Smart Kitchen Manager

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1 Introduction

Smart Kitchen Manager is a web platform that aims to make cooking at home easy and stress free for people with a busy schedule. The platform includes 4 major systems:

- An ingredient management system for users' inventory and shopping lists

Figure 1: Inventory Management and Ingredient Search Page

- A recipe recommendation system based on users' initial preferences and continuous feedback using an embedding machine learning model
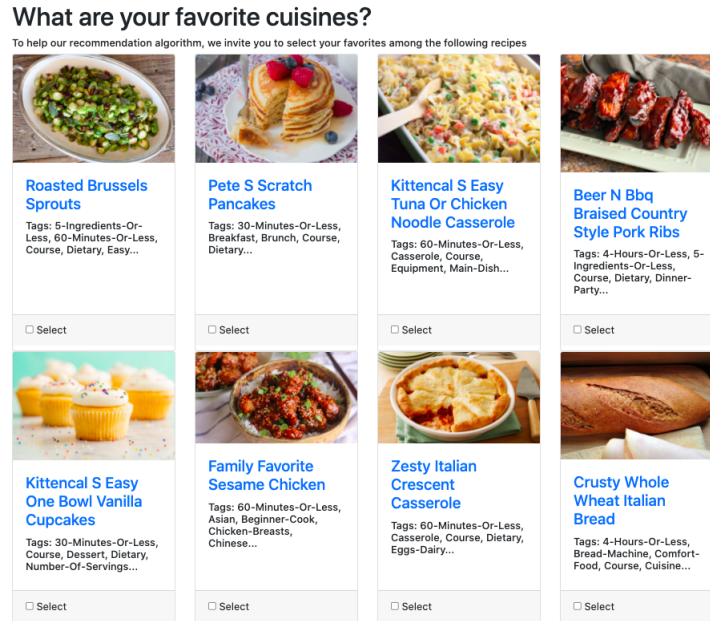
Figure 2: Initial Preference Selection Page

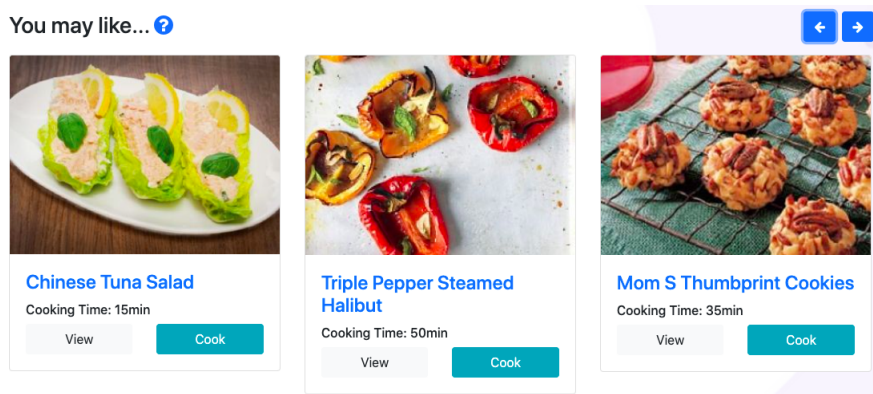Figure 3: Personalized Recommendation Carousel on Homepage

