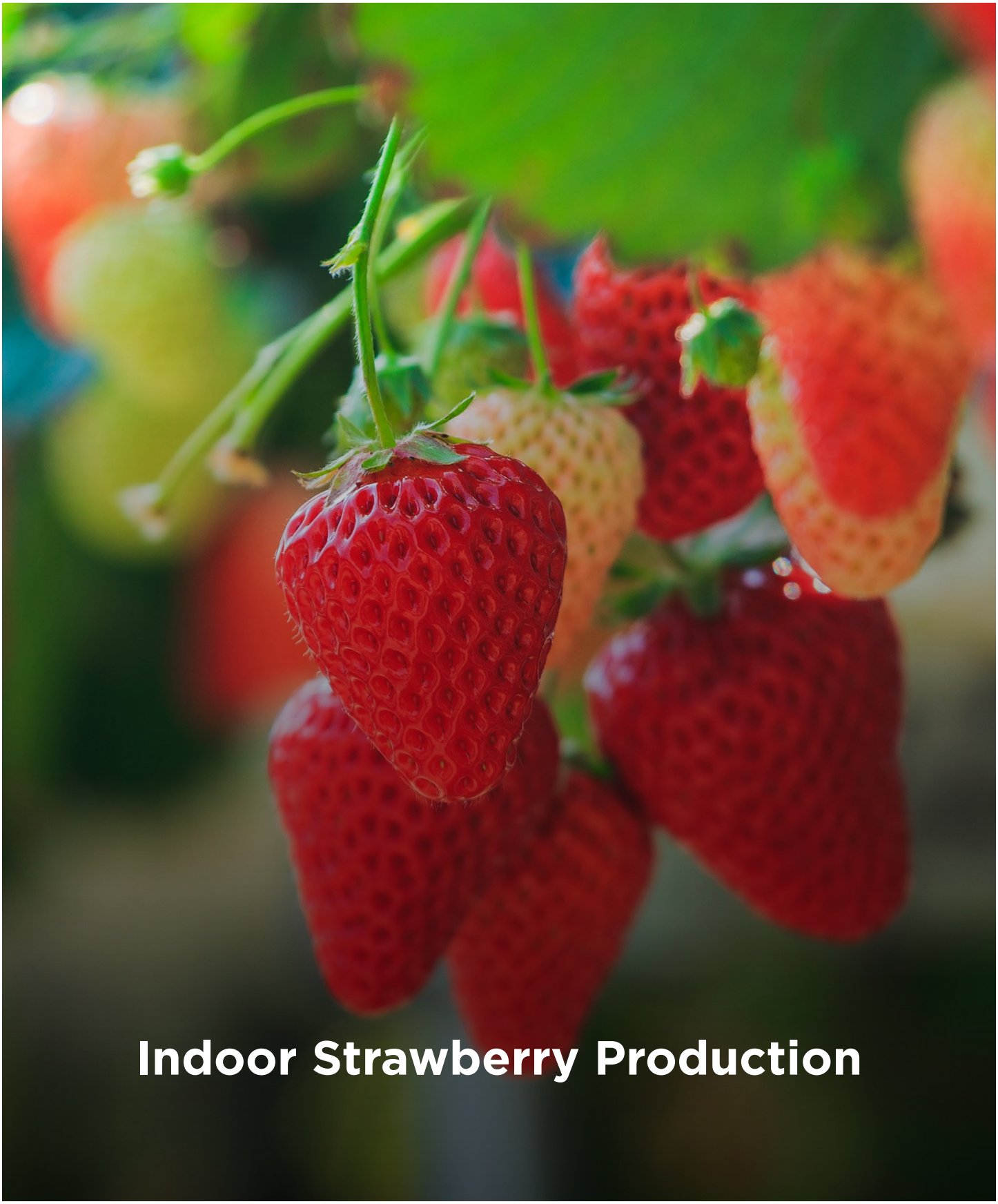
