

Diet Optimization

Juan Ovalle Vega
Yina Liang Li
Jean Nieto Cordova
Liliana Garcia Caraballo
Maisy Mofakhami



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What is the problem?



The popularity of diet apps has surged in recent years, with more people using technology to track their food intake, manage weight, and improve health.

The economic cost of diet-related illnesses in Canada is substantial, estimated to be **\$26 billion annually**.

In 2023, venture capital investments in startups reached **\$3.5 billion**, focusing on personalized nutrition tracking, AI-driven meal planning, and dietary coaching.

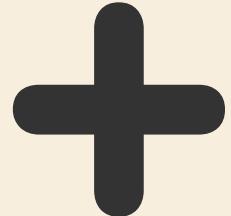
Production activities in food system produces up to 37% of the total Greenhouse Gas emissions like CO₂.

What is our proposed solution?

Meal planning could be an excellent tool to promote home meal preparation which is related to having an **improved diet quality**.



Healthy



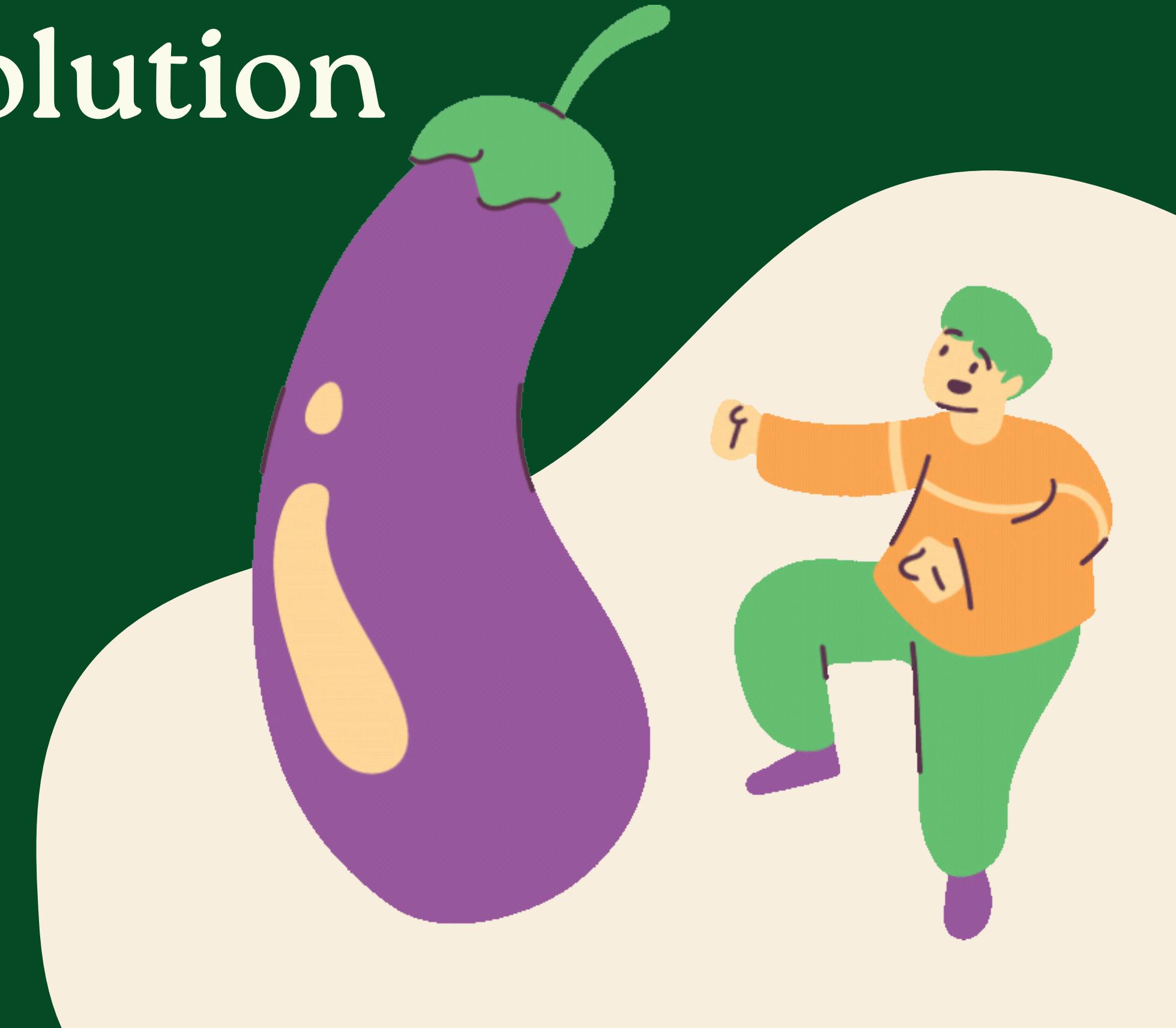
Sustainable



Best Diet for your week

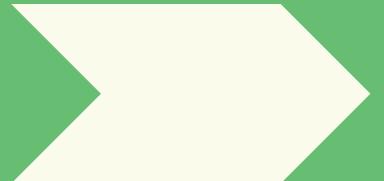
Developing a **personalized multi-objective recommender system for food diets**, which seeks to suggest to the user a diverse list of three meals a day (breakfast, lunch, dinner) in a week.

Problem Formulation & Mathematical Solution



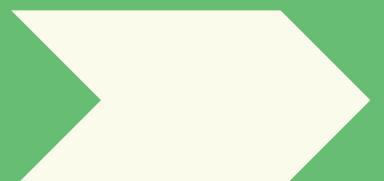
User preferences for a meal plan

1. Person objective



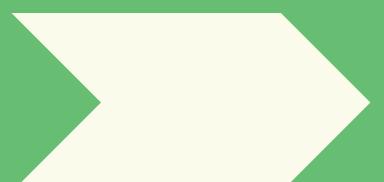
- weight loss
- muscle gain

2. Weight in Kg



- men
- women

4. Prefer a vegetarian plan?



- Maximize protein value
- Reduce footprint of water and CO₂

5. Any priority?

6. Prefer a vegetarian plan?



Problem Formulation



Meal
Plan

- 3 meals per day
- Each dish proportion contains 100gr
- The meal plan for a week

How many grams of a dish per meal in the week?



01 - Maximize proteins



