EXPLORING THE EXTENT OF THE MARKET FOR U.S. MUSHROOM PRODUCTION EXPANSION

By

Aastha Pudasainee

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

Agricultural, Food and Resource Economics—Master of Science

2022

ABSTRACT

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This study focuses on U.S. consumer preferences for common mushrooms (*Agaricus bisporus*), specialty mushrooms, and morels (*Morchella* spp.). It analyses consumer preferences for mushrooms by demographic group at national and regional scales. Instead of focusing on the entire U.S. mushroom market, prior studies have focused on consumer preferences and market segments for organic, genetically modified, and local mushrooms, dealing with one or few types of mushrooms. Previous studies discuss a few aspects of the wild supply chain, but the potential for niche mushrooms remains understudied. I pay special attention to wild mushrooms and their supply chain, as they are increasingly popular, though only a few edible mushrooms are successfully cultivated. I conducted a nationwide online of primary shoppers in U.S. households. My descriptive statistical analysis suggests that with better information on potential buyers, mushrooms could be an important enterprise for growers. As nearly half of U.S. households purchase mushrooms in a typical year at a restaurant or to be consumed at home (49.0%), versus only (31.6%) who do not, there is great potential to expand the market. If new mushroom species can be cultivated in the U.S., specialty mushroom producers may wish to target the 18 to 24 age group nationally, the 55 to 64 age group in the West, African Americans from the South, and higher income and educated purchasers nationally. The value added by this study is that consumer preferences of morels versus other specialty mushrooms were analyzed to know its market extent which can help to assess the potential market segments, the scope of cultivation expansion, and preferences for additional wild mushroom species like morels.

Dedicated to my parents, Shreeram Pudasainee and Gita Pudasainee,
and my brother Aashish Pudasainee

ACKNOWLEDGMENTS

First and foremost, I am extremely grateful to my esteemed advisers Profs. Scott M. Swinton and Trey Malone for their invaluable advice, continuous support, and encouragement during my master's study. I want to thank the chair of my thesis guidance committee, Dr. Trey Malone for providing input, solid framework, and feedback on my thesis. I am thankful to Prof. Scott M. Swinton, who has the substance of a genius, Chairperson of the Department of Agricultural, Food, and Resource Economics (AFRE) for highlighting core economics concepts and providing valuable comments and a structure for my thesis. I want to thank Prof. Gregory Bonito for his input regarding the technical aspects of mushrooms and for insightful feedback on my thesis. I am overwhelmed in all humbleness and thankfulness to acknowledge them for providing their valuable contributions and hard questions in the thesis.

I want to thank all the respondents of the survey who took out their valuable time and provided their information. I want to thank the resource people of Michigan State University (MSU) Writing Center for their invaluable feedback and comments on my thesis. I am grateful for the funding sources that allowed me to pursue my master's studies at MSU. I am also highly thankful to be a part of the North Central Region, SARE project which is about cultivating the morel mushroom industry in the North-Central United States. I want to thank Prof. Nicole Mason-Wardell, the Graduate Program Director for her administrative and other support. I am grateful to all the professors and staff of the department for all kinds of support. I want to thank all my colleagues at AFRE who always responded to me when I had queries. I'm grateful to my father, Shreeram Pudasainee, my mother, Gita Pudasainee, and my brother, Aashish Pudasainee, for their love and support. Lastly, I want to thank all of them who have helped me directly or indirectly.

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KEY TO ABBREVIATIONS

CI Confidence Interval

GMO Genetically Modified Organisms

MT Million Tonnes

SE Standard Error

USDA United States Department of Agriculture

WTP Willingness to Pay

1. INTRODUCTION

Though people have consumed mushrooms for centuries, advancements in mushroom cultivation have allowed for the development of a commercial mushroom industry only in the past few centuries (Chang 1999; Valverde, Hernández-Pérez and Paredes-López 2015). In the past half-century, there has been an especially sharp increase in mushroom consumption in the U.S. as per capita availability of mushrooms in the country increased from 1.3 pounds in 1970 to nearly 4 pounds by 2019 (Lucier et al. 2003; United States Department of Agriculture (USDA) 2020). Improvements in cultivation technology have created opportunities to expand mushroom production, but questions remain regarding the extent of the market.

Instead of focusing on the size and scope of U.S. mushroom markets, prior studies have focused on individual consumer preferences and market segments for organic, genetically modified, and local mushrooms (Chakrabarti, Campbell and Shonkwiler 2019; Onianwa, Wesson and Wheelock 2000). As mycological technology develops novel methods for cultivating unique mushroom cultivars, the current and future potential for niche mushrooms remains important, albeit relatively understudied.

My research uses a quantitative survey method and descriptive statistics to characterize the extent of the mushroom market within a representative sample of U.S. primary shoppers for their households. I pay special attention to wild mushrooms, as they are increasingly popular but only a few edible mushrooms are successfully cultivated (Farr 2018). This is particularly important as farm-cultivated mushrooms are considered more environmentally sustainable than wild-foraged mushrooms since wild foraging can increase pressure on wild mushroom ecosystems (Wendiro, Wacoo and Wise 2019).

The remainder of my thesis is organized as follows. The next section describes my conceptual framework, where I provide a background on the U.S. mushroom market with an emphasis on differences in consumer preferences. Second, I describe my survey methods, which involve descriptive statistics with data from 1,555 U.S. households. I used measures of frequency to calculate the percentage of respondents preferring different types of mushrooms. I then detail my results and characterize market segments in the U.S. mushroom market. I then conclude with a discussion of the implications of this study for the future development of additional mushroom species supply chains in the U.S. The questions that my study tries to explore are: 1) What is the scope and size of the U.S. mushroom market? 2) if new mushroom species can be cultivated in the U.S., which consumers would buy them?

1.1 Mushroom Supply Chains

In 2018, the global mushroom market was estimated to be worth 12.74 million tonnes (MT), and by 2026, it is expected to be worth 20.84 MT, growing at a compound annual growth rate of 6.41 percent (Market Intelligence Team 2020). Though edible mushrooms are harvested from the wild or cultivated, about two-thirds of *Agaricus bisporus* (common mushrooms like White button and brown strains, baby bella, and portabella) are commercially grown in Pennsylvania (O'Reilly 2016; USDA 2021). It is important to examine mushroom production in the United States in the direction of analyzing the market's potential for growth. Commercial production of mushrooms has occurred in the U.S. for over a century, initially developing in Kennett Square, Pennsylvania, at the beginning of the twentieth century due to abundant horse manure, the proximity of urban East Coast markets, and the existence of good transportation connection to those markets (Al-Bahadli and Al-Zahron 1991; Beyer 2003; Flammini 1999). The development of mushroom production in Kennett Square due to the existence of a good market is an important fact because

we can see a connection to how effective production and marketing could make Kennett Square a mushroom capital of the world (Figure A1, Section A). With a share of 16% of global output, the United States is currently the second-largest mushroom grower behind China which accounts for 32% of output (Lucier et al. 2003). It is important to explore how the entire U.S. can boost its marketing schemes for growers to increase profits, boost sales, and extend to more customers.

I go from top to bottom of the mushroom supply chains to understand the marketing extent of mushrooms in the U.S. (Figure A1). There are two supply chains of mushrooms, one is the supply chain of farmed mushrooms and the other one is the supply chain of wild mushrooms. Obtaining a pure mycelium of the chosen mushroom strain is the first step in the mushroom cultivation process. The mycelium grows on cereal grain such as millet, rye, or wheat, also known as spawn, once the grain is colonized, to produce inoculum. The needs for substrate preparation, inoculation, incubation, and production vary according to the variety of mushrooms that is to be grown (Sánchez 2004). Commonly cultivated *Agaricus* spp. i.e., *Agaricus bisporus* (e.g., "white button" and brown mushrooms like Crimini and Portabella) mushrooms and both wild-foraged and cultivated specialty mushrooms (Species other than genus *Agaricus*), e.g., shiitake (*Lentinula edodes*), oyster (*Pleurotus* spp)., chanterelles (*Cantharellus cibarius)* and morels (*Morchella* spp.) are increasing in popularity in the U.S. (The Packer 2017; USDA 2020). Though some *Agaricus* species like *Agaricus campestris* are harvested in the wild, *Agaricus bisporus* is commercially cultivated but specialty mushrooms come both from the wild and commercial cultivation (Bubueanu et al. 2015).

The development of a commercial mushroom industry and year-round availability of mushrooms in the U.S. is due in part to the adoption of novel cultivation mechanisms. New mushroom cultivation methods such as greenhouse farming, thermodynamically engineered

systems, computerized monitoring systems, and automated harvesting systems, have enabled mushroom growers, in high resource settings, to maximize production while minimizing cost due to economies of scale (Higgins et al. 2017; Lu et al. 2017). Here, economies of scale explain a situation where the average cost of producing mushrooms, falls as the quantity produced grows due to high-level technology. Cost minimization is an essential condition for profit maximization in competitive markets like that of the mushroom industry. Mushroom cultivation is labor-intensive, so the development of labor-saving automation might increase the economic potential for the industry (Barney 2000). New spawn culture techniques and substrate innovation have been effective in increasing yields (Sánchez 2004; Zhang et al. 2002). Biotechnological advances like the breeding of new strains, the development of the common white button mushroom to resist browning, CRISPR-Cas9-assisted functional gene editing, and many other advancements are developing the mushroom cultivation industry (Waltz 2016; Wang et al. 2020).

Despite advancements in mushroom cultivation, U.S. mushroom consumers often purchase imported products[1]. China is one of the leading exporters of mushrooms to the U.S. and the largest producer of cultivated mushrooms, cultivating a third of global production (Research and Markets 2020; Royse, Baars and Tan 2017). Outdoor cultivation is the norm in China, while most U.S. mushroom production occurs inside climate-controlled greenhouses (Grimm and Wösten 2018; Lambert 1967). Indoor cultivation is a higher-cost method with a higher yield, season independency, and a controlled environment while outdoor cultivation is typically a lower-cost

[1] Some U.S. mushrooms are also exported. In the years 2017-2021, the U.S. exported dried *Agaricus* mushrooms and fresh *Agaricus* mushrooms with a total volume of 885 thousand pounds and 15.5 million pounds respectively. U.S. exported fresh specialty mushrooms with a total volume of 2.08 million pounds which is about seven times less than that of fresh *Agaricus* mushrooms (USDA, 2022).

method with a lower yield and an uncontrolled environment that is season-dependent (Chen 2001; Shen et al. 2004).

