1. Methods:

The goal with using linear programming for the diet problem is to optimize meal costs while meeting weekly nutritional requirements (Table 1). The computation of the optimization was through Python's PuLP library. Meals were selected from a set that I like to cook and eat, but I wasn't sure what the nutritional value for each meal would end up being until entering the values for each ingredient.

The selected meals are each prepared from multiple ingredients, including a mix of packaged goods and home cooked meals. Using the USDA's FoodData Central resource alongside the Kroger website, I logged the nutritional value and price of each ingredient's contribution to the meal in Google Sheets (Table 2, Table 3). For fully cooked meals, it was easy to take the holistic nutritional value and then divide into portions, whereas for the breakfast and lunch meals, it was easier to calculate the value from one meal serving. This is because for the meals, you end up with one complete product, while the others had nutritional value already shown in the serving-form. For example, it's easier to get the nutrition facts for a slice of bread in the rhythm of data collection.

After the initial data collection, the base value for each meal was summed up (Table 4), distinguishing the meals that describe one serving and those that don't. This led to a final table to use in the linear programming method with values for each meal per portion.

Table 4: Per portion meal nutrition and price values

Meal	*Sodium (mg)*	*Calories (kcal)*	*Protein (g)*	*Vitamin D (mcg)*	*Calcium (mg)*	*Iron (mg)*	*Potassium (mg)*	*price*

Honey Salmon	914.25	368.00	40.04	20.88	40.13	2.15	1372.75	$9.23
Chicken Dinner	670.00	804.25	60.86	0.18	113.75	3.82	1682.25	$8.19
Lunch Sandwich	1196.50	573.00	22.85	0.00	227.75	3.60	517.00	$2.37
Breakfast	720.00	790.00	30.00	5.10	860.00	5.60	960.00	$3.51
Fish Tacos	277.13	447.47	54.53	7.63	115.87	3.17	1064.87	$4.28

The meals did go through a few rounds of iteration. Initially, I anticipated potassium to be a challenging nutrient to optimize, but vitamin D and iron proved to be more difficult to balance. To address the vitamin D deficiency, I incorporated the more expensive Sockeye Wild Caught Salmon and changed the taco recipe from ground turkey to tilapia. I also built out the breakfast meal a bit more to include orange juice and yogurt as a source of vitamin D, as well as granola as a source of iron.

2. Results:

Before inputting the problem into Python, the constraints needed to be shifted into standard form. The variable names are from the first letter of each meal, so let Honey Salmon = H, Chicken Dinner = C, Lunch Sandwich = L, Breakfast = B, and Fish Tacos = F. The objective is to minimize the following function

$$z = 9.23H + 8.19C + 2.37L + 3.51B + 4.28F$$

Subject to the following constraints:

$$914.25H+670C+1196.5L+720B+277.13F <= 35000$$

$$368H+804.25C+573L+790B+447.47F >= 14000$$

$$40.04H+60.86C+22.85L+30B+54.53F >= 350$$

$$40.13H+113.75C+227.75L+860B+115.87F >= 140$$

$$2.15H+3.82C+3.6L+5.6B+3.17F >= 9100$$

$$372.75H+1682.25C+517L+960B+1064.87F >= 32900$$

$$H >= 0; C >= 0; L >= 0; B >= 0; F >= 0$$

This output unexpectedly suggests 34.27 servings of Breakfast and zero for everything else. The next step is to find a more reasonable suggestion with variety. To achieve this, I added an additional set of constraints.

$$H + C + L + B + F <= 28$$

$$H >= 1; C >= 1; L >= 1; B >= 1; F >= 1$$

The result from this was more reasonable if not for the additional meal each day. Ideally, I would have wanted to keep the total amount of servings at 21, to match 3 meals each day, but this limitation made the equation infeasible. This seems to indicate that the meals I selected are a bit too high in calories.

Table 5: Variety Solution Optimal Meal Portions

Meal	*Optimal Value*
Honey Salmon	1.81
Chicken Dinner	7.35
Lunch Sandwich	1
Breakfast	13.94
Fish Tacos	3.90

I would certainly prefer this path, the added cost of about $25 is worth the benefit of having variety throughout the week (Table 6).

