CERTIFICATION OF APPROVAL

Design of Food Processing Mechanism for An Automatic Sandwich-Making Vending Machine with Filling Selection

by

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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KHAIRUL ANWAR BIN AZHARI

ABSTRACT

Vending Machine is one of the ways for people to buy food while commuting or in hurry during inconvenient hours. However, there are limited choices of food sold in vending machine, especially in Malaysia. Food sold at 24 hours convenient stores or vending machines currently in market are mostly pre-packed and not fresh. A vending machine which is able to prepare foods such as sandwiches, as ordered and customized is a great product for the market. The study is done as the first step towards the completion of such a vending machine. The focus is given on mechanisms to prepare for food in a way that can maximize the capacity or a small machine.

The steps to design the machine are by observing the similar product already in the market, decomposing it into subsystems, and choose new feature and improvise the new system. In this case, the freshness of food plus ability to customize are considered. Main components for food preparation are bread storage and dispenser, meat storage and dispenser, conveyor/moving means, and heating devices. A lot more components has to be included such as refrigeration/chilling system, control system, humidity control system, food counter, coin/money counter, etcetera.

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CHAPTER 1

INTRODUCTION

1.1 Background Study

Sandwich is a food item made of two pieces of bread with filling between them. Because of the simplicity of preparing sandwich, it is very popular as the breakfast food as people often rush in the morning. Besides, sandwiches are typically taken to work, school or picnics to be eaten as part of a packed lunch. Typically, now sandwich is prepared manually and sold in packs. It is usually not freshly prepared and the selection of fillings is limited. Burger can be also considered as sandwich. [1]

A vending machine is used to sell various items such as food, beverages, tickets and even insurance policy without the need for cashier. Previously, only coins or token were accepted by vending machines. Now, bills and credits card are acceptable, thus making the sale of more expensive items possible through vending machine. Vending machine is very convenient for both the merchants and also the customers for various reasons. Besides eliminating the need for cashier, thus reducing the cost significantly, vending machine is also operating around the clock and consumes much smaller space compared to any shop or kiosk. [2]

Foods sold by vending machine are usually pre-packed. Examples are breads, chocolates, sandwiches and snacks. Most business owners prefer this kind of machines as they simply pick the customers' selected products and drop it in the dispensing box. Not much complication or maintenance should be done for this

kind of machine. Furthermore, there is no issue of contamination or hygiene since the packaging of the food itself is sufficient.

Food-preparing vending machines are also available although they have more issues to deal with especially hygiene. Among the foods sold using this kind of vending machine is French fries and Japanese noodle. The food-preparing vending machine must be equipped with refrigeration system and also cooking system. With these systems, food can be served hot and with some innovation, people can customized and choose foods to their liking.

Nowadays, people are more aware about the importance of healthy and timely meals. However, as they, especially those living in big cities, have to rush for their daily live, they often skip those meals of just take pre-packed meal on the go. Time is a valuable commodity for most people and most people can't afford to have a proper, hotly prepared food for every meal. Therefore, it would be great for a lot of people if such a food can be sold while they are waiting or rushing to go to work at places such as train stations, airports, or perhaps even at their workplaces. One of the ways for that to happen is through providing vending machines (as vending machines only occupy small space and have low operating cost) that can prepare and deliver hot, nutritious and very popular food such as sandwiches.

In Malaysia, two groups of people who most likely will be good consumers of fast food/vending machine items are university students (1.05 million student enrolled in Malaysian higher learning institutions in 2009) [3] and public transport users (156,084 users per day for Kelana Jaya Line LRT only).[4]

1.2 Problem Statement

1.2.1 Problem Identification

People are aware of the importance of nutritious, timely meals for health. However, since they always have to rush every day, they will either buy a pre-packed meal or just simply skip the meals while on the go. There is a need for a device (such as vending machine) that can prepare quick, nutritious, freshly prepared meals especially in crowded, public areas. Such a machine is very rare and limited in the current market.

1.2.2 Significance of the Project

This project, if done satisfactorily will have high marketability and will promote healthier eating habits especially for people who are commuting and rushing every day.

