

Optimization of Economic Viability for Meat Alternatives

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Abstract

The goal of meat alternatives, specifically plant-based and cultured meat, is to provide an environmentally friendly food source that has the same cost, taste, and nutritional value as real meat. Currently, the main issue for alternative meat sources is the production expenses that contribute to the elevated prices observed by consumers in the market. This paper focuses on maintaining a high-quality product in terms of nutritional value while minimizing the production expenses associated with raw materials, manufacturing, transportation, and storage for a single serving (142 g) of a plant-based beef patty. Raw material constraints were established from a dataset of 20 different plant-based beef patty products currently found on the market. Transportation and storage costs and constraints were based on literature values with a variable market share. Additionally, the maximum amount of allowable greenhouse gas emissions per year was set. Optimal formulations of one plant-based beef patty were determined with a raw material cost of around \$3.54 per serving and \$0.41 per second in distribution and storage costs. The optimal market size was 0.083% of a total market consumption of 84.6 million kg of meat alternatives consumed annually in 2021.

Keywords

Meat alternatives, nutrition, sustainability, optimization, and plant-based meat.

1. Introduction

Valued at around \$9 trillion, the food industry encompasses about 10% of the world's gross domestic product (Plunkett Research 2023). The four major sectors include farm service, producers, processors, and marketers. During the past two centuries, the population across the globe has increased many folds a surge of innovations aimed at enhancing food production and distribution (John Hopkins 2023). These efforts resulted in incredibly efficient crop yields and food processing plants. An example of a specific innovation was the implementation of industrialized livestock production. Through the augmentation of livestock nutrition and medical care, it became feasible to rear animals indoors in densely populated settings, with minimal consequences (Food Print 2020).

While these advancements in technology were favored during the population boom, some activists found revulsion in slaughterhouses and the methods used to raise livestock for human consumption (Orzechowski 2020). During this time, other movements like environmentalism became popular as well, resulting in an association between the two.

From animal rights and environmental movements, several meat alternatives rose to help America cut back on meat consumption. Previously, protein alternatives such as tofu, beans, and lentils were widespread among the community, but greater change was desired.

To tackle the quantity of industrial livestock production, two alternatives paved the way. The first was plant-based meats, and the second was lab-grown meats (Long 2020). Optimization of the food quality, as well as distribution channels are promising tools to increase meat alternative awareness.

1.1 Objectives

The meat alternative industry has been growing at a steady pace and it has the potential of penetrating the food industry if quality and cost production factors are addressed. Since the meat industry is dominated by industrial livestock producers, it has little room for the costly process of plant-based and lab-grown alternatives. Ideally, the market would be able to offer the two options at similar prices to mark a real change in the industry for more human livestock production processes. The objectives of this paper are:

- Compare the market size and demand for plant-based and synthetic meats
- Develop a model to describe the cost to manufacture and transport meat alternatives
- Obtain an objective function using the values found to produce a serving of meat alternative
- Describe all boundary conditions and constraints for raw materials, as well as additional costs and regulations
- Optimize the objective function using the constraints to minimize the cost

2. Literature Review

2.1. Plant-Based Meat

2.1.1. Production

The first step for producing plant-based meat is protein isolation and functionalization. Protein isolation is the process of targeting and extracting plant proteins from plants. Some of the plant proteins are then hydrolyzed to enhance their functionalities, including solubility and cross-linking capacity (Rubio et al. 2020).

The next step is formulation: the plant proteins are mixed with ingredients, such as food adhesives, plant-based fat, and flour, to develop a meat-like texture. Nutrients are also added to match or exceed the nutrient profile of the meat (Rubio et al. 2020). Additionally, other ingredients may be added to the plant-based meat to imitate the smell and coloring of real meat.

Common raw materials used for the first and second steps are based on plants like cereals, legumes, or oilseeds, in order to industrially produce protein ingredients such as soybeans, rapeseed/canola, wheat, rice, oats, peas, beans, lupines, and algae (Tziva et al. 2020).