Table 6: Variety Solution Optimal Meal Portions

Solution Type	*Objective Function Solution*
Plain, Unrestrictive	$120.29
Variety	$144.89

For the LLM part of this assignment I used the Llama 3.1-70B-Instruct model through HuggingChat, an open-source UI for free LLM chatbots. I did not give it any data from my collection, rather, I asked if it could solve the assignment end-to-end. This of course risks hallucination with nutrition value and price values, but perhaps it could assist with the code generation. The LLM correctly chose the path of Linear Programming and Python's PuLP package. The code as is fails to execute because it does not import the necessary minimization function, but after correcting that

error, the code does execute. However, the output solution from this code does not match what the LLM's program offered in the write up. The LLM assumes a more balanced output of meals, while the true solution only includes servings from two of its meals. There's also a limiting factor with simply placing chicken breast as a meal on its own, and brown rice as a meal on its own. These are only one ingredient and don't exactly make up a balanced diet. Perhaps the commercial LLM's would have a better take, but I don't think the LLM is able to succinctly complete this assignment from end to end.

Appendix

Table 1: Nutritional Constraints

Component	*Max/Min*	*Daily Amount and measure*
Sodium	Maximum	5,000 milligrams (mg)
Energy	Minimum	2,000 Calories (kilocalories, kcal)
Protein	Minimum	50 grams (g)
Vitamin D	Minimum	20 micrograms (mcg)
Calcium	Minimum	1,300 milligrams (mg)
Iron	Minimum	18 milligrams (mg)
Potassium	Minimum	4,700 milligrams (mg)

Table 2: Nutritional Values per Ingredient

Ingredient	*Meal*	*Sodium (mg)*	*Calories (kcal)*	*Protein (g)*	*Vitamin D (mcg)*	*Calcium (mg)*	*Iron (mg)*	*Potassium (mg)*
Sockeye Wild Caught Salmon	Honey Salmon	460	780	132.5	83.5	55	2.6	2180

Red Potatoes	Honey Salmon	60	435	11.5	0	45	3.5	2725
Asparagus	Honey Salmon	35	55	6	0	57.5	2.275	560
Honey	Honey Salmon	2	152	0.15	0	3	0.21	26
Soy Sauce	Honey Salmon	3100	50	10	0	0	0	0
Chicken Breast	Chicken Dinner	235	790	160.5	0	30	2.45	1715
Cavatappi Noodles	Chicken Dinner	0	1600	56	0	0	6.4	880
Rao's Tomato Sauce	Chicken Dinner	2100	400	10	0	100	1.5	1850
Broccoli	Chicken Dinner	180	195	12.85	0	230	3.45	1515
Carrot	Chicken Dinner	58	35	0.76	0	30	0.34	235

Celery	Chicken Dinner	91	18	0.83	0	42	0.42	284
Onion	Chicken Dinner	12	123	0.95	0	20	0.27	133
Shiitake Mushrooms	Chicken Dinner	4	56	1.56	0.7	3	0.44	117
White Bread	Lunch Sandwich	280	140	6	0	62	1.6	52
Ham	Lunch Sandwich	570	70	9	0	0	1	0
Pepper Jack Cheese	Lunch Sandwich	140	80	5	0	150	0	0
Mayo	Lunch Sandwich	62.5	30	0	0	0	0	0
Sun Chips	Lunch Sandwich	140	140	2	0	10	0.6	90
Banana	Lunch Sandwich	4	113	0.851	0	5.75	0.4	375
Breakfast Sandwich	Breakfast	610	400	13	0	150	2.7	200

Orange Juice	Breakfast	5	110	2	3.2	400	1	500
Vanilla Yogurt	Breakfast	105	70	9	1.9	280	0	80
Almond Vanilla Granola	Breakfast	0	210	6	0	30	1.9	180
Tilapia	Fish Tacos	280	640	131	18.5	70	3.45	1900
Corn Tortillas	Fish Tacos	64.8	313.8	8.22	0	116.4	1.77	267.6
Eggs	Fish Tacos	353.6	363.6	24.36	4.4	161.2	3.196	322
Chipotle Peppers	Fish Tacos	133	25	0	0	0	1.1	705

