AN ABSTRACT OF THE PROJECT OF

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Title: End-user programming tool for analyzing food composition data from Automated Multiple-Pass Method (AMPM) food surveys and building a comprehensive food profile.

Abstract approved: ____________________________________________________________

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Surveys are often used in health studies to collect data about participants for scientific research. An increasing number of health scientists are turning to online data collection methods because they are less costly and can reach a large diverse population quickly. Online surveys also make it easy to track and manage the responses from participants. The WAVE project is a 5 year childhood obesity prevention study being conducted at Oregon State University by health scientists utilizing a web application called WavePipe. WavePipe enables the health scientists to create studies, enroll subjects, assign mobile devices, collect physical activity data, collect nutritional data through online surveys, and analyze the data. This Master’s project presents a new sub-system that enables health scientists to analyze and visualize large quantities of AMPM 24-hour dietary recalls for sub-groups of participants over any desired period of time. In addition, the sub-system enables scientists to import new food information from multiple food composition databases and create entries of new foods to build a comprehensive food profile. The output from this sub-system is customized report that shows a selection of nutrients by a sub-group of subjects.
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1. Introduction

The WavePipe project is a collaboration between researchers in health science and computer science to collect, analyze, and visualize large food survey datasets. As part of the WavePipe project, the health scientists send out Automated Multiple-Pass Method (AMPM) Surveys to collect 24-hour dietary recalls [1] [2]. In the existing system, the scientists have access to the large amounts of raw nutritional data, but they lack the software to effectively customize the nutrient analysis to develop a food frequency questionnaire. This master’s project provides the scientists with the functionality to analyze the 24-hour dietary recall data, input new food composition datasheets, and visualize the nutrient analysis in a customized report. The software provides the scientist with a continuous flow of data through the system to make the visualization process clear and efficient.

The new sub-system has two components. The first is the AMPM Diet Analysis component, which enables the scientist to import AMPM survey responses from the WavePipe system and visualize the nutrient profile of the foods. The scientists can also use this component to analyze food survey data for a particular sub-group of subjects. The second component allows the scientist to extend the system with additional food composition databases. This enables the software to be more versatile and helps to achieve a more comprehensive master food composition database.

For validation the system was compared to the Super Tracker developed by the United States Department of Agriculture (USDA) and the Center for Nutrition Policy and Promotion (CNPP) [3][6]. In addition, the WavePipe Diet Analysis tool and the report generated were evaluated by two students in the health science studies department. The students evaluated the AMPM survey through a one-on-one interview (study approved by OSU IRB protocol #6078).
The remainder of this project report is organized as follows. Section 2 presents Related Work which is a literature review of comparable nutrient analysis software. Section 3 summarizes the WavePipe system as it stood prior to this Master’s project and explains the rationale behind the two new system components. Section 4 discusses the new diet analysis component and the food import component, respectively. Section 5 describes implementation details, Section 6 presents the evaluation of the WavePipe Diet Analysis Tool, and Section 7 concludes the results and discusses future work directions.
2. Related Work

2.1 Diet Analysis Tools

Multiple web-based apps exist to aid scientists with tracking and analyzing the dietary intake of a target population. All the tools listed below have the drawback that the scientist has to manually download the AMPM 24-hour dietary recall data and enter it into a dietary assessment software, and analyze the data. This creates a break in the flow of data through the system.

- **Super Tracker**

  Super Tracker is a web-based tool developed by the United States Department of Agriculture (USDA) and the Center for Nutrition Policy and Promotion (CNPP) that allows the user to track diet and physical activity [3][6]. With user permission and access to the study subject’s login information, scientists can download dietary data into a separate tool for nutrient analysis. For the subjects themselves, it provides a wide range of features to help them track and manage their own diet—such as features for setting calorie goals, for viewing personal dietary history, and for recording their favorite foods [4]. The core of the system is a database of over 8000 foods, which has become a de facto standard for nutrition researchers working in this field [2]. The Super Tracker Food Tracker’s food composition database contains foods from various sources including the Food and Nutrient Database for Dietary Studies (FNDDS) and the Food Patterns Equivalents Database (FPED). The Super Tracker Food Tracker system is also the basis for initiatives and “toolkit” extensions aimed at improving the health of workers [5]. Compared to the WavePipe, Super
Tracker Food Tracker system does not provide group-data analysis within the web-based application. Thus the need to download data into a separate analysis tool remains.

- **FoodWorks 17**

  Food Works tools was designed by The Nutrition Company to be a cost effective nutrient analysis software tool. Data that can be analyzed by Food Works includes meal, a 24-hour dietary recall, a multiple-day record, a recipe, a menu, or even a single food item [18]. Its database contains over 40,000 food items from USDA Standard Reference 27, the Food and Nutrition Database for Dietary Studies, and the Canadian Nutrient File 2010 among several others [47]. The tool also has features to add individual foods to the database and generate reports. Compared to the WavePipe system, Food Works does not have the capability of analyzing the nutrition information for several participants at a time.

- **SELF Nutrition Data**

  SELF Nutrition data tool [22] developed by Conde Nast, is a free web based nutrition analysis tool that allows the users to track their daily food intake, create recipes and analyze the nutrient content of a single-day record. The tool allows the users to search for foods based on nutrients. The users can also add foods to the database to further customize it. Its database contains nutrient data from the USDA Standard Reference 21. Compared to WavePipe, the SELF Nutrition data lacks the features to analyze nutrient intake for subjects in a group or multiple-day records.

- **NUT Nutrition Software**

  NUT [19] is an open-source, free nutrition software developed by Jim Jozwiak, which records what the user eats and analyses the meals in terms of “Daily Value”, is a standard
reference to daily recommendation for a 2000 kcal diet on food labelling in the US. The software was written for desktop systems and uses Tcl/Tk/SQLite and uses the USDA Standard Reference 27 to populate its database. The tool has a unique meal planning feature where the NUT adjusts the quantities of the foods chosen according to the user’s plan. The tool can analyze meal data and generate nutritional analysis reports. Compared to WavePipe the need to download, configure and setup the NUT software and database can be a time consuming and intimidating process.