To check on the market acceptance of the vending machine, n online market survey was done at the following URL; www.surveymonkey.com/s/CS38TGHB. 153 respondents with the age ranging from 18 to 49 years old had participated in the market survey. The purpose of the survey is to get the opinion of the public about the sandwich-making vending machine. Most of the participants of the survey are between 20 to 25 years old and the average age is 22.8 years old (Due to the fact that's the range of age most of the author's acquaintances' are). The answer summaries for close-ended questions are tabulated and prepared in the appendix.

Discussion on Survey Result

Based on the result gathered, it can be concluded that the machine is acceptable for the crowd taking the survey. For example, for Question 4, 75.8% respondents answered that they would buy sandwiches from the sandwich machine if it existed. Besides, the market should be huge, considering the response for Question 3, 49.7% respondents really enjoy (answered option 1) eating custom made sandwich while 21.6% enjoy (answered option 2) eating custom made sandwiches. From this, we can deduce that sandwich is a popular food item and a sandwich-making vending machine can sell.

Universities, Airports and Train Stations were voted as the three most suitable place to put the machine compared to other venues suggested. The percentages are 74.5%, 60.1% and 53.6% respectively.

In Question 6, the respondents were asked to rate their most important criteria for the vending machine. Five options were given namely taste, hygiene, price, freshness and duration to prepare sandwich. The most important criteria was hygiene with 90 votes (58.8%). In the one of the open-ended questions, it is clear that most people people that don't want to buy from the vending machine because they doubt the hygienity of the sandwich prepared by the machine. Therefore, the processes involved in preparing the sandwiches must not compromise the hygiene factor. Furthermore, all of the regulations and standards reviewed put cleanliness and hygiene among the top factors that must be taken care of by the owner/operator.

1.3 Objectives and Scope of Study

The objectives of the project are to;

i. Develop the architecture of the system for food production and preparation.

ii. Validate the designed system using simulation and mathematical calculations.

The scope of the project includes determining and developing the sub-systems of the food preparation inside the vending machine, integrating the designed systems and simulating the system to validate the design parameters. The development of the model and prototype and thermodynamic constraintsare not included in the scope of project but will be considered if time permits.

1.4 Feasibility of the Project within the Scope and Time Frame

For this project, the first semester will cover formulation of methodology, conceptualization of design and data gathering. The second semester will be concentrated on detail design and simulation and analysis of the vending machine. Based on the draft methodology, the project's objectives are considered achievable within the given time frame.

CHAPTER 2

LITERATURE REVIEW

Before designing and developing a sandwich-making vending machine, we have to understand current development and the components of existing vending machines especially the ones used to cook and sell foods. Related rules and regulations by several authorities from various countries also will be considered, as they are the guidelines and limiting factors for existing products. Patents of food-preparing vending machines and related machineries will be the basis in the formulation of methodology and concept generation that applies the theoretical knowledge.

2.1 Case Study of Existing Product Available in Market

A bakery based in Singapore, Hotbake Pte Ltd has started selling sandwiches in vending machine since 2003. The company pre-pack sandwiches at its premise, into a special container, and deliver the food by refrigerated trucks to the vending machines across the island. The trucks will also pick up any expired sandwich. The vending machines are serviced daily.[5]

According to the company website, each machine has a capacity to hold 140 sandwiches, and can dispense two varieties of sandwiches at one time. Two sandwiches can be toasted at the same time. The dispensing from chilled compartment to heating section and heating process will take 90 seconds. The heating method is using two hot plates, toasting the above and lower bread simultaneously.

Further research showed that this company bought the machine from a supplier in Barcelona, Spain. Below are the full specs taken from the supplier website. [6]

- **Dimensions:** 1850 x 995 x 960 mm (height x width x depth)
- **Weight:** 375 Kg
- **Voltage:** 220 V, 50 Hz (110V version available)
- **Power:** 1,5 KW
- **Capacity:** Two carousels of stainless steel of 60 units each.

A demonstration video of the vending machine in operation is included in the presentation and also the CD accompanying this report.

