

# A Greener Protein Option: Examining the Viability of Plant-Based Meat with Green Lentils

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## Abstract

*Plant-based meat alternatives have been developed and are becoming more and more popular as a result of the desire for environmentally friendly and sustainable protein sources. The feasibility of using green lentils as the main ingredient in plant-based meat alternatives is investigated in this study. A viable possibility for plant-based meat production, green lentils provide a plentiful supply of protein, fibre, and other minerals. The study assesses the nutritional makeup of green lentils, including their protein concentration, amino acid profile, and micronutrient content, and compares it to conventional meat sources. Green lentils (*Lens culinaris*), which are a great alternative to meat since they are high in protein, fibre, and other vital elements. The edible seeds of green lentils, formally known as *Lens culinaris*, a species of legume, are a major reason for their widespread cultivation. They are a great source of protein, dietary fibre, vitamins, and minerals, all of which are vital elements. Given their flavor-friendly taste, texture, and capacity to absorb flavours, green lentils present an appealing choice for creating plant-based meat substitutes. They're a distinct flavour and texture that can replicate the sensation and flavour of conventional meat products. The research also looks into the useful qualities of green lentils, such as their resemblance to the texture, appearance, and flavour of regular meat. It examines various methods of processing, such as extrusion and texturization, to improve the sensory qualities and general acceptability of items derived from green lentils that resemble meat. This study also investigates the environmental impact of using green lentils as a protein source. When compared to the production of traditional meat, lentil farming uses less land, water, and energy. According to the study, green lentils have the potential to be a more environmentally friendly source of protein than sources based on animals by evaluating the carbon and water footprints they leave behind during every stage of production. The study also looks into how green lentil-based plant-based meat products are perceived by consumers and how they are accepted by the market. In order to determine consumer acceptance and potential adoption hurdles, surveys and sensory evaluations are used to examine consumer attitudes towards sustainability, health, and flavour preferences. Overall, this study sheds light on the potential of green lentils as a more environmentally friendly source of protein for plant-based meat. It draws attention to their nutrient profiles, practical qualities, effects on the environment, and market possibilities. The findings support continuing initiatives to create environmentally friendly protein sources and advance a more sustainable food system.*

## Keywords

*Green Lentils, Plant-based Meat, Sustainability, Protein Content, Environmental Impact, Consumer Acceptance.*

## INTRODUCTION

Traditional animal-based meat products can be replaced with healthful and sustainable plant-based meat manufactured from green lentils. One type of legume that is high in fiber, protein, and other vital components is lentil. Their nutritional worth and environmental benefits have led to their increasing appeal as a plant-based source of protein. The high concentration of bioactive substances found in green lentils, such as phenolic acids and flavonoids, has been connected to a number of health advantages, including their ability to reduce inflammation and function as an antioxidant [1]. These substances also enhance the flavor and texture of plant-based meat derived from green lentils. Green lentils may be used to produce plant-based meat that is also more environmentally friendly than conventional meat products derived from animals. Compared to animal products, lentils require less water, land, and resources to cultivate, making them a more ecologically responsible choice. Furthermore, compared to animal agriculture, the production of plant-based meat from green lentils produces lower greenhouse gas emissions [2]. Without sacrificing the product's sensory appeal, green lentils may be utilized in vegetarian burgers in

place of soy protein [3]. Green Lentil Foods is one firm that is setting the standard for plant-based meat made from green lentils. Green Lentil Foods, which was founded in 2016 by two brothers, makes a variety of plant-based meat products, such as crumbles, sausages, and burgers. The company's goal is to offer delicious, sustainable, and healthful substitutes for conventional meat products. Grand View Research reports that the growing demand for vegan and vegetarian goods would propel the worldwide market for plant-based meat to reach \$35.4 billion by 2026 [4]. Because of their meaty texture and capacity to absorb tastes, they have gained popularity as a plant-based meat substitute in recent times. The distinctive feature of these little green lentils is their ability to maintain their structure throughout cooking, preventing them from becoming too soft. Green lentils are an excellent source of plant-based protein, with around 18 grams of protein per 100 grams [5]. Moreover, they provide dietary fiber, which can aid in promoting digestive health and warding off chronic illnesses including diabetes and heart disease [6]. Cooking with green lentils is quite flexible; they work well in soups, stews, salads, and even veggie burgers. Their meaty texture and flavor-absorbing capacity allow them to be used as a meat replacement. Indeed, a research that

appeared in the Journal of Food Science discovered that substituting green lentils for beef in meatballs could be done without substantially altering the meatballs' sensory qualities [7]. Green lentils are better for the environment than other meat-producing techniques because they use less water and land, in addition to their nutritional advantage [8]. They are therefore an eco-friendly option for anyone trying to lower their carbon impact.

## METHODOLOGY

### Research Design

The research design would normally combine experimental and analytical methods to examine the viability of plant-based meat with green lentils. Assessing green lentils' potential as a wholesome and sustainable source of protein for plant-based meat production would be the main goal. These elements could be part of the research design

- **Literature review:** Conducting an extensive analysis of the body of work in order to ascertain the present level of understanding of the nutritional, production, and processing of plant-based meat. This would aid in identifying research priorities and knowledge gaps.
- **Formulation of the hypothesis:** Creating precise hypotheses or research questions that may be tested through experiments and data analysis based on the literature evaluation. One possibility, for instance, would be that green lentils, which have favourable sensory and nutritional qualities, can serve as a reliable source of protein for plant-based meat.
- **Experimental Layout:** Controlled tests to contrast several versions of plant-based meat using green lentils as a significant component. This may involve experimenting with different lentil concentrations, processing techniques, additions, and other ingredients to determine how they affect the end result.
- **Groups under control:** Including controls that serve as comparative points for current meat-free products or traditional meat. As a result, it is possible to compare the effectiveness and acceptance of plant-based meat made from green lentils to their existing counterparts.