The third step is processing where the mixture of plant proteins and the other aforementioned ingredients undergo protein reshaping processes (e.g., extrusion, stretching, kneading, etc.) to further aid in the formation of a meat-like texture. Shear technology, mycelium cultivation, 3D printing, and recombinant protein additive are some examples of novel technologies used to improve the properties of plant-based meat (Rubio et al. 2020).

Presently, high-moisture extrusion is the most common process to create plant-based meat. During extrusion, proteins undergo thermal and mechanical stresses through heating the barrel and shearing the screws. This process alters the protein structure and leads to the formation of aggregates, which may be soluble and/or insoluble. A long, cooling die can be found at the end of the extruder, where proteins can be aligned in the flow direction forming an anisotropic protein network (McHugh 2019). High-moisture extrusion has allowed the development of high-performing products; resulting products are characterized by well-defined fiber formations that closely resemble meat structures and have enhanced taste sensation (Tziva et al. 2020).

2.1.2. Economics

Plant protein inputs for plant-based meat are relatively inexpensive. Most plant-based products are mainly formulated with pea, soy, or wheat protein. According to Rubio et al. (2020), for farmers in the United States, the agricultural prices received for these proteins are approximately 4 to 13 times lower than prices received for cattle, hogs, and

broilers. Rubio et al. (2020) also mentions that “when standardized by cost per gram of protein, soybeans (\$0.01/g) and wheat (\$0.03) are still remarkably less costly than cows (\$0.32/g), pigs (\$0.22/g), and chickens (\$0.12/g).”

Although the agricultural cost of plant protein inputs is low, plant-based meats tend to cost more than regular meat on the market; this is partially due to processing costs. Approximately 94.3% of retail costs for crop products are related to post-harvest processes. On the other hand, for beef, only 50% of the retail costs are due to processing costs. Furthermore, plant-based meats often include plant-based fats, flavor enhancers, and color additives, which further contribute to the cost (Rubio et al. 2020).

2.2.Lab-Grown/Cultured Meat

2.2.1. Production

Lab-grown or cultured meat is meat that is produced by cultivating animal cells as opposed to farming animals. Stem cell biology and tissue engineering are the main technological methods used to produce cultured meat; these were originally purposed for medical applications. The production of cultured meat involves four main steps or components:

- 1.Muscle and fat cell isolation and culture
- 2.Xeno-free culture medium formulation
- 3.Scaffold development
- 4.Bioreactor design

Specific details on each process mentioned above may be found in literature Rubio et al. (2020), Stephens et al. (2018), and Choudhury et al. (2020). Cultured meat is still a novel concept and is not highly marketed, but there has been significant progress made over the past few decades. Today, some start-up companies are working to bring cultured meat to the market (Rubio et al. 2020).

2.2.2.Economics

There are many challenges associated with the commercialization of cultured meat. According to Rubio et al. (2020), the first cultured beef burger was reported to have cost \$280,400 or \$2,470,000/kg to produce. The production process was based on lab-scale experimentation for over three months and did not have any goal to scale up the process. Rubio et al. (2020) also mention that the preliminary projected cost of cultured meat for large-scale production was estimated to be approximately twice as much as chicken.

Along with the two examples listed above, more studies and experimentation needs to be done to bring cultured meat to the market. However, it is clear that the main challenges of commercializing cultured meat are based on the growth media for cells, scale-up production, regulations, and consumer perception (Choudhury et al. 2020).

2.3. Meat Alternatives Industry Market Statistics

2.3.1. Meat Alternatives Revenue by Country

The survey in Figure 1 was taken in 2021 to estimate the relative market size of alternative meats by country. It was found that the three leading countries in alternative meats were China, the United States, and the United Kingdom with values of \$2.135 billion, \$1.479 billion, and \$0.847 billion respectively. The focus of this report will be solely on American and Canadian products.

This statistic is surprising because India was not found at the top, despite their eating habits. When observing vegetarian or vegan practices, India ranks first for adoption by population share while the United States ranks fourth and China ranks fifth (Wunsch 2021). This is because India has many vegetarian dishes widely available to their people; therefore, they do not require options in the form of meat substitutes.