I also try to explore the supply chain of wild mushrooms alongside the farmed mushrooms. Some species of mushrooms like chanterelles and morels are difficult to grow (Kaiser and Ernst 2016). Chinese growers have been successful in cultivating morels outdoors in recent years while in the U.S., growers are still trying to commercially cultivate morels successfully (Liu et al. 2018). Some previous studies have discussed the supply chain of wild-foraged mushrooms. The supply of wild mushrooms is higher during the harvest season than off-season as wild mushrooms in the U.S. harvest regions are seasonal (Schlosser and Blatner 1995). Malone et al. (2022) found that much of the wild mushroom gathering is a by-product of tourism or recreational activities enjoyed by visitors and the local community. The study determined that most foragers reported spending fewer than 10 days each year foraging. Since the foraging season is short, indoor greenhouse wild mushroom production can extend the season and fill a potential gap in the marketplace during the off-season (Benucci et al. 2019; Longley et al. 2019).

In North America, the Pacific Northwest (which includes Oregon, Washington, Idaho, Northern California, and Western Montana) and areas of the North Central United States, are the two regions where wild mushrooms are primarily harvested for commercial purposes (Malone et al. 2022; Pilz and Molina 2002). The wild mushroom gathering sector in the Pacific Northwest includes gatherers, purchasers, processors, and brokers. Finding and collecting mushrooms are the tasks of harvesters, also known as pickers. Buyers, regularly associated with a processor, buy mushrooms from harvesters, usually in a field close to where the mushrooms are being picked. Mushrooms are handled, cleaned, packed, and shipped by processors. Globally, brokers trade processed mushrooms (Pilz and Molina 1996). Wild mushroom foraging has a more complicated

supply chain because it is haphazard, unpredictable, inconsistent, and unsystematic compared to the supply chain of farmed mushrooms. It is a precarious supply chain without any guarantee of the supply chain flowing as wild mushrooms are seasonal. There is no guarantee of finding wild mushrooms even during the season. The wild mushroom supply chain may skip the processing step which gives a possibility of a lack of value addition resulting in low profit for wild mushrooms (Section B of Figure A1). Though farm-cultivated mushroom supply chains are longer, they are also more systematic and consistent as seen in section A of Figure A1. Both the supply chains remain separate in the initial stages of production. Products of both the chains tend to be interlinked at the final distribution and retail levels as seen in Figure A1.

Many mushrooms found in the wild need a certain mix of environmental factors to thrive and spread (Beetz and Greer 1999). Wild mushrooms have a premium price because they are prized seasonal delicacies with inadequate production. Prices are highest in winter during periods of low supply and lowest in summer during periods of high production (Beetz and Kustudia 2004). Expanding cultivation of specialty mushrooms helps to decrease their price and fulfill the rising popularity of specialty mushrooms (The Packer 2017). In the U.S., mostly specialty mushrooms like shiitake and oyster are grown in natural outdoor logs, indoors, and in synthetic media (USDA 2021). Specialty mushroom production is decreasing in natural wood outdoor logs and increasing in indoors and other synthetic production media (Figures D1, D2, and D3, Appendix D). The price of specialty mushrooms is seen to be decreasing due to higher production caused by growing on synthetic media as seen in Figures F1 and F2, Appendix F.

Some studies have discussed production aspects of cultivated specialty mushrooms like shiitake. Specialty mushrooms like shiitakes grown on logs may develop into a separate niche market with premium mushrooms because they are of better quality. Additionally, shiitake

mushrooms that are cultivated on logs may have a longer shelf life than those that are mass-produced and grown on sawdust substrates (Beetz and Greer 1999). Shiitake mushroom growers may harvest the mushrooms all year round and create three to four times the yield using synthetic logs in only a tenth of the time needed with real logs (Barney 2000). When using readily available resources and needing little upfront expenditure, shiitake mushroom cultivation on logs might generate additional revenue (Gold et al. 2008). The next question will be whether cultivated specialty mushrooms can be commercially successful. The answer depends in part on the existing market for wild–foraged mushrooms. Like morels, chanterelles and oysters grow in the wild and are gathered and sold at farmers' markets or retail stores (Fewell and Gustafson 2007; Wurtz et al. 2005). Malone et al. (2022) found that most foragers sold their morels fresh. The study discovered that foragers sell mostly to local restaurants, and informally to hunters' friends. It was found that a smaller number of foragers sell at farmers' markets, online, and at regional grocery stores.

1.2 Production, price, and market sales differences

It is also important to understand the production, price, and market sales differences between commercial *Agaricus bisporus* and specialty mushrooms to dissect the mushroom markets properly (Figure A1, Section C). Compared to the leading segment, *Agaricus bisporus* mushrooms, the price per pound of specialty mushrooms is three times higher as seen in Figure F2 (USDA 2021). The longer period needed to develop specialty mushrooms compared to *Agaricus bisporus* mushrooms and the requirements of controlled production processes could both contribute to this price differential, as could the perception of specialty mushrooms as a higher-end product, which would justify a higher price (Chakrabarti et al. 2019). The value of sales of *Agaricus bisporus* mushrooms increased from 2008 to 2016 but is decreasing since 2016 as seen in Figure F3. The yield of *Agaricus bisporus* mushrooms has increased from 2008 to 2018 but has decreased from

2018 to 2021 (USDA 2017). We can see that the price per pound of *Agaricus bisporus* mushrooms is increasing, suggesting a low supply growth due to decreased yield (Figure F2). The price per pound of specialty mushrooms is decreasing over the years 2016 to 2021. The decrease in price may in part be due to the higher production of specialty mushrooms caused by an increase in the growth of these mushrooms in synthetic media (Figure F1).

The market value of specialty mushrooms remained flat between 2008 and 2021 (Figure F3). Contrary to specialty mushroom producers, *Agaricus bisporus* growers frequently have high production levels and substantial expenditures on technology and infrastructure that are geared toward mass markets (Barney 2000). Improvement of the value chain from producer to end-user, without any connections between the producers and the consumers, is their primary commercial objective. These businesses have an edge over smaller businesses since they already have the production facilities and supply networks in place (Gold et al. 2008). Thus, the supply chain of farmed *Agaricus bisporus* mushrooms is consistent while the supply chain of farmed specialty mushrooms is still not developed properly.

The total production of specialty mushrooms increased from 2008 to 2021 as seen in Figure F1. A likely reason is that larger companies are growing *Agaricus bisporus* mushrooms, and smaller mushroom growing enthusiasts are unable to enter the *Agaricus bisporus* industry. Consequently, they turn to the production of specialty mushrooms because they cannot compete with larger *Agaricus bisporus* mushroom growing companies. The production of specialty mushrooms such as shiitake and oyster has risen faster than *Agaricus bisporus* mushrooms in the U.S. (Fewell and Gustafson 2007). Large *Agaricus bisporus* mushroom growing companies have started growing specialty mushrooms as well (Beetz and Greer 2004). *Agaricus bisporus* and specialty mushroom production in the U.S. tends to be consolidated and vertically integrated

(Garcia 2005). Thus, the number of *Agaricus bisporus* mushroom growers is decreasing and getting bigger. (Barney 2000; USDA 2017). Growers of specialty mushrooms range in size from small ventures of a few logs to large corporations with hundreds of thousands of logs, and many specialty mushrooms are grown on nutrient blocks (Anderson and Marcouiller 2004; Chen 2001). The steady production of specialty mushrooms by a varied range of suppliers may also have resulted in the lowering of the price of specialty mushrooms. An increased range of cultivators for specialty mushrooms from large farms to small and large operations creates competition, meaning that growers must carefully consider and manage marketing.

Agaricus bisporus mushroom production is labor-intensive and necessitates more advanced equipment than a small or beginning producer could afford. Economies of size prevent smaller producers from producing *Agaricus bisporus* mushrooms because the average cost per unit of production increases as the size of the farm decreases. Specialty mushrooms can be grown easily by a beginner producer without requiring a lot of labor or complicated equipment (Fewell and Gustafson 2007). This indicates the opportunity for specialty mushroom production and future development of additional species supply chain in the U.S. (Fewell and Gustafson 2007). Other considerations that may deter some people from launching a shiitake mushroom business include the demanding work needs, commitment to production and marketing, and competition from foreign and sawdust-grown shiitake mushrooms (Gold et al. 2008).

1.3 Marketing of Specialty Mushrooms

The marketing of *Agaricus bisporus* mushrooms is much simpler due to mass marketing by large companies. Some studies have investigated the marketing of specialty mushrooms like shiitake. In northern Alabama, shiitake mushrooms rank third in terms of retail sales, behind only white button and portabella mushrooms and ahead of oyster and enoki mushrooms. Most retail outlets

prefer small to big packages, and supermarkets and specialty shops in densely populated areas are more likely to have specialty mushrooms like shiitake. Very few stores get their supply of shiitake mushrooms from a local source, indicating a deviation from niche marketing. When retailing, shiitake mushrooms, quality is the most important criterion considered by retailers, followed by freshness, price, color, and quantity (Onianwa, Wesson and Wheelock 2000).

According to a study by Gold et al. (2008), most vendors (81 %) sell shiitake mushrooms locally, followed by regionally (39 %), nationally (14 %), and globally (3 %). The primary markets for shiitake mushrooms are fine dining establishments, farmers' markets, and on-farm stores. Businesses develop competitive advantages through quality, customer service, and reliable supply to survive in the market. Among the numerous away-from-home outlets, the regular full-service restaurant market was the most popular (Lucier et al. 2003). The retail, wholesale, food service, and consumer segments are all seeing an increase in demand for shiitake mushrooms. Health food stores (39%), luxury shops (25%), wholesalers (25%), and distributors (25%), among other market outlets, are less popular (25 %). Only 14% of retailers have online sales, despite the internet's enormous popularity as a tool for marketing (Gold et al. 2008) (Figure A1, Section C).

1.4 Consumer preferences for Agaricus bisporus versus specialty mushrooms

A few studies have discussed factors that might determine mushroom-consuming behavior. Females, people between 20 and 39 years old, Asians and non-Hispanic whites, people from the West and Midwest, consumers who are college graduates or above, and higher-income groups, were the strongest consumers of mushrooms (Ba et al. 2021; Lucier et al. 2003). Some studies have discussed the factors determining consumer preferences by focusing on specialty mushrooms like *Pleurotus eryngii* (king oysters). According to Shadlousofla (2021), the consumption of king oyster mushrooms was positively influenced by several variables, including pre-and post-cooking

appearance traits, food and medicine awareness, sales promotion, product accessibility, and mushroom familiarity.