### Collection

In order to assess the viability of plant-based meat with green lentils, data collecting is an important step. During the course of the experiments, pertinent data and measurements are gathered. Data collection techniques that might be used include:

- **Sensory Analysis:** Evaluating the flavour, texture, aroma, and general acceptability of the plant-based meat products by sensory testing with expert panellists or consumer panels. This can be carried out utilising sensory evaluation methods such as hedonic scales, ranking, or scoring.

- **Evaluation:** Performing nutritional analysis to ascertain the protein amount, amino acid profile, lipid content, and other important nutritional factors of the plant-based meat made from green lentils. This information would be used to evaluate the product's nutritional value and sufficiency.
- **Parameters:** Measuring the plant-based meat samples' physical characteristics, such as colour, hardness, moisture content, and cooking yield. These metrics shed light on the products' textural qualities and culinary capabilities.

### Experimental Setup:

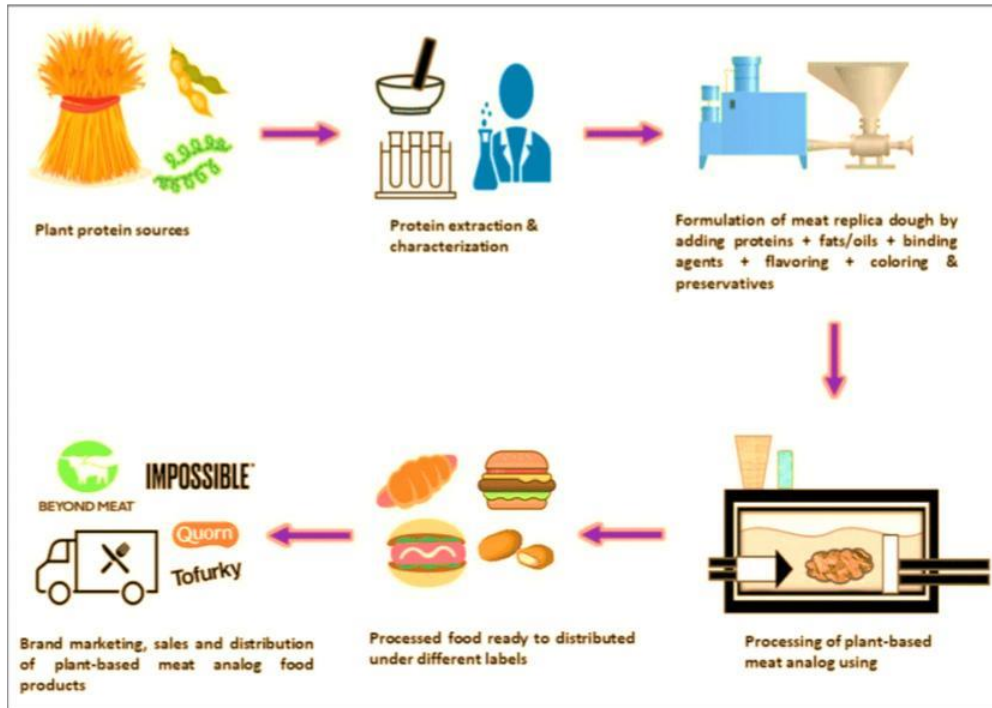
Setting up a controlled setting and conditions for the experiments would be the experimental setup. This might comprise:

- **Pilot-scale or laboratory production facilities:** Establishing a special location with the necessary tools and resources to make the plant-based meat samples. To reproduce the production process on a smaller scale, equipment for food processing, such as mixers, grinders, extruders, and ovens, would normally be used.
- **Selection of Ingredients:** High-quality green lentils were sourced and chosen as the main component of the plant-based meat. Based on their suitability for lentils and the desired qualities of the finished product, additional components like binders, flavours, and seasonings may also be chosen.
- **Experimental Parameters:** Identifying the precise parameters and variables to be examined, such as formulation modifications, processing techniques, and lentil concentration. Based on the study's goals and premise, these parameters should be selected.

### Sample Preparation

A crucial stage in the research procedure is preparing the plant-based meat samples. To ensure uniformity and reproducibility, this calls for adhering to standardised production procedures and recipes. The example preparatory steps could consist of:

1. **Lentil Processing:** The green lentils are cleaned, sorted, and precooked to make them ready for inclusion in the plant-based meat. To give the lentils the correct texture and functioning, this may entail soaking, boiling, or steaming them.
2. **Formulation Development:** Blending the already-cooked lentils with other ingredients and additives to produce a composition that resembles the feel and sensory qualities of meat. To acquire the desired product qualities, iterative studies may be required to optimise the formulation.



**Figure 1.** Processing Techniques

3. **Processing Techniques:** Extrusion, grinding, or emulsification are a few suitable food processing methods that might be used to further improve the plant-based meat recipe. The end product's texture, appearance, and general quality are all improved by using these approaches. (Show in this figure 1)

#### Analytical Methods

The features and traits of the samples of plant-based meat are assessed using analytical techniques. In this study, some typical analytical techniques that may be used include:

- **Approximate analysis:** Determining the moisture, protein, fat, and carbohydrate content of the plant-based meat samples. The nutritional composition of the product is revealed by this examination.
- **Analysis of the amino acids:** Analysing the essential amino acid content and protein quality of the plant-based meat. Techniques like gas chromatography (GC) or high-performance liquid chromatography (HPLC) can be used to carry out this analysis.
- **Texture Analysis:** Using texture analyzers to evaluate the firmness, springiness, chewiness, and other textural characteristics of the plant-based meat. These metrics aid in understanding the product's mouthfeel and sensory experience.
- **Colour Measurement:** Quantifying the L\*, a\*, and b\* values of the plant-based meat samples using colorimeters or spectrophotometers. This research reveals details regarding the visual appearance and similarity to regular meat.
- **Microbiological Evaluation:** Conducting microbiological tests to make sure the plant-based meat products are safe and of high quality. This entails

determining the presence of diseases and evaluating microbial numbers.