• **Food Processor**

Food Processor, developed by Esha Research, is a web-based tool for nutrient analysis with a food composition database that includes foods from the USDA Standard Reference 27, the USDA Database for the Continuing Survey of Food Intake by Individuals (CSFII) and the Canadian Nutrient File [9]. It contains information on approximately 55,000 foods [10]. It has a variety of features to help users plan their meals, track their diet and physical activity, and view the result of the nutrient analysis in a report. Food Processor enables its users to add new foods and recipes and new nutrient profiles to the database. The Food Processor can analyze diets at a single record level. Compared to the WavePipe, the Food Processor does not analyze group records.

• **Food a Fact of Life**

Food a Fact of Life [32] is an educational tool developed by the British Nutrition Foundation. It is an easy to use online, age-specific nutritional analysis component designed to educate children ages 3 - 8 about the nutrients present in the foods that they consume. The tool
guides the students through the analysis of a recipe or a day’s diet and helps them compare the nutrients provided by different foods and drinks.

- **ProNutra**

ProNutra [34] is a web-based tool developed by Viocare Technologies to help organizations conduct clinical research studies. ProNutra helps its users plan menus, analyze nutrient intake and create custom intervention menus. This tool uses USDA Standard Reference (SR) 27 and optional FNDDS databases. It analyzes nutrient plans over certain periods of time and also creates custom reports of nutrition fact labels, menus, and diets. Users can modify the menu to meet constraints for several nutrients in an effort to reach their dietary goals.

ProNESSy is a module built to allow dietetic professionals to track weighed food intakes [33]. ProNESSy together with ProNutra software modules provide health care researchers the ability to design precise nutrient-intake studies and to efficiently measure and manage the preparation and consumption of the provided foods and nutrients [33]. Compared to WavePipe, ProNutra does not provide group-data analysis within the web-based application, and users need to download data into a separate analysis tool. ProNutra displays results of the nutrient analysis from multiple individuals on the same screen but it does not analyze aggregated menus for multiple users.

- **Food and Nutrition Data System for Research (NDSR)**

The NDSR [35] is a dietary analysis program developed by University of Minnesota, to collect and analyze data from 24-hour dietary recall surveys. The foods from the survey needs to be entered into the NDSR and the tool starts searching for the foods by name in the database and codes the food and its ingredients. The nutrient analysis calculation
occurs soon after the coding step and provides the data per ingredient, food, meal and day in the form of a report. The 24-hour diet recall data is gathered over the phone. The NDSR software links to two separate databases: the NCC Food and Nutrient Database and the DSAM Database [48]. This database contains over 18,000 foods with 165 nutrients and other food components with very few missing data entries. The data base is updated every year with new foods [36]. Compared to the WavePipe the NDSR does not automate the process of importing the responses from the AMPM dietary recall survey into the nutrient analysis tool.

- **GSSI (Gatorade Sports Science Institute) Dietary Analysis tools for Athletes**

This is a web-based dietary analysis tool [37] specifically designed for athletes and can be used to collect and analyze the responses from 24-hr dietary recall surveys. The report generated by the nutrient analysis includes total daily nutrient intake, pre-during-post sport nutrition intakes and an estimation of energy expenditure during the activities. The food composition database used for the tool contains information from the USDA database, restaurant websites, and sports nutrition product labels. This tool focuses on nutritional analysis for individual and does not support the analysis of group data.
2.2 Recipe and Menu Analysis Tools

The tools listed below are used by professionals in the healthcare industry, food manufactures, restaurant owners and schools/school districts to create and analyze recipes and menus. All the tools listed below have one common limitation. They analyze menus and recipes and they are not designed to analyze foods actually consumed by individuals. They lack the functionality to help scientists analyze data gathered from AMPM 24-hour dietary recall surveys for groups of subjects.

- **FoodCALC**

  FoodCALC has two web based products that perform nutrition analysis. The first product is MenuCalc a system designed specifically for restaurant owners to provide them with a “do-it-yourself” approach to the nutritional analysis of menu items. The software is based on FDA methods of analyzing nutrient values [11][12]. It lets the user analyze how each ingredient in the recipe contributes nutritionally to the overall values. However, compared to WavePipe, the MenuCalc is not geared towards analyzing the nutrient content of single-day records.

  “The second product developed by FoodCALC is LabelCalc an online nutrient analysis tool that instantly generates accurate, up-to-date, FDA-compliant facts panels.” [7]

  LabelCalc is considered an industry standard when it comes to labeling foods because it is backed by the FDA and contains and extensive database of more than 20,000 ingredients [7]. Again this tool is not designed to perform nutrient analysis for multiple-day food records.
• **Food Value Analysis**

The Food Value Analysis tool developed by RTI International allows its users to compare the cost, nutrient value and time of preparation of home recipes of foods to their restaurant versions or store-bought versions. [39][40] They can be used to meet dietary guidelines and while taking into account the money, time and food preparation skills. The Food Value Analysis tool uses variants of different databases for its data analysis purposes. For serving sizes and nutrients, it uses USDA FNDDS 5.0, USDA National Nutrient Database for SR 24, and the Gladson Nutrition Database. For information about food groups, it uses Food Patterns Equivalents Database 2009-2010, and for food prices it uses USDA, CNPP Food Prices Database 2003-2004 and the National Consumer Panel databases. Lastly, for the preparation time, the tool uses Betty Crocker Cookbook, Better Homes and Gardens New Cookbook and FoodNetwork.com's "Recipes and Cooking". [38][40]

• **Nutritionist Pro**

Nutritionist Pro is a web-based tool developed by Axxya Systems that contains modules to create nutrition fact labels in many different languages for countries like the USA, Canada, UK/Europe, China/Hong Kong [13]. It also contains other modules to create and analyze the nutritional breakdown of menus and recipes and manage the diets and recipes for clients and create nutrient goals for them. The user can also record 24-hour dietary recalls from clients and perform nutritional analysis on the results, and has been used in studies to validate brief diet survey instruments [14]. At the core of the tool is an extensive database of over 75,000 foods from around the world [13]. Compared to WavePipe, Nutritionist Pro
can only be used to analyze the nutrient content of the foods consumed by one client at a time. It is not designed to analyze food data for a group of clients.