- A recipe sharing system for users to upload original recipes and find recipes based on ingredient availability, cooking time and dietary restrictions
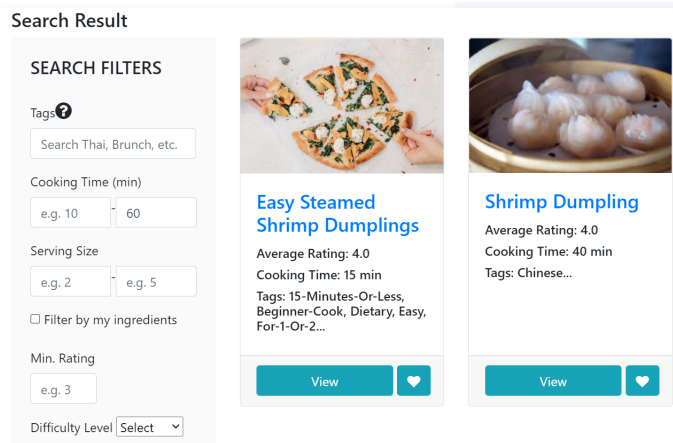
Figure 4: Recipe Filtering and Searching Page
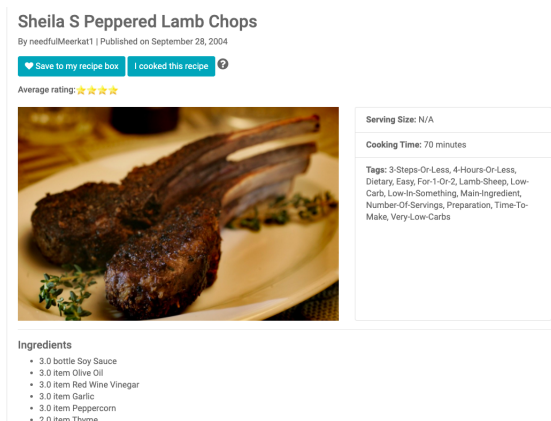
Figure 5: Example Recipe Card

- A weekly planner system for users to select which recipes to cook each day and to compile a list of needed ingredients
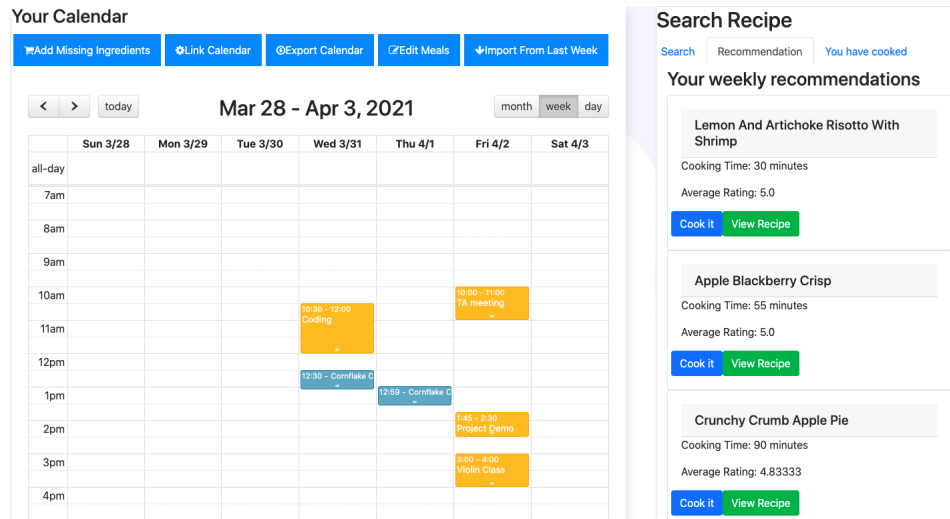
Figure 6: Meal Planning Page

2   Implemented Features

The implemented features in our platform are listed below.

- Accounts:

    - Users can sign up for new accounts.
    - Users that have an account can log in/out.
    - Users can see their username, number of recipes rated and created, and update profile pictures on homepage.
    - The platform enforces use of strong passwords.

- Inventory Management

    - Users can input ingredients with approximate quantities and expiration dates.
    - Ingredients that expire are automatically removed, and users will be alerted via Twilio.
    - Expiration dates will be automatically inferred based on exact content of the ingredients if users don't specify a date.
    - Ingredients that will expire soon are highlighted in red.
    - Users will get an alert for ingredients that will expire soon via Twilio.
    - Users can add ingredients that are not currently in our database using the search bar.

- Users can indicate how the quantity of different ingredients they used when cooking a recipe via the "I cooked this" button.
- Users can add reminders to replenish certain ingredients at regular intervals.
- Users can add items in their inventory directly to their shopping list.