#### GREEN LENTILS PRODUCTS

##### Lentils Meatballs

Green Lentil "Meatballs" are a delicious and nutritious plant-based alternative to traditional meatballs. Here's how you can make them:

Ingredients
- 2 cups cooked green lentils
- 1 cup breadcrumbs
- 1 small onion, chopped
- 2 cloves garlic, minced
- 2 tbsp tomato paste
- 1 flaxseed "egg" (1 tbsp ground flaxseed mixed with 3 tbsp water)
- 2 tbsp soy sauce or tamari
- 1 tsp dried oregano
- 1 tsp dried thyme
- ½ tsp salt
- ¼ tsp black pepper
- Olive oil for cooking
For the flaxseed "egg":
- 1 tbsp ground flaxseed
- 3 tbsp water

##### Instructions

1. In a large mixing bowl, combine the cooked green lentils, breadcrumbs, chopped onions, minced garlic, tomato paste, flaxseed "egg" mixture, soy sauce or tamari, dried oregano, dried thyme, salt, and pepper.

2. Combine each item thoroughly in the mixture. If the mixture feels too dry, you can add a little water or vegetable broth, one tablespoon at a time, until it holds together.
3. Let the mixture sit for about 10-15 minutes to allow the flavors to meld together and for the breadcrumbs to absorb any excess moisture.
4. Preheat your oven to 375°F (190°C).
5. Shape the lentil mixture into small meatball-sized balls, using about 1-2 tablespoons of the mixture for each ball. Roll the mixture between your hands to form smooth balls.
6. Add a drizzle of olive oil to a non-stick skillet that is already hot over medium heat. Place the lentil meatballs in the skillet, being careful not to overcrowd them, and cook for about 2-3 minutes on each side until they are browned and slightly crispy.
7. Once the lentil meatballs are browned, transfer them to a baking sheet lined with parchment paper.
8. Bake the lentil meatballs in the preheated oven for about 15-20 minutes until they are cooked through and firm.
9. Remove the lentil meatballs from the oven and let them cool slightly before serving.

**Serving Suggestions**

Serve the lentil meatballs with your favorite pasta and tomato sauce for a classic spaghetti and meatballs dish. Use the lentil meatballs as a filling for sandwiches or wraps, along with some fresh veggies and sauce. Serve the lentil meatballs on top of a bed of greens for a hearty salad. Enjoy the lentil meatballs as a standalone appetizer or snack, served with a dipping sauce like marinara or vegan aioli.

**Green Lentil “Burger” Patties**



**Figure 2.** burger

<b>Ingredients:</b>
- 1 cup cooked green lentils
- 1/2 cup breadcrumbs (regular or gluten-free)
- 1/4 cup finely chopped onions
- 2 cloves garlic, minced
- 2 tablespoons tomato paste
- 1 tablespoon soy sauce or tamari
- 1 tablespoon ground flaxseeds mixed with 3 tablespoons water (flaxseed "egg" substitute)

- 1 teaspoon dried oregano
- 1/2 teaspoon smoked paprika (optional)
- Salt and pepper to taste
- Olive oil for cooking

**Instructions**

1. In a bowl, mash the cooked green lentils using a fork or potato masher until they form a coarse texture.
2. Add the breadcrumbs, chopped onions, minced garlic, tomato paste, soy sauce or tamari, flaxseed "egg" mixture, dried oregano, smoked paprika (if using), salt, and pepper to the bowl. Mix thoroughly until each item is distributed equally.
3. Let the mixture sit for 10-15 minutes to allow the flavors to meld together and for the breadcrumbs to absorb any excess moisture.
4. Shape the lentil mixture into burger patties using your hands. Aim for about 1/4 to 1/2 inch thick patties.
5. Heat a non-stick skillet or grill pan over medium heat and add a drizzle of olive oil. Cook the lentil burger patties for 4-5 minutes on each side, until they are browned and heated through.
6. Serve the green lentil burger patties on buns or lettuce wraps with your choice of toppings, such as lettuce, tomatoes, onions, pickles, and condiments.

**Serving Suggestions:** Enjoy the green lentil burger patties as a classic burger meal with fries or a side salad. You can also serve them as a protein-rich patty in wraps or sandwiches.

**Green Lentil "Taco" Filling**

<b>Ingredients:</b>
- 1 cup cooked green lentils
- 1 tablespoon olive oil
- 1 small onion, diced
- 2 cloves garlic, minced
- 1 tablespoon taco seasoning (store-bought or homemade)
- Salt and pepper to taste
- Optional toppings: diced tomatoes, shredded lettuce, sliced avocado, chopped cilantro, vegan sour cream, salsa, etc.

**Instructions**

1. Over medium heat, warm the olive oil in a skillet. Sauté the onion till it turns transparent and smells good after adding the minced garlic.
2. Add the cooked green lentils to the skillet and sprinkle the taco seasoning over the lentils. Stir well to coat the lentils evenly with the seasoning. Cook for 3-4 minutes to heat the lentils and allow the flavors to blend.
3. Add salt and pepper to taste.
4. Serve the green lentil taco filling in taco shells, tortillas, or lettuce wraps. Top with your favorite taco toppings, such as diced tomatoes, shredded lettuce, sliced avocado, chopped cilantro, vegan sour cream, and salsa.



**Serving Suggestions:** Use the green lentil "taco" filling as a plant-based alternative for traditional taco fillings. Serve with your choice of taco toppings for a flavorful and protein-packed taco experience.