2.3.2. Meat Alternative Opportunities

There is an increasing demand for meat alternatives (Figure 2) due to an increased awareness of industrial livestock production and rising prices of real meat. There is also a large portion of the country that is adopting vegetarian diets for health-related reasons or due to personal choice. This increasing market value is a good opportunity for investment, and by removing the limitations between the cost of production and the sale price, the market share can increase.

Optimization projects have already been performed on the process. Over the last few years, the cost of alternative meat has decreased by a third. However, the savings have stagnated and require a breakthrough to develop cheaper production methods (Figure 3).

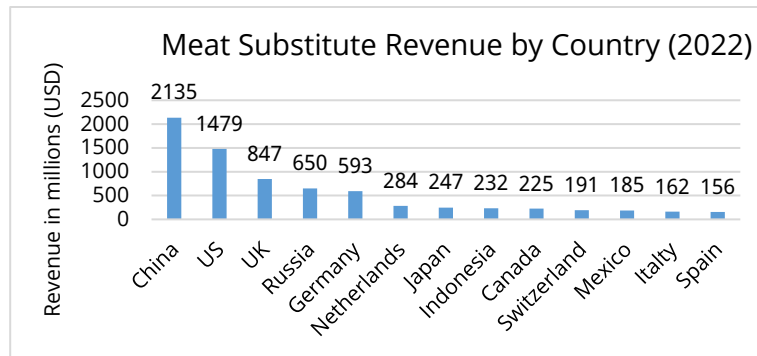


Figure 1. Meat substitute revenue in 2022 by Country (SR Department 2023)

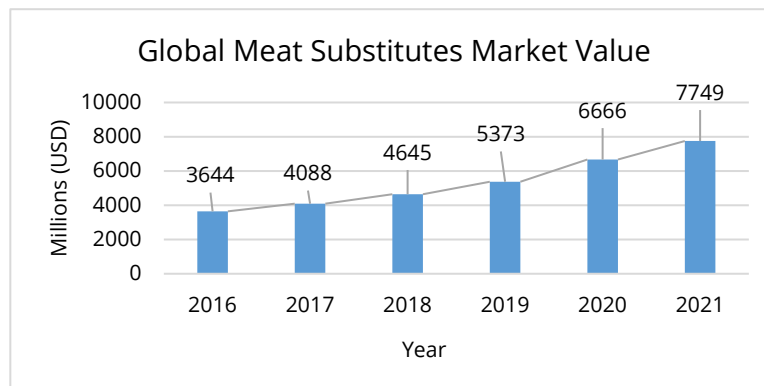


Figure 2. Global meat substitutes market value from 2016 to 2021 (SR Department 2021)

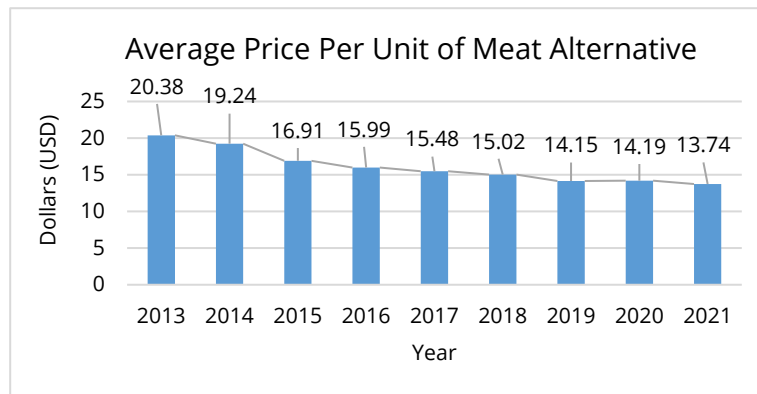


Figure 3. Average price per unit of meat alternatives from 2013 to 2021 (SR Department 2021)

2.3.3. Plant-Based vs. Lab-Grown

It is necessary to observe the interest in plant-based and lab-grown meat alternatives to determine which market has greater potential. A survey in 2021 (Figure 4) discovered that consumers are much more readily open to try plant-based or alternative protein meats while not many want to try fermented food products or lab-grown meats. One

difference is that lab-grown meat does not cater to vegans because it still uses cultivated animal cells. As a result, it is much more profitable to focus on the plant-based market.