Chakrabarti et al. (2019) determined market segments based on Connecticut consumers' preferences and willingness to pay for popular *Agaricus bisporus* (White button, Baby Bella, and Portabella) and specialty mushrooms (Shiitake). They also scrutinized the drivers of these consumers' demands. Three classes were determined: a) Price and Genetically Modified Organisms (GMO) sensitive class; b) Labeling Oriented Class, which showed a preference for organically grown labels compared to no label and c) Class three consumers which showed a preference for traditional mushrooms like portabella and baby Bella mushrooms. Class two consumers were willing to pay a premium for "Local" or "Organic" labels and more premium for "Local" labels. Moreover, the "Non-GMO" label had no impact on consumers' choice of mushrooms as compared to "No Label".

1.5 Mushroom attributes and processing of mushrooms

Consumers value different mushroom types based on their attributes like whether they are organic, fresh, or processed. Organic mushroom demand is increasing. Certified organic mushroom growers have increased from 2008 to 2021 and in the year 2021, 131 million pounds of certified organic mushrooms were produced by growers. *Agaricus bisporus* mushrooms accounted for 92 percent of the mushrooms sold as certified organic, and specialty mushrooms made up the remainder (Batte et al. 2007; USDA 2021). Mushrooms have a low shelf life and are traded worldwide in processed forms like frozen, canned, pickled, and dried which increases shelf life, adds value, and shipping distance (Jahan and Singh 2019).

Processing of mushrooms is also an oversupply remedy (Bachtel, Tinsley and Porter 2002). *Agaricus bisporus* mushrooms are sold mostly in fresh and processed forms, with 91%

of *Agaricus bisporus* mushrooms sold in fresh form while the remaining 9% sold in processed form from 2020-2021. Most cultivated specialty mushrooms are sold fresh (USDA 2021). Most processed mushrooms are sold in canned form, with frozen and dehydrated goods making up a smaller portion of sales. Fresh mushrooms are less frequently eaten at home than processed mushrooms. Frozen mushrooms are frequently used in restaurant chains, although more frozen mushroom items are sold in stores (Lucier et al. 2003). The market for processed mushrooms may have potential if effective marketing tactics are used, as the percentage of prospective consumers for processed mushrooms is higher than that for fresh mushrooms (Jiang et al. 2017).

Previous studies have focused on the demographic attributes of mushroom consumers versus non-consumers (Jiang et al. 2017; Lucier et al. 2003). My study contributes to the literature by exploring the attributes of U.S. mushroom purchasers, comparing the demographic attributes of *Agaricus bisporus* versus specialty mushroom purchasers, and purchasers of morels versus other specialty mushrooms. It also analyses mushroom preferences within each region and differences in demographic attributes of specialty mushroom purchasers within each region of the U.S. Previous studies only discussed consumer market segments based on preferences for genetically modified, organic mushrooms and local mushrooms (Chakrabarti et al. 2019). Some studies focused on market studies and factors affecting consumer preferences for common mushrooms like *Agaricus bisporus* mushrooms, and specialty mushrooms like shiitake, or oyster (Chakrabarti et al. 2019; Gold et al. 2008; Onianwa et al. 2000; Shadlousofla et al. 2021). Research on wild *Agaricus* spp. is, however, an open gap that needs to be studied.

My study focuses on market segments based on their preferences for the total mushroom industry including *Agaricus bisporus* versus specialty mushroom purchasers along with morels versus other specialty mushrooms purchasers. Few studies have discussed the marketing aspects

of the wild supply chain (Fewell and Gustafson 2007; Wurtz et al. 2005). My study considers the possible tradeoffs between farm-raised and wild foraged mushrooms discussing the necessity of farming specialty mushrooms. It discusses the differences in the supply chain of wild and farmed mushrooms to effectively learn about the two markets. Morels are emerging and popular wild mushrooms and their cultivation process is being tried out in the U.S. (Liu et al. 2018; The Packer 2017). It is important to figure out the consumer preferences of morels versus other specialty mushrooms to know its market scope which can help to assess the potential market segments and preferences for additional wild mushroom species like morels. My study provides an assessment of the size and scope of US mushroom markets.

2. SURVEY INSTRUMENT

In collaboration with Malone and Quintero (2022), I designed a survey to characterize the mushroom preferences of U.S. primary shoppers for their households based on their demographic attributes. I conducted a nationwide online survey from January 28, 2022, to February 25, 2022. The survey was developed in Qualtrics® and distributed to an online panel of U.S. primary shoppers for their households. Respondents were also required to complete all survey sections to be considered in the final analysis. The survey was organized into two sections, the first related to demographics and the second dedicated to consumer behavior regarding mushroom consumption.

In the first section of the survey, I gathered information on respondents' socio-demographics to better characterize and highlight differences between sample versus U.S. population, mushroom purchasers versus non-purchasers, *Agaricus bisporus* versus specialty mushroom purchasers, morel versus other specialty mushroom purchasers. I gathered information on their characteristics such as age, gender, income, education, as well as where respondents lived, and their race and ethnicity. At the end of the survey, I asked respondents about the mushrooms they purchase at home or in restaurants. I included different *Agaricus bisporus* mushrooms like buttons, creminis, portobellos, and specialty mushrooms like morels, oysters, chanterelles, and shiitakes in the survey to determine their preferences for various categories of mushrooms. Purchasers of mushrooms like buttons, creminis, and portobellos were *Agaricus bisporus* mushroom purchasers and purchasers of morels, oysters, chanterelles, and shiitakes were specialty mushroom purchasers. For example, to be a morel mushroom purchaser the respondent needed to purchase morels at restaurants or for consumption at home.

My sample was designed to be stratified by region which means that the percentage of the sample population in each region matches the percentage of people living in each region of the

country. The percentage of survey respondents from the South was similar to the percentage of Americans who live in the south, the percentage of survey respondents from the Northeast was similar to the percentage of Americans who live in the Northeast, and so on. It was important to stratify by regions to have representative respondents from each geographical region of the U.S. In the general U.S. population, according to the 2020 census, 23.7% of people were from the West, 20.8% people were from the Midwest, 17.4% of people were from the Northeast and 38.1% of people were from the South. In my sample, 20.8% of respondents were from the West, 20.8% of respondents were from the Midwest, 20.7% of respondents were from the Northeast and 20.8% of respondents were from the South. I divided the sampling frame of U.S. primary shoppers of households into each stratum based on region, analyzed mushroom preferences within each region and determined differences in demographic attributes of specialty mushroom purchasers within each region.

A series of samples drawn from one population will not be identical. They will show chance variations from one to another, and the variation may be slight or considerable. The variation may be due to the difference in the sample populations, or it may be due to chance. A technique of comparing differences in proportions can be used to determine if the two estimated proportions are different (Altman and Bland 2003). To compare differences in proportions, a hypothesis test can help determine if a difference in the estimated proportions reflects a difference in the population proportions. A null hypothesis states that the two proportions p_A and p_B are the same i.e. $H_o: p_A = p_B$ or $p_A - p_B = 0$ (Any difference in proportion is due to chance) and the alternative hypothesis states that the two sample proportions are different (The difference in the sample populations is not due to chance) i.e. $H_A: p_A \neq p_B$ or $p_A - p_B \neq 0$. We need a significance test to

verify that the difference is too large to not easily result from the role of chance in choosing the sample.

I assume a normal distribution for the sampling process. The central limit theorem states that the sampling distribution of a statistic (sample mean, sample proportion, etc.) will be normal or nearly normal if the sample size is large enough. There are two ways of calculating the standard error of the difference between two percentages: one is based on the null hypothesis that the two groups come from the same population with the formula:

$$SE_{(Difference)} = \sqrt{\frac{p(100-p)}{n_1} + \frac{p(100-p)}{n_2}}$$

where p is the common population proportion. The alternative hypothesis is that the proportions are different with the formula:

$$SE_{(p_1-p_2)} = \sqrt{\frac{p_1(100-p_1)}{n_1} + \frac{p_2(100-p_2)}{n_2}}$$

For normally distributed variables, these two are the same, so I used the formula based on the alternative hypothesis that the two groups come from different populations to calculate the standard error of the difference between two percentages.

I calculated the difference between two percentages (d) for comparison. To determine if the difference is of any significance, I calculated the standard error (SE) of two proportions, summed the squares of the individual standard errors, and then took the square root. If the proportion of sample 1 is p_1 and sample 2 is p_2 and the number of observations of sample 1 is n_1 and sample 2 is n_2,

SE of sample proportion = $\sqrt{\frac{p_1(100-p_1)}{n_1}}$ and $\sqrt{\frac{p_2(100-p_2)}{n_2}}$

I assumed that the two samples were independent while determining the standard error. n can vary due to different response rates for different variables. That is the reason for not using the same n. When two samples are independent of each other, the standard error for a difference between two sample proportions is:

$$SE_{(p_1-p_2)} = \sqrt{\frac{p_1(100-p_1)}{n_1} + \frac{p_2(100-p_2)}{n_2}}$$

I determined the confidence interval for hypothesis testing using the following formula

Confidence Interval (CI) = difference ± (z) * SE

where z is z-score. z is 1.96 at a 95% confidence level. The confidence level describes the uncertainty of a sampling method. It is useful in capturing the true difference of proportions in the intervals. If the value of the parameter specified by the null hypothesis is contained in the 95% interval (In our case "0"), then the null hypothesis cannot be rejected at a 5% level of significance. If the value specified by the null hypothesis (0) is not in the interval, then the null hypothesis can be rejected at a 5% level of significance (Swinscow and Campbell 2002). To determine whether the difference between more than two proportions is statistically significant, I compared the confidence intervals for those groups (Table B5 and B6). If those intervals overlap, we conclude that the difference between groups is not statistically significant (Greenland et al. 2016)

My survey sampled just 1,508 responses from the U.S. population of 330 million. It is natural that there will be sampling error which means that the sample percentages will not be identical to population-level percentages. I determined the confidence limits for percentages of the total sample of household respondents. There might be sampling error in sample groups versus the total sample as well. I determined the statistical confidence limits for percentages of total purchasers of all mushrooms, non-purchasers of mushrooms, purchasers of *Agaricus*

bisporus mushrooms, specialty mushrooms, morels, and other specialty mushrooms. I also determined the confidence limit for percentages of purchasers based on the demographic attributes of sample groups (Agresti and Coull 1998).

The formula I used to determine the CI was:

$$CI = \hat{p} \pm z^{*} \sqrt{\frac{\hat{p}(1-\hat{p})}{n}}$$

z^{*}=1.96 for 95% confidence interval

n= Total number of people in the sample

$\hat{p}$= Sample proportion

3. RESULTS

In my survey, 1,555 responses were collected. The incomplete responses were removed, and this screening process led to 1,508 valid responses. My sample was representative of all U.S. primary shoppers for their households. I compared the demographic attributes of the sample population with the U.S. population and mushroom purchasers with the non-purchasers of mushrooms. Then I compared, *Agaricus bisporus* (white button, portobellos, and cremini) versus specialty mushrooms (morels, shiitake, oyster, and chanterelles), and morel versus other specialty mushrooms (shiitake, oyster, chanterelles) purchasers. After dividing the sampling frame into strata based on region, I analyzed the preferences of mushrooms and the differences in demographic attributes of mushroom purchasers within each region.