### Green Lentil "Sausage" Crumbles

Ingredients:
- 1 cup cooked green lentils
- 1 tablespoon olive oil
- 1 small onion, diced
- 2 cloves garlic, minced
- 1 teaspoon fennel seeds (optional)
- 1 teaspoon smoked paprika
- 1/2 teaspoon dried thyme
- 1/2 teaspoon dried sage
- (Adjust to taste) 1/4 teaspoon red pepper flakes
- dash of salt and pepper

#### Instructions

- Place a skillet with olive oil over medium heat. Sauté the onion till it turns transparent and smells good after adding the minced garlic.
- Add the cooked green lentils to the skillet and break them up with a spoon or fork to create a crumbled texture.
- Add fennel seeds (if using), smoked paprika, dried thyme, dried sage, red pepper flakes, salt, and pepper to the skillet. Stir well to combine all the ingredients and distribute the spices evenly.
- Cook for 5-7 minutes, stirring occasionally, until the lentil crumbles are heated through and lightly browned.
- Use the green lentil "sausage" crumbles as a topping for pizzas, pasta dishes, breakfast scrambles, or any recipe where you desire a savory and flavorful "sausage" texture.

**Serving Suggestions:** Incorporate the green lentil "sausage" crumbles into various dishes like pizzas, pasta sauces, breakfast scrambles, or stir-fries to add a plant-based protein element with a sausage-like flavor profile.

### Green Lentil "Meatloaf":

Ingredients:
- 1 1/2 cups cooked green lentils
- 1 cup breadcrumbs (regular or gluten-free)
- 1/2 cup finely chopped onions
- 1/2 cup finely chopped bell peppers
- 2 cloves garlic, minced
- 2 tablespoons tomato paste
- 2 tablespoons ground flaxseeds mixed with 6 tablespoons water (flaxseed "egg" substitute)
- 2 tablespoons soy sauce or tamari
- 1 tablespoon Worcestershire sauce (vegan if desired)
- 1 tablespoon Dijon mustard
- 1 teaspoon dried thyme
- 1/2 teaspoon dried oregano

- Salt and pepper to taste
- Optional glaze: ketchup, barbecue sauce, or tomato-based glaze

#### Instructions:

- Preheat your oven to 375°F (190°C) and lightly grease a loaf pan.
- In a large mixing bowl, combine the cooked green lentils, breadcrumbs, chopped onions, chopped bell peppers, minced garlic, tomato paste, flaxseed "egg" mixture, soy sauce or tamari, Worcestershire sauce, Dijon mustard, dried thyme, dried oregano, salt, and pepper. Mix thoroughly until each item is distributed equally.
- Transfer the lentil mixture to the greased loaf pan and press it down firmly to form a loaf shape.
- Optional: Spread your choice of glaze (ketchup, barbecue sauce, or tomato-based glaze) on top of the lentil loaf.
- Bake in the preheated oven for about 45-50 minutes or until the lentil loaf is firm and the top is slightly browned.
- Remove from the oven and let the lentil loaf cool for a few minutes before slicing.

**Serving Suggestions:** Serve the green lentil "meatloaf" as a main dish, accompanied by mashed potatoes or roasted vegetables. It can be enjoyed with a side of gravy or a tangy sauce of your choice.

### Green Lentil "Chili"

Ingredients:
- 1 cup cooked green lentils
- 1 tablespoon olive oil
- 1 small onion, diced
- 2 cloves garlic, minced
- 1 bell pepper, diced
- 1 jalapeno pepper, seeded and minced (optional)
- 1 can diced tomatoes
- 1 can kidney beans, drained and rinsed
- 1 cup vegetable broth
- 2 tablespoons tomato paste
- 1 1/2 tablespoons chili powder
- 1 teaspoon ground cumin
- 1 teaspoon paprika
- 1/2 teaspoon dried oregano
- Salt and pepper to taste

#### Instructions

- Heat olive oil in a large pot or Dutch oven over medium heat. Add the diced onion, minced garlic, diced bell pepper, and minced jalapeno (if using). Sauté until the vegetables are softened and fragrant.
- Add the cooked green lentils, diced tomatoes, kidney beans, vegetable broth, tomato paste, chili powder, ground cumin, paprika, dried oregano, salt, and pepper to the pot. Stir well to combine all the ingredients.

3. Bring the chili to a boil, then reduce the heat to low and simmer for about 20-30 minutes to allow the flavors to meld together. Stir occasionally.
4. Adjust the seasoning with salt and pepper to taste.
5. Serve the green lentil chili hot, garnished with your choice of toppings such as chopped green onions, diced avocado, vegan sour cream, or shredded vegan cheese.

**Serving Suggestions:** Enjoy the green lentil chili on its own as a hearty and satisfying meal. It can be served with cornbread, rice, or crusty bread for a complete and comforting dining experience.

### Green lentil "Shepherd's Pie"

Ingredients:
- 2 cups cooked green lentils
- 1 tablespoon olive oil
- 1 small onion, diced
- 2 cloves garlic, minced
- 1 carrot, diced
- 1 celery stalk, diced
- 1 cup diced mushrooms (optional)
- 1 teaspoon dried thyme
- 1 teaspoon dried rosemary
- 1 cup vegetable broth
- 2 tablespoons tomato paste
- Salt and pepper to taste
- Mashed potatoes (made from about 4-5 medium potatoes)

#### Instructions

1. Preheat your oven to 375°F (190°C).
2. Heat olive oil in a large skillet or pan over medium heat. Add the diced onion, minced garlic, diced carrot, diced celery, and diced mushrooms (if using). Sauté until the vegetables are softened and lightly browned.
3. Add the cooked green lentils, dried thyme, dried rosemary, vegetable broth, tomato paste, salt, and pepper to the skillet. Stir well to combine all the ingredients. Cook for 5-7 minutes to allow the flavors to meld together.
4. Transfer the lentil mixture to a baking dish and spread it evenly.
5. Top the lentil mixture with a layer of mashed potatoes, spreading them evenly to cover the lentils completely.
6. Bake in the preheated oven for about 25-30 minutes or until the mashed potatoes are golden and the filling is heated through.
7. Remove from the oven and let the Shepherd's Pie cool for a few minutes before serving.