lunch day 1



dinner day 3



breakfast day 7

02 - Minimize environmental impact



- 27kg of CO₂
- 15,000 liters



- 6.9kg of CO₂
- 4,300 liters

Sustainability Score

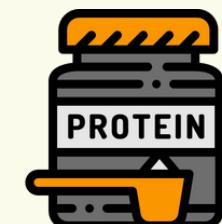


- Water footprint
- CO₂ footprint

Minimize the selection of dishes with high sustainability Score

Multiobjective Function

Priority will depend on the user valuation of minimizing the footprint or maximize the protein value of the meal plan



Mathematical Formulation

Decision variables

X_{ijk}	Number of portions of 100gr from dish j for meal j and in day k
y_{ijk}	Auxiliary binary variable to determinate if dish j for meal j and in day k will be use

$$\text{Sustainability Score}_i = 0.5 \times CO2_i + 0.5 \times H2O_i$$

$$\text{Min} \sum_{i=1}^{502} \sum_{j=1}^3 \sum_{k=1}^7 X_{ijk} \times \text{Sustainability Score}_i$$

$$\text{Min} \sum_{i=1}^{502} \sum_{j=1}^3 \sum_{k=1}^7 -X_{ijk} \times P_i$$



Constraints

1. Only one dish per meal, combination of dishes aren't allowed

$$X_{ijk} \leq M \times y_{ijk} \quad \text{for each } i = 1, \dots, 512 ; j = 1, 2, 3 ; k = 1, \dots, 7$$



$$\sum_{i=1}^{512} y_{ijk} = 1 \quad \text{for each } j = 1, 2, 3 ; k = 1, \dots, 7$$

2. The meal plan should provide 3 dishes daily

$$y_{ijk} \leq X_{ijk} \quad \text{for each } i = 1, \dots, 512 ; j = 1, 2, 3 ; k = 1, \dots, 7$$

3. All the selected dishes must be different. No repetitions

$$\sum_{j=1}^3 \sum_{k=1}^7 y_{ijk} \leq 1 \quad \text{for each } i = 1, \dots, 502$$



Constraints

4. Not all dishes are available for meal options ... Like no hamburgers for breakfast!!! but lunch and dinner options are the same.



$$X_{ijk} \leq M \times B_i \quad j = 1 \text{ for each } i = 1, \dots, 512 ; k = 1, \dots, 7$$

$$X_{ijk} \leq M \times (1 - B_i) \quad \text{for each } i = 1, \dots, 512 ; j = 2,3 ; k = 1, \dots, 7$$