3.1 Comparison of demographic attributes of different groups of mushroom purchasers

Forty-nine percent with a 95% confidence interval (CI) [46.5, 51.5] of respondent households purchase mushrooms in a typical year at a restaurant or to be consumed at home and 31.6% of respondents with a 95% CI [29.2, 33.9] do not purchase mushrooms in a typical year at a restaurant or to be consumed at home (Table B2). We can see that there were a greater number of participants who purchase *Agaricus bisporus* mushrooms (43.4%) with 95% CI [40.9, 45.9] rather than specialty mushrooms (24.5%) with 95% CI [22.3, 26.6] (Table B3). Around 7.8% with 95 % CI [6.5, 9.2] of the sample purchase morels rather than other specialty mushrooms (21.2 %) with 95% CI [19.2, 23.3] (Table B4).

We can see that most of the principal shoppers from respondents' households were females (55.0%) with 95% CI [52.5, 57.5] (Table B1). There was no statistical difference in percentages in the two samples for females who purchase and do not purchase mushrooms (56.7 % versus 60.3%) d= -3.6 % with 95% CI [-9.3, 2.1] (Table B2). There was no statistical difference in

percentages in the two samples for females who purchase *Agaricus bisporus* and specialty mushrooms (57.7 % versus 55.6%) d= 2.2 % with 95% CI [-4.2, 8.5] (Table B3). There was no statistical difference in percentages in the two samples for females who purchase morels and other specialty mushrooms (51.7% versus 55.3%) (d=-3.6 %) with 95% CI of [-14.2, 6.9] (Table B4).

In my sample, there were more respondents in the 55-64 (29.3%) years of age group than in other age groups with a 95% CI of [27.0, 31.6] (Table B1). People from the 18 to 24 age group tended to prefer purchasing mushrooms over not purchasing them (16.8% versus 11.3%). People from the 55 to 64 age group tended to not purchase mushrooms over purchasing them (38.0% versus 33.7%) (See Table B2). People from 18 to 24 years of age tended to prefer specialty mushrooms over *Agaricus bisporus* mushrooms (22.0% versus 15.7%). People from the 55 to 64 age group tended to prefer *Agaricus bisporus* mushrooms over specialty mushrooms (34.8% versus 23.8%) (Table B3). There was no statistical difference in percentages in respondents age groups from 18 to 64 years preferring morels versus other specialty mushrooms (Table B4).

With respect to ethnic backgrounds, my sample population was predominantly Caucasian (76.5%) with a 95% CI of [74.4, 78.6]. There was no statistical difference in percentages among various races of respondents purchasing mushroom over not purchasing them. Caucasians tended to purchase *Agaricus bisporus* mushrooms over specialty mushrooms (76.8 % versus 66.1%). African Americans tended to prefer specialty mushrooms over *Agaricus bisporus* mushrooms (15.2% versus 9.9%) (Table B3). There was no statistical difference in percentages among racial or ethnic groups like Black or African American, Hispanic/Latinx/Chicanx, Asians, and other races preferring morels versus other specialty mushroom purchasers (Table B4).

In my sample, there was a greater percentage of respondents with lower incomes ranging from $20,000 to $39,999 (24.4%) with a 95% CI of [22.2, 26.6] as compared to other income

groups (Table B1). It was found that the percentage of mushroom purchasers increased as income increased (Table B2). There was no statistical difference in percentages among income ranges of respondents preferring *Agaricus bisporus* versus specialty mushrooms (Table B3). There was no statistical difference in percentages among income ranges of respondents preferring morels versus other specialty mushrooms (see Table B4).

A greater percentage of my sample population had completed bachelor's level and graduate level education, as compared to the U.S. population (41.7% versus 16.9%) and (19.2% versus 9.6%) (see Table B1). Compared with the non-purchasers, mushroom purchasers had higher levels of university education. Among mushroom purchasers, 42.9% had bachelor's degrees compared to 24.2 % in the mushroom non-purchasing population (see Table B2). Likewise, 20.4% of mushroom purchasers had graduate degrees compared to 9.9 % with graduate degrees in the mushroom non-purchasing population (See Table B2). Purchasers of both *Agaricus bisporus* and specialty mushrooms had similar education levels (Table B3). Purchasers of both morels and other specialty mushrooms had similar education levels (Table B4).

3.2 Region-wise mushroom preferences

Comparison across the four geographic regions of the United States reveals few significant differences in the preferences of mushroom purchasers (Table B5). There were no statistical differences in percentages of people purchasing and not purchasing mushrooms in the four regions of the U.S. Analyzing the types of mushrooms purchased by region (Table B5), in the West region, 57.5% of respondents purchase *Agaricus bisporus* mushrooms, 32.9% of respondents purchase specialty mushrooms, 30.7% purchase specialty mushrooms other than morels, and 8.3% purchase morel mushrooms. Among respondents from the Midwest, 51.8 % purchase *Agaricus bisporus* mushrooms, 25.2% purchase specialty mushrooms, 18.8% purchase specialty

mushrooms other than morels, and 11.5 % purchase morel mushrooms. Among respondents from the Northeast, 51.9 % purchase *Agaricus bisporus* mushrooms, 29.2% specialty mushrooms, 26.6% purchase specialty mushrooms other than morels, and 7.1 % purchase morel mushrooms. Among respondents from the South, 48.1 % purchase *Agaricus bisporus* mushrooms, 30.6 % specialty mushrooms, and 26.1% purchase specialty mushrooms other than morels, and 10.8 % purchase morels. There was no difference in people purchasing specialty mushrooms in the four regions of the U.S. Likewise, there were no differences in preferences for specialty mushrooms other than morels with one exception: Households in the West were more likely to purchase specialty mushrooms other than morels (30.7%) CI [25.6, 35.8] than were households in the Midwest (18.8%) [14.5, 23.2] (see Table B5).

3.3 Demographic attributes of specialty mushroom purchasers within each region

Comparison across the four geographic regions of the United States reveals few significant differences in the demographic traits of specialty mushroom purchasers (Table B6). Two differences, however, do stand out. First, among specialty mushroom purchasers in the 55- to 64-year-old age group, those from the West made were more likely to purchase (13.1 %) CI [9.4, 16.8] than those from the other regions. Second, comparing specialty mushroom purchasers across regions by race, African Americans from the West were less likely to make purchases (2.2) % CI [0.6, 3.9] than African Americans from the South (7.3%) CI [4.4, 10.2] (see Table B6).

4. DISCUSSION

My study provides some baseline information regarding differences in demographics of U.S. mushroom consumers. Some limitations remain. For one, this study has focused on the basic extent of the market but omitted preference differences between fresh and processed mushrooms. Processed mushroom markets might respond differently. Figure E3 Appendix E displays the price ratio between fresh and processed *Agaricus bisporus* mushrooms from 2008 to 2020. It shows that the price ratio between fresh and processed *Agaricus bisporus* mushrooms has been constant over these years. There is a greater market sales value of fresh *Agaricus bisporus* as compared to processed *Agaricus bisporus*, indicating a bigger market for fresh *Agaricus bisporus* mushrooms (USDA 2021). Further studies can study the demand, scope, economic value, and required marketing innovations of processed *Agaricus bisporus* as compared to fresh *Agaricus bisporus* mushrooms considering their perishability, cost of climate control, and handling (Figures E1 and E2).

Outside of the outdoor mushroom gathering season, only dried specialty mushrooms would be commonly sold in the past, but now due to the season-independent indoor cultivation of mushrooms, fresh specialty mushrooms are also commonly sold in the market. There is an advantage to poor-quality mushroom slices being dried and sold in the market. Since the drying process extracts the superior umami flavor by breaking down proteins into amino acids, many people prefer dried shiitake to fresh (García-Segovia et al. 2011). In addition, fresh morels are sold at $35-37 per pound while dried morels are sold at $130-140 per pound (Malone et al. 2022). The prices of dried specialty mushrooms can be much higher than the same weight of fresh specialty mushrooms. However, a producer gets less value for dried specialty than fresh specialty due to the cost of drying mushrooms and losing substantial water weight in fresh mushrooms. For every

pound of dried morels, eight to ten pounds of fresh morels are needed (Wurtz and Wiita 2004). While a consumer needs to pay a higher amount for the same weight of dried mushrooms, a producer gets a lower value for dried mushrooms in compensation for his/her higher cost of drying, the use of more fresh mushrooms, and losing water weight. This is an amusing paradox, so future studies can determine differences in markets, preferences, and scope for fresh/ processed *Agaricus bisporus* and specialty mushrooms.

Aiming focus on niche marketing of fresh wild mushrooms is important as the low shelf life of specialty mushrooms does not allow for long transportation for marketing. As foragers and log-based specialty mushroom growers fear competition from synthetic media-based growers and imported mushrooms, it is better if certain local fresh wild-foraged mushrooms and locally log-grown specialty mushrooms could effectively create or maintain their niche market segment, and not enter the market integration that most specialty varieties will enter with mass-produced and imported production. It is important for mushrooms to go through all the steps of the supply chain and remain fresh till it gets to the consumers. Developing a niche market is the best alternative for small mushroom producers which can provide them with an increased producer share of consumer end prices. The best chance for profitability is to sell directly to neighborhood supermarkets, farmers' markets, or other retail establishments by eliminating intermediaries. A producer could benefit from having a market for their product by joining a cooperative or other organization that cultivates mushrooms (Fewell and Gustafson 2007). In this digital age, many growers can sell their crops via online commodity marketing (Fewell and Gustafson 2007). Adopting these tactics can be a special plus to the local grower who markets directly and can consistently deliver a fresh, high-quality product.

Our study indicates several important directions for future studies. For one, there may be a gap in consumer willingness to pay (WTP) for farm-cultivated and wild-foraged mushrooms. Though no prior studies have explored differences in WTP between farm-cultivated and wild-foraged mushrooms, a robust literature has explored a similar WTP gap in fish markets (Claret et al. 2014; Davidson et al. 2012; Menozzi et al. 2020; Verbeke et al. 2007). As farmed fish are usually cheaper than wild fish, people may suppose that they are of lower quality (Claret et al. 2012). The data reveal that wild-caught fish receive higher premiums than farm-raised alternatives due to the wildness factor in fish leading to perceived superior quality, healthy, freshness, safety, and reliability (Claret et al. 2014; Menozzi et al. 2020; Verbeke et al. 2007). Fish farming, according to Verbeke et al. (2007), is more controlled than wild fisheries because farmers may alter the diets of farmed fish, get rid of dangerous contaminants, and adjust the fish's composition using sound site evaluation techniques. Farmers have a competitive advantage over fishers in terms of product availability because they have more control over the timing, season, consistency, and quantity of output.