- Shopping List

  - Users can create a shopping list of ingredients.
  - Users can click "I went shopping" to add bought items from the shopping list to inventory.
  - Users can add ingredients from a recipe that are not in their inventory into their shopping list with one click.

- Recipe Sharing

  - Users can upload recipes with required ingredients, steps, tags, serving size, cooking time, and images.
  - Users can click the 'browse recipes' button to view 50 recipes.
  - Users can filter recipes based on cooking time, serving size and tags in the search results page.
  - Users can give ratings and feedback to recipes.
  - Users can add personal annotations for recipes.
  - Users can add favorite recipes to their recipe boxes to save for later. They can also remove recipes from the recipe box.
  - The platform automatically suggests top recipes to search when users type in the search bar.

- Recipe Recommendation

  - When users register for a new account, they can indicate their recipe preferences by selecting the recipes they like from a list.
  - Users can see a list of recommended recipes and rated recipes on their homepage.
  - When users rate recipes, the recommendation model is updated accordingly.

- Meal Planning

  - Users can select which recipes to cook and when to cook and add them to a calendar.
  - Users can link their Google calendars on the platform.
  - Users can add recipes from the previous week directly to the current week.

- Users can export and download the filled out calendars.
- Users can add all required ingredients for next week's recipes to their shopping lists.

- General UI

  - The platform is mobile friendly.

3 Technology Stack

We use Flask as our server framework. We use Twilio to send text alerts to users and use PyTorch to build our recommendation model. We use Jinja templates which are rendered as HTML and CSS pages for our frontend. We use MySQL hosted on AWS RDS as our database.
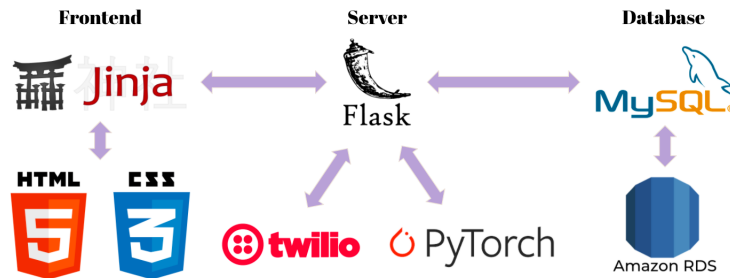
Figure 7: Technology Stack Diagram

4 Database Population

We have 12 tables in our database, which is in third normal form: User, Recipe, Ingredient, Recipe_Ingredients, Inventory, Shopping_List, Tag, Temp_Recipe, Feedback, Annotation, Meal_Schedule, Recipe_Box.

We use Food.com Recipes and Interactions dataset from Kaggle to initialize our database with ingredients, recipes, and ratings[1]. Specifically, we use the RAW_interactions.csv and RAW_recipes.csv files.

We first extracted 13500+ distinct ingredients from the "ingredients" column in the RAW_recipes dataset and inserted them into the INGREDIENT table.

We then extracted 11100+ recipes and average rating by merging RAW_interactions and RAW_recipes. We inserted recipe information into the RECIPE table. We also extracted tags and inserted them into the TAG table. Lastly, we extracted ingredients of each recipe and inserted them into the RECIPE_INGREDIENTS table.

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[1]https://www.kaggle.com/shuyangli94/food-com-recipes-and-user-interactions

The database continues to grow as more users sign up for accounts on my platform and upload new ingredients and recipes.

5 Recommendation Model

5.1 Dataset

We used the aforementioned Food.com dataset to train our recommendation model. We sampled a training set and a validation set from the dataset such that each user has at least one different rating in the sampled training set and one rating in the sampled validation set. The training dataset contained 36,294 different ratings and 11,103 different recipes.

5.2 Model

We use an embedding machine learning model to generate personalized recommendations for each user. Each user has an initial embedding created based on initial recipe preferences indicated during registration. Embeddings are updated whenever users make new recipe ratings. Each recipe added to our database also has its own embedding created. Cosine similarities are calculated between a user embedding and all recipe embeddings to measure users' potential interest in a recipe. The model is currently implemented in PyTorch.