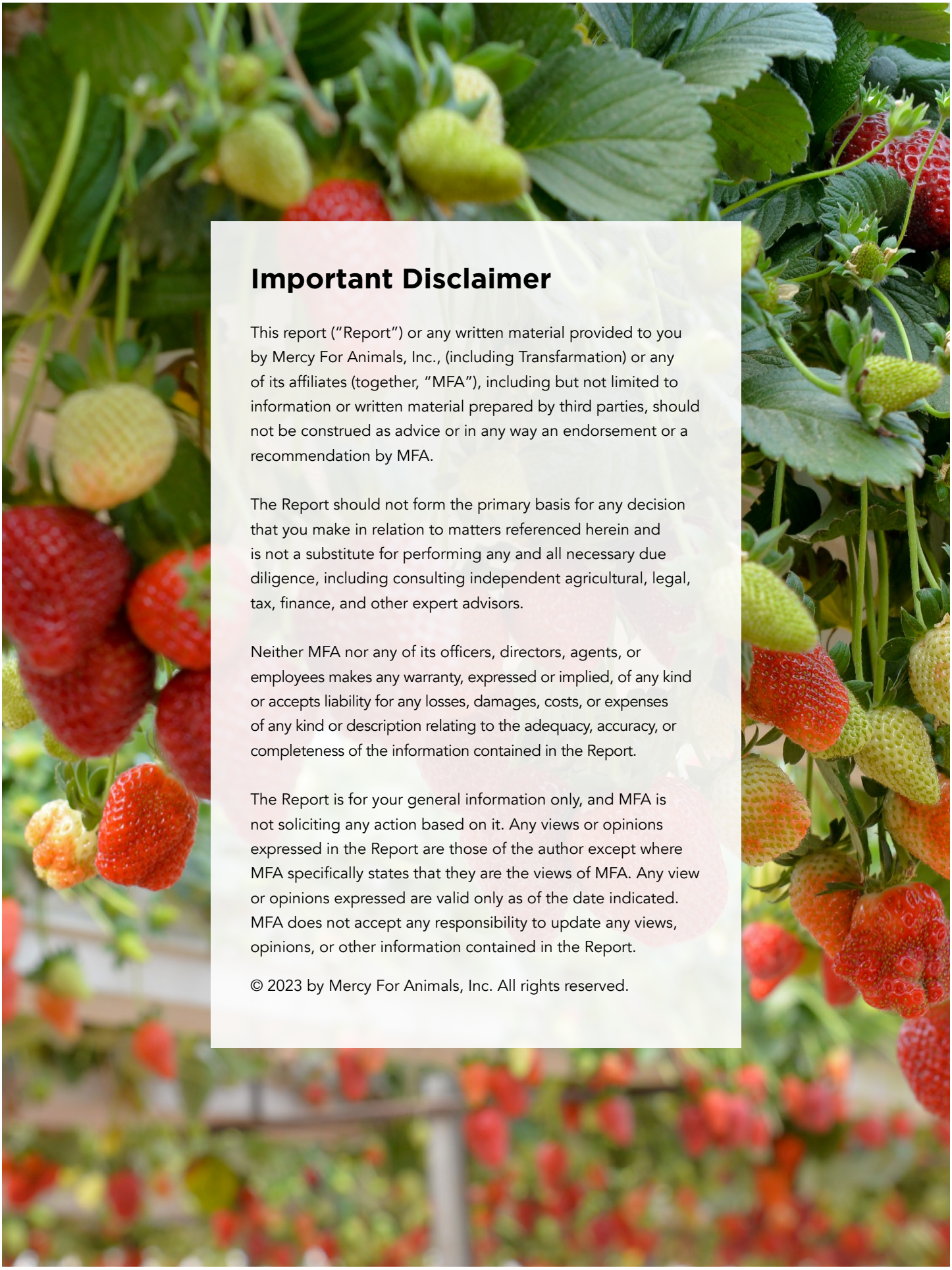