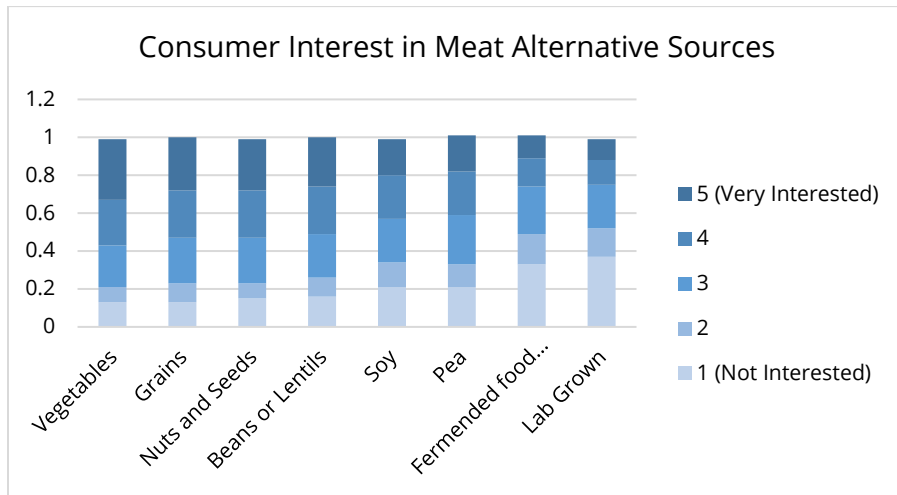


Figure 4. Consumer interest in meat alternative sources on relative scale (Wunsch 2021)

2.3.4. Leading Brands

Currently in the United States, there are two competitors in the alternative meat industry that have been partnering with different fast-food franchises to provide alternative meat burgers. From Figure 5, it is apparent that these two are Beyond Meat, which have partnered with McDonald's, Pizza Hut, Taco Bell, and KFC, as well as Impossible Foods, which have partnered with Burger King.



Figure 5. Global market value of US alternative meat brands (Wunsch 2021)

3. Key Variables and Parameters

3.1. Raw Materials

Due to the lack of available cost data for raw materials, another approach was taken to estimate the cost of harvesting and manufacturing ingredients. This was done by reviewing brands available in American and Canadian markets and collecting nutritional facts data including fats, proteins, and carbohydrates, while the rest of the serving size was assumed to be water. Additionally, the cost per package was recorded. Appendix A provides the list of product names, respective brands, costs, and nutritional data used to determine the final costs for each nutritional value (Table 1). Only plant-based meat products that imitated beef patties made from plant proteins were considered.

Table 1. Estimated cost of nutritional facts

Nutritional Fact	Cost (CAD)
Fats	\$0.06/g fat
Proteins	\$0.04/g protein
Carbohydrates	\$0.06/g carbohydrate
Water	\$0.01/g water

The assumptions related to finding the above costs include:

- The recorded cost only represents the cost of harvesting and manufacturing raw materials for the respective nutritional fact.
- All costs are greater than or equal to \$0.01.
- Weight of water was assumed to be the remaining component after subtracting the fats, proteins, and carbohydrates from the serving size.

A constraint that can be added to the raw materials or nutritional facts is the minimum and maximum amount of fats, proteins, carbohydrates, and water that is needed for a high-quality product. Based on the data found in Appendix A, the minimum and maximum weight of fats, proteins, carbohydrates, and water are given in Table 2. There are other considerations when imposing such upper and lower bounds on the amounts of the constituents. In industrial practice, a water content of less than 60% is usually desirable. Additionally, for health considerations, the fats or cholesterol content should be as low as possible. In the case study solved in this paper, an upper bound of 20% on fat content is used.

Table 2. Minimum and maximum weights of fats, proteins, carbohydrates, and water based on Appendix A.