2.2 Vending Machine (General)

A vending machine is a coin-actuated machine through which various goods may be retailed. Nowadays, vending machine can even accept bills and credit/debit cards, thus enabling it to sell relatively expensive items. The ability of vending machines to sell products at competitive prices around the clock without regard to holidays is now widely recognized. The business has grown beyond plants and factories, and machines are commonly used in schools, colleges and universities, recreation centers, health care facilities, offices, and the like.

Food is among the product most widely sold using vending machine. Among the types of food sold with vending machine are snacks, French fries, pre-packed sandwiches, hot dogs, frozen foods, ice creams and many more. Below are the pictures of food vending machine available around the world.

2.3 Components of Existing Vending Machine based on Patents.

US Patents related the project especially vending machine capable of refrigerating and cook/prepare food were reviewed. Below are the summaries of the available patents.

Patent No.	Description
4783582 (1988)	**Microwave Heating Apparatus for Use in Automatic Vending Machine** A heating apparatus to be included for vending machine. Consisted of heating room with upper opening, high-frequency wave generator, a support shaft penetrating the bottom wall of heating room, a receptacle connected to upper end of support shaft for receiving food, raising and lowering mechanism. Upon receiving food, the receptacle is lowered into the heating room where food is heated using high-frequency waves. The receptacle will be raised again after the food has been cooked.
5555793 (1996)	**Food Vending Machine Particularly Warm Food Such As Toasts, Sandwiches, Pizzas and Brioches** Food vending machine particularly for warm food, toasts in the specific case, including multiple per se known stations which are combined so as to obtain a machine which starts from a blister-packaged container inside which a pre-packaged uncooked toast is wrapped and transfers said toast by means of an appropriate drive to a pickup station so that the product to be cooked is placed at a moving cooking station and so that the product is extracted with special extractors after cooking so as to offer it, at the end of the cycle, completely wrapped in an appropriate hygienic napkin for taking on the part of the consumer.

5566856 (1996)	**Hot Food and Frozen Food Vending Machine** This invention includes a method and apparatus for vending frozen foods and also for vending hot previously frozen foods. The invention includes the use of a microwave oven, and a delivery system that maintains the food in an upright orientation so as to prevent spilling of hot foods. An important feature is that the invention does not destroy the microwave containment integrity of the microwave oven and therefore is safer from a radiation perspective.
6383542 (2002)	**Method and Apparatus for Preparing and Dispensing a Combination of Food Products in a Vending Machine** Method and apparatus for preparing and dispensing a combination of food products in a vending machine from a selection of components prepackaged in a plurality of trays sealed with a single peel off tape. The method comprises dispensing a top component onto a positioning releasable support and moving it into an oven, independently dispensing a tray with bottom component, sliding it to and raising into a moveable oven, independently heating components, removing components from ovens, moving said moveable oven out of the tray path, moving components to close proximity of each other and releasing top component into the tray. The apparatus has means for dispensing each of the individual components toward front of said vending machine; means for three-dimensional positioning of the releasable support for top components; means for bottom component tray lateral displacement; stationary oven, moveable oven, and an elevator laterally aligned with said product delivery opening.

Table 2.1:Table for Summary of Patents Studied

2.3.1 Refrigeration/Freezing System

Refrigeration is used to prolong the time of storage for foods. Freezing to 0 °F inactivates any microbes -- bacteria, yeasts and molds - - present in food. The freezing process itself does not destroy nutrients. In meat and poultry products, there is little change in nutrient value during freezer storage.Different type of foods will need different storage temperatures and different storage limit time. Below are the Freezer Storage Chart for -18°C storage temperature from the Food Safety and Inspection Service of the United States Department of Agriculture. [7]

Item	Months
Bacon and Sausage	1 to 2
Casseroles	2 to 3
Egg whites or egg substitutes	12
Frozen Dinners and Entrees	3 to 4
Gravy, meat or poultry	2 to 3
Ham, Hotdogs and Lunchmeats	1 to 2
Meat, uncooked roasts	4 to 12
Meat, uncooked steaks or chops	4 to 12
Meat, uncooked ground	3 to 4
Meat, cooked	2 to 3
Poultry, uncooked whole	12
Poultry, uncooked parts	9
Poultry, uncooked giblets	3 to 4
Poultry, cooked	4
Soups and Stews	2 to 3
Wild game, uncooked	8 to 12

Table 2.2: Freezer Storage Chart (0 °F/ -18 °C)

2.3.2 Heating/Cooking Components

Heating or cooking methods depend on the type of food to be dispensed. For frozen foods, ovens and microwave is usually used. As for the data gathered, microwave use less time and cook more uniformly compared to the oven. Below is the table comparing the relative cost of cooking for various appliances. It assumes the cost of gas is $.60, and electricity is $.08 a kWh.

