the questions that I have for you today. I have really enjoyed getting to talk to you and appreciate your input. Thank you!”

*Salutations and end remote meeting session.*

## Appendix C

Interview questionnaire for people who have NOT consumed specialty cultivated mushrooms in the last six months.

### Part 1: Introduction

[MSU Researcher]:

“Hello, my name is Ali, and I am a master’s student at Montana State University studying Sustainable Food Systems. Today I am going to ask you a series of questions regarding your perceptions of and knowledge surrounding specialty cultivated mushrooms.”

“Before we begin, I would like to remind you that in order to participate in this study I need to receive your consent to record this session. Recording is required for participation in this study but will remain confidential. The recording may be used to make educational materials and research articles.”

“Do I have your permission to record this interview?”

[Informant]: Yes.

*If permission is not granted to record the session, extend thanks for their time, and end the remote meeting.*

[MSU Researcher]:

“I want to start out by explaining how mushrooms are categorized for the sake of this study. For this study, mushrooms are grouped into four categories. These include: *Agaricus bisporus*, specialty cultivated, edible wild, and psychedelic mushrooms.

*Agaricus bisporus* includes white buttons, Portobello, and cremini mushrooms. These are all actually the same mushroom just in different stages of growth!

Specialty cultivated includes mushrooms **grown** by farmers such as oysters and shitakes. They also included medicinal mushrooms such as reishi and cordyceps. This is the group of mushrooms most of our questions today will focus on today.

Edible wild includes mushrooms such as boletes, morels, and chanterelles.

Psychedelic includes any mushrooms with psychoactive agents.

Do you have any questions regarding the distinction between these categories?”

[Informant]:

Screening question: “Have you consumed **specialty cultivated mushrooms** within the last 6 months?”

[Informant]:

### Part 2: Consumption and purchasing patterns

Q1: [MSU Researcher]: “Has your consumption level of specialty cultivated mushrooms changed in the past 5 years? Has it increased, decreased, or stayed the same?”

[Informant]:

Q2: [MSU Researcher]: “Has COVID-19 changed your consumption of specialty cultivated mushrooms or wild edible mushrooms?”

[Informant]:

Q3: [MSU Researcher]: If they say yes . . . “In what ways?”

[Informant]:

Q4: [MSU Researcher]: “Do you ever consciously use **any type** of mushroom as a meat replacement, meat substitute, or meat extender? This includes Portobello, cremini, or white button.

[Informant]:

Q5: [MSU Researcher]: If they say yes . . . “What does that look like for you?”

[Informant]:

### Part 3: Barriers and opportunities for mushroom consumption

Q6: [MSU Researcher]: “Are there any varieties of specialty cultivated mushrooms you would choose to consume if they were available locally?”

[Informant]:

Q7: [MSU Researcher]: If they say yes . . . “Which varieties?”

[Informant]:

Q8: [MSU Researcher]: “When you think of mushrooms in general, what do you most associate them with? For example, mold, sustainability, drugs, spirituality, etc. When you hear the word mushroom what comes to mind?”

[Informant]:

Q9: [MSU Researcher]: “Can you describe a memory you have attached to mushrooms? This can be positive or negative, mushrooms of any kind.”

[Informant]:

Q10: [MSU Researcher]: “Why do you choose not to consume specialty cultivated mushrooms?”

[Informant]:

#### Part 4: Consumer knowledge

Q11: [MSU Researcher]: “Do you feel like there are medicinal benefits related to consuming specialty cultivated mushrooms?”

[Informant]:

Q12: [MSU Researcher]: If they say yes . . . “What do you think some of those benefits are?”

[Informant]:

Q13: [MSU Researcher]: “Do you feel like there are nutritional benefits related to consuming specialty cultivated mushrooms?”

[Informant]:

Q14: [MSU Researcher]: If they say yes . . . “What do you think some of those benefits are?”

[Informant]:

Q15: [MSU Researcher]: “Do you feel like there is a link between sustainability and specialty cultivated mushroom production?”

[Informant]:

Q16: [MSU Researcher]: If they say yes . . . “How do you feel like sustainability is related to specialty cultivated mushrooms?”

[Informant]:

#### Part 5: Consumer background

Q17: [MSU Researcher]: “Do you value sustainability, medicinal, or nutritional value when making food purchasing decisions?”

[Informant]:

Q18: [MSU Researcher]: If they say yes . . . “Do you value them fairly equally or is there one that is the most important to you.”

[Informant]:

Q19: [MSU Researcher]: “Do you feel like you have a cultural link to mushrooms of any kind?”

[Informant]:

Q20: [MSU Researcher]: If they say yes . . . “Would you be willing to speak to that?”

[Informant]:

[MSU Researcher]: “Would you like to receive a \$15 Amazon gift card? Please note, the gift cards will be mailed to participants within a week after the survey closes on December 30th, 2020.”

[Informant]:

- Yes- ask for mailing address, record in excel
- No- continue on with script

[MSU Researcher]: “That is all of the questions that I have for you today. I have really enjoyed getting to talk to you and appreciate your input. Thank you!”