Indoor Strawberry Production

Transfarmation
MERCY FOR ANIMALS

Highland
ECONOMICS



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Introduction

Strawberries are soft fruit that must be picked when they are nearly fully ripe to capture the full flavor of the fruit. Because of this, their shelf life is generally limited, which requires advanced postharvest technologies for shippers in California and Florida to distribute berries nationally and internationally. This is the main reason particular cultivars with good postharvest shelf life have been preferable in commercial production schemes.

Strawberries were mainly a locally grown crop in most states until the 20th century, when large-scale centralized production and distribution capacity began to develop in select areas of California and Florida. The current trend is to decentralize production by reestablishing local production in a more sustainable manner. Controlled-environment agriculture can significantly contribute to this trend and provide consumers with a year-round supply of strawberries. But local greenhouse-produced strawberries must fetch a premium price over imported strawberries for local operations to be viable. This report explores the market demand and production practices for locally grown strawberries and presents an enterprise budget for converting a 20,000-square-foot poultry house into a greenhouse producing strawberries.

Market

- Strawberries have traditionally been a field crop in the United States. California dominates production, supplying over 90 percent of strawberries produced domestically (Ag MRC 2021). The three main production areas in California are Watsonville, Santa Maria, and Oxnard (Kubota 2019).
- The existing supply chain for strawberries involves selecting cultivars that can ship well and transporting the fruit great distances, often with the addition of gases and cold-chain technology to give them a two-week shelf life. Large marketing and distribution companies have contracted production acreage for strawberries in other parts of the world, mainly Mexico, to supply American consumers with fresh strawberries at the retail level throughout the year.
- Outdoor commercial strawberry production in California relied on methyl bromide for fumigation until the chemical was banned in 2005 due to its harmful environmental effects. Outdoor producers face increasing labor costs, especially in California, and drought frequency (Kubota 2019). Likely because of these pressures, outdoor production acreage for strawberries has declined since 2014 (Kubota 2021).[1]

[1] During the same period, the market price of fresh strawberries increased. Thus, production decline was not likely attributable to market price.

- In most years the United States exports more strawberries than it imports. But in fall and winter months (October to March) the United States is a net importer. From November 2020 to April 2021 alone, the United States imported 300 million pounds more than it exported. This trend of importing more strawberries than exported from the fall to spring has increased over the past few years, as shown in the figure below.

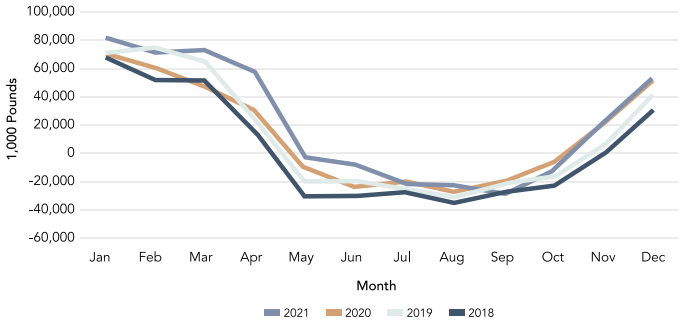

Figure 1. Net imports of strawberries to the United States (imports minus exports) by month. (USDA ERS 2022.)

- In Asia and Europe, strawberries are commonly produced in greenhouses from autumn to spring. Interest in this production practice is growing in the United States, where consumers increasingly seek local, flavorful strawberries outside peak season for local production (Kroggel 2020).
- Several private companies have begun transitioning to greenhouse strawberry production or other forms of controlled-environment agriculture, such as for leafy greens and tomatoes:
  - Plans for the country's largest indoor hydroponic strawberry growing operation went before Janesville City Council in Wisconsin in May 2022 (WCLO 2022).
  - In March 2022, Bowery Farming in New Jersey started selling fresh market strawberries grown in its indoor production facility.
  - Farming technology company Plenty announced in March 2022 that it planned to build an indoor strawberry farm to serve customers and retailers in the Northeast with major berry producer and distributor Driscoll's (Repko 2022).
  - Other companies in this sector include AeroFarms, PlantLab, and BrightFarms.
- Per capita, U.S. consumers eat 8.5 pounds of strawberries each year. Of these, about five pounds are fresh strawberries (USDA AMS, n.d.).

- The quantity of fresh strawberries produced in a 16,000-square-foot growing area would supply the per capita consumption of about 12,000 people over an eight-month period.