Nutritional Fact	Minimum Weight (g)	Maximum Weight (g)
Fats	1	20
Proteins	9	29
Carbohydrates	5	14
Water	42.5	88

3.2. Transportation and Storage

There is insufficient literature information on the transportation and storage costs associated with plant-based meats. As a result, an assumption is made that the average cost for plant-based meats is similar to the cost for organic meats. According to Agri Benchmark, the average cost of transportation of beef carcasses in the United States is 3.49 USD/kg or 4.36 CAD/kg (Schütte 2018). Compared to other countries, this is relatively low as a result of built roads from government incentives for infrastructure, low gas taxes from abundant resources, and minimal state and government control. As for the storage costs of preserving food in a freezer, it was found that it costs 0.89USD/kg or 1.11 CAD/kg.

A key constraint in the balancing of transportation and storage costs is the working capital ratio; this is equal to the ratio of assets (or storage) to liabilities (transportation). The constraint is the balance of the working capital ratio between 1.2 and 2 to maintain a healthy and positive working capital ratio. Negative ratios result in poor asset management while high ratios result in abundant products (Freshbooks Blog 2018).

Another constraint for transportation was in terms of demand. The demand calculation is dependent on the total market demand as well as the market share of the company. In this paper, the total market demand used was the consumption of plant-based meats in 2021, 84.6 million kilograms, and a variable market share (Statistica 2021). Converting to consumption per second, the total market demand is 2.68 kg/s.

3.3. Emissions

According to Environment and Climate Change Canada (ECCC) (2022), “all facilities that emit the equivalent of 10 kilotonnes or more of greenhouse gases (GHGs) (in carbon dioxide equivalent units) per year” must report their emissions to ECCC. Using the information from ECCC (2022), this manuscript’s GHG emissions constraint will be less than or equal to 10 kilotonnes or 1.0×10^7 kg CO₂ eq. released per year.

According to Quantis (2019) and Heller and Keoleian (2018), emissions data per gram of plant-based beef patty is on average 0.0035 kg CO₂eq. Based on the sources, the emissions system boundary excludes the consumer stage. This project's boundaries will be the same and will assume that each patty produces the same amount of emissions.

4. Mathematical Programming Formulation

A typical optimization problem contains decision variables, an objective function, and constraints. Decision variables are the variables that can be controlled to improve the objective function and should completely describe the set of decisions to be made (Ravindran et al., 2006). The objective function, shown by Equation (1), is the mathematical function that is to be minimized or maximized. Typically, objective functions are subject to inequality and/or equality constraints, as seen in Equation (2). A feasible solution is obtained if the calculated solution obeys all constraints (Ravindran et al. 2006).

$$\text{Minimize or Maximize: } f(x) \quad (1)$$

$$\text{Subject to: } h(x) = 0; g(x) \geq 0 \text{ or } g(x) \leq 0 \quad (2)$$

where, x can be a vector of variables and the constraints may be of different dimensions.

The variables that will be controlled in the objective function are based on the nutritional values as described in Section 3.1, and the transportation and storage factors described in Section 3.2. Table 3 below gives a listing of the decision variables and what each variable represents.

Table 3. Decision variables
F

Decision Variable	Meaning
X_1	Mass of fats in plant-based meat (g)
X_2	Mass of proteins in plant-based meat (g)
X_3	Mass of carbohydrates in plant-based meat (g)
X_4	Mass of water in plant-based meat (g)
T	Mass of plant-based meat to be transported (g/s)
S	Mass of plant-based meat in storage (g/s)
MS	Market share

As mentioned in Section 3.3, the GHG emissions data found in the literature only include the stages before the consumer stage (Quantis 2019) and (Heller and Keoleian 2018). The system boundary of this project will be the same and is illustrated in Figure 6 (Quantis 2016).