Appliance	Temperature	Time	Energy	Cost
Electric Oven	350	1 hour	2.0 kWh	$.16
Electric Convection Oven	325	45 minutes	1.39 kWh	$.11
Gas Oven	350	1 hour	.112 therm	$.07
Electric Frying Pan	420	1 hour	.9 KWh	$.07
Toaster Oven	425	50 minutes	.95 kWh	$.08
Electric Crockpot	200	7 hours	.7 kWh	$.06
Microwave Oven	"High"	15 minutes	.36 kWh	$.03

Table 2.3 Table of Comparison of Characteristics of Different Heating Mechanism

Based on the table above, microwave oven shows good quality in many aspects to be considered to use in a vending machine. Microwave food processes offer a lot of advantages such as less start-up time, faster heating, energy efficiency, space savings, precise process control, selective heating and food with high nutritional quality (Marra et al., 2010) [8]. Quality problems associated with microwave baking include reduced height of the product, dense or gummy texture, crumb hardness and an undesirable moisture gradient along a vertical axis in the final baked product (Sumnu and Sahin, 2005) [9].

2.3.3 Bill Collector

Bill collector is commonly used in vending machines, replacing or complementing the coin collector. It is more convenient to use bill collector as high inflation rates made items to be more expensive and it is inconvenient to bring a large amount of coins.

Common bill collector consisted of a bill-receiving roller device, positioned internally and bill slot, at the front end of the roller device to receive bills from customer. Upon receiving a bill through the bill slot, the roller device will roll the bill in while an identifying device will check the authenticity of the bill. The bill will then rolled into the bill collection canister.

2.3.4 Mechanical System for Preparing and Dispensing Food

Based on the patents reviewed, there are many special/custom mechanism applied to achieve certain movement/action. However, these mechanisms were designed using the power transfer mechanism.Included under power transfer mechanisms are belts, chain, plastic-and-cable chain, friction drives, gears and springs. The functions of these mechanisms are to reduce or increase torque, reduce or increase speed, and to transmit power. [10]

2.4 Related Food Standards, Rules and Regulations

Food Standards, Rules and Regulations of various authorities can be a good guidance to determine the parameters and design condition of a device. Below are a few of the regulations that had been reviewed;

2.4.1 Food Hygiene Regulation 2009 (Malaysia Ministry of Health) [11]

The regulation is exercised under the Food Act 1983, an Act to protect the public against health hazards and fraud in the preparation, sale and use of food, and for matters incidental thereto or connected therewith.

Interpretation of Related Words and Phrases in the Regulation;

"Food vending machine" means any self-service machine that upon the insertion of a coin, token or by any other means automatically dispenses unit food or drink in units either in bulk or in packaged form.

"Clean" means a condition or such circumstances, which shall not lead to, or cause any contamination to food with filth or other objectionable matter such as food residue, soil, dirt or grease.

"Sanitary" means free from any condition or circumstances affecting health, and includes such conditions or circumstances, which may lead to, or cause contamination of food with microbiological contaminants or toxic substances which can render the food hazardous to health.

"Microbiological contaminant" includes viruses, bacteria, fungi and their toxins but does not include microorganisms which are permitted to be added into food under the Food Regulations 1985.

"Pest" means any animal capable of directly or indirectly contaminating food.

Regulations Regarding Food Vending Machine

An owner or operator of a food vending machine shall comply with the following requirements:

(a) The food vending machine is kept in a good working order and condition.

(b) The food vending machine is kept in a clean and sanitary condition and free from pest.

(c) The food vending machine is used exclusively for the sale of food**.**

(d) The surrounding area where the food vending machine is located is kept clean, tidy and free from pest.