Production Practices

As late as 2005, lettuce and tomatoes were assumed to be the only crops economically feasible for hydroponic food production, but food prices have more than doubled since then, and other crops can be economically viable for both commercial operations and small-scale farmers (Treftz and Omaye 2015). In controlled environments, the two main parameters to consider are nighttime temperature and day length. These are discussed below along with other key production factors.

Temperature

Nighttime temperatures from 50°F to 55°F are ideal for strawberry production; nighttime temperatures above 55°F result in small, tart strawberries (Kubota 2019). This is the main reason greenhouses in Arizona produce strawberries only through April. After this, cooling costs prohibit continued operation (Kubota 2019). Nighttime temperature in the greenhouse location will largely determine the length of the strawberry harvest period, with more northern (cooler) climates typically having a longer harvest period.

The ideal average daytime temperature for controlled-environment strawberry production is around 65°F. Warmer temperatures (above 80°F) affect flower development (Kubota 2019; AGrowTronics, n.d.).

Light

Strawberries are photoperiodic, meaning flower initiation is triggered by day length (light exposure). June-bearing (short-day) plants have optimal yields when light exposure is 13 hours at most. Everbearing (long-day) plants respond positively to longer photoperiods. Both varieties can be used in controlled environments, but light requirements differ slightly (Kroggel 2020). Supplemental lighting would be necessary.

A commonly cited value for minimum light at the canopy level needed to produce a reasonable yield for many greenhouse crops is 12 moles (m-2 d-1). But if 14 to 15 moles (m-2 d-1) can be provided, crop yield and fruit quality will be much improved (Kroggel 2020).

A study from The Ohio State University demonstrates that "targeted lighting" (where light beams are focused on the plants and not wasted on the alleys) results in profitable production of strawberries indoors, whereas uniform lighting systems can be cost prohibitive (Kubota 2019).

Seasonality

As indicated above, temperature and light parameters establish controlled-environment strawberry season as October to May for most of the country. Figure 2 shows a typical Midwest production cycle.

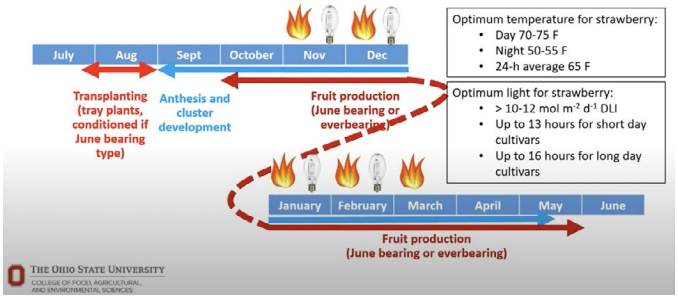

Figure 2. Controlled-environment strawberry production cycle, midwestern United States. (Kubota 2019.)

Production Systems

Several production systems exist, such as hanging gutter, nutrient film technique, vertical grow tube, and moveable gutter with gutters mechanized to raise or lower depending on the work performed. For this analysis, we model a hanging-gutter system and follow industry-standard specifications for space between gutters (3.3 feet, or one meter) and planting density (eight to 10 plants per meter of gutter).

Growth and Nutrients

Hydroponic nutrient recipes for strawberry production have much lower concentrations of essential nutrients than those for high-wire crops such as tomatoes and cucumbers, as strawberry plants have less foliar growth and fruit mass (Kroggel 2020). The recommended NH4+ (ammonium) to NO3- (nitrate) ratio is 1:10, which prevents the plants from being too vegetative because of too much ammonium (Kroggel 2020).

Strawberry plant roots have a very high oxygen demand and require a substrate with good moisture-holding capacity that is also well aerated, with higher oxygen availability than substrates used for other greenhouse crops (Kroggel 2020). Several recommended mixes for strawberries are available, but most are around half perlite and half coconut coir and peat or some other substrate mixture (Kubota 2019).

Pest Management

One key advantage of controlled-environment systems over open-field production is the lack of pest and disease issues in controlled environments. Pests that can be an issue in high tunnels during the growing season (e.g., red mites, spotted wing drosophila) are not an issue in the winter months. Several studies suggest that beneficial insects can be used to control pests (Treftz and Omaye 2015; Paranjpe and Cantliffe 2004).