5.3 Future Optimization

Our recommendation model currently is not distributed. All the recipe and user embeddings need to be loaded into memory of one machine to perform cosine similarity calculations sequentially. A better approach is a distributed implementation using frameworks such as Spark. Embeddings will be stored across different machines. A master machine stores a map of embedding ids to machines. The master retrieves the user embedding from the corresponding machine and sends it to each machine containing recipe embeddings with the parameter k. Each machine can calculate and send its top-k recipes along with cosine similarities to the master, which then aggregates the results and returns top-k recipes. For updates, the master can compute the updated embeddings and send them to corresponding machines.

Another optimization is to pre-compute top-k recipes for each user offline and store them in a key-value store. We respond to queries using the key-value store and recompute top-k recipes periodically in offline batches to respond to updates. Moreover, we can partition users into smaller groups and rotate among groups for recomputations to decrease processing time. LinkedIn uses a similar architecture with offline batch processing with online queries. [1] LinkedIn uses HDFS with a Browsemap engine to batch process activity data from the frontend and send processed information to a key-value store, which responds to queries with low latency. Benefits include better scalability and lower latency. Instead of looking for a single machine with larger memory and faster

processors, we can add more machines to our cluster without migrating the entire model. Using a distributed design also allows parallel processing with no communication among the worker machines and limited communication between the master and workers. Another benefit would be reduced latency for generating recommendations. The current design requires cosine similarities between the queried user embedding and every recipe embedding, causing high latency. With precomputed top-k recipes, the key-value store can simply return the precomputed recipes.

A major tradeoff with the new design would be the delay in updating recommendations. With the top-k recipes only updated periodically, the impact of new user ratings would not be reflected in the recommendations immediately, but until the next update of the top-k recipes. Some users may be frustrated to see that their interactions do not lead to new recommendations immediately.

6 User Feedback

We conducted user testing of our MVP among 41 users between February 19, 2021 and March 5, 2021. The results are shown in the bar graph below. All features received a satisfaction rate of more than 75%. The overall platform received a satisfaction rate of 83%. We then further improved our platform based on recommendations given in user feedback. UI changes, such as adding tooltips, displaying default values and adopting a consistent frontend style, were implemented to provide help and documentation and increase visibility of system status. New features were also implemented upon users' requests, including but not limited to a recipe box for users to store favorite recipes, new recipe filters based on dietary restrictions and difficulty level, and a comment section for each recipe card.
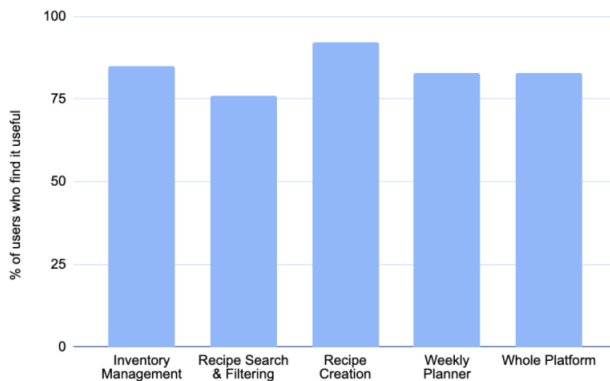

Figure 8: User Testing Results in February 2021

7 Business Analysis

7.1 Need and Value Proposition

Due to the pandemic, we have been in our kitchens more than ever and learning how to cook like never before. Our market research conducted in November 2020 finds that:

- 76.9% of the surveyed population cook more than once per week

- 82.1% of the surveyed population never used a cooking management app before

- 61.5% of the surveyed population do not have enough time to manage ingredients

- 61.5% of the surveyed population will likely need Smart Kitchen Manager

- 79.5% of the surveyed population will likely cook more with the help of our app