Table 3: Ingredient Price and references

Ingredient	Meal	Nutrition Source	Price	Price Source	Notes

Sockeye Wild Caught Salmon	Honey Salmon	https://fdc.nal.usda.gov/fdc-app.html#/food-details/173692/nutrients	$26.76	https://www.kroger.com/p/wild-caught-sockeye-salmon-fillet/0026864740000	in 100g -- multiplied by 5 to get ~1.1 lbs, multiply price by 2
Red Potatoes	Honey Salmon	https://fdc.nal.usda.gov/fdc-app.html#/food-details/170435/nutrients	$3.50	https://www.kroger.com/p/private-selection-petite-red-gourmet-potatoes/0001111079541?searchType=default_search	in 100g -- multiplied by 5 to get ~1.1 lbs
Asparagus	Honey Salmon	https://fdc.nal.usda.gov/fdc-app.html#/food-	$5.00	https://www.kroger.com/p/organic-green-	in 100g -- multiplied by 2.5 to get ~.55 lbs

		details/168390/nutrients		asparagus/000000009408 0?searchType=default_search	
Honey	Honey Salmon	https://fdc.nal.usda.gov/fdc-app.html#/food-details/169640/nutrients	$0.90	https://www.kroger.com/p/kroger-clover-honey-bear/0001111086170?searchType=default_search	in 100g -- divided by 2 to get 1/3 cup, 5$ for 12 ounces, dividing cost by 5
Soy Sauce	Honey Salmon	https://fdc.nal.usda.gov/fdc-app.html#/food-details/2189002/nutrients	$0.75	https://www.kroger.com/p/bragg-liquid-aminos-gluten-free-soy-protein-seasonin/0007430500001	in 100mL -- divided by 2 to get 1/4 cup, divide price by 8 in a 16oz bottle

				6?searchTyp e=default_s earch	
Chicken Breast	Chicken Dinner	https://fdc.nal. usda.gov/fdc- app.html#/foo d- details/331960 /nutrients	$5.00	https://www .kroger.com/ p/simple- truth-all- natural- boneless- skinless- family-pack- fresh- chicken- breast/0020 094700000? searchType= default_sear ch	in 100g -- multiplied by 5 to get ~1.1 lbs, taking price at per pound value
Cavatappi Noodles	Chicken Dinner	https://www.kr oger.com/p/pri vate-selection- italian- cavatappi-	$3.59	https://www .kroger.com/ p/private- selection- italian-	multiplied by 8 to get full box

		pasta/0001111012065		cavatappi-pasta/0001111012065	
Rao's Tomato Sauce	Chicken Dinner	https://www.kroger.com/p/rao-s-homemade-tomato-basil-sauce/0074747900105?searchType=default_search	$8.00	https://www.kroger.com/p/rao-s-homemade-tomato-basil-sauce/0074747900105?searchType=default_search	multiplied by 5 to get full container
Broccoli	Chicken Dinner	https://fdc.nal.usda.gov/fdc-app.html#/food-details/747447/nutrients	$3.69	https://www.kroger.com/p/broccoli-crowns/0000000003082?searchType=default_search	in 100g -- multiplied by 5 to get ~1.1 lbs, multiplying price by 3 to get 3 crowns

Carrot	Chicken Dinner	https://fdc.nal.usda.gov/fdc-app.html#/food-details/170394/nutrients	$0.88	https://www.kroger.com/p/carrots/0000000004562?searchType=default_search	in 100g -- using base value, multiplying price by 4 to get 4 carrots
Celery	Chicken Dinner	https://fdc.nal.usda.gov/fdc-app.html#/food-details/169989/nutrients	$5.00	https://www.kroger.com/p/simple-truth-organic-celery-hearts/0001111091660?searchType=default_search	in 100g -- using base value
Onion	Chicken Dinner	https://fdc.nal.usda.gov/fdc-app.html#/food-	$0.60	https://www.kroger.com/p/medium-yellow-onions/0000	in 100g -- using base value

		details/170004/nutrients		000004093?searchType=default_search	
Shiitake Mushrooms	Chicken Dinner	https://fdc.nal.usda.gov/fdc-app.html#/food-details/168437/nutrients	$6.00	https://www.kroger.com/p/simple-truth-organic-sliced-shiitake-mushrooms/0001111022177?searchType=default_search	in 100g -- using base value
White Bread	Lunch Sandwich	https://www.kroger.com/p/lewis-bake-shop-butter-half-loaf-white-bread/000241	$0.29	https://www.kroger.com/p/lewis-bake-shop-butter-half-loaf-white-bread/00024	multiplied by 2 to get two slices, divide price by 7