**Serving Suggestions:** Serve the Green Lentil "Shepherd's Pie" as a comforting and satisfying meal on its own. It pairs well with a side of steamed vegetables or a fresh salad.

### Lentil "Meat Sauce" for Pasta

Ingredients:
- 1 cup cooked green lentils
- 1 tablespoon olive oil
- 1 small onion, diced
- 2 cloves garlic, minced
- 1 can crushed tomatoes
- 1 can tomato sauce
- 1 tablespoon tomato paste
- 1 teaspoon dried basil
- 1 teaspoon dried oregano
- ½ teaspoon dried thyme
- Salt and pepper to taste
- Optional: red pepper flakes for heat, fresh basil for garnish

#### Instructions

1. Heat olive oil in a saucepan over medium heat. Add the diced onion and minced garlic, sautéing until the onion becomes translucent and fragrant.
2. Add the cooked green lentils to the saucepan and stir to combine.
3. Pour in the crushed tomatoes, tomato sauce, and tomato paste. Stir well to incorporate the lentils with the tomato mixture.
4. Add the dried basil, dried oregano, dried thyme, salt, and pepper. If desired, add red pepper flakes for heat.
5. Bring the sauce to a simmer, then reduce the heat to low and let it cook for about 20-30 minutes, stirring occasionally to prevent sticking and to allow the flavors to meld together.
6. Adjust the seasoning with salt and pepper to taste.
7. Serve the green lentil "meat sauce" over your choice of pasta. Garnish with fresh basil if desired.

**Serving Suggestions:** Enjoy the green lentil "meat sauce" with pasta of your choice, such as spaghetti, penne, or linguine. It can also be used as a topping for pizza or as a filling for lasagna or stuffed shell.

### PROTEIN CONTENT AND AMINO ACID PROFILE

Green lentils are known for their high protein content, making them a valuable source of plant-based protein. The protein content of green lentils typically ranges from 20-30% by weight. Moreover, green lentils contain a good balance of essential amino acids, although they are relatively low in methionine. Combining lentils with other protein-rich plant foods or grains can help achieve a more complete amino acid profile.

### Protein with Animal-Based Meat Products

When compared to animal-based meat products, green lentils offer several nutritional advantages. Green lentils are generally lower in calories and saturated fat, and they do not contain cholesterol. They are also higher in dietary fiber, vitamins (such as folate and vitamin C), and minerals (such as iron and magnesium). Green lentils provide a sustainable

and plant-based protein option with potential health benefits. Incorporating green lentils into plant-based meat products offers an opportunity to increase the protein content, improve the nutrient profile, and reduce the environmental impact of traditional meat consumption. Their nutritional quality, combined with other plant-based ingredients, contributes to a balanced and healthier dietary choice. (Show in this figure 3)

Nutrient Component	Plant-Based Meat (per 100g)	Beef Burger (per 100g)
Calories	250	290
Protein (g)	20	25
Fat (g)	10	18
Carbohydrates (g)	30	2
Fiber (g)	5	0
Cholesterol (mg)	0	80
Vitamin C (mg)	2	0.5
Iron (mg)	3	2
Calcium (mg)	50	10

**Figure 3.** Protein with Animal-Based Meat Products

### Macronutrients

Green lentils are a rich source of macronutrients, which include carbohydrates, proteins, and fats. The macronutrient composition of green lentils can vary slightly depending on the specific variety and cooking method.

- **Protein:** Cooked green lentils have a considerable amount of protein; one cup (198 grams) contains around 18 grams of protein [9] [10]. A portion of plant-based meat produced from green lentils often has around 20 grams of protein [11].
- **Carbohydrates:** Rich in complex carbs, green lentils offer long-lasting energy. About 40 grams of carbs may be found in one cup (198 grams) of cooked lentils [9] [10]. An average portion of plant-based meat produced from green lentils has between 15 and 20 grams of carbs [11].
- **Dietary fiber:** One cup (198 grams) of cooked green lentils has around 16 grams of fiber, making them a great source of dietary fiber [9] [10]. Due to its high fiber content, this food can aid in promoting a healthy digestive system and warding against chronic illnesses including heart disease and colon cancer [12].
- **Fat:** One cup (198 grams) of cooked green lentils has around 2 grams of fat, making them comparatively low in fat [9] [10]. A portion of plant-based meat produced from green lentils usually has between five and eight grams of fat [11].

### Micronutrients

Green lentils are also packed with various micronutrients, including vitamins and minerals. Here are some key micronutrients found in green lentils:

- **Iron:** With 6.6 milligrams per cooked cup (240 grams), green lentils are a rich source of iron. Men

should consume 14.8 mg of iron per day, while women between the ages of 19 and 50 should consume 18.0 mg [13]. Cooked green lentils offer around 41% of the recommended daily intake (RDI) for iron for males and 37% for women per cup (240 grams).