With busy schedules, full time students, working professionals and people who manage a whole household find it hard to manage ingredients effectively, and to find the right recipes that match their ingredient availability, time constraints, taste preferences and dietary restrictions. Meanwhile, they still want to eat healthy and stay on budget by cutting down deliveries and cooking more often at home.
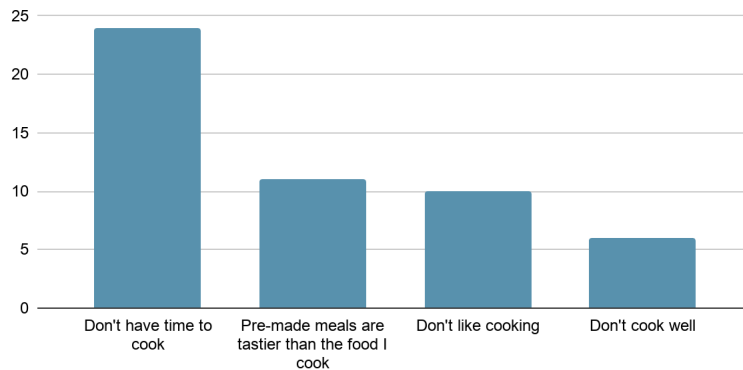

Figure 9: User Survey Responses for "Why do you purchase pre-made meals/take outs instead of cooking a meal from scratch?" in November 2020
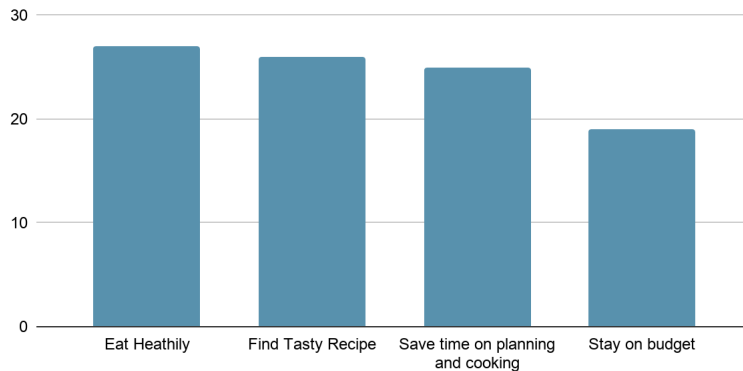
Figure 10: User Survey Responses for "If you use a cooking management app, what goals do you hope to achieve the most?" in November 2020

Smart Kitchen Manager can make cooking at home easy and help users achieve their health goals while saving time.

7.2 Stakeholders

1. Food.com provides us with the starting recipes and ingredients dataset for users to browse and receive recommendations.

2. Spoonacular provides us with the recipe images. However, as more and more users upload their own recipes, the majority of the images in our database will be user uploaded to decrease reliance on Spoonacular API.

3. Our customers, including but not limited to full time professionals, students and people who manage a whole household, will seek the best and most convenient kitchen management experience from our platform. They want to cut down on time spent preparing food while still maintaining a healthy diet.

4. Meal kit service providers such as HelloFresh and Blue Apron can collaborate with us on the meal planning system and inventory system to allow users to pick meals from their service and keep track of needed ingredients with just one click.

5. Google Calendar can collaborate with us to integrate our platform as a plug-in to allow users to plan cooking easily.

6. Delivery services such as Uber, DoorDash, and Grubhub can collaborate with us on the meal planning system to allow users to quickly order delivery on a busy day.

7. The Smart Kitchen Manager development team will continue to grow and provide new features for the platform.

7.3 Market Opportunity

Due to the pandemic, more and more people are learning how to cook to cut down the times they eat out. According to a survey conducted by Sensodyne toothpaste, 74% of respondents said cooking has been a successful coping mechanism for them as they deal with the stress of being home. 44% of those surveyed even learned a new recipe during quarantine and 32% took an online cooking class. [2] This trend has led to an increase in demand for efficient recipe searching and recipe recommendation system.