Mushroom consumers may have prior assumptions about cultivated versus wild mushrooms. With consumers' limited knowledge of mushroom systems, consumers might believe that wild mushrooms are healthier, fresher, tastier, and safer. Farmed mushrooms are grown in different synthetic media and artificial substrates and people may think that farmed mushrooms are not safe. There is likely a price-quality paradox that due to the lower price, people assume that farmed mushrooms are of low quality. Thus, the general lack of substitutability between farmed and wild-caught products can be explained. So, future studies can assess substitutability between farmed and wild mushrooms and determine the gap in willingness to pay for farmed versus wild mushrooms.

Future studies might also consider consumer distrust of novel food production technology and determine people's distrust for indoor and synthetic mushroom cultivation (Galanakis 2019); McFadden and Lusk 2016). Consumers who had more objective knowledge and a higher degree of education were often more willing to accept scientific data and, as a result, more inclined to make better judgments (Claret et al. 2014). In this sense, the design of effective information strategies about farmed mushrooms and their production system might help to increase their image and acceptance. The goal would be to provide consumers with information that helps them to value the novel methods of mushroom cultivation based on objective facts and not on preconceived ideas or unfounded beliefs. So, future studies can analyze whether the consumers will increase trust in farmed specialty mushrooms if they are provided better information regarding mushroom cultivation methods.

Future studies might consider information campaigns about how to prepare and consume different types of mushrooms. Some other factors which are pushing the growth graph of the market are the changing preferences of customers toward adopting vegan food and the rising demand for meat substitutes in the market (Ismail et al. 2020). Increasing vegan/vegetarian culture is creating demand for meat substitutes. As a result, *Agaricus bisporus* and specialty mushrooms are gaining popularity due to their high protein content.

Specialty mushrooms have a better scope for production expansion and marketing than *Agaricus bisporus* mushrooms because of the ease of cultivation, fewer production technology requirements for an aspiring producer, and growing popularity of specialty mushrooms (Fewell and Gustafson 2007, The Packer 2017). This gives an opportunity for mushroom-growing enthusiasts to cultivate specialty mushrooms and diversify cultivation with additional species of mushrooms. Specialty mushrooms market value is flat, and the market sales value of *Agaricus*

bisporus is also decreasing (Appendix F, Figure F3). Future studies would benefit from a more comprehensive focus on the price elasticity of demand for different types of mushrooms to inform marketing efforts and to know about their market demand and sales. One of the reasons why market sales value usually declines is when we are not keeping up with new marketing trends. Specialty mushrooms have a large range of producers, so there is producer competition when producers need to compete by lowering prices. Price competition can be lowered by finding new markets and developing unique products. There is no consistent marketing or supply chain for cultivated specialty mushrooms like that of the large farms of *Agaricus bisporus* mushrooms. Evidence suggests that with better information on market outlets and potential buyers, specialty mushrooms could be an important alternative enterprise for farmers.

Innovative and distinct marketing solutions need to be developed depending on different types of mushrooms based on production methods and forms. *Agaricus bisporus* mushroom stakeholders need to further develop their production levels and mass marketing schemes. My sample had (49.0 %) of respondents preferring to purchase mushrooms over not purchasing mushrooms (31.6 %). My sample had (43.4 % of respondents preferring *Agaricus bisporus* mushrooms over specialty mushrooms (24.5 %). Furthermore, my sample had (7.8 %) of respondents preferring morels over other specialty mushrooms (21.2%). People from 18 to 24, higher income groups, and people with bachelor's and graduate level education tended to purchase mushrooms over not purchasing them. People from 55 to 64 tended to not purchase mushrooms over purchasing them. People from the 18 to 24 age group, and African Americans, tended to prefer specialty mushrooms over *Agaricus bisporus* mushrooms. People from 55 to 64 age group and whites tended to prefer *Agaricus bisporus* versus specialty mushrooms. Among specialty mushroom purchasers in the 55- to 64-year-old age group, those from the West made were more

likely to purchase than those from the other regions. African Americans from the West were less likely to make specialty mushrooms purchases than African Americans from the South. There was no statistical difference in percentages of demographic attributes of respondents preferring morels versus other specialty mushrooms.

As my sample is representative of U.S. primary shoppers for their households, a large consumer base shows that there is a potential to expand the U.S. mushrooms market. If new mushroom species can be cultivated in the U.S., specialty mushroom producers may wish to target the 18 to 24 age group nationally, the 55 to 64 age group in the West, African Americans in the South, and higher income and educated purchasers nationally. Specialty mushroom growers who cultivate mushrooms on logs can focus on developing separate niche markets and joining market cooperatives, while synthetic media-based specialty mushroom growers need to focus on production and targeted marketing. A strong fresh and processed mushroom market is of paramount importance to the prosperity of the mushroom industry. With targeted and judicious marketing, mushroom producers can adapt their marketing strategies to capture heterogeneous consumers in the U.S.

APPENDICES

APPENDIX A

Supply chain of mushrooms in the U.S.

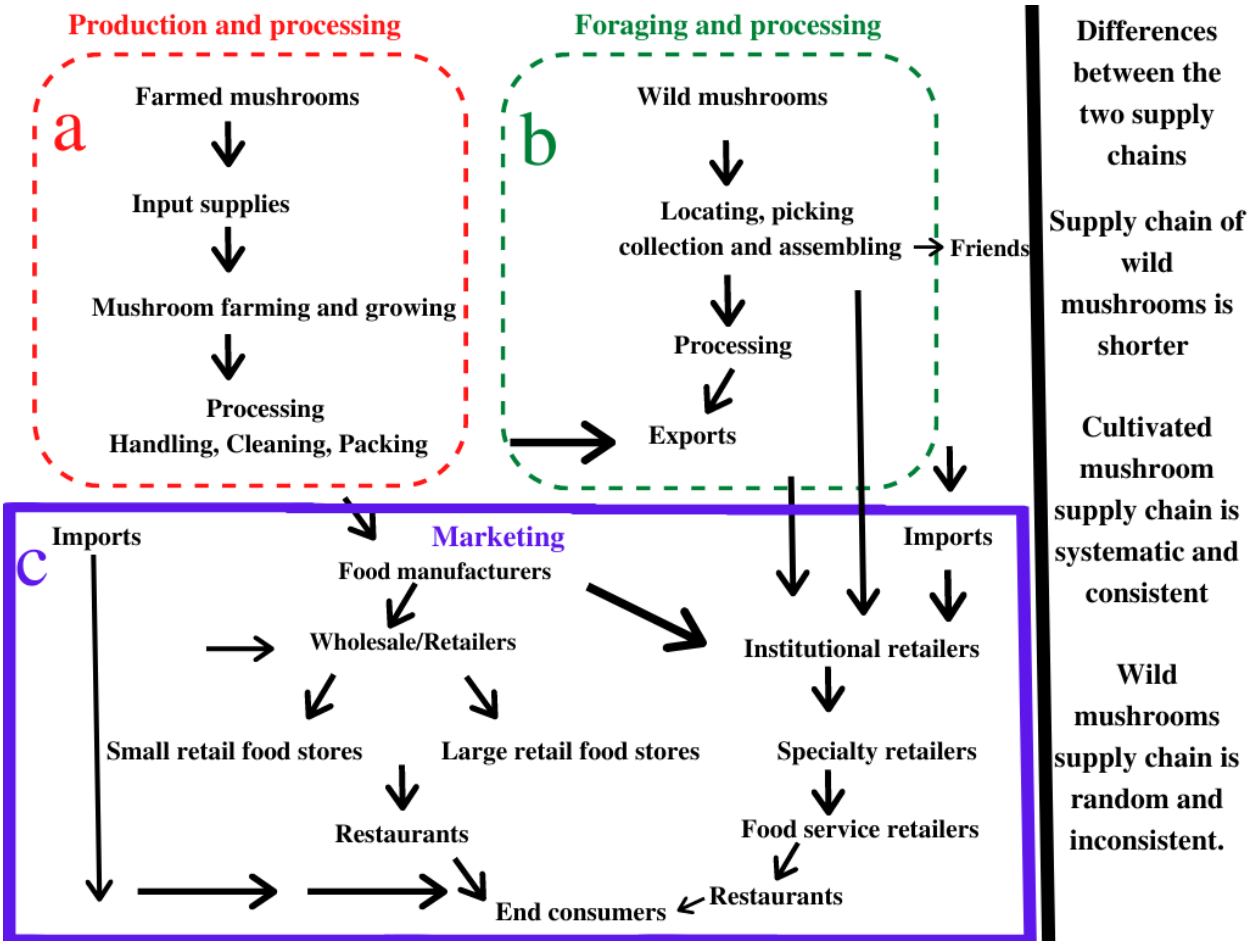

Figure A1: Comparison and Differences Between Wild-Foraged and Farm-Cultivated Mushroom Supply Chains

APPENDIX B

Tables comparing demographic characteristics between various groups of respondents

Table B1. Comparison of demographic characteristics between sample population versus U.S. population

	Total (Sample)%	U.S. Population (2020 %)
Gender		
Female	55.0 [52.5, 57.5]	50.5
Age		
Under 18	3.7 [2.7, 4.7]	23.4
18-24 years old	19.6 [17.6, 21.6]	9.1
25-34 years old	18.7 [16.7, 20.7]	14.0
35 to 44 years old	13.4 [11.7, 15.1]	12.8
45-54 years old	15.2 [13.4, 17.0]	12.3
55-64 years old	29.3 [27.0, 31.6]	12.9
Race		
White	76.5 [74.4, 78.6]	60.1
Black or African American	11.0 [9.4, 12.6]	12.2
Hispanic/Latinx/Chicanx	5.7 [4.5, 6.9]	18.5
Asian	4.0 [3.0, 5.0]	5.6
Other	2.7 [2.0, 3.6]	3.6
Region		
West	20.8 [18.8, 22.8]	23.7
Midwest	20.8 [18.8, 22.8]	20.8
Northeast	20.7 [18.7, 22.7]	17.4
South	20.8 [18.8, 22.8]	38.1
Income		
Less than $20,000	19.6 [17.6, 21.6]	13.8

Table B1 (Cont'd)