• **Meals Plus 8**

Meals Plus [15] developed by Education Management Systems, Inc provides software for the management of K-12 cafeterias. This tool has several components for sale of foods, inventory management, billing and financial management, menu planning nutrient analysis etc. The nutrient analysis component analyses foods by item and menu and generates reports with the nutrient content for the items on the menu. The tool references the USDA Child Nutrition Database 19 for its data analysis and it allows the users to add ingredients to the database. This tool is geared towards analyzing nutrients in the ingredients for recipes.

• **Nutritics**

Nutritics is a nutrient analysis tool developed by UK based company called Nutritics [16]. It is used by sports coaches, top athletes and personal trainers to improve athletic performance and nutritionists and health scientists for teaching and research purposes and also by chefs and restaurant owners to apply labelling to their recipes [16]. Their database contains over 9000 foods which includes special user-requested foods and supplements [16]. The database contains information from sources like UK Composition of Foods Integrated Dataset (COFIDS), Irish Foods Composition Database, and specialized nutrition products from various other sources. The tool is most popularly used in the sports industry to help maximize the performance of athletes by analyzing their diet logs [17].
• **Clinical Nutrition Software**

Clinical Nutrition Software developed by Vision Software, is used by over 500 healthcare practices around the UK to track, manage patient data and analyze the diets of their patients [21]. It has a clinical nutrition component that can be used to analyze the nutritional composition of recipes, menus and the nutritional intake of patients. Other components include tracking the Diet History of patients and generating multiple-day composite analysis reports [20]. The tool has a nutrient database that is routinely updated and foods can also be added to the database by the user. Compared to WavePipe, Vision Clinical Software cannot be used to analyze the nutrient data for groups.

• **CookenPro**

CookenPro [25] developed by Barrington Software, is a recipe/menu management tool that has a module that can be used to analyze the nutrient content of recipes. This tool is targeted toward students and professionals in the food service management fields. CookenPro uses the USDA’s SR 15 database for its nutritional analysis. The tool allows the users to add foods to the database and generate reports containing the results of the nutrient analysis. CookenPro is designed to analyze menus and recipes rather than foods consumed by people. Also the database is extremely out of date.

• **eTrition**

eTrition [26] developed by Harris School Solutions, is a web-based application with a nutrient analysis component that is used by schools for planning meal programs. The tool uses a centralized USDA’s SR 27 database for its nutrient analysis. This tool analyzes food items and uses it to create menus for schools. Foods are analyzed individually and then
paired with other foods to create healthy menus for schools. Compared to the WavePipe, eTrition is not designed to perform nutrient analysis for multiple subjects in a study.

• **KidServe**

KidServe [27] developed by Horizon Software International, is a menu planning and nutrition analysis tool. The nutrition analysis component is used to analyze the nutrient content of menus, recipes and individual foods. This tool uses the USDA Child Nutrition Database 19 and preloaded USDA Team Nutrition Recipes for its nutrient analysis. The tool performs its analysis to indicate nutrient values that are out of compliance and identify differences from standards. Compared to WavePipe, Horizon is not equipped to analyze 24-hour diet recall data for groups of people.

• **NUTRIKIDS**

NUTRIKIDS [29] developed by Heartland School Solutions, is a USDA recommended nutrient analysis tool that is geared towards menu and inventory planning for school districts. It comes preloaded with the latest Child Nutrition Database 18, hundreds of ingredients and USDA Recipes. The tool has been used to show the positive influence of menu planning strategies on the nutrient composition of lunches [28]. Again, NUTRIKIDS is geared towards analyzing foods on menus and not diets consumed by people.

• **Meal Magic Suite – Nutrition Magic 7.90**

Meal Magic Suite [30] developed by Meal Magic Corporation, is a food service management tool that is used by local school districts to help manage their cafeterias. Meal Magic suite contains components to help manage money at registers and vending machines, to help create menus and recipes in cafeterias, and to help parents apply and pay for school lunch
programs. The component that we are most interested in is the nutrient analysis component for the creation of menus and recipes. The main selling point is that it makes the nutrient analysis process fast by updating the analysis when changes are made to a recipe or menu in real-time. Like most of the menu planning tools the Meal Magic suit is not designed to analyze nutrient data consumed by individuals in groups.

• **TRAKNow**

TRAKNow [41] developed by PCS Revenue Control Systems, Inc has a menu planning, inventory control and purchasing tool that has a nutrient analysis component. The purpose of the nutrient analysis tool is to aid menu planning. TRAKNow uses the Child Nutrition Database 18 and also allows its users to enter foods into the system. The tool divides its foods into sub-groups such as Fruits, Grains, and Milk. TRAKNow is not geared towards analyzing survey data for groups.

• **Nutrihand**

Nutrihand [42] developed by Nutrihand Inc, is a web based tool that allows healthcare professionals to create and manage personalized plans for their clients. Clients can follow the personalized plans created for them by tracking their food and exercise data using the tool. The tool has over 250,000 foods and recipes to help the clients track their food intake and for healthcare professionals to perform nutritional analysis. Nutrihand Wellness Center is a component used by clients to track their food and fitness data. Nutrihand Pro is another component of the tool that is used by healthcare professional to deliver questionnaires, health assessments and analyze nutrition and fitness data [43]. They can also perform statistical analysis on the data and communicate with their clients using the
tool. This tool, however, is built to analyze the nutrient data of individual clients and not groups of people.

- **NutriBase**

NutriBase [44] developed by CyberSoft, allows its users to track their daily nutrient intake, physical activity and body weight. It could be used by fitness professionals to track the eating and exercise habits of their clients. NutriBase has a variety of meal plans and recipes that its users can follow, but it also allows them to import their own meal plans and recipes as well. The tool uses the USDA’s Nutrient Database SR 23 and the Canadian Nutrient file for its nutrient analysis. The tool also allows the user to generate nutrient analysis reports and Nutrient Density Index Reports to view the results of the nutrient analysis conducted. Compared to WavePipe, NutriBase does not have the ability to analyze nutrients for groups, and the scientist would have to manually enter the foods from the 24-hour diet recall data to be able to analyze the nutrient content of the foods.