Coming with the increase in people who cook at home is the increase in fresh produce purchase online and the demand for a way to manage ingredients properly. According to Forbes, online grocery purchases have jumped to 10% of the $1 trillion industry, more than triple what they were at the end of 2019. [3]

Thus, there is a growing market opportunity for our app as we provide a one-stop solution for people who want both a platform for recipe searching and recommendation and also an inventory management system. Moreover, there is great synergy by combining the two systems as now users can have access to features such as finding recipes that use only ingredients in their inventories by one-click of a button called "Filter by my ingredients" and .

7.4 Customer Segments

Our core customer segment includes full time college students and full time working professionals. These customers often do not have the time or energy to carefully check every item in their kitchen and keep track of their expiration date. Furthermore, these users will unlikely have time to create new recipes and will need an efficient way to quickly find recipes based on what ingredients they have and how much time they have for cooking. Hence those users can benefit a lot from all of the 4 systems we provide by saving time on managing inventory and finding the perfect recipes that they want.

Other customer segments include those who manage a whole household and foodies. People who manage a whole household can benefit from our weekly planner and inventory management systems as they will likely need to plan ahead of what to cook each week and to keep track of the ingredients in their kitchens. Foodies can benefit from our recipe sharing platform as they will likely want to share their own recipes and also try other people's recipes.

7.5 Estimation of Market Size

There are about 19.7 million US college students enrolled in a school in Fall 2020. The number will continue to grow at around 0.12% each year. [4] Moreover, there are about 123.188 million full time employees currently in the US. [5] According to a survey conducted by HUNTER in January 2021, 51% of Americans are cooking more than they did at the same time last year and 71% of those who are cooking more intend to continue doing so after the pandemic

ends. [6] Thus, the market size after the pandemic ends is estimated to be $(19.7 + 123.188) \times 51\% \times 71\% = 51.74$ million in the US.

7.6 Competition and Differentiation

- Spoonacular[2]: Spoonacular has a system for uploading, organizing, and filtering recipes. It also has a meal planning system and a shopping list system. We are different from Spoonacular because we have a more detailed inventory system and provide integration of our meal planner with all major types of digital calendars. Moreover, we use a machine learning algorithm to learn each user's preferences and recommend users recipes based on past feedback.

- NYT Cooking[3]: NYT Cooking has a large database of recipes created by NYT staff and well-known cookbook authors; however, users cannot upload recipes. Recipe recommendations are general, but grouped into categories so that users can find a collection (e.g. "one pot weeknight dinners") that will appeal to them. It also has a recipe box feature and a recipe rating system. It has a grocery list system, but no inventory tracking, so the only functionality is to add all of the ingredients from a single recipe into your list using the "add to your grocery list button". We are different because we have ML-based recommendations, and an inventory tracker. Even though some might enjoy the fact that the recipes are curated, other people will prefer to be able to upload their own recipes. Moreover, NYT adopts a subscription model while we adopt a freemium model.

- Kitchenpal[4]: Kitchenpal is an app on the Play store. It has an inventory tracking system for quantities and expiration dates. It can also filter recipes based on the ingredients in the user's inventory. Unlike our app, it offers nutritional information; however, it does not appear to recommend recipes on any basis other than whether the user has all the ingredients for the recipes.

- Paprika[5]: Paprika is an app that helps users organize recipes, make meal plans and create grocery lists. It also provides cloud syncing and web importing that will allow users to access their recipes and grocery lists very easily. Even though Paprika and Smart Kitchen Manager have an overlapping feature set, Paprika does not provide a machine learning recommendation model based on users' past ratings and initial preferences. Moreover, Paprika requires users to buy each version (Mac, iOS, Windows, Android) separately while our website can be accessed on any device free

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[2]https://spoonacular.com/

[3]https://cooking.nytimes.com/

[4]https://play.google.com/store/apps/details?id=fr.icuisto.icuisto&hl=en_US&gl=US

[5]https://www.paprikaapp.com/

of charge. Lastly, Paprika has 4 different long user guides for 4 versions while our website is intuitive to use and user friendly.