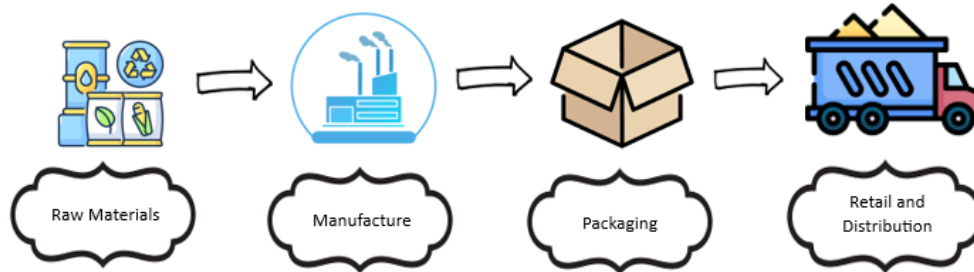


Figure 6. System boundary (Quantis 2016)

In the context of this manuscript, the objective is to minimize the cost of production, $F(x)$, while maintaining a high-quality product vis a vis nutritional value. The three costs considered are the costs of raw materials, the cost to transport the products to the first delivery site, and storage/inventory costs, i.e.

$$\text{Minimize: } F(x) = \text{Raw Materials Costs} + \text{Transportation Costs} + \text{Storage Costs} \quad (3)$$

By substituting the values given earlier, the following objective function is represented by Equation (4).

$$F(x) = F(X_1, X_2, X_3, X_4, T, S) \quad (4)$$

$$= 0.06X_1 + 0.04X_2 + 0.06X_3 + 0.01X_4 + \frac{4.36}{1000}M \times \left(\frac{T}{T+S}\right) + \frac{1.11}{1000}M \times \left(\frac{S}{T+S}\right)$$

There are several constraints for this problem. The first are the positivity constraints:

$$\{T, S\} \geq 0 \quad (5)$$

Next, the material balance constraint indicates that the total mass is the sum of the components and setting the serving size to 142 g. As shown in Appendix A, the maximum serving size found was 142 g, thus it was used as the basis for this case study. Additionally, from Table 2, the lower and upper bounds on the variables must be imposed:

$$M = X_1 + X_2 + X_3 + X_4 \quad (6)$$

$$M = 142g \quad (7)$$

$$20 \geq X_1 \geq 1; 29 \geq X_2 \geq 9; 14 \geq X_3 \geq 5; 88 \geq X_4 \geq 42.5 \quad (8)$$

The Working Capital Ratio should be between 1.2 and 2 to represent a good allocation of resources as explained earlier and the transportation costs should also not surpass the total demand of the industry multiplied by the market share.

$$1.2 \leq \frac{T}{S} \leq 2 \quad (9)$$

$$T \leq 2680 \frac{g}{s} \times MS \quad (10)$$

Finally, the emissions should not exceed the amount where it would be required to report to the ECCC.

$$0.0035 \frac{kg CO_2eq}{g} \times 2680 \frac{g}{s} \times MS \leq 0.3170 \frac{kg CO_2eq}{s} \quad (11)$$

5. Results

Based on the objective function and constraints, LINGO (developed by LINDO systems Inc.) was used to determine the optimal meat substitute formulation. LINGO is a computer-aided optimization software that allows the process of constructing and solving optimization models, encompassing Linear, Nonlinear, Stochastic, Integer, and other related programming problems (Schrage, 1999). It offers a fully integrated package that encompasses a robust language for expressing optimization models. With LINGO, building and solving the above model becomes faster, simpler, and more efficient. The optimal formulation is shown in Table 4.

Table 4. Optimal meat substitute formulation.

Decision Variables	Optimal Value
X_1	20 g
X_2	29 g
X_3	5 g
X_4	88 g
T	2.2285 g/s
S	1.8571 g/s
MS	0.8315×10^{-3}

The results above show that the optimal formulation to minimize the cost of production of a 142 g (one serving size) plant-based beef patty is 20 g of fat, 29 g of protein, 5 g of carbohydrates, and 88 g of water. Based on data collected from existing commercial products (Appendix A), the average fat, protein, carbohydrates, and water content is compared to the optimal recipe of Table 5. As can be seen, the difference is not significant and the optimal formulation obtained in this work is similar to products numbered 3, 4, 10, 13, 14, and 18 in Appendix A. Therefore, the procedure illustrated in this table employing mathematical programming is a promising way to come up with formulations. Constraints with respect to nutrients can be easily added to the model to obtain healthier formulation.