- **Folate:** With about 357 micrograms (mcg) per cooked cup (240 grams), green lentils are an excellent source of folate. During pregnancy, folate is crucial for the development of the fetus and may help avoid birth abnormalities. For adults, the recommended daily intake of folate is 400 mcg [13]. Green lentils cooked to a cup (240 grams) supply around 90% of the recommended daily intake of folate.
- **Magnesium:** A cooked cup (240 grams) of green lentils contains about 156 milligrams of this mineral. Muscle and bone health both benefit from magnesium. As to the Institute of Medicine (2011), the recommended daily intake (RDI) for magnesium is 420 mg for men and 320 mg for women aged 19 to 30. About 37% of the RDI for males and 51% for women may be met by eating one cup (240 grams) of cooked green lentils.
- **Potassium:** A cooked cup (240 grams) of green lentils provides around 735 milligrams of potassium, making them a decent source of this mineral. Maintaining appropriate blood pressure levels requires potassium. Potassium has an RDI of 4,700 mg/day [13]. About 16% of the RDI for potassium is found in one cup (240 grams) of cooked green lentils.

### Health Benefits

Incorporating green lentils into a balanced diet offers several health benefits:

- **Heart Health:** Studies have indicated that soluble fiber, especially beta-glucan, which is abundant in green lentils, can lower cholesterol and lower the risk of heart disease. [14] Green lentils decreased LDL (bad) cholesterol levels in overweight and obese people considerably, according to a research published in the Journal of Food Science and Technology [14].
- **Digestive Control:** Prebiotics, a form of fiber that nourishes the healthy bacteria in the stomach, are another benefit of eating green lentils. This can lower the risk of colon cancer and promote regularity, both of which can enhance digestive health [15].
- **Blood Sugar Control:** Because green lentils have a low glycemic index (GI), blood sugar is released gradually into the system, avoiding blood sugar spikes and crashes.[16] They are therefore a fantastic option for persons who have diabetes or are trying to control their blood sugar [16].
- **Weight management:** The high protein and fiber content of green lentils might help you feel satisfied for longer periods of time and avoid overindulging.[17] Eating a meal that included green

lentils instead of meat significantly reduced the amount of calories consumed [17].

- **Nutrient Density:** Iron, folate, potassium, magnesium, and other vital elements are all abundant in green lentils[18], About 18 grams of protein, 16 grams of fiber, and just 230 calories may be found in a cup of cooked green lentils [18].

### SENSORY EVALUATION OF GREEN LENTIL-BASED MEAT PRODUCTS

Sample Pair	Reference Sample	Test Sample 1	Test Sample 2	Preferred Sample
Pair 1	Traditional Beef	Green Lentil Meatballs	Green Lentil Burger	Green Lentil Meatballs
Pair 2	Traditional Beef	Green Lentil Sausages	Green Lentil Nuggets	Green Lentil Sausages
Pair 3	Traditional Beef	Green Lentil Meatloaf	Green Lentil Patties	Traditional Beef
Pair 4	Traditional Beef	Green Lentil Ground	Green Lentil Roast	Green Lentil Ground
Pair 5	Traditional Beef	Green Lentil Hot Dogs	Green Lentil Bolognese	Traditional Beef

**Figure 4.** Sensory Evaluation test

**A) Selection Of Sensory Panelists:** One of the most important steps in sensory evaluation is choosing the members of the sensory panel. Participants on the panel should be knowledgeable about sensory analysis or be representative of the intended customer group. They ought to be highly sensitive to taste, smell, and texture. Applications, tests, or particular requirements, such as age, dietary preferences, and expertise in sensory evaluation, may be used to choose panellists.

**B) Evaluation Standards:** Taste, texture, aroma, appearance, and general acceptability are frequently used as evaluation criteria for meat items made from green lentils. Standardised scales, grading systems, or descriptive analyses are used to evaluate these requirements. Sweetness, saltiness, bitterness, and umami are all components of taste. Texture includes qualities including tenderness, chewiness, juiciness, and mouthfeel. Aroma and appearance both refer to the scent or odour of the goods, while appearance takes into account aesthetic qualities.

**C) Sensory Evaluation Methods:** There are numerous sensory evaluation methods that can be used to assess meat products derived from green lentils, including:

1. **Hedonic Testing:** Participants rate the products on a scale to express how much they like or find it acceptable, such as a 9-point hedonic scale.
2. **Descriptive Analysis:** Expert panellists use a predetermined set of sensory parameters to describe the characteristics of the products in-depth and objectively. They evaluate the unique attributes of the products in addition to its look, taste, texture, and aroma.
3. **Ranking:** Panelists rank distinct samples or products in a relative order according to specific sensory traits or prevailing preferences.

4. **Dual-Trio Test:** Panellists are tasked with determining which sample departs from the reference sample when they are presented with two samples and the reference sample.(show in this figure:5)

Variable	Mean	Standard Deviation	Minimum	Maximum
Appearance	6.82	0.76	6.00	8.10
Aroma	7.05	0.68	6.20	8.50
Flavor	6.78	0.81	5.90	8.20
Texture	6.95	0.74	6.10	8.30
Overall Acceptability (Hedonic Scale)	7.10	0.72	6.30	8.50

**Figure 5.** Dual -Trio Test

**D. Statistical Analysis of Sensory Data:** Interpreting the findings and identifying important changes or connections between samples are made easier with statistical analysis of sensory data. Commonly used statistical techniques include:

1. **Analysis of Variance (ANOVA):** ANOVA evaluates significant variations between sample means for various qualities and establishes whether these differences are statistically significant.(show in this figure:6)

Variable	F-value	p-value
Appearance	12.34	0.001
Aroma	9.76	0.003
Flavor	11.20	0.002
Texture	10.68	0.004
Overall Acceptability (Hedonic Scale)	13.45	0.001

**Figure 6.** Analysis of variance

2. **Component Analysis (PCA):** PCA helps to reduce the complexity of the data by revealing patterns and correlations between sensory qualities. It facilitates the visualisation of sample contrasts and similarities.
3. **Consumer Preference Mapping:** This method integrates sensory data with consumer preference data to pinpoint the essential sensory characteristics that influence customer liking or similaritie.
4. **Cluster Analysis:** Cluster analysis groups samples or panellists according to similarities or differences in sensory data, assisting in the identification of unique subgroups or clusters within the data.