7.7 Cost

To maintain the website, we have the following fixed costs:

- AWS MySQL RDS (Reserve 1 yr 16GiB 4vCPU): $175.93/month

- AWS EC2 (Reserve 1 yr 8GiB 2vCPU): $30.73/month

- Spoonacular API: $149/month

- General website maintenance: $100/month

We also estimate to have the following variable costs depending on the number of users we acquire and expansion of our recipe dataset:

- User acquisition via advertisement: $10/user

- User acquisition via referral: $5/user

- Premium recipe: $50/recipe

7.8 Revenue Models

7.8.1 Premium Membership

While most features on Smart Kitchen Manager are free to use, we plan to provide a premium membership at a rate of $9.99/month. With the premium membership, users can access the following exclusive features that will be implemented in future iterations:

- **"Cost for Dinner"** - budget estimation based on ingredients: When a user selects meals for a week or generates a shopping list, we can estimate the total cost of the meals to help the user stay on budget.

- **"Healthy Eating"** - recipe recommendation based on dietary goals: Whether a user wants to lose weight, go low-carb, or simply to eat healthy, Smart Kitchen Manager can estimate nutrition values and recommend personalized meal plans for the user based on their goals.

- **"The Michelin Pick"** - access to premium recipes: Users can browse high-quality recipes that are catered to them by professional chefs.

Among the market size of 51.74 million, we aim to reach a market share of 10%. Among those users, we estimate the percentage of premium users to be 30%. We estimate our annual revenue to be $51.74 \times 10\% \times 30\% \times \$9.99 \times 12 = \$186.08$ million.

7.8.2 Advertisement

Smart Kitchen Manager can collaborate with meal kit services (such as HelloFresh, BlueApron) and food delivery services (such as Uber Eats, Doordash) to promote their businesses. According to our market research, 92% of the users who cook at home also use meal kit services or food delivery services at least once a month. Moving forward, we will allow users to add meal kits or meal delivery into their weekly schedule. Companies such as Uber and HelloFresh can put advertisement on our meal planning page. When users plan their week ahead, they will be nudged into thinking about trying meal kits services and/or ordering deliveries when they see a super busy day in the upcoming week. This feature can help those companies acquire new customers to use their services.
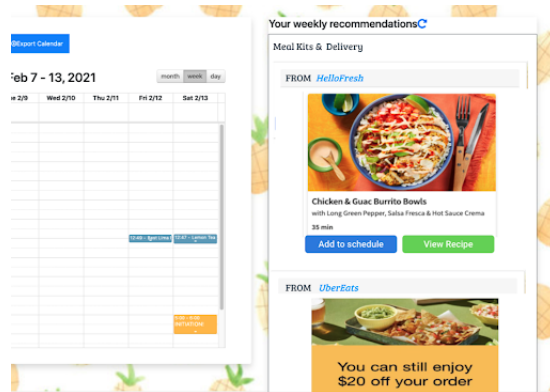

Figure 11: Mock Page for Meal Planner Incorporating Meal Kit and Delivery Services

8   Conclusion

Smart Kitchen Manager is a one-stop solution for making cooking at home easy and stress free. It integrates four components: inventory management, recipe sharing, recipe recommendations, and meal planning, serving different needs for people who cook at home. Our platform differentiates itself by taking advantage of the synergy created by combining multiple systems: we provide inter-component features such as filtering recipes by ingredient availability in users' inventories and filling in weekly meal planner with personalized recommended recipes. We provide a platform with an intuitive and easy-to-use user interface. The results from our user testing show a high satisfaction rate with our platform.

Our platform can help people who prefer home cooked meals but do not have much time to spend on cooking. Our survey results and our calculations indicate that the market size is large being around 51.74 million in the US.

Moving forward, we will continue to develop new features including the im-

plementation of premium membership features. We plan to acquire a larger user base through advertisement and referral programs in collaboration with universities. We will also seek partnerships with meal kit services and food delivery services.

References

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