Table 5. Comparison of nutritional facts between the average of existing commercial plant-based beef patties and the optimal formulation of this work.

Nutritional Fact	Average (based on Appendix A)	Optimal Formulation	Difference
Fats	10%	14%	+4%
Proteins	18%	20%	+2%
Carbohydrates	9%	4%	-5%
Water	63%	62%	-1%

To minimize the cost of production for one plant-based beef patty, the optimal total cost of raw materials is \$3.54. Based on Appendix A, the average cost per serving is \$2.58 ± \$1.25. Therefore, the final cost of raw materials is within a reasonable range.

In terms of transportation and storage, the mass of plant-based beef patty to be transported and stored are 2.2285 g/s and 1.8571 g/s, respectively. This results in a working capital ratio of about 1.2. This shows that a lower ratio results in a lower cost because the cost of transportation is much higher than the cost of storage. However, because of the constraint to have a ratio between 1.2 and 2 for healthy inventory, storage is required. Additionally, the optimal total cost of transportation and storage are \$0.34 and \$0.07, respectively.

The market share reflects the size of the company and the demand that constrains the transportation cost. In the optimal solution, the market share is 0.083% which is about the size of a smaller plant-based meat producing company.

6. Conclusions and Recommendations

In conclusion, the optimal solution for the manufacturing and distribution of plant-based meat was \$3.54 in raw materials per 142 g serving as well as \$0.41 in distribution and storage costs. The solution met the constraints for minimal raw materials, working capital ratio, and emission limits. The market size for this solution was 0.083% of a total market consumption of 84.6 million kg of meat alternatives consumed annually in 2021. As this is a general solution, it is not suitable for each individual company. If a specific solution is required, the market share can be set as a parameter instead of a variable to determine more appropriate optimal conditions.

For this optimization problem, there are many more qualitative considerations, and manufacturing differences that need to be accounted for. The information is highly technical, and more research should be conducted to consider feasibility.

Acknowledgements/ Disclaimer

The work presented in this paper is for academic purposes only. This paper represents the opinions of the authors and is the product of professional research. It is not meant to represent the position or opinions of Beyond Meat Inc.

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Appendix A – Product Data

NUMBER & NAME	BRAND & COUNTRY	COST PER PACKAGE	TOTAL PACKAGE (G)	SERVING SIZE (G)	CALORIES	CARBOHYDRATES (G)	FATS (G)	PROTEINS (G)	WATER (G)
(1) Extreme Griller	Sol Cuisine Inc (Canada)	\$6.29	226	71	100	8	4	9	50
(2) Supreme Plant-Based Burger	Gardein (Canada)	\$6.99	284	113	210	9	11	20	73
(3) Beyond Burger	Beyond Meat (USA)	\$7.99	226	113	270	5	19	20	69
(4) Impossible Burger	Impossible Foods Inc. (USA)	\$8.99	227	113	240	9	14	19	71
(5) The Good Veggie Burger	Yves Veggie Cuisine (Canada)	\$5.99	300	75	100	7	2	13	53
(6) Harvest Veggie	MorningStar Farms (USA)	\$4.97	268	67	110	9	4.5	11	42.5
(7) The Ultimate Meatless Burger	Great Value (Canada)	\$9.00	904	113	200	12	10	19	72
(8) Original Vegan Veggie Burger	Boca (USA)	\$4.33	284	71	80	7	1	14	49
(9) Chef's Signature Plant-Based Burger	Field Roast (USA)	\$6.97	368	92	240	12	12	21	47
(10) Plant Based Burger	Lightlife (Canada)	\$7.47	227	113	250	8	16	20	69
(11) Veggie Bistro Burgers	Yves Veggie Cuisine (Canada)	\$5.27	352	88	130	8	4.5	15	60.5
(12) The Very Good Burger	Very Good Butchers (Canada)	\$13.99	432	108	210	13	8	23	64
(13) Plant Based Burger!	Raised & Roasted (USA)	\$6.24	224	112	280	8	18	21	65
(14) Plant-Based Burger by BTB	UNCUT (USA)	\$10.61	226	113	260	8	17	19	69
(15) Protein Patties	Trader Joe's (USA)	\$5.61	226	113	290	11	20	18	64
(16) Incogmeato	MorningStar Farms (USA)	\$7.49	240	120	280	14	18	20	68
(17) Vegan Meatless Burger Patties	Simple Truth (USA)	\$5.99	400	100	160	10	7	20	63
(18) Beefless Undeniable Burger	President's Choice (Canada)	\$11.99	452	113	250	5	14	27	67
(19) Meatless Plant-Based Burgers Traditional	365 Whole Foods Market (USA)	\$5.49	284	71	80	7	3	10	51
(20) Meatless Burgers	President's Choice (Canada)	\$8.99	568	142	260	13	12	29	88