- **Nutritional Computing Concepts**

This is a web based menu and recipe planning tool developed by Nutritional Computing Concepts [45]. The tool can be used by healthcare professionals and regular individuals to plan their menus and analyze the nutritional content of the foods that they include in their menus. The tool has over 30,000 foods in its food composition database that contains nutrient information from the current versions of the USDA 26 and FNDDS 2011-2012 food databases. The users can also add their own foods into the database. The user can also add their own recipes and food into the database and nutritionally analyze them. Compared to WavePipe, the tool is not designed to analyze food data for large groups of individuals.
• **NutriData**

NutriData [46] developed by NutriData is a tool geared towards professionals in the food manufacturing industry, restaurants and food services and schools and institutions to create and analyze recipes and menus. The tool also allows its user to create nutrition labels with the results from the nutrient analysis. NutriData performs database nutrient analysis (based on formulation) and laboratory nutrient analysis (based on sample testing). The laboratory testing is more expensive and takes longer than the database testing. Both these methods have been approved by the FDA. The tool provides its users with a comprehensive report that includes over 30 nutrients. It also provides them with additional reports like the ORAC (Oxygen Radical Absorbance Capacity) Score, Diabetic Exchange Lists and Pyramid Guide Lists upon request. However NutriData is designed to analyze recipes and menus, rather than foods consumed by individuals.
3. Background

The WAVE Project is a multidisciplinary childhood obesity prevention study conducted at Oregon State University to study whether mixed-reality experiential learning involving virtual world immersive environments are feasible to prevent childhood obesity in high school athletes. WavePipe is an online system to enable the health scientists involved in the WAVE Project to customize sub-groups, enroll subjects, and gather data. WavePipe enables scientists to collect dietary data via online surveys and physical activity data via personal mobile devices and Fitbits. This master’s project will add versatility and functionality to the existing system in order to make a more robust and comprehensive tool for health scientists to analyze 24-hour dietary recall data and customize the nutrient analysis report.

3.1 Process whereby a scientist sets up a study, creates groups, and enrolls subjects in the study:

The WavePipe system contains a dashboard that allows the scientist to create new studies, enroll subjects, send surveys via emails and SMS, and assign personal mobile devices or Fitbits. The dashboard also allows the scientists to view the data collected from the surveys and motion tracking devices. Figure 1 illustrates where the WavePipe Diet Analysis component fits into the WavePipe System.
There are a few steps that have to be completed before the Survey Analysis system can function. **Step 1:** The scientist has to create a study and configure it on the WavePipe system. Figure 2 shows the page where that scientist can create the study.

**Figure 1. Structure of components in the WavePipe system**

**Figure 2. Screen to create a study**
**Step 2:** The scientist has to create study groups, enroll subjects, and assign the subjects to the study groups. Study groups can be created based on selected parameters such as geographic location and physical activity level of the subjects.

![WavePipe Health Research Dashboard](image1)

**Figure 3.** Screen to create study groups

Figure 4 is the page that scientists can use to manage study groups.

![WavePipe Health Research Dashboard](image2)

**Figure 4.** Screen to manage study groups

**Step 3:** That scientists can use the page in Figure 5 to enroll subjects in a study and assign them to a particular study group.
Figure 5. Screen to enroll subjects

Figure 6 shows the page where scientists can view all the subjects in the study.

Figure 6. Screen to manage subject enrollment

**Step 4:** To distribute the AMPM Surveys (automated surveys to collect 24-hour dietary recalls) to all the subjects in the study, the scientist uses the dashboard to check the “Send AMPM Survey now?” box in figure 2. When the subjects fill out the AMPM surveys, the WavePipe system collects the responses and stores them in the database.
Automated multiple-pass method (AMPM) is an improved 24-hour dietary recall method that was developed by the USDA to help keep the respondents interested and engaged throughout the interview process. The AMPM survey is designed to add memory cues and increasing the opportunities for respondents to remember and report additional they consumed over the course of a 24 hour period [8].

The USDA has put together a five-pass guideline for the AMPM surveys: 1) Quick List; 2) Forgotten Foods List; 3) Time and Occasion; 4) Detail Cycle; and 5) Final Probe. The design of the survey used in the WavePipe system follows these passes mentioned above to a certain extent. In the first pass (Quick List) of the WavePipe’s AMPM Survey, the participants are asked to list the foods that they consumed for every meal of the day. The second pass (Forgotten Foods List) prompts the participants to recall any coffee, tea, soft drink, milk, juice or other beverage that they may have forgotten to mention after each meal. The scientists in the WAVE project decided to exclude the third pass (Time and Occasion) from the survey.

After the participant has enter all foods that they consumed, the fourth pass (Detail Cycle) prompts them to enter the quantity and serving sizes of each of the foods that they listed in the previous two steps. In the final pass (Final Probe), the survey prompts the user one last time to remember any foods or beverages that they ate or drank, even small amounts, in the car, at meetings, or while shopping, cooking, or cleaning up.
3.2 The need for AMPM Survey data analysis capabilities:

Handling large datasets:

The scientists in the WAVE project [4] collect large amounts of AMPM food survey data. The AMPM food surveys are sent out to 720 subjects in several different study groups a few times a year. Each student consumes several different foods for each meal, and they consume several different meals over the course of the day. If 10 foods are consumed per person per day, it can add up to 7200 food items per day. This gives an idea about the amount of data that the health scientists have to analyze.

Without any software, the process that food scientists would have to go through in order to analyze this data is tedious and time consuming. The scientist would have to download the dietary data from a subject and then further analyze the nutrient intake for each food consumed by the subject. The existing nutrient analysis software does not have the functionality to analyze the dietary data of multiple participants over a duration of time. Using an existing nutrient analysis software for the manual analysis of large amounts of data may cause breaks in the flow of data, increases the complexity of the analysis, and makes the entire process more prone to errors.

Therefore, the new WavePipe Diet Analysis tool is geared toward streamlining the analysis, reducing the complexity, and reducing time required to create a food survey profile.