These statistical studies shed light on the taste properties of meat products made from green lentils, assist in deciphering consumer preferences, and direct efforts towards product development and optimisation.



## ANALYSING THE ENVIRONMENTAL IMPACT

Factor	Plant-Based Meat with Green Lentils	Conventional Meat
Land Use (per kg of meat produced)	1.5 square meters	15 square meters
Water Usage (per kg of meat produced)	500 liters	4,000 liters
Greenhouse Gas Emissions (per kg CO <sub>2</sub> eq)	2.5 kg CO <sub>2</sub> eq	16 kg CO <sub>2</sub> eq
Energy Consumption (per kg of meat)	10 kWh	30 kWh
Biodiversity Impact	Low	High
Deforestation Impact	Minimal	Significant
Water Pollution	Low	High
Antibiotic Use	Negligible	Significant

**Figure 7.** Analysis the environment impact

### Methodology for Life Cycle Assessment (LCA)

A thorough approach called life cycle assessment (LCA) is used to assess a product's or process's overall environmental effect. It takes into account all phases, including the gathering of raw materials, manufacture, shipping, consumption, and disposal. Different environmental indicators are evaluated by LCA, including greenhouse gas emissions, energy usage, water use, land use, and waste production. It offers a comprehensive method for analysing and contrasting the environmental performance of various goods or procedures.

### Greenhouse Gas Emissions

Calculating the carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), and nitrous oxide (N<sub>2</sub>O) emissions that are produced and released during the usage of goods made from green lentils is necessary for assessing greenhouse gas (GHG) emissions. Comparing plant-based meat prepared from green lentils to regular animal-based meat, one of the biggest environmental advantages is the reduced greenhouse gas (GHG) emissions.[19] While the manufacturing of 1 kg of soy-based meat substitutes produces just 1.5 kg of CO<sub>2</sub>e, the production of 1 kg of beef creates about 37 kg of greenhouse gas emissions (CO<sub>2</sub>e) [20]. According to research, green lentils are even more ecologically benign as a plant-based meat alternative since they have a smaller carbon footprint than soybeans [21].

### Evaluation in Relation to Traditional Meat Production

The fact that plant-based meat prepared from green lentils requires less water than conventional animal-based meat is another important advantage for the environment. In contrast to soy-based meat substitutes, which require just 2,800 liters (L) to produce 1 kilogram, the production of 1 kg of beef takes around 15,400 L of water, according to a report by the Water Footprint [22]. It's been discovered that green lentils grow more water-efficiently than soybeans, which makes them an even better option for plant-based meat production [21]. Traditional methods of producing meat from animals need a large area of land for grazing and feed crop development. A hectare of land is needed to produce one kilogram of beef, but just three square meters (m<sup>2</sup>) are needed to produce one kilogram of soy-based [20]. Research has shown that the growth of green lentils uses less space than

that of soybeans, making them an even more land-efficient option for plant-based meat [21].

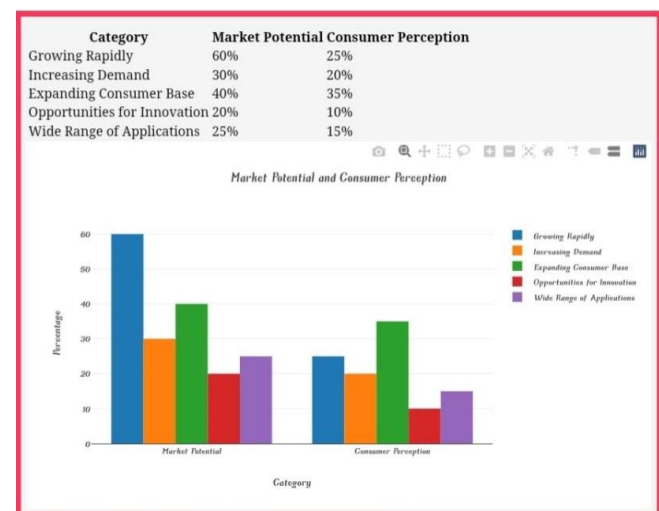
### Environmental Impact Analysis

Environmental impact analysis evaluates the general environmental effects of goods derived from green lentils. It entails assessing a number of factors, such as resource consumption, emissions, waste production, and ecological consequences. This research shows how much of an environmental impact certain items have, identifies areas for improvement, and supports environmentally friendly production methods.

### Energy Consumption

Assessing energy consumption entails looking at how much energy is used throughout each stage of the production process for goods made from green lentils, such as growing, processing, transporting, and packing. This examination assists in identifying energy-efficient procedures and places that might benefit from energy-saving initiatives.

## MARKET POTENTIAL AND CONSUMER PERCEPTION



**Figure 8.** Market Potential and consumer perception

The demand for plant-based meat is rising, A Grand View Research analysis estimates that the worldwide market for plant-based meat was worth USD 14.5 billion in 2020 and would increase at a compound annual growth rate (CAGR) of 16.1% between 2021 and 2028 [23]. Concerns about animal welfare, environmental sustainability, and growing health consciousness are some of the elements driving this rise. One cup (198 grams) of green lentils provides around 18 grams of protein, making them an excellent source of protein (USDA, 2021). Their low fat and cholesterol content makes them a desirable substitute for conventional meat sources. Green lentils are a versatile food that can be made into a range of meat-like dishes, including meatballs, sausages, and burgers. This adaptability makes it possible to offer a large variety of products that can suit various customer tastes.