(1) Extreme Griller	\$1.98	(11) Veggie Bistro Burgers	\$1.32
(2) Supreme Plant-Based Burger	\$2.78	(12) The Very Good Burger	\$3.50
(3) Beyond Burger	\$4.00	(13) Plant Based Burger!	\$3.12
(4) Impossible Burger	\$4.48	(14) Plant-Based Burger by BTB	\$5.31
(5) The Good Veggie Burger	\$1.50	(15) Protein Patties	\$2.81
(6) Harvest Veggie	\$1.24	(16) Incogmeato	\$3.74
(7) The Ultimate Meatless Burger	\$1.13	(17) Vegan Meatless Burger Patties	\$1.50
(8) Original Vegan Veggie Burger	\$1.08	(18) Beefless Undeniable Burger	\$3.00
(9) Chef's Signature Plant-Based Burger	\$1.74	(19) Meatless Plant-Based Burgers Traditional	\$1.37
(10) Plant Based Burger	\$3.72	(20) Meatless Burgers	\$2.25

AVERAGE PRICE	DEVIATION
\$2.58	\$1.25

Biographies

Helen Zhong is an Engineering Technical Associate at The Estee Lauder Companies; as part of the Commercialization Engineering team, she is responsible for managing and executing line trials for new product launches for liquid makeup. She has applied her learnings and experiences from her studies at the University of Waterloo, where she graduated with a Bachelor of Applied Science in Chemical Engineering in 2022. As part of her studies, she also received a specialization in Chemical Process Modelling, Optimization, and Control.

Bedis Elkamel is affiliated with the University of Central Florida Department of Health Sciences. With a multifaceted range of interests, he has devoted his expertise to the areas of nutrition and health, sports, and scientific research, with a particular focus on exploring the fascinating intersection of these fields. Bedis demonstrates a deep passion for understanding the impact of nutrition on overall health and well-being. Bedis has a keen interest in sports and its profound influence on physical fitness and performance. Bedis Elkamel's research pursuits are fueled by a strong commitment to scientific inquiry and discovery.

Tong Li Han is an Engineering Analyst at Toyota Motor manufacturing, leveraging a Bachelor of Applied Science degree. Tong Li is an expert in modeling, optimization, and engineering analysis. Tong previously contributed to the success of BioIntegral Surgical, Inc. as a Medical Devices Associate.

Gholamreza Zahedi is an R&D engineer at Beyond Meat, Food and Beverage Services El Segundo overseeing pilot plant activities for successful product scale up, new product and process development, managing and team development for process engineers, maintenance, and pilot staff for successful product scale up. Implementing lean manufacturing, stage gate and process optimization during scale up for reduced cost products for BM US and Global production facilities. His research interests are in sustainable systems engineering, modeling and optimization, scale up, and commercialization. He was previously a Production Leader Engineer at Leprino Foods, Principal Engineer at Orion Food Systems, Director of Engineering at Design Tanks, and Director of Engineering and R&D at Ozone Solutions. He held also academic positions at Missouri S&T and Universiti Teknologi Malaysia.