5. Vegetarians plans should consider only vegetarian dishes

if vegetarian option is selected: $X_{ijk} \leq M \times V_i \quad \text{for each } i = 1, \dots, 512 ; j = 1,2,3 ; k = 1, \dots, 7$

6. Maximum grams/dish depend on users' fitness goals and preferences.

$$\sum_{i=1}^{512} X_{ijk} \leq \text{max_portions}_i \quad \text{for each } j = 1,2,3 ; k = 1, \dots, 7$$

if vegetarian option and muscle gain is selected: $\text{max_portions}_1 = 4$

if vegetarian option and weight loss is selected: $\text{max_portions}_2 = 3$

if only weight loss is selected: $\text{max_portions}_3 = 2$

if only muscle gain is selected: $\text{max_portions}_4 = 3$



Constraints

7. Minimum protein requirement and maximum sugar

$\text{min_protein}_1 = 1 \times \text{weight_kg}$ if the target is weight loss

$\text{min_protein}_2 = 1.7 \times \text{weight_kg}$ if the target is muscle gain

$$\sum_{j=1}^3 \sum_{i=1}^{502} X_{ijk} \times P_i \geq \text{min_protein}_t \quad \text{for each } k = 1, \dots, 7$$

$\text{max_sugar} = 25$, if sex = women; else, $\text{max_sugar} = 36$

$$\sum_{j=1}^3 \sum_{i=1}^{502} X_{ijk} \times S_i \leq \text{max_sugar} \quad \text{for each } k = 1, \dots, 7$$

8. Budget Constraint according to user

$$\sum_{i=1}^{502} \sum_{j=1}^3 \sum_{k=1}^7 X_{ijk} \times C_i \leq \text{Budget}$$



Results of the customized plans & their Interpretations



Profile 1-1: Tired of eating fastfood!



Want to loose weight

Not Vegetarian

Weight: 100 Kg

Budget: 270 CAD

Priority: Protein

Total Cost :
\$225.84

Total Protein Intake :
904.40g

Total CO2 emission:
65,150.40g

Total Water Usage:
38,160.94l



Profile 1-1: Weekly Schedule

On average 200 g per meal

Meals / Days	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Breakfast	Breakfast link (meat alternative products)	Bacon biscuit sandwich	Sausage English muffin sandwich	Egg sandwich on English muffin	Quail egg	Egg-stuffed flatbread	Goose egg
Lunch	Textured vegetable protein	Stuffed chicken	Chicken or turkey with cheese	Beef with gravy	Beef with cream or white sauce	Venison or deer with tomato sauce	Meat with tomato-based sauce
Dinner	Chicken or turkey cordon	Beef with tomato-based sauce	Veal cordon bleu	Beef with mushroom sauce	Venison or deer with gravy	Stewed goat	Meat with gravy

Profile 1-2: He needs to save money!

Want to loose weight

Not Vegetarian

Weight: 100 Kg

Budget: 200 CAD

Priority: Protein

Total Cost :
\$199.82

Total Protein Intake :
885.91g

Total CO2 emission:
57,356.25g

Total Water Usage:
33,844.71l



Profile 1-2: Weekly Schedule

On average 200 g per meal

Meals / Days	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Breakfast	Egg casserole with bread	Breakfast pizza with egg	Quail egg	Breakfast link (meat alternative)	Egg white	Bacon biscuit sandwich	Egg omelet or scrambled egg
Lunch	Venison or deer with gravy	Beef with mushroom sauce	Veal cordon bleu	Textured vegetable protein	Chicken or turkey with cheese sauce	Meat with tomato-based sauce	Stuffed chicken
Dinner	Hot dog (meat alternative)	Stewed goat	Cheese steak sandwich or sub on wheat	Beef with cream or white sauce	Beef with tomato-based sauce	Venison or deer with tomato-based sauce	Chicken or turkey cordon bleu

Profile 2-1: He wants to get in better shape!