Versatility and customization:

In addition to the need for diet analysis tools, there was a need to support unlimited addition of new foods to the food composition database. This need arose from several factors.
First, the scientists in the WAVE Project use the SR27 USDA National Database for the analysis of the AMPM 24-hour dietary recall data. This database is updated every two years, but it is not realistic to wait this long to get access to the new foods that are out in the market. In addition, the SR27 USDA National Database is not a comprehensive list of all the foods available in the market being consumed by the subjects. Therefore, the researchers in the study requested that we maintain a supplementary database of our own, where we can add new foods as they become available to the market and are commonly consumed by high school students. These are essential foods that might be missing from the SR27 USDA National Database.

In addition, despite the volume of food/nutrient data provided with WavePipe, inevitably there are a lot of foods that are not mentioned in standard databases. To compound this issue, foods are constantly being reformulated, removed from the market, or replaced with new offerings [49]. Regionally unique foods and ethnic imports further increase the likelihood that new data will have to be added frequently to the database.

As a result, the software developed for this Master’s project includes a feature to allow the scientists to add new foods to the database. This includes the nutritional information, serving sizes, and conversion units for standardization. Since the updates are made to the SR27 USDA National Database every two years, the tool also has an option to allow for the contents of the database to be updated. The updated file can be downloaded from the USDA website in the form of an Excel file. The WAVE team scientists requested a tool that has a feature that can read the contents of the nutrition data Excel file and populate the database with the information. The scientists noted that this new feature will only be used by system administrators for bulk updates of the database once in a while, rather than on a regular basis by the scientists themselves.
4. New System Components

This section describes how scientists can use the new system components.

4.1  **Step-by-step process whereby a scientist imports and analyzes the survey data:**

Once the AMPM 24-hour dietary recall survey responses are collected, the scientist can go to the study in the WavePipe dashboard and click on the new option in the study menu called “Food Nutrition Analysis”. This option is used by the scientist to import the AMPM survey data from the database and analyze it. Clicking the option prompts the scientist to enter the start date, end date, and the study group that the scientist is interested in analyzing information for, as shown in Figure 7.

![WavePipe Health Research Dashboard](image)

**Figure 7. Screen to enter bounds for the data to be analyzed**

The start date could be the start date of the study or the date that the scientists want to start the data analysis. The data from the start date is included in the analysis. Likewise the end date could
be the end date of the study or the date that the scientists want to end the data analysis. Once the dates and study group is selected, the researcher must press the ‘Save’ button. The tool then takes the scientist to a page where they can select a list of nutrients to be analyzed.

Figure 8 represents the nutrient selection page.

Figure 8. Screen to select the nutrients that need to be analyzed
The list of nutrients for the scientist to select is fairly long. So the nutrients are grouped by water, energy, macronutrients, vitamins and minerals. This is an attempt to avoid overwhelming the user. On clicking the ‘Save Nutrients’ button the scientist is taken to the screen where the nutrient data for all the foods, consumed by the subjects in the study group, are displayed. This screen is represented in Figure 9.

![WavePipe Health Research Dashboard](image)

**Figure 9. Display of foods and their nutrient content**

The first column contains all the foods that were consumed by the subjects in the study. The first row in the report contains the names and amount of all the nutrients that the scientist selected in the previous step.
The nutrient data in this table is an aggregate of the foods consumed by the subjects. If multiple subjects in the study consumed the same food, the gram weight for each serving size is obtained, and multiplied with the nutrient concentration for the food. These numbers are added together to obtain a single nutrient value for the food. If the food does not contain a nutrient value in the database, its value is represented as ‘null’ in the table. At this point the scientists can narrow down the list of nutrients that they are interested in analyzing. The foods selected in this step will appear in the report.

To generate the final report, the scientist clicks on the ‘Display Report’ button. The report generated contains a table for each nutrient previously selected by the scientist. Each nutrient table contains three columns. The first column contains the names of the foods consumed by the subjects in the study. The second column contains the nutrient value of the food. The third column contains the percentage that the food contributes to the total consumption of that nutrient by the group. All the percentages in the third column add up to a 100% so that the scientist view the nutritional percentage breakdown of each food. A sample report is shown in Figure 10 below.
Once the report is generated, the scientists then can download the report in html format.

4.2 Adding new foods to the database:

One of the other major components of the system enables the scientist to add new foods to the database. This feature can be accessed by clicking on the ‘Add new Foods’ button, which is present on the WavePipe dashboard. On clicking this option the scientist is taken to a simple web-form where the scientist can enter information about the food (Figure 11).

The first text box requires the scientist to enter the name of the food; the second checkbox requires a food ID called a ‘NDB Number’. The NDB number can be between three and five digits long and can contain alphabets, but not symbols or punctuation. This ID needs to be a unique
because foods in the database are queried based on this ID. There is validation in place to prevent the scientist from entering a non-unique ID.

Next the scientist can add the ‘Measurement Description’ which is also known as the serving size and the ‘GramWeight/100mg’ for the measurement description. Each food can have multiple measurement descriptions, and the scientist has the option of adding multiple rows of measurement data.

Lastly the scientist can enter the nutrient values for the food. The unit that the nutrient value needs to be in is indicated next to the textbox, and the scientist is responsible for entering appropriate values for the nutrients. The scientist is allowed to add a total of 39 nutrients and therefore most of the nutrients are hidden under the dropdown option. By clicking the ‘Add More Nutrients’ button the scientist can access the complete list of nutrients. If the scientist does not wish to enter the value for a particular nutrient, the scientist is advised to leave the textbox blank and the tool will automatically insert a null value for the nutrient in the database. The nutrient information entered in the form is validated before the scientist can submit the form. This prevents the scientist from inserting invalid information into the database. The form also accepts the nutrition information in certain units. This rule is in place to maintain consistency.

After entering all the information in the web-form, the scientist can click the ‘Save Button’ to save the food and its nutrient information in the database. Once the food is saved in the database it will appear in the AMPM food survey as well. This gives the subjects a wider range of foods to choose from when they are filling out the survey.
Figure 11. Screen for adding an individual food to the database.
5. Implementation Details

The WavePipe system is a typical Java based web application. The system has been deployed on an Apache Tomcat 7.0.42 [7] server. The backend relational database used for the application is MySQL 5.6. [8] The IDE used to write the code is Eclipse Java EE.