Cultivars

As mentioned, California producers dominate traditional outdoor production in the United States. The varieties used in outdoor production systems are typically chosen primarily for their shelf life and then for flavor. Controlled environments enable local production of off-season strawberries chosen for flavor, with little need to consider extended shelf life.

Specific types of short-day cultivars produced in controlled environments include Chandler, Camarosa, Camino Real, Florida Radiance, FL-127 (Festival), Ruby June, Sonata, and Elsanta.

Long-day or everbearing cultivars include Monterey, San Andreas, Albion, Portola, Sweet Ann, and Seascape.

Although there is movement toward providing greenhouse strawberry growers with timely transplants, most plants currently available are produced and timed for field production (Kroggel 2020). These can be grown in high-density benchtop arrangements over the summer and planted in the production system in late summer, an approach that offers larger, more developed plants at planting time (Kroggel 2020). Tray strawberry plants are the type developed in Belgium and Holland for production in greenhouses over the winter with multiple crowns that are already conditioned for flower initiation, if June bearing (Kroggel 2020). These tray plants are not widely available in North America.

Enterprise Budget

There are few enterprise budgets for greenhouse production of strawberries in the United States. This estimate of production expenses and revenues is primarily derived from three sources: a publication from Florida State Horticultural Society from 2004, research from the University of Arizona College of Agriculture and Life Sciences, and research from The Ohio State University (Kubota Lab). Cost and return estimates are presented in 2022 dollar values and compiled in a representative strawberry enterprise budget presented in table 4 below. The budget is a general reference and should be adapted to a specific production operation.

Yields and Prices Received

Yield of strawberries varies by cultivar, light exposure, temperature, and nutrients, among other factors. Reported yields of greenhouse production in the United States are 2.25 to 2.5 pounds per square foot of production area (3.1 to 3.45 pounds per plant) over a 24-week harvest period (or six months). In more northern climates where production could extend to eight months, we estimate production could reach three pounds per square foot of production area, or just over four pounds per plant.

The price points of imports to the United States from October to April ranged from $2.16 to $3.08 per pound in the 2021 market season (USDA AMS). As mentioned, imported strawberries are likely bred for shipping; locally produced berries would be grown for flavor and would likely fetch a market premium over imported ones. Consumer willingness to pay is not well known but likely varies by region. Anecdotal information suggests fresh market prices of strawberries in farmers markets during the growing season can exceed $5 per pound (Salisbury et al. 2018). Further, a recent vertical-farming operation in New York, Bowery Farming, is selling fresh market strawberries at the retail level for $30 per pound ($14.99 for an eight-ounce package).

Figure 3. Bowery Farming strawberries (New York), retail price $14.99 for eight ounces. (Repko 2022.)

So while greenhouse strawberries often cost more as out-of-season fresh local produce, the actual price varies by location. In this analysis we consider the import value as the floor and midpoint of the range and then consider $5 per pound as the high end of a grower's potential price point.

Labor

Labor requirements of indoor strawberry production depend on several factors, including the type of growing system, laborers' efficiency and familiarity with tasks, and general conditions of the site. Labor requirements of strawberries are lower than those of other crops produced in greenhouses.

The table below outlines typical labor operations (apart from construction) for indoor production of strawberries.

Table 1. Typical labor for greenhouse strawberries

Operation	Frequency	Duration	Description
Sanitizing greenhouse	Once per season	Estimated to require 5 seconds per square foot (~28 hours total)	Removing substrate and disinfecting surfaces
Filling growing system with soilless media	Once per season	Estimated to require 5 seconds per square foot (~28 hours total)	Filling gutter system with growing media
Planting	Once per season	Estimated to require 10–15 seconds per plant (~40 hours total)	Planting tray plants into media and laying drip tape along gutter
Scouting	Weekly	2–3 hours each week (~150 hours total)	Picking ripening fruit and placing in crates
Releasing beneficials	5 times per season	~12 hours total	Evenly distributing beneficial insects throughout the growing area
Mixing fertilizer	1 time per week	Two hours per batch	Thoroughly mixing the water-soluble fertilizer into the irrigation tank
Harvest	Weekly, between October and April or May	Each picker is estimated to pick 42 to 88 pounds per hour (5.25 to 11 trays). This is ~704 hours per season, or 22 hours per week.	Picking strawberries in the raised-gutter system, likely more efficient than outdoor production systems
Packing and cooling	Weekly, after harvest	Accounts for 10 to 15 percent of the time required for harvest, 68 to 142 hours per year	Packing strawberries into clamshells and flats, and putting these into the walk-in cooler