Want to loose weight

Vegetarian

Weight: 80 Kg

Budget: 200 CAD

Priority: Protein

Total Cost :
\$196.68

Total Protein Intake :
826.25g

Total CO2 emission:
41,383.85g

Total Water Usage:
26,860.95l



Profile 2-1: Weekly Schedule

On average 296 g per meal

Meals / Days	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Breakfast	Breakfast link (meat alternative products)	Quail egg	Egg white	Egg white omelet	Goose egg	Egg omelet or scrambled egg	Egg casserole with bread
Lunch	Textured vegetable protein	Grilled cheese sandwich	Soybean curd cheese	Veggie burger	Tomato sandwich on white	Spinach and cheese casserole	Cake with glutinous rice and dried beans
Dinner	Hot dog (meat alternative products)	Soybean curd	Cheese sandwich	Vegetarian stroganoff	Tomato sandwich on wheat	Falafel	Veggie burger patty

Profile 2-2: He chooses to embrace sustainability

Want to loose weight

Vegetarian

Weight: 80 Kg

Budget: 200 CAD

Priority: Sustainability

Total Cost :
\$173.40

Total Protein Intake :
560.10g

Total CO2 emission:
21,972.05g

Total Water Usage:
13,809.28l



Profile 2-2: Weekly Schedule

On average 238 g per meal

Meals / Days	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Breakfast	Oatmeal	Quail egg	Egg white omelet	Egg salad	Egg white	Breakfast link (meat alternative)	Egg omelet or scrambled egg
Lunch	Textured vegetable protein	Broccoli casserole with rice	Congee	Veggie burger	Greek Salad	Soybean curd cheese	Stew (Vegetable dishes)
Dinner	Green bean casserole	Eggplant with cheese and tomato	Spinach salad	Black bean salad	Soybean curd	Vegetarian stew	Hot dog (meat alternative)

Profile 3-1: She goes to the Gym every day!

Want to gain muscle

Not Vegetarian

Weight: 60 Kg

Budget: 290 CAD

Priority: Protein

Total Cost :
\$280.00

Total Protein Intake :
1,238.16g

Total CO2 emission:
74,655.17g

Total Water Usage:
43,821.95l



Profile 3-1: Weekly Schedule

On average 292 g per meal

Meals / Days	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Breakfast	Egg white	Breakfast link	Breakfast pizza with egg	Egg casserole with bread	Bacon biscuit sandwich	Egg omelet or scrambled egg	Quail egg
Lunch	Cheese steak sandwich or sub on wheat	Hot dog (meat alternative products)	Chicken or turkey with cheese sauce	Ham or pork with mushroom sauce	Meat with tomato-based sauce	Stuffed chicken	Chicken or turkey cordon bleu
Dinner	Stewed goat	Textured vegetable protein	Veal cordon bleu	Venison or deer with gravy	Beef with mushroom sauce	Beef with cream or white sauce	Deer with tomato-based sauce

Profile 3-2: She decides to become Vegetarian!