$20,000 to $39,999	24.4 [22.2, 26.6]	16.3
$40,000 to $59,999	20.2 [18.2, 22.2]	14.3
$60,000 to $79,999	14.3 [12.5, 16.1]	12.3
$80,000 to $99,999	8.0 [6.6, 9.4]	9.8
$100,000 to $119,999	4.7 [3.6, 5.8]	6.1
$120,000 to $139,999	2.9 [2.1, 3.7]	6.1
$140,000 to $159,999	2.5 [1.7, 3.3]	4.7
$160,000 or more	3.3 [2.4, 4.2]	16.7
Graduate degree		
Yes	19.2 [17.2, 21.2]	9.6
Bachelor's degree		
Yes	41.7 [39.2, 44.2]	16.9

Note: Values in parentheses denote 95% confidence intervals.
U.S. population (2020) = 329.5 million
Total observations=1,508

Table B2. Comparison of demographic characteristics between mushroom purchasers in a typical year at a restaurant or to be consumed at home versus non-purchasers of mushrooms

	Mushroom purchasers (%)	Mushroom non-purchasers (%)	Difference	95% confidence interval for the difference in percentages in the two samples
Percent of sample	49.0 [46.5, 51.5]	31.6 [29.2, 33.9]		
Gender				
Female	56.7	60.3	-3.6	[-9.3, 2.1]
Age				
Under 18	4.1	3.2	0.9	[-0.5,2.3]
18-24 years old	16.8	11.3	5.4	[2.7, 8.1]
25-34 years old	15.7	16.6	-0.9	[-3.5, 1.7]
35 to 44 years old	13.1	13.7	-0.5	[-3.0, 1.9]
45-54 years old	16.6	17.2	-0.6	[-3.3, 2.1]
55-64 years old	33.7	38.0	-4.3	[-7.7, -0.9]
Race				
White	75.0	76.5	-1.5	[-6.9, 3.9]
Black or African American	10.8	12.8	-2.0	[-4.2, 0.3]
Hispanic/Latinx/Chicanx	5.8	5.7	0.1	[-2.2, 2.5]
Asian	4.6	3.2	1.4	[-1.8, 4.7]
Other	3.8	1.9	1.9	[-1.7, 5.5]
Income				
Less than $20,000	17.6	28.2	-10.6	[-14.0, -7.1]
$20,000 to $39,999	23.7	28.6	-4.9	[-8.3, -1.4]
$40,000 to $59,999	18.8	15.5	3.3	[0.2, 6.3]
$60,000 to $79,999	14.2	11.1	3.1	[0.6, 5.6]
$80,000 to $99,999	8.3	6.3	2.0	[0.0, 3.9]
$100,000 to $119,999	5.8	3.8	2.0	[0.3, 3.7]
$120,000 to $139,999	3.8	2.3	1.5	[0.1, 2.9]
$140,000 to $159,999	3.7	1.1	2.6	[1.3, 4.0]
$160,000 or more	4.2	3.2	1.0	[-0.4, 2.5]
Graduate degree				
Yes	20.4	9.9	10.6	[5.6, 15.6]
Bachelor's degree				
Yes	42.9	24.2	18.7	[14.2, 23.3]

Note: Values in parentheses denote 95% confidence intervals.
Number of mushroom purchasers= 739
Number of non-purchasers of mushrooms=476

Table B3. Demographics of Agaricus bisporus mushrooms versus specialty mushrooms purchasers

	Agaricus bisporus **mushrooms purchasers (%)**	**Specialty mushrooms purchasers (%)**	**Difference**	**95% confidence interval for the difference in percentages in the two samples**
Percent of sample	43.4 [40.9, 45.9]	24.5 [22.3, 26.6]		
Gender				
Female	57.7	55.6	2.2	[-4.2, 8.5]
Age				
Under 18	3.4	5.4	-2.1	[-4.8, 0.6]
18-24 years old	15.7	22.0	-6.2	[-11.3, -1.2]
25-34 years old	16.0	20.9	-4.8	[-9.8, 0.2]
35 to 44 years old	13.0	13.0	0.0	[-4.3, 4.3]
45-54 years old	17.1	14.9	2.2	[-2.4, 6.8]
55-64 years old	34.8	23.8	11.0	[5.3, 16.6]
Race				
White	76.8	66.1	10.7	[4.9, 16.5]
Black or African American	9.9	15.2	-5.3	[-9.6, -0.9]
Hispanic/Latinx/Chicanx	5.6	7.6	-1.9	[-5.2, 1.3]
Asian	3.8	6.2	-2.4	[-5.3, 0.5]
Other	3.8	4.9	-1.1	[-3.7, 1.6]
Income				
Less than $20,000	17.1	16.8	0.3	[-4.5, 5.1]
$20,000 to $39,999	23.5	20.6	2.9	[-2.3, 8.2]
$40,000 to $59,999	18.8	20.1	-1.3	[-6.3, 3.8]
$60,000 to $79,999	14.5	14.1	0.4	[-4.0, 4.9]
$80,000 to $99,999	8.4	8.1	0.3	[-3.2, 3.8]
$100,000 to $119,999	6.0	6.5	-0.5	[-3.7, 2.6]
$120,000 to $139,999	3.7	5.1	-1.5	[-4.2, 1.2]
$140,000 to $159,999	4.1	3.3	0.9	[-1.5, 3.2]
$160,000 or more	4.0	5.4	-1.5	[-4.2, 1.3]
Graduate degree				
Yes	20.3	23.0	-2.7	[-8.0, 2.6]
Bachelor's degree				
Yes	43.2	46.9	-3.7	[-10.0, 2.7]

Note: Values in parentheses denote 95% confidence intervals.
Number of *Agaricus bisporus* purchasers=655
Number of specialty mushroom purchasers=369

Table B4. Demographics of morel versus other specialty mushroom purchasers

	Morel purchases (%)	Other specialty mushrooms purchasers (%)	Difference	95% confidence interval for the difference in percentages in the two samples
Percent of sample	7.8 [6.5, 9.2]	21.2 [19.2, 23.3]		
Gender				
Female	51.7	55.3	-3.6	[-14.2, 6.9]
Age				
Under 18	6.8	5.0	1.8	[-3.3, 6.9]
18-24 years old	28.8	19.7	9.1	[-0.1, 18.4]
25-34 years old	16.9	22.2	-5.2	[-13.4, 2.9]
35 to 44 years old	14.4	12.8	1.6	[-5.7, 8.9]
45-54 years old	10.2	16.3	-6.1	[-12.9, 0.7]
55-64 years old	22.9	24.1	-1.2	[-10.1, 7.7]
Race				
White	66.9	65.0	1.9	[-8.0, 11.9]
Black or African American	15.3	15.3	-0.1	[-7.7, 7.5]
Hispanic/Latinx/Chicanx	9.3	7.8	1.5	[-4.5, 7.5]
Asian	4.2	6.6	-2.3	[-6.9, 2.2]
Other	4.2	5.3	-1.1	[-5.5, 3.3]
Income				
Less than $20,000	22.0	13.8	8.3	[-0.1, 16.7]
$20,000 to $39,999	19.5	20.3	-0.8	[-9.2, 7.6]
$40,000 to $59,999	17.8	21.3	-3.5	[-11.7, 4.8]
$60,000 to $79,999	12.7	15.3	-2.6	[-9.8, 4.6]
$80,000 to $99,999	6.8	7.8	-1.0	[-6.4, 4.4]
$100,000 to $119,999	10.2	6.3	3.9	[-2.1, 10.0]
$120,000 to $139,999	5.1	5.6	-0.5	[-5.2, 4.2]
$140,000 to $159,999	1.7	3.8	-2.1	[-5.2, 1.1]
$160,000 or more	4.2	5.9	-1.7	[-6.2, 2.8]
Graduate degree				
Yes	29.0	23.1	5.7	[-3.7, 15.1]
Bachelor's degree				
Yes	51.7	47.2	4.5	[-6.0, 15.1]

Number of morel consumers=118
Number of other specialty mushroom consumers=320
Note: Values in parentheses denote 95% confidence intervals.

Table B5. Analysis of mushroom preferences within each r*egio*n

	West (%)	Midwest (%)	Northeast (%)	South (%)
Morel mushroom purchasers	8.3 [5.3, 11.4]	11.5 [8.0, 15.0]	7.1 [4.2, 9.9]	10.8 [7.4, 14.3]
Specialty mushrooms purchasers	32.9 [27.7, 38.1]	25.2 [20.4, 30.0]	29.2 [24.1, 34.2]	30.6 [25.5, 35.7]
Agaricus bisporus mushroom purchasers	57.5 [52.0, 63.0]	51.8 [46.2, 57.3]	51.9 [46.4, 57.4]	48.1 [42.6, 53.6]
Other specialty mushroom purchasers	30.7 [25.6, 35.8]	18.8 [14.5, 23.2]	26.6 [21.7, 31.5]	26.1 [21.3, 31.0]
Mushrooms purchasers	65.2 [59.9, 70.4]	57.5 [52.0, 63.0]	58.7 [53.2, 64.1]	54.8 [49.3, 60.3]
Non-purchasers of mushrooms	32.9 [27.7, 38.1]	39.6 [34.2, 45.0]	38.5 [33.1, 43.8]	41.1 [35.6, 46.5]

Total purchasers in the West=313
Total purchasers in the Midwest=313
Total purchasers in the Northeast=312
Total purchasers in the South=314
Note: Values in parentheses denote 95% confidence intervals.