		2601715?searchType=default_search		12601715?searchType=default_search	
Ham	Lunch Sandwich	https://www.kroger.com/p/hillshire-farm-ultra-thin-sliced-honey-ham-sandwich-meat/00044500097648?searchType=default_search	$0.78	https://www.kroger.com/p/hillshire-farm-ultra-thin-sliced-honey-ham-sandwich-meat/0004450097648?searchType=default_search	using base value of one serving, divide price by 7
Pepper Jack Cheese	Lunch Sandwich	https://www.kroger.com/p/kroger-pepper-jack-sliced-cheese/0001111058720?sea	$0.36	https://www.kroger.com/p/kroger-pepper-jack-sliced-cheese/0001111058720	using base value of one serving, divide price by 7

		rchType=default_search		?searchType=default_search	
Mayo	Lunch Sandwich	https://www.kroger.com/p/kroger-olive-oil-mayo/00011111001968?searchType=default_search	$0.05	https://www.kroger.com/p/kroger-olive-oil-mayo/00011111001968?searchType=default_search	dividing by 1/2 to get 1/2 tbsp, price is almost negligible for this, but offering a small amount
Sun Chips	Lunch Sandwich	https://www.kroger.com/p/sunchips-garden-salsa-whole-grain-chips/00028400014740?searchType=default_search	$0.68	https://www.kroger.com/p/sunchips-garden-salsa-whole-grain-chips/00028400014740?searchType=default_search	using base value of one serving, divide price by 7

Banana	Lunch Sandwich	https://fdc.nal.usda.gov/fdc-app.html#/food-details/1105314/nutrients	$0.21	https://www.kroger.com/p/fresh-banana-each/0000000004011?searchType=default_search	using base value of 1 banana
Breakfast Sandwich	Breakfast	https://www.kroger.com/p/jimmy-dean-sausage-egg-cheese-croissant-frozen-breakfast-sandwiches/0007790050308?searchType=default_search	$1.69	https://www.kroger.com/p/jimmy-dean-sausage-egg-cheese-croissant-frozen-breakfast-sandwiches/0007790050308?searchType=default_search	using base value of one serving, divide price by 8 (8ct box)

Orange Juice	Breakfast	https://www.kroger.com/p/kroger-100-orange-juice-with-calcium-vitamin-d/0001111050703	$0.43	https://www.kroger.com/p/kroger-100-orange-juice-with-calcium-vitamin-d/0001111050703	using base value of one serving, divide price by 8 (8ct box)
Vanilla Yogurt	Breakfast	https://www.kroger.com/p/kroger-carbmaster-vanilla-yogurt/0001111014411?searchType=default_search	$0.60	https://www.kroger.com/p/kroger-carbmaster-vanilla-yogurt/0001111014411?searchType=default_search	using base value of one serving
Almond Vanilla Granola	Breakfast	https://www.kroger.com/p/bear-naked-vanilla-	$0.80	https://www.kroger.com/p/bear-naked-	using base value of one serving, divide price by 6

		almond-crisp-granola/0085641600071?searchType=default_search		vanilla-almond-crisp-granola/0085641600071?searchType=default_search	
Tilapia	Fish Tacos	https://fdc.nal.usda.gov/fdc-app.html#/food-details/175177/nutrients	$10.00	https://www.kroger.com/p/kroger-fresh-tilapia/0001111062160?searchType=default_search	in 100g -- multiplied by 5 to get ~1.1 lbs
Corn Tortillas	Fish Tacos	https://fdc.nal.usda.gov/fdc-app.html#/food-details/175036/nutrients	$0.44	https://www.kroger.com/p/la-banderita-yellow-corn-tortillas/000	in 1 tortilla, multiplied by 6, divide price by 5

				2733100061?searchType=default_search	
Eggs	Fish Tacos	https://fdc.nal.usda.gov/fdc-app.html#/food-details/172187/nutrients	$2.16	https://www.kroger.com/p/vital-farms-pasture-raised-large-brown-eggs/0086174500001?searchType=default_search	in large egg form, multiplied by 4, divide price by 3
Chipotle Peppers	Fish Tacos	https://www.kroger.com/p/kroger-gluten-free-whole-chipotle-peppers-in-adobo-sauce/000111	$0.23	https://www.kroger.com/p/kroger-gluten-free-whole-chipotle-peppers-in-adobo-	using 1 serving size, divide price by 7

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