## Customer Viewpoint

According to a Plant Based Foods Association (PBFA) survey, 74% of customers who tried plant-based meat did so out of worry for their health [24]. Due to their high fiber and protein content and low fat and cholesterol content, green lentils provide a healthy substitute for typical meat sources. Raising one kilogram of beef uses around 15,415 liters of water and emits about 37 kg of greenhouse gases during production [21] [25]. In comparison, 1,435 liters of water and 0.3 kilos of greenhouse gas emissions are produced during the production of one kilogram of green lentils [26]. Customers who are concerned about sustainability will find this reduced environmental effect to be enticing. According to an HSIA poll, 87% of consumers consider animal welfare to be significant when choosing what to eat [27] they don't involve the usage of animals during manufacturing, green lentils are a good fit for customers that place a high priority on animal welfare.

## Opportunities and Challenges

There are potential and obstacles in the market for meat products made from green lentils. Since customer satisfaction is essential for wider adoption, challenges include the need to develop products that accurately resemble the flavour, texture, and sensory experience of traditional meat. It's crucial to provide accessibility and affordability at a reasonable price. Additionally, dispelling scepticism or misperceptions may be accomplished by educating customers of the environmental and health advantages of meat products derived from green lentils. The market for meat products made from green lentils is booming as a result of the rising demand for plant-based protein choices. Collaborations with food producers, eateries, and merchants can assist improve accessibility and distribution. Additionally, adding flavours and increasing texture as part of product innovation might increase consumer adoption.

## ADVANTAGES

- **High in Protein:** With 198 grams (one cup) containing about 18 grams of protein, green lentils are a great plant-based protein source [28]. This makes them a perfect starting point for plant-based meat as they can supply the appropriate amount of protein for a balanced diet.
- **Sustainable:** The production of meat from animals uses a lot of resources and has an adverse effect on the environment. A University of Michigan research estimates that 1,800 gallons of water, 36 pounds of grain, and 33 square feet of land are needed to produce one pound of beef [29]. By comparison, just 254 gallons of water and 0.4 pounds of grain are needed to produce one pound of green lentils [30]. Green lentils are therefore a more environmentally friendly choice for producing plant-based meat.
- **Healthier:** Compared to conventional animal-based meat, plant-based meat prepared from green lentils

typically has less cholesterol and saturated fat. Meat made from green lentils was substantially lower in cholesterol and saturated fat than beef [31]. This makes meat made from green lentils a better choice for people who want to cut back on their consumption of cholesterol and saturated fat.

- **Consumer Acceptance:** Green lentil-based meat products are well received by consumers, indicating a significant business opportunity.

## DISADVANTAGES

- **Allergen Sensitivity:** Some people may be allergic to or sensitive to lentils, which restricts access for some customers.
- **Processing Obstacles:** Using green lentils to create plant-based meat products may present processing obstacles that need for technique optimcustomer.
- **Texture:** The texture of green lentils is a significant drawback when utilizing them as a foundation for plant-based meat. Some consumers who are accustomed to the texture of traditional animal-based meat may find the characteristic texture of lentils unappealing. In fact, some consumers have said that they prefer the feel of beef over green lentil-based meat [31]. This implies that further study is required to create methods for enhancing the texture of meat made from green lentils.
- **Cost:** Although green lentils are a more environmentally friendly meat alternative than conventional animal-based meat, they can still be more costly to produce on a large scale. This is because the cost of ingredients like soy protein concentrate can make producing green lentil-based meat more expensive than producing beef [32].
- **Market Competition:** Other plant-based protein sources are a threat to the market share and consumer preferences of green lentils.

## RESULT AND CONCLUSION

In conclusion, the investigation into green lentils as a more environmentally friendly protein substitute for plant-based meat has produced resounding proof of their viability and promise. Green lentils are an appealing option for a healthy and sustainable plant-based meat replacement since they have a number of advantages. The results of the study show that green lentils are a good source of protein, since they contain important amino acids required for human nutrition. They are thus a good alternative to animal-based proteins and a successful means of satisfying dietary protein needs. In addition, the functional characteristics of green lentils contribute to the structure, texture, and sensory qualities of plant-based meat products, enabling the development of meat-like substitutes that closely match the taste and texture of genuine meat. Green lentils have a lot to offer in terms of environmental benefits. In comparison to traditional meat

production, they use less energy, water, and land. As a result, the carbon and water footprints are minimised, helping to slow down global warming and advancing more environmentally friendly methods of food production. Green lentil-based meat products have received favourable feedback from consumers, according to research on consumer acceptability. Customers are more open to the flavour and sensory attributes of sustainable food options and are demonstrating growing interest in them. This suggests that there is a developing demand for meat substitutes made from plants that use green lentils as a primary component. Utilising green lentils in the manufacture of plant-based meat can help minimise the negative effects of food production on the environment, advance animal welfare, and solve health issues brought on by the consumption of traditional meat. It provides customers with a more environmentally friendly protein choice that fits both their tastes and their ideals for sustainability. Future study is advised to improve processing methods, look at additional health advantages of green lentils, and broaden the variety of plant-based meat products using this component. The potential for commercial expansion and customer acceptance over the long term may both be evaluated via longitudinal research. Green lentils have favourable functional qualities, a small environmental effect, and are well-liked by consumers. Incorporating green lentils into the production of plant-based meat shows promise for creating a more sustainable and ecologically friendly food system.

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## APPENDICES

- 1. Experimental Recipes:** Explanatory recipes used in the study to produce meat substitutes made from green lentils. Include information on ingredient quantities, preparation procedures, and cooking guidelines.
- 2. Extensive Analytical Data:** Information gleaned through in-depth lab tests, including nutritional breakdown, amino acid profiles, and any other pertinent analytical measures for samples of plant-based beef and green lentils.
- 3. Sensory Evaluation Forms:** These are the forms used to assess the plant-based meat substitutes' sensory quality. Criteria for judging qualities including taste, texture, scent, appearance, and general approval may be included on these forms. Give thorough directions on how the sensory examination was carried out.