Sources: Paranjpe and Cantliffe (2004); Kroggel (2020).

Inputs

The main inputs required for indoor production of strawberries include plants, soilless media, drip tape (for irrigation), beneficial insects, and fertilizer.

Plants: Purchasing tray plants from a reputable nursery in late summer (August) is ideal. Recommended planting density is 2.4 plants per square foot of growing area, which is about three plants per foot of gutter with gutters spaced 3.3 feet apart (center to center) (Kubota 2019). Thus, a 16,000-square-foot growing area would require 9,700 plants. Tray plants are recommended over plug or bare-root ones, which take longer to get to the flowering stage. Nourse Farms in Massachusetts is one supplier of tray strawberries in the United States. Ordering trays should occur in the winter before needing them (about eight months before shipment). Costs for tray plants are $0.80 per plant for day-neutral varieties (150 cc trays) and slightly more for June bearing (which come in 250 cc trays) and do not include freight costs (Nourse Farms representative, interview by Travis Greenwalt, May 2022). For this analysis, we estimate tray strawberries cost $1 per plant, including shipping costs.

Soilless Media: The ideal ratio of perlite to coco peat is modeled here. We estimate that each square foot of production area would require 0.002 cubic meters of soilless media (Paranjpe and Cantliffe 2004). Accordingly, the producer in this analysis would need 565 cubic feet[2] of material. Mother Earth coco-peat mix comes in 1.5 cubic foot bags, 60 bags per pallet, for $808 per pallet, or $8.97 per cubic meter (Hydrobuilder.com, n.d.).

Drip Tape: Drip tape with emitters spaced every four inches or fewer is recommended for this production style (Paranjpe and Cantliffe 2004). With two lines per gutter (Kroggel 2020), 4,000 linear feet of drip tape would be required. Current prices for this type of drip tape are $330 for 10,000 feet, or $0.033 per foot (Drip Depot, n.d.).

Beneficial Insects: One important advantage of greenhouse strawberry production is that the structure excludes to a certain extent insect and arthropod pests and contamination of biological controls (OSU, n.d.). In a controlled setting, biological controls help maintain preferred conditions. The table below models predatory mites, parasitic wasps, and bees for pollination at costs compiled from online sources (Arbico Organics, n.d.).

[2] 1 cubic meter = 35.3 cubic feet.

Table 2. Cost of beneficial insects and arachnids

Type of insect or arachnid	Unit	Quantity	Price	Total cost
Neoseiulus californicus predatory mite	bottles	60	$21.50	$1,290.00
Aphidius colemani parasitic wasp	bottles	5	$189.00	$945.00
Amblyseius cucumeris predatory mite	bottles	1	$45.00	$45.00
Bombus impatiens pollinators	hives	2	$240.00	$480.00
Shipping				$414.00
Total				**$3,174.00**

Source: Arbico Organics (n.d.).

Nutrient Solution: Available information on hydroponic nutrient solution specifically for strawberries is limited. The Ohio State University has used two types of Japanese hydroponic strawberry solutions (OSU, n.d.). The table below presents the ion concentrations of major essential nutrients in each. Formulations that are too high in NH4 should be avoided, as plants will become too vegetative (Kroggel 2020; Kubota 2019).

Table 3. Major elemental concentrations (mg/L or ppm)

Recipe	NO3-N	NH4-N	PO4-P	K	Ca	Mg	SO4-S
Yamazaki	70	7	15	117	40	12	16
Tochigi	111	10	30	156	86	22	11

Source: OSU (n.d.).