The front-end of the application uses Java Server Pages (JSP) to help create dynamic webpages that are written in languages like HTML. JQuery, a cross-platform JavaScript library, is used to manipulate and add functionality to the HTML pages and CSS is used to style them. The backend of the system consists of Data Access Objects (DAO) written in Java and allow interactions with the database. Another component of the back-end is the DataNucleus which provides abstraction and transparent persistence to the Java Data Objects (JDO). A group of servlets are used to facilitate communication between the front-end and the backend of the system.

Because the AMPM Diet Analysis is a part of the of the WavePipe systems, it has the same design and architecture. The tool can be accessed on the dashboard of the WavePipe system. Additional implementation details of the AMPM Diet Analysis tool and the tool to build a food composition database are explained in the following sub-sections.

5.1 Current database standards:

While no official standards exist for the interchange of food/nutrient data between different software applications, nutrient databases tend to follow the de facto standards established by the USDA. In that standard, each food item contains a minimum of the food item description and the amount of one or more nutrients found in 100 grams of food. Additionally, it is common to include a description for at least one household portion of the food along with that
portion's gram weight and a code number or ID number for the food. This is the data standard to which WavePipe nutrient database adheres.

5.2 Implementation of the AMPM Survey Data Analysis

The WavePipe system uses a CRON job that is set to send out the AMPM surveys every day to all the subjects enrolled in the study. CRON is a server configuration that can be used to schedule jobs to run periodically at fixed times or dates. When the subject opens the email, he or she clicks on a link and fills out the AMPM survey. Once the subject successfully submits the filled out survey, the survey data is stored in a table in the database.

When the scientists are ready to analyze the survey data, they select a date range and the subgroup that they are interested in. Then the tool queries the database to get this information. The information is returned in the form of JSON. This JSON is then parsed to get the unique id, the name, the quantity, and the serving size of the foods item that were consumed by the students in the sub-group. From this information the gram-weight for each food is obtained according to the serving size and then the quantity is factored in. If the tool finds that multiple students in the same group have consumed the same food, the number obtained in the previous step is added together for the item. This is later used to calculate nutrient percentages for the entire group.

Based on the nutrients that the scientist is interested in, the nutrition information for all the foods consumed by the students in the study is presented to the scientist. All the calculations described above are done in the backend using Java and then sent to the front end to be displayed. This was done because calculations performed in the backend are faster than if they are performed in the front end.
5.3 Bulk Data Import

System administrators can upload food data from Excel file into the database (Feature not available to the scientist).

The first step in this process is the data cleaning step. The instructions for the data cleaning are mentioned in the appendix. Once the data in the Excel file has been cleaned, the file is stored in the server the data upload can begin. The upload will take a few minutes because the Excel file contains close to 9000 food items and 42 nutrients for each food. Once the upload has finished another Excel file that contains gram weight data for all the serving sizes also needs to be uploaded. The same process described above needs to be followed for the cleaning the gram weight Excel file.
The Apache POI [9], an open source library is used to read data from the Excel files. The Apache POI library iterates every single row in the Excel file and inserts its contents into the database. There is validation in place to make sure that the data is going into the right column because the order of nutrients in the Excel file is going to be different than the order of columns in the database.

It important to differentiate between a zero value and an empty cell needed to be made. Therefore during the data cleaning process, the system inserts a “null” value into the database whenever an empty cell is encountered in the Excel sheet.

![Diagram of data import feature](image)

**Figure 13. Flow of data for the data import feature**
6. WavePipe Diet Analysis Software Summative Evaluation

Two evaluations were done to examine different aspects of the Master’s project:

6.1 Verification of the nutrient data in the report generated by the WavePipe Diet Analysis Tool

Data in the report generated by the WavePipe Nutrient Analysis tool was verified by comparing it to the nutrient values generated by Super Tracker Food Tracker. These tools use different databases. The WavePipe Nutrient Analysis tool uses the USDA’s Nutrient Database SR27, whereas the Super Tracker uses the FNDDS and the FPED databases. The nutrient values in the Super Tracker tool’s database are rounded to the nearest whole number or the nearest one decimal place.

A list of 40 foods were entered in both the tools and the nutrient data from both these tools were compared. The foods for the list were selected from a variety of food groups like fruits, vegetables, meats, beverages, deserts and brand name foods. Once the nutrient data for the tools were obtained, a percentage difference between the nutrients for each food was calculated. The results of the comparison are displayed in the graph in Figure 14.

Each data point in Figure 14 is the percentage difference between a nutrient value in the WavePipe Nutrient Analysis Tool and the Super Tracker. There were a total of 1073 data points (i.e. approximately 27 nutrients for each of the 40 foods). The x-axis represents the percent difference in the nutrient data and the y-axis represents the number of data points that fell in the percent difference range.
From the Figure 14, there are 336 data points in the 0 to 2 percent difference range that can be attributed to rounding and 26 data points in that range are not because of rounding etc. In summary, only 130 out of 1073 (12%) nutrient entries differed for reasons not attributed to rounding. This further supports the fact that data values produced by the WavePipe Nutrient Analysis tool are accurate.
6.2. Qualitative analysis of the AMPM Survey and Nutrient Analysis Tool and Qualitative evaluation of the nutrition analysis report

The User Study had two goals:

- Evaluating the usability of the AMPM Survey and the Nutrient Analysis Tool
- Evaluate a sample nutrient Analysis Report for its design, content and understandability.

The recruitment criteria was to consider two students from the College of Public Health and Human Sciences at OSU. One graduate student and one undergraduate student were interviewed. The study was designed to be completed in 30 minutes. The participants were asked to assume the role of the scientist and a subject. The participants were encouraged to think out loud and suggest useful feedback to improve the system.

Process for recruitment of participants

The participants were first mailed the recruitment text approved by the Institutional Review Board (IRB) at OSU. Once the participants replied to the mail, the consent form was mailed to them. They gave their consent by replying to meet for the in person interview.

Filling out the consent form

On the day of the study the participants were handed the consent form on arrival. Once the consent form was signed, the study started.