Table B6. Demographic attributes of specialty mushroom purchasers within each region

	West (%)	Midwest (%)	Northeast (%)	South (%)
Gender				
Female	16.3	12.5	17.9	18.8
	[12.2, 20.4]	[8.8, 16.1]	[13.7, 22.2]	[14.5, 23.1]
Age				
Under 18	2.2	0.3	1.9	1.9
	[0.6, 3.9]	[-0.3, 0.9]	[0.4, 3.4]	[0.4, 3.4]
18-24 years old	4.2	6.7	5.8	9.2
	[1.9, 6.4]	[3.9, 9.5]	[3.2, 8.3]	[6.0, 12.4]
25-34 years old	5.1	4.8	7.4	7.3
	[2.7, 7.5]	[2.4, 7.2]	[4.5, 10.3]	[4.4, 10.2]
35 to 44 years old	2.9	2.6	4.5	5.4
	[1.0, 4.7]	[0.8, 4.3]	[2.2, 6.8]	[2.9, 7.9]
45-54 years old	5.4	5.1	3.8	3.2
	[2.9, 7.9]	[2.7, 7.5]	[1.7, 6.0]	[1.2, 5.1]
55-64 years old	13.1	5.8	5.8	3.5
	[9.4, 16.8]	[3.2, 8.3]	[3.2, 8.3]	[1.5, 5.5]
Race				
White	20.8	18.2	19.9	19.1
	[16.3, 25.3]	[13.9, 22.5]	[15.5, 24.3]	[14.8, 23.5]
Black or African American	2.2	2.9	5.4	7.3
	[0.6, 3.9]	[1.0, 4.7]	[2.9, 8.0]	[4.4, 10.2]
Hispanic/Latinx/Chicanx	3.5	1.3	1.6	2.5
	[1.5, 5.6]	[0.0, 2.5]	[0.2, 3.0]	[0.8, 4.3]
Asian	3.2	1.0	1.9	1.3
	[1.2, 5.1]	[-0.1, 2.0]	[0.4, 3.4]	[0.0, 2.5]
Other	3.2	1.9	0.3	0.3
	[1.2, 5.1]	[0.4, 3.4]	[-0.3, 0.9]	[-0.3, 0.9]
Income				
Less than $20,000	4.8	3.8	5.4	5.7
	[2.4, 7.2]	[1.7, 6.0]	[2.9, 8.0]	[3.2, 8.3]
$20,000 to $39,999	9.6	5.1	4.5	5.1
	[6.3, 12.8]	[2.7, 7.5]	[2.2, 6.8]	[2.7, 7.5]
$40,000 to $59,999	5.1	6.4	4.8	7.3
	[2.7, 7.5]	[3.7, 9.1]	[2.4, 7.2]	[4.4, 10.2]
$60,000 to $79,999	5.1	1.6	5.1	4.8
	[2.7, 7.5]	[0.2, 3.0]	[2.7, 7.6]	[2.4, 7.1]
$80,000 to $99,999	1.6	3.2	2.6	2.2
	[0.2, 3.0]	[1.2, 5.1]	[0.8, 4.3]	[0.6, 3.9]
$100,000 to $119,999	3.2	1.3	1.9	1.3
	[1.2, 5.1]	[0.0, 2.5]	[0.4, 3.4]	[0.0, 2.5]
$120,000 to $139,999	1.3	1.9	1.6	1.3
	[0.0, 2.5]	[0.4, 3.4]	[0.2, 3.0]	[0.0, 2.5]

Table B6 (Cont'd)

$140,000 to $159,999	0.3	0.3	1.6	1.6
	[-0.3, 0.9]	[-0.3, 0.9]	[0.2, 3.0]	[0.2, 3.0]
$160,000 or more	1.9	1.6	1.6	1.3
	[0.4, 3.4]	[0.2, 3.0]	[0.2, 3.0]	[0.0, 2.5]
Graduate degree				
Yes	6.1	5.1	8.0	8.0
	[3.4, 8.7]	[2.7, 7.5]	[5.0, 11.0]	[5.0, 11.0]
Bachelor's degree				
Yes	13.1	13.7	15.1	13.4
	[9.4, 16.8]	[9.9, 17.5]	[11.1, 19.0]	[9.6, 17.1]

Note: All values in parentheses denote 95% confidence intervals.

APPENDIX C

Imports of mushrooms to the U.S.

Dried *Agaricus* mushrooms are imported mostly from China followed by France, Germany, Hongkong, and Italy. The total share of imports of dried *Agaricus* mushrooms from the years 2017 to 2021 was around 6.3 million pounds. Fresh *Agaricus* mushrooms. are imported mostly from Canada, Mexico, China, South Korea, and Belgium. The average share of imports of fresh *Agaricus* mushrooms was around 142 million pounds which is twenty-three times higher than that of dried *Agaricus* mushrooms The U.S. government is incessantly increasing import duties, which is also contributing to the higher prices of mushrooms (Grand View Research, 2022). Fresh specialty mushrooms are imported from Canada and Asian countries like South Korea, China, Japan, and Taiwan. The total share of imports of specialty mushrooms from the years 2017 to 2021 in the U.S.A. was about 22.4 million pounds which is six times less than fresh *Agaricus* mushrooms. (USDA, 2022).

APPENDIX D

Specialty mushroom area in production

While wild foraging continues, specialty mushrooms are commercially grown in different media mimicking their growth in nature. Figure D1 displays that in natural wood outdoor logs, specialty mushrooms area of production had increased till 2015 and decreased significantly afterward. However, in natural wood undercover and indoor logs, the area of production of specialty mushrooms has increased drastically till the year 2019 and decreased from 2019 onwards as shown in Figure D2. Similarly, according to Figure D3, in all other production media, the area of production increased till 2017, then decreased drastically, and is in a relatively increasing trend from 2018 to 21. Log-grown shiitakes enjoy strong demand and are higher in quality and value than mass-produced indoor-grown shiitakes. Indoor production on sawdust generates higher income than outdoor production on logs, but log production is more suitable for a small-scale operation in an agroforestry setting (Gold et al., 2008).

Figure D1: Area in production of specialty mushrooms in natural wood outdoor logs (USDA 2008) to (USDA 2021)

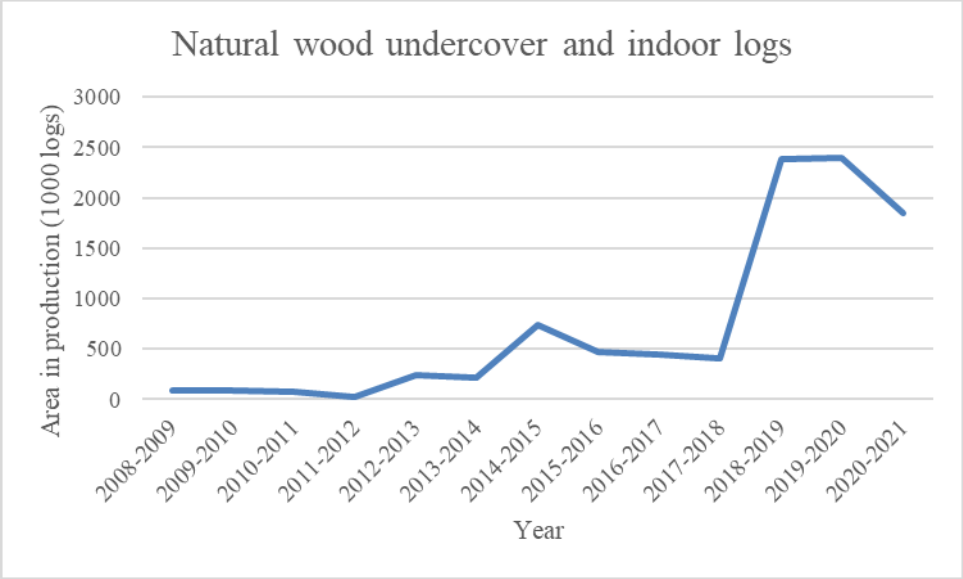

Figure D2: Area in production of specialty mushrooms in natural wood undercover and indoor logs (USDA 2008) to (USDA 2021)

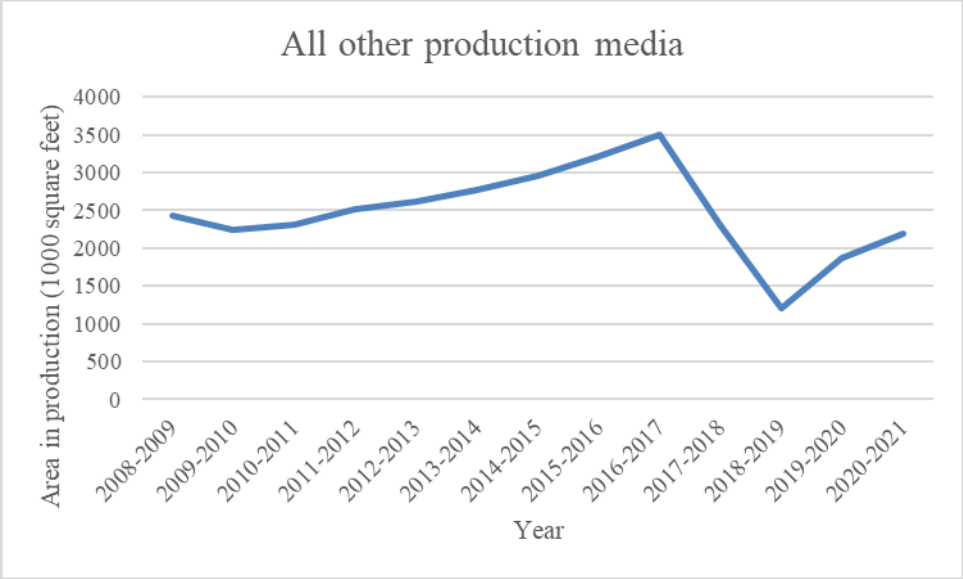

Figure D3: Area in production of specialty mushrooms in all other production media (USDA 2008) to (USDA 2021)

APPENDIX E

Price per pound and price ratio of fresh and processed mushrooms

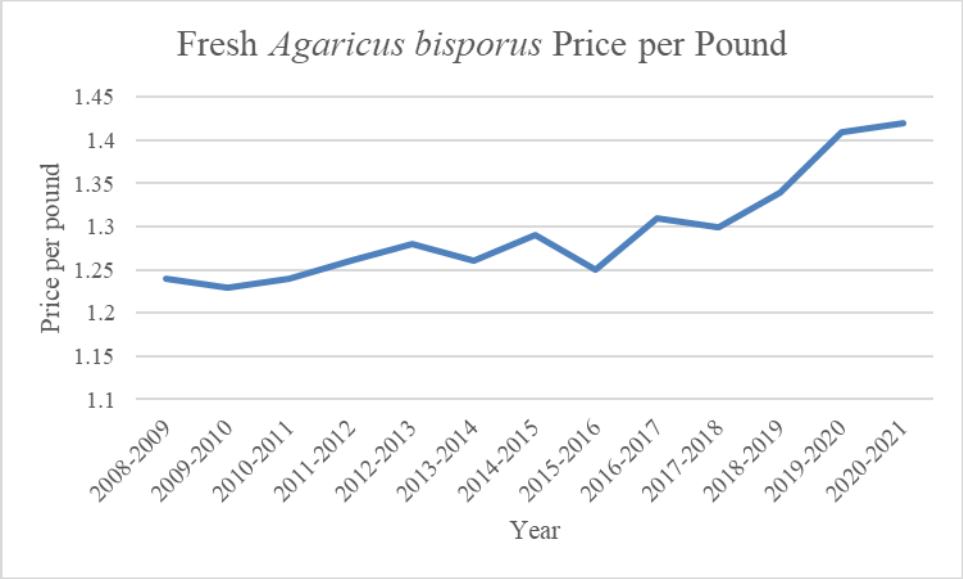

Figure E1: Fresh *Agaricus bisporus* price per pound (USDA 2008) to (USDA 2021)