For the operation modeled here, we use estimates of cost per square foot from The Ohio State University: $0.17 per square foot, or $2,688 per year.

Other Consumables (plastic, disinfectant, etc.): We model these other inputs at $0.05 per square foot of production area, a rate based on research from The Ohio State University (Kroggel 2020) and updated to 2022 values using the CPI Index.

Packaging and Cooling

Strawberries are packed into quart clamshell containers (about one pound per quart) and put into flats (eight quarts per flat). These flats are stored in a walk-in cooler prior to shipping to the customer. We compiled prices for clamshells ($0.18) and flats ($0.76) from online sources (WebstaurantStore, n.d.).

Utilities

The utility requirements of a greenhouse include fuel for heating, electricity for fans, water, sewer, and communication. Our budget assumes that heating will require 958,000 cubic feet of natural gas at $9.52 per 1,000 cubic feet. We expect electricity requirements to be 112,000 kilowatt hours per year at $0.12 per kilowatt hour (Electric Choice, n.d.). We model cellular telephone and internet costs at $1,440 per year.

Utilities represent around 30 percent of the total variable costs of the greenhouse operation.

Other Operating Costs

Miscellaneous costs include office supplies ($600), postage, and marketing materials ($600). We expect this category to represent $1,200 per year, or 1 percent of variable costs.

Cash Overhead

Property taxes for the grow operation will be specific to the location but are modeled here at $250 per month, or $3,000 per year. Some states may impose income or other additional taxes, but we do not model these here.

This analysis assumes no land costs; thus, the profit identified is considered a return-on-land estimate. We model general liability insurance at $70 per month and property insurance at an estimated $200 per month. Total insurance costs are therefore estimated at $3,240 annually.

Capital Costs and Noncash Overhead

The capital cost of the greenhouse conversion from the existing poultry house is an estimated $5.47 per square foot, or $87,520 for the structure (16,000 square feet of production

area).[3] In addition, this analysis models Carolina Greenhouses' Dutch bucket system as the hydroponic production system at an estimated $35,760.[4] The greenhouse operation will also require environmental controls, such as lighting and heating equipment, at an estimated $15,000. We model additional requirements, developed by The Ohio State University Extension, with costs indexed to 2022 dollar values:

- Plastic covers for cutters: $0.15 per square foot, or $1,180 total
- Walk-in cooler (100 square feet): $10,230
- Strawberry gutter system: $1.03 per square foot, or $8,241
- Irrigation system: $1.29 per square foot, or $10,349

In total, we estimate the capital requirements of the conversion of the poultry house to be **$150,870**. This analysis further assumes the owner could finance the conversion through existing programs offered by the Small Business Administration (SBA), the United States Department of Agriculture, and possibly other lenders. For this analysis, we model the debt-service terms of the SBA 504 program: 10 percent equity requirement (90 percent financed), or $15,087. Further, 10- and 20-year notes, at 6.5 and 6 percent interest, respectively, are considered in the financial analysis below (CDC Loans, n.d.).

Net Profit

On the basis of the assumptions outlined above, including projected yield, we estimate the break-even price of strawberries from a 16,000-square-foot greenhouse to be around $2.72 per pound. This is higher than the import value of strawberries, which suggests that the venture would be profitable only if the producer were able to command a premium price. We anticipate consumers would be willing to pay a premium for this product, as the quality (freshness and flavor) would likely be superior to that of other fresh-market

[3] Quotes for the conversion of a chicken house to crop production (Sullivan and Howard 2022) ranged from $3 to $8 per square foot, depending on the type of material used to cover the structure. The $5.47 estimate represents the midpoint between the double-layered film ($4.23) and corrugated polycarbonate ($6.23). This cost includes fans, groundcover, ventilation control, and shade cloth, as well as labor and material costs (Kardos, Kuzma, and Ragon 2022; Sullivan and Howard 2022).

[4] Quotes are for a 100-foot section of a 50-foot-wide greenhouse at $11,175. Our budget assumes that a 320-foot section (50 feet wide) of greenhouse will be used in crop production at $24,585, or $35,760 for both the structure and production (Sullivan and Howard 2022).

strawberries available. For this analysis, we assume a price point of $4 per pound, as presented below.