Want to gain muscle

Vegetarian

Weight: 60 Kg

Budget: 290 CAD

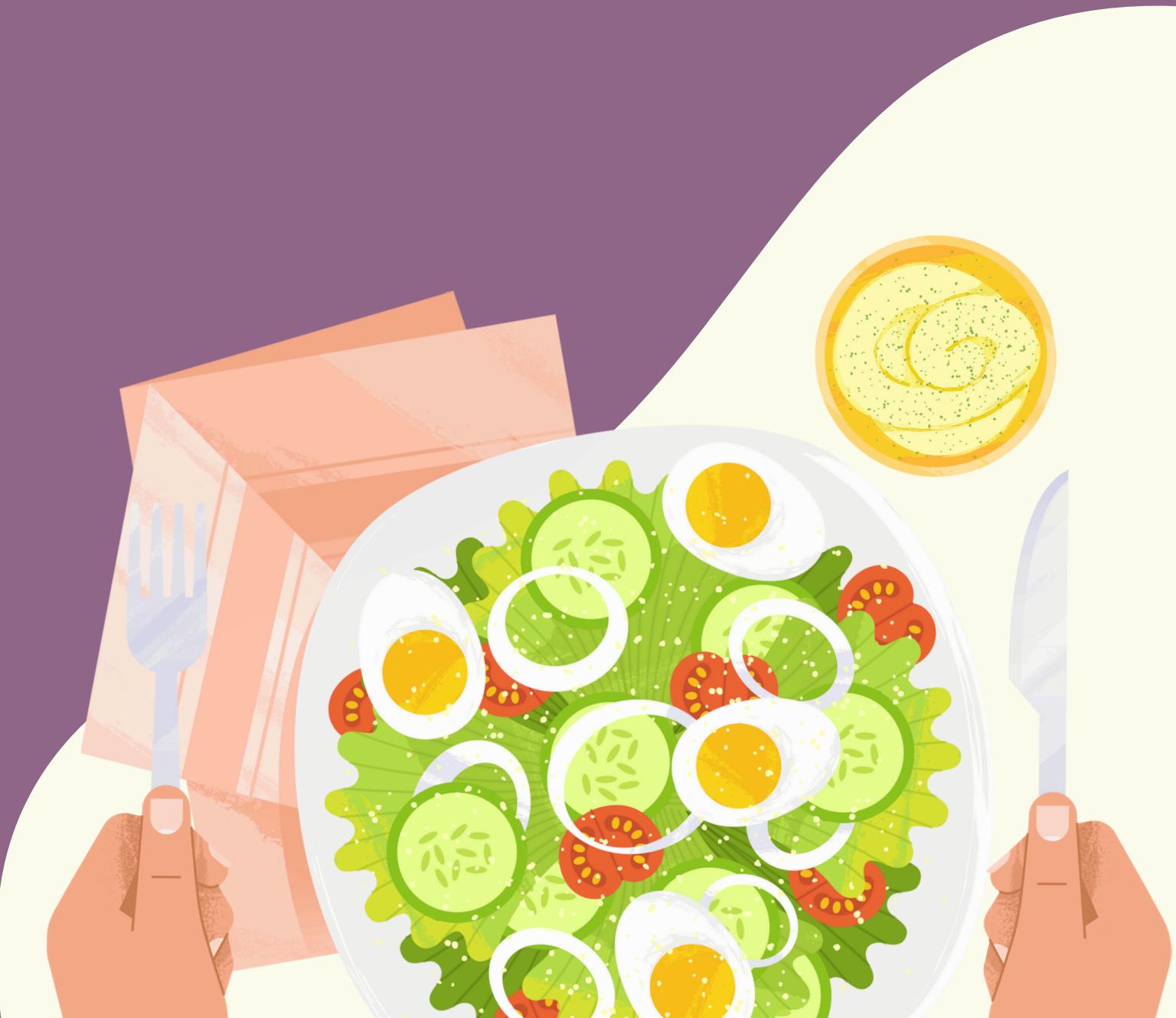
Priority: Sustainability

Total Cost :
\$225.34

Total Protein Intake :
714.07g

Total CO2 emission:
28,203.29g

Total Water Usage:
17,795.46l



Profile 3-2: Weekly Schedule

On average 331 g per meal

Meals / Days	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Breakfast	Goose egg	Egg white omelet	Egg white	Quail egg	Egg omelet	Breakfast link(meat alternative products)	Egg salad
Lunch	Hot dog (meat alternative products)	Broccoli casserole	Soybean curd cheese	Eggplant casserole	Congee	Eggplant parmesan	Veggie burger
Dinner	Greek salad	Soybean curd	Vegetable sandwich	Spinach salad	Textured veg protein	Stew (Vegetable dishes)	Vegetarian stew

Analysis of the optimized results

Profile 1-1

- Decreasing the budget from 270\$ to 200\$ resulted in a 25\$ decrease in the cost of the meals. The cost was a binding constraint only in 1-2 scenarios.
- In both scenarios, the maximum number of servings was binding, which is '2' for a non-vegetarian who wants to lose weight.

Profile 1-2

Profile 2-1

- Changing the priority from “Maximizing Protein” to “Minimizing Environmental Impact” as expected, reduced the protein intake by 266.15 g, the CO2 footprint by 19.4 Kg and the water usage by 13,051.7 liters.
- Also, the average portion size decreased by near 20% due to a lower priority for protein maximization in the multiple objective function.

Profile 2-2

Profile 3-1

- Becoming vegetarian saved \$54.55, reduced protein consumption by 524.1 g, lowered the carbon footprint by 46.5 kg, and water usage by 26,026.5 liters.
- The average portion size increased by 13% to meet the minimum nutritional requirements using vegetarian dishes.

Profile 3-2

Solution Impact and Business Implications



Empower Decision Making

- Clarity on trade offs
- Accessibility

Sustainability Impact

- Eco-friendly choices
- Environmental impact awareness



Scalability for Businesses

- Meal Kit Services
- Subscription Platforms.

Partnership Opportunities

- Food-brands
- Fitness Apps

Possible Improvements & Future Implementations



Adapt User behaviors

- Specify general appetite.
- Custom portion adjustments (provide range).
- Dietary restrictions on cultural practices.

Enhanced Metrics

- Dietary needs for households or multiple people.
- Broader range of macro/micronutrients.



Cut Environmental Footprints

- Locally available ingredients.
- Reduce dependency on long-distance food transportation.

Dynamic User Inputs

- Taste preferences (spicy/bitter).
- Considering food allergies
- Alternatives/suggestions for meal substitutions.

Thank You