Interview
At the start of the interview the participants were asked if they have any questions about the study. Once any questions were answered, the participants were given a choice of answering questions verbally, in writing, using clickers, or by typing answers into an online questionnaire. All the participants chose the paper questionnaire.

**Actual Task**

The participants were given an information sheet containing a list of food, their quantities and a list of nutrients. This information sheet did not contain any real data from the participants. It was just mock data for the participants to use during their evaluation of the AMPM Survey and WavePipe Diet Analysis tool. The tasks performed by the subjects are listed below:

The first task was to fill out an AMPM survey with the foods data from the information sheet. The second task was to generate the nutrient analysis report using the Diet Analysis Tool. The third task was to evaluate the nutrient report generated by the tool.

Once the participant completed the tasks they were asked to answer the following questions on paper:

- What is your job or year at OSU?
- What is your field or major?
- What is your experience working with dietary assessment, particularly 24-hour dietary recalls and food frequency questionnaire?
- What is your experience working with food composition database such as SR27?
- Did the AMPM Diet survey allow you to effectively record the food items given to you?
• One key purpose is to speed up the nutrient analysis process when using 24-hour dietary recall data, by automating the nutrient analysis and providing % of nutrient contribution by food sources. Do you think this goal is achieved?

• Foods from the AMPM survey and their nutrient profiles are presented in the form of a table. How easy is it to understand this visualization of the data?

• Does this report give you the information to rank food sources based on nutrients of interest?

In addition to these questions, the participant answered two questions on the WavePipe Survey Reporter in general:

• Would you like to continue using the tool?

• Is there any other feature that you would like to see in this tool?

End

Finally, the participant was paid $25 for participating in the study and sharing feedback about the system. A confirmation of payment (signature and date) was collected from the participant.
Results and feedback of the study

1) What is your job or year at OSU?

One participant was undergraduate student and the other participant was graduate student.

2) What is your field or major?

One participant was from the Public Health department and the other participant was from the Exercise and Sport Science (EXSS) department.

3) What is your experience working with dietary assessment, particularly 24-hour dietary recalls and food frequency questionnaire?

One of the participants had 1 or less than 1 year experience with 24-hour dietary recalls and food frequency questionnaire, and the other participant had 2 or more years of experience with 24-hour dietary recalls and food frequency questionnaire.

4) What is your experience working with food composition database such as SR27?

One of the participants had no experience working with food composition database such as SR27, and the second participant had 1 or more years of experience working with food composition database such as SR27.

For the following questions, these were the rules that were considered for evaluating positive or negative responses:

• ‘Yes’ and ‘Mostly’ are positive responses

• ‘Somewhat’ and ‘Not at all’ are negative responses
5) Did the AMPM Diet survey allow you to effectively record the food items given to you?

![Figure 15: Participant's approval of AMPM Diet survey to effectively record the food items](image)

As seen in figure 15 the participants were able to effectively record food times given to them in the AMPM survey. One of the participants felt that the text box for entering the serving size needs to be labeled to make it seem less ambiguous.

6) One key purpose is to speed up the nutrient analysis process when using 24-hour dietary recall data, by automating the nutrient analysis and providing % of nutrient contribution by food sources. Do you think this goal is achieved?

![Figure 16: Participant's approval of automation of nutrient analysis process](image)
A seen in figure 16, both the participants strongly agreed that the goal to speed up the nutrient analysis process when using 24-hour dietary recall data was achieved. They also agreed that automating the nutrient analysis process and providing % of nutrient contribution by food sources were the two main contributing factors to achieving this goal. Based on the pre-established rules both the participants had a positive opinion about the goal being achieved.

7) Foods from the AMPM survey and their nutrient profiles are presented in the form of a table. How easy is it to understand this visualization of the data?

As seen in figure 17, they agreed that the visualization of the nutrient analysis data in the form of a table was easy to understand. One of the participants suggested that specifying what the % refers to would make the visualization clear.
8) Does this report give you the information to rank food sources based on nutrients of interest?

As seen in figure 18 both participants agreed that the report gave them the information to rank food sources based on nutrients of interest.

The following feedback was received for the general questions on the WavePipe Nutrient Analysis tool:

**Q1. Would you like to continue using the tool?**

Both the participants answered 'Yes' to this question.

**Q2. Is there any other feature that you would like to see in this tool?**

One of the participants suggested that an interface to view individual student’s data might be a good feature to add for the future.

Based on the feedback received by the participants for the WavePipe Nutrient Analysis Tool and the fact that the participants are novice scientists with less experience than scientists on the
WAVE team, it is reasonable to expect that the other scientists would be able to understand how to use the WavePipe Nutrient Analysis tool. The participants were not confused with any feature of the tool and were able to navigate their way through the tool efficiently.
7. Conclusions and future work

In conclusion, this master’s project has provided researchers in health science and computer science with a 3-in-1 tool to collect, analyze, and visualize large food datasets from AMPM Surveys for sub-groups of participants over any desired period of time. The added functionality also enables importing new food information from various nutritional databases as well as creating new entries for individual foods in an effort to build a comprehensive food profile. As an output from this sub-system, a clear and concise report is generated in order show a snapshot of nutritional intake for participants in a specified sub-group.

Current nutrition analysis tools that are commonly used are not able to analyze the survey data collected by the WavePipe system without breaking the flow of information. As a result, this new subsystem combines the two required tasks of collection and analysis into one. A qualitative evaluation of the sub-system has shown that it is user friendly and understandable. A quantitative evaluation was conducted to verify the nutrient data outputted to the report and checked against USDA SR27 database and Super Tracker tool.

7.1 Potential future work

In the current system the reports generated by the Nutrient Analysis tool are not stored. The scientist has to download the report after it is created and store it on their computer. An additional feature could be implemented that allows the scientist to save the report in the system and access it at a later date. Also giving the scientist the ability to add their notes to the report before saving it might be an additional customization that could be desirable. This could allow the scientist to remember details about the report and the nutrition analysis.
The scientist can currently download the report in the form of an HTML file. It might be useful to provide the scientist with different options like Microsoft Word, Excel and PDF in which they could download the report.