Table 4. Representative greenhouse strawberry enterprise budget

	Unit	Quantity	Price	Value
Gross returns	**lb.**	**40,000**	**$3.50**	**$140,000**
Variable costs:				
Plants	Plants	9,697	$1	$9,697
Soilless media	Cu. ft.	1,130	$8.97	$10,141
Irrigation tape	Linear ft.	8,000	$0.033	$264
Irrigation fittings	Each			$26
Beneficial insects[5]				$3,174
Fertilizer	$ / sq. ft.	16,000	$0.17	$2,688
Other consumables	$ / sq. ft.	16,000	$0.05	$744
Natural gas	1,000 cu. ft.	958	$9.52	$9,120
Electricity	kWh	112,000	$0.12	$13,440
Communications	Monthly rate	12	$120	$1,440
Flats (boxes)	Each	5,000	$0.76	$3,800
Clamshells	Each	40,000	$0.18	$7,250
Labor	Hours	1,014	$17.58	$17,831
Other, misc.				$1,200
Property tax				$3,000
Insurance				$3,240
Total operating cost				**$87,056**
Operating profit				**$52,944**
			Debt-service obligation (10 years, 6.5% interest)	$18,888
			Debt-service coverage ratio	**2.80**
			Debt-service obligation (20 years, 6% interest)	$11,838
			Debt-service coverage ratio	**4.47**

The expected operating profit of $52,944 from the converted poultry house represents a profit of $1.32 per pound of strawberries yielded from greenhouse production. Debt-service coverage ratio (DSCR) is a measurement of a firm's available cash flow to pay current debt obligations, calculated as the net operating income divided by debt obligations (principal and interest payments). A DSCR less than 1.0 would indicate potential solvency problems, while a ratio of at least 2.0 is generally considered very strong. The DSCR for this enterprise would be strong to very strong, depending on the terms of the loan undertaken.

Sensitivity

A sensitivity analysis was undertaken to evaluate the impact of key assumptions on the net profit estimate for the enterprise in question. The key assumptions in the sensitivity analysis include the following:

- Yield (2.25 to three pounds per square foot)
- Price received ($2.16 to $5 per pound)
- Cost of plants ($0.50 to $2 per plant)
- Labor rate ($15 to $20 per hour)
- Capital cost of structure remodel ($40,000 to $60,000)

[5] See table 2.

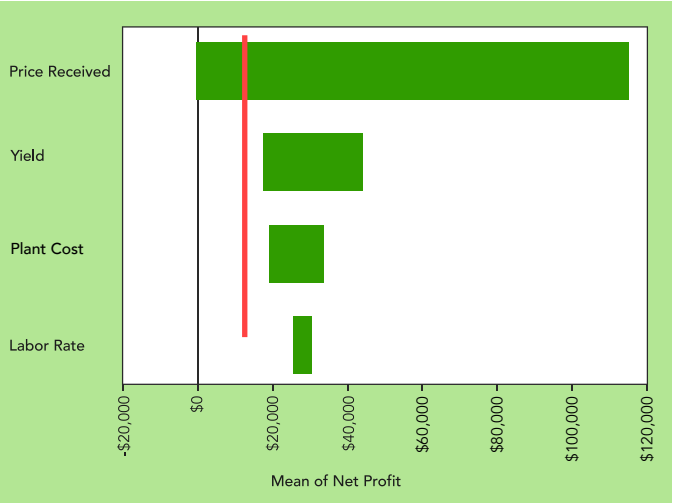

Figure 4. Sensitivity analysis results.

Price is the most sensitive variable considered in this model. As mentioned, at the scale modeled here, published market prices for conventional strawberries would not likely generate a profit. But producers would likely find a market for locally produced off-season strawberries at price points that result in a positive return. Thus, it is important to identify market channels before investing in a greenhouse operation for strawberry production in the winter months. The red line in figure 4 indicates the level at which the DSCR would fall below 1.0, which occurs only in the low end of the price and yield range considered in the analysis.

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