*Salutations and end remote meeting session.*

#### Appendix D

| State         | # of Known SCM Farms | # of Grower Responses | Population | # of Consumer Interviews Conducted |
|---------------|----------------------|-----------------------|------------|------------------------------------|
| Alabama       | 3                    | 1                     | 4,934,193  | 0                                  |
| Alaska        | 4                    | 0                     | 724,357    | 1                                  |
| Arizona       | 7                    | 1                     | 7,520,103  | 0                                  |
| Arkansas      | 5                    | 0                     | 3,033,946  | 2                                  |
| California    | 26                   | 2                     | 39,613,493 | 4                                  |
| Colorado      | 9                    | 2                     | 5,893,634  | 3                                  |
| Connecticut   | 8                    | 0                     | 3,552,821  | 0                                  |
| Delaware      | 0                    | 0                     | 990,334    | 0                                  |
| Florida       | 12                   | 0                     | 21,944,577 | 1                                  |
| Georgia       | 10                   | 1                     | 10,830,007 | 4                                  |
| Hawaii        | 6                    | 0                     | 1,406,430  | 0                                  |
| Idaho         | 2                    | 0                     | 1,860,123  | 0                                  |
| Illinois      | 13                   | 2                     | 12,569,321 | 1                                  |
| Indiana       | 8                    | 0                     | 6,805,663  | 0                                  |
| Iowa          | 7                    | 1                     | 3,167,974  | 0                                  |
| Kansas        | 3                    | 1                     | 2,917,224  | 0                                  |
| Kentucky      | 9                    | 0                     | 4,480,713  | 0                                  |
| Louisiana     | 3                    | 1                     | 4,627,002  | 0                                  |
| Maine         | 8                    | 0                     | 1,354,522  | 0                                  |
| Maryland      | 8                    | 1                     | 6,065,436  | 1                                  |
| Massachusetts | 10                   | 0                     | 6,912,239  | 0                                  |
| Michigan      | 20                   | 4                     | 9,992,427  | 0                                  |
| Minnesota     | 11                   | 3                     | 5,706,398  | 0                                  |
| Mississippi   | 2                    | 0                     | 2,966,407  | 0                                  |
| Missouri      | 13                   | 1                     | 6,169,038  | 0                                  |
| Montana       | 6                    | 1                     | 1,085,004  | 3                                  |
| Nebraska      | 1                    | 0                     | 1,951,996  | 0                                  |
| Nevada        | 5                    | 0                     | 3,185,786  | 1                                  |
| New Hampshire | 6                    | 0                     | 1,372,203  | 0                                  |
| New Jersey    | 4                    | 0                     | 8,874,520  | 0                                  |
| New Mexico    | 5                    | 0                     | 2,105,005  | 0                                  |
| New York      | 32                   | 2                     | 19,299,981 | 2                                  |

| State           | # of Known SCM Farms | # of Grower Responses | Population         | # of Consumer Interviews Conducted |
|-----------------|----------------------|-----------------------|--------------------|------------------------------------|
| North Carolina  | 23                   | 2                     | 10,701,022         | 2                                  |
| North Dakota    | 0                    | 0                     | 770,026            | 0                                  |
| Ohio            | 14                   | 0                     | 11,714,618         | 2                                  |
| Oklahoma        | 3                    | 1                     | 3,990,443          | 0                                  |
| Oregon          | 18                   | 3                     | 4,289,439          | 3                                  |
| Pennsylvania    | 24                   | 0                     | 12,804,123         | 0                                  |
| Rhode Island    | 2                    | 0                     | 1,061,509          | 0                                  |
| South Carolina  | 5                    | 0                     | 5,277,830          | 0                                  |
| South Dakota    | 1                    | 0                     | 896,581            | 0                                  |
| Tennessee       | 16                   | 2                     | 6,944,260          | 3                                  |
| Texas           | 10                   | 3                     | 29,730,311         | 2                                  |
| Utah            | 3                    | 0                     | 3,310,774          | 0                                  |
| Vermont         | 10                   | 0                     | 623,251            | 0                                  |
| Virginia        | 17                   | 1                     | 8,603,985          | 4                                  |
| Washington      | 20                   | 0                     | 7,796,941          | 0                                  |
| West Virginia   | 5                    | 1                     | 1,767,859          | 0                                  |
| Wisconsin       | 13                   | 2                     | 5,852,490          | 0                                  |
| Wyoming         | 1                    | 0                     | 581,075            | 1                                  |
| Washington, D.C | 1                    | 0                     | 714,153            | 0                                  |
| <b>Total</b>    | <b>452</b>           | <b>39</b>             | <b>331,343,567</b> | <b>40</b>                          |

## Appendix E

| Indicator  | Frequencies |
|--|-------------|
| <b>Age (<math>n = 63</math>)</b>                     |             |
| 18–45  | 78%         |
| 46–75  | 21%         |
| 76+  | 1%          |
| <b>Years of SCM production (<math>n = 63</math>)</b> |             |
| Under a year   | 13%         |
| 1–8 years  | 62%         |
| 9+ years   | 25%         |
| <b>Other crops produced (<math>n = 61</math>)</b>    |             |
| Yes  | 43%         |
| No   | 54%         |

| Indicator   | Frequencies |
|---|-------------|
| <b>Type of other crops produced</b> (multiple mentions possible) ( <i>n</i> = 61) |             |
| Vegetables  | 22%         |
| Herbs/Medicinal plants  | 11%         |
| Livestock   | 11%         |
| Field Crops   | 10%         |
| Bees  | 6%          |
| Flowers   | 6%          |
| Fruit   | 5%          |
| Eggs  | 3%          |
| Other   | 8%          |
| N/A   | 62%         |
| <b>Growing Location</b> ( <i>n</i> = 63)  |             |
| Both indoors and outdoors   | 37%         |
| Indoors only  | 54%         |
| Outdoors only   | 9%          |
| Indicator   | Frequencies |
| <b>Consume SCM</b> ( <i>n</i> = 40)   |             |
| Yes   | 75%         |
| No  | 25%         |
| <b>Frequency of consumption</b> ( <i>n</i> = 30)                                  |             |
| 1 or more times a week  | 27%         |
| 1–3 times a month   | 43%         |
| Less than 1 time a month  | 5%          |

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