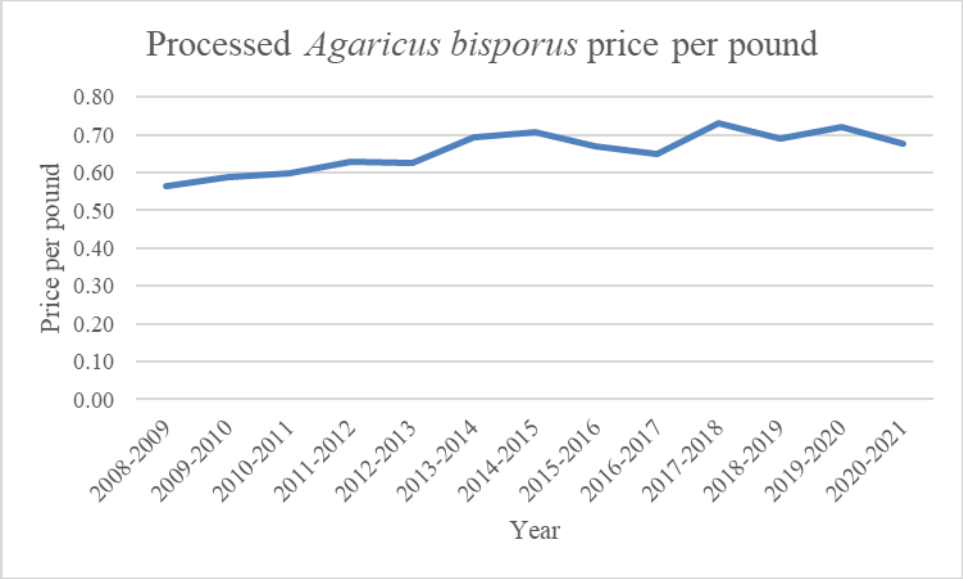

Figure E2: Processed *Agaricus bisporus* price per pound (USDA 2008) to (USDA 2021)

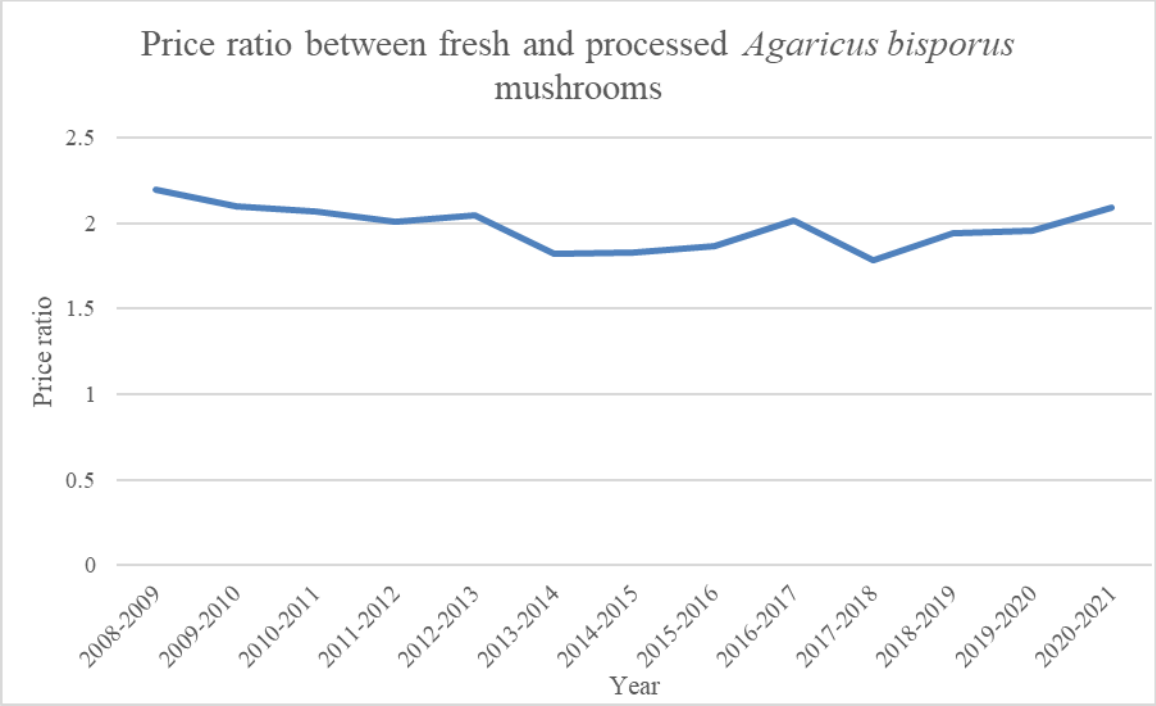

Figure E3: Price ratio between fresh and processed *Agaricus bisporus* mushrooms (USDA 2008) to (USDA 2021)

APPENDIX F

Price per pound, value of sales and total production of *Agaricus bisporus* and specialty mushrooms

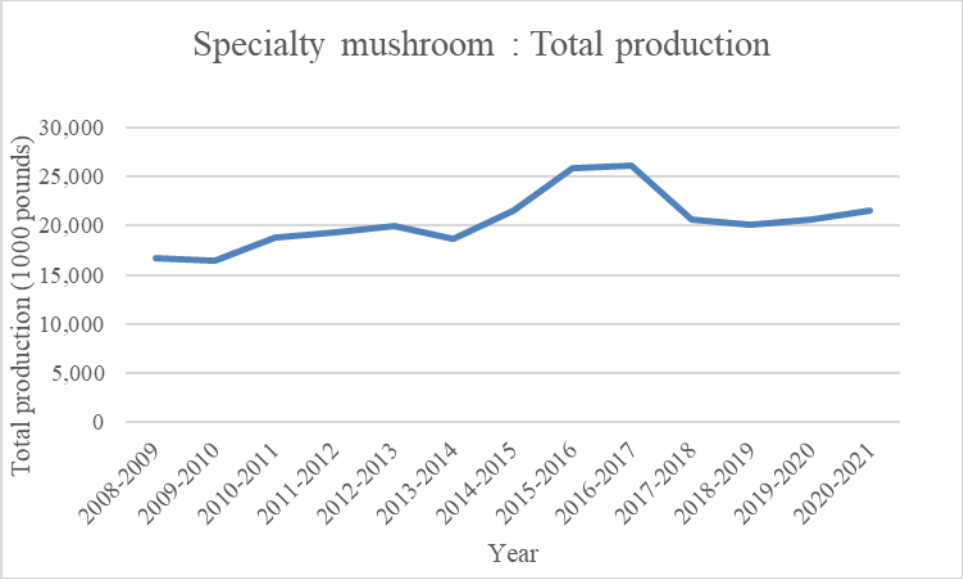

Figure F1: Specialty mushrooms total production (1000 pounds) from the year 2008 to 2021 (USDA)

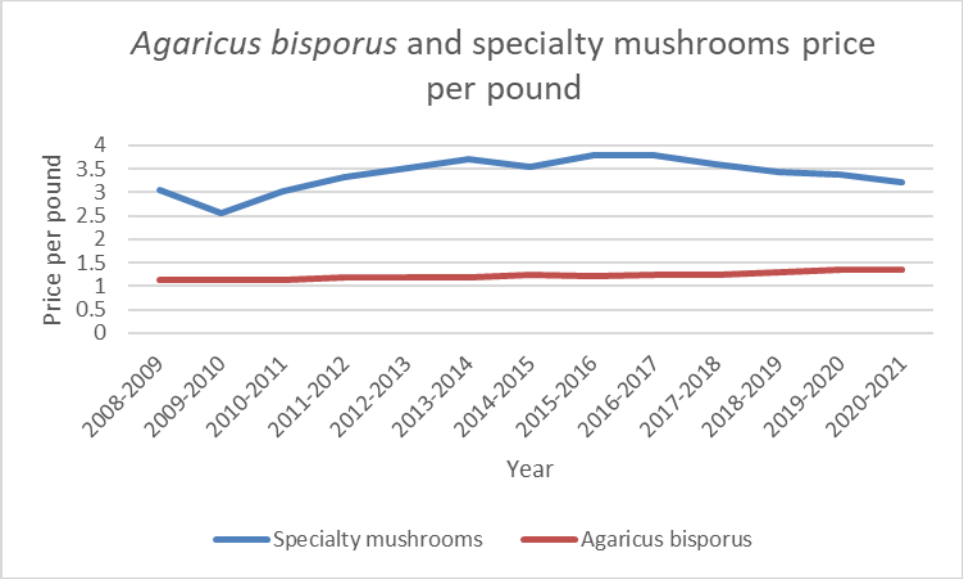

Figure F2: *Agaricus bisporus* and specialty mushrooms price per pound (Dollars) (USDA 2008) to (USDA 2021)

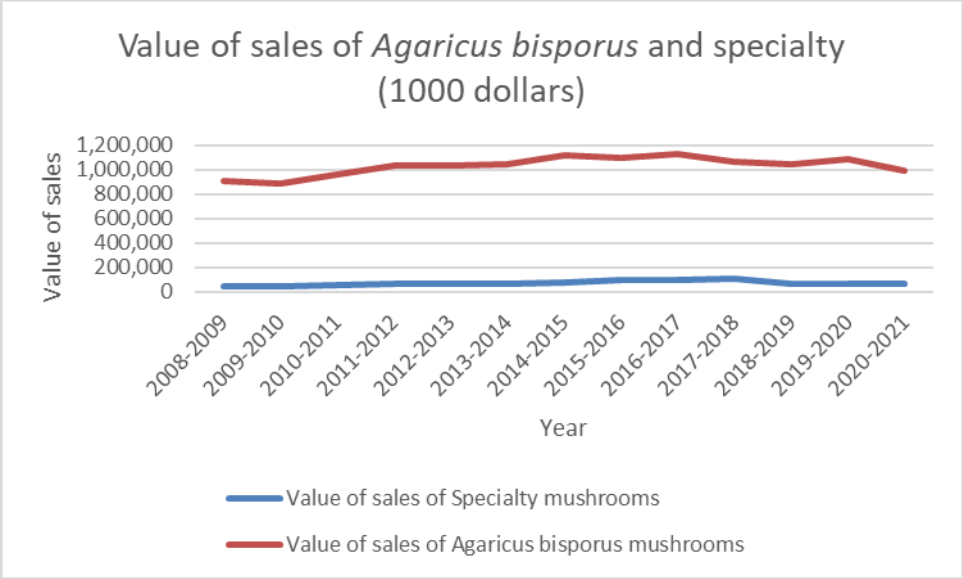

Figure F3: *Agaricus bisporus* and specialty mushrooms value of sales (1000 dollars) (USDA 2008) to (USDA 2021)

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