Now that the AMPM survey data is parsed and easily available, different visualization could be created to help the scientist analyze the survey data. The visualizations could be created using the D3 [48], a JavaScript library. Giving the scientist the option to choose between different visualizations could be beneficial. The scientist could create custom reports depending on the quantity of data that they want to analyze. The scientist could choose between bar graphs, pie charts and other visualizations. The study group’s nutrient consumption on a daily basis or weekly basis could be represented on a timeline graph.

The current system does not support the concept of data highlighting [49]. A feature that allows the scientist to set expected consumption values for each nutrient, for the group on a daily or weekly basis would be desirable. The nutrient values in the table could be assigned different colors depending on whether they are higher, lower or are the same as the expected consumption values. The colors for the nutrient values could be fixed or they could be assigned by an algorithm that calculates how close the value gets to the expected consumption value.

A new component to view the AMPM survey data for individual participants in a study group might be useful. This feature is not supported in the current system. This feature could be used for smaller studies with fewer participants, and the scientist could focus on the foods each individual participant is consuming. The nutrient data for the individual participant could be analyzed through a variety of visualizations. Again the D3 JavaScript library can be used to create the visualizations. A
larger variety of visualizations could be created because the amount of data that needs to be visualized is significantly smaller for individual participants. Once the report with the visualizations is created the scientist could send it to the participant and give the participant feedback about their daily food consumption.

Another interesting feature that could be added is related to the fact that when multiple nutrient data sheets are imported into the system, there will be instances where the different datasheets have foods that are in common. The scientist could be given the option of averaging out the nutrient values for the common foods from the different data sheets. This could make the nutrient values in the system more accurate along with expanding the system’s nutrient database. This also could be handy when one of the datasheets does not contain nutrient information for certain foods. The nutrient data for the same food from a different datasheet could be used in this case. This would be a big step towards building a complete food profile.

Customizing the AMPM survey based on previous data collected for that sub-group could also prove to be useful. The scientist could make the foods previously eaten by the participants in the study group appear on top of the list of food options that the participants choose from while filling out the survey. This could make the process of filling out the survey a lot faster and efficient.

Lastly a statistical analysis component might be a good addition to the tool. Significance tests could be performed comparing the survey data from participant’s first day to the following consecutive days. A T-test could be performed to see if there is a change in the distribution of data for consecutive days or consecutive weeks.
8. Bibliography


[16] NUTRITICS Internet: https://www.nutritics.com/p/home


[34] ProNutra, Viocare Technologies http://www.viocare.com/pronutra.html


9. Appendix

In order to upload foods from an excel file to the database the data in the file needs to be cleaned.

The following are the steps involved in the data cleaning process:

- Rename the columns of the table according to the names in the database i.e. The names of the nutrients need to be expanded from their abbreviated versions.
- Remove the columns from the excel file that are not present in the database.
- Remove the units that are present right after the column names.
- Remove the columns that contain gram weight information.
- Verify that the number of columns in the excel file match the number of columns in the database.
- The empty cells in the columns need to be replaced with “null”.
- The extension of the Excel file needs to be changed to .xls (Excel 97-2003 Workbook).
- Verify the units of the columns in the excel file so that they match up columns in the database.
- The spaces in the column names need to be replaced by underscores.
Columns and Values in the Food database table

<table>
<thead>
<tr>
<th>NDB_Number</th>
<th>1001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long_Food_Description</td>
<td>Butter, salted</td>
</tr>
<tr>
<td>Short_Food_Description</td>
<td>BUTTER, WITH SALT</td>
</tr>
<tr>
<td>Water</td>
<td>15.87</td>
</tr>
<tr>
<td>Energy</td>
<td>717</td>
</tr>
<tr>
<td>Protein</td>
<td>0.85</td>
</tr>
<tr>
<td>Lipid</td>
<td>81.11</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>0.06</td>
</tr>
<tr>
<td>Fiber</td>
<td>0</td>
</tr>
<tr>
<td>Sugar</td>
<td>0.06</td>
</tr>
<tr>
<td>Calcium</td>
<td>24</td>
</tr>
<tr>
<td>Iron</td>
<td>0.02</td>
</tr>
<tr>
<td>Magnesium</td>
<td>2</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>24</td>
</tr>
<tr>
<td>Potassium</td>
<td>24</td>
</tr>
<tr>
<td>Sodium</td>
<td>643</td>
</tr>
<tr>
<td>Zinc</td>
<td>0.09</td>
</tr>
<tr>
<td>Copper</td>
<td>0</td>
</tr>
<tr>
<td>Manganese</td>
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</tr>
<tr>
<td>Selenium</td>
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</tr>
<tr>
<td>Vitamin_C</td>
<td>0</td>
</tr>
<tr>
<td>Thiamine</td>
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</tr>
<tr>
<td>Riboflavin</td>
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</tr>
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<td>Niacin</td>
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<td>Panto_Acid</td>
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</tr>
<tr>
<td>Vitamin_B6</td>
<td>0.003</td>
</tr>
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</tr>
<tr>
<td>Folic_Acid</td>
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<tr>
<td>Food_Folate</td>
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</tr>
<tr>
<td>Choline</td>
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</tr>
<tr>
<td>Vitamin_B12</td>
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</tr>
<tr>
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</tr>
<tr>
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</tr>
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<tr>
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</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td>-------</td>
</tr>
<tr>
<td>Vitamin_K</td>
<td>7</td>
</tr>
<tr>
<td>Sat_Fat</td>
<td>51.368</td>
</tr>
<tr>
<td>Mono_Sat_Fat</td>
<td>21.021</td>
</tr>
<tr>
<td>Poly_Sat_Fat</td>
<td>3.043</td>
</tr>
<tr>
<td>Cholesterol</td>
<td>215</td>
</tr>
</tbody>
</table>

Columns and Values in the GramWeight database table

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>NDB_Number</td>
<td>1001</td>
</tr>
<tr>
<td>Sequence</td>
<td>1</td>
</tr>
<tr>
<td>Amount</td>
<td>1</td>
</tr>
<tr>
<td>Measurement_Description</td>
<td>pat (1&quot; sq, 1/3&quot; high)</td>
</tr>
<tr>
<td>GramWeight</td>
<td>5</td>
</tr>
</tbody>
</table>