(e) The floor where the food vending machine or water vending is intended to be installed is constructed of smooth impervious material that is easily cleaned and able to withstand repeated washing and scrubbing.

2.4.2 Recommended Guidance for Permanent Outdoor Cooking Establishments 2003 (United State Food and Drug Association)[12]

The minimum guidelines set forth in the document for cooking foods outdoors are extracted from, or consistent with, the requirements of the current version of the U.S. Public Health Service, Food and Drug Administration's Food Code (hereafter referred to as the Food Code).These guidelines provide the basis on which regulatory authorities can evaluate and permit permanent outdoor cooking establishments.

According to recent data from the Centers for Disease Control and Prevention (CDC), [Reference information: CDC publication, MMWR "Surveillance for Foodborne Disease Outbreaks – United States, 1993-1997, March 17, 2000/ 49 (SS01):1-51, the most commonly reported risk factor that contributed to foodborne disease was improper holding temperature. The second most commonly reported risk factor was inadequate cooking of food. Other risk factors include poor personal hygiene, contaminated equipment, and foods from unsafe sources. Regardless of whether food is prepared outdoors or indoors, or at permanent, seasonal, or temporary sites, these risk factors must be controlled in order to ensure the safety of the foods being prepared, served, and consumed.

Related Guidelines under the Recommended Guidance

(a) Temperatures

Potentially hazardous food must be maintained at 135 °F (57°C) or higher or 41°F or below. Food must be cooked to the minimum temperatures and times specified below:

- 165°F (74°C) for 15 seconds--poultry; stuffing containing fish, meat, or poultry; stuffed fish, meat, pasta, or poultry;
- 155°F (68°C) for 15 seconds--comminuted fish; comminuted meat (hamburgers); pooled raw eggs or as specified in the Food Code Part 3-401.11 (A) (2);

(b) Cold Storage

Commercial refrigeration units should be provided to keep potentially hazardous foods at 41°F (5°C) or below. Equipment shall be installed and used in accordance with the manufacturer's instructions. An effectively insulated, hard sided, cleanable container with sufficient ice or other means to maintain potentially hazardous foods at 41°F (5°C) or below may be approved for the storage of small quantities of potentially hazardous foods. Unpackaged food may not be stored in direct contact with undrained ice.

(c) Temperature Measuring Device

A thermocouple, thermistor or metal stem thermometer shall be provided to check the internal temperatures of potentially hazardous hot and cold food items. Food temperature measuring devices shall be accurate to ±2°F, and should have a suggested range of 0°F (-18°C) to 220°F (105°C). Refrigeration units should have a numerically scaled thermometer accurate to ±3°F to measure the temperature of the unit.

2.5 Related Journal on Food Safety

Food safety is an important concern in this project. Any mistreatment of food during storage or preparation can cause a huge problem for many parties. Food safety has been an increasing concern for consumers, retailers, and all production and processing areas of the food industry. [13] Food safety is also of crucial importance to a nation's economy and health systems. In fact, the safety of the entire food supply chain depends on food engineering innovations and designs that apply the latest technologies to real-world problems in production and processing [14, 15, 16, 17].After CFSE in 2007 it was clear that engineering should be an integral component of food safety research. Engineering is necessary in the development of physical and chemical mechanisms and devices for detection of microbial and chemical hazards in the food supply. In fact, if we define engineering as the hardware that makes it possible to carry out a technology (using software or ''know how''), food safety engineering could be considered as a type of food engineering hardware (e.g., the physical solutions for processing; packaging, and storage equipment; facilities—including control systems; rooms in food factory; other facilities used in food supply chain) that could be used to achieve the required levels of food safety and security in the food supply chain [18]. Marks [16] stated that while epidemiologists, food microbiologists, and chemists advance the understanding of foodborne microorganisms (e.g., explaining how microorganisms cause diseases, react to environmental influences, and can be isolated and identified), this knowledge must ultimately be scaled-up by food engineers to design and implement technical solutions to the real problems facing the food industry.

CHAPTER 3

METHODOLOGY

3.1. Research Methodology

The research methodology will follow the flowchart below. The flowchart is taken and modified from two sources, Dieter (2000) [19] and Dym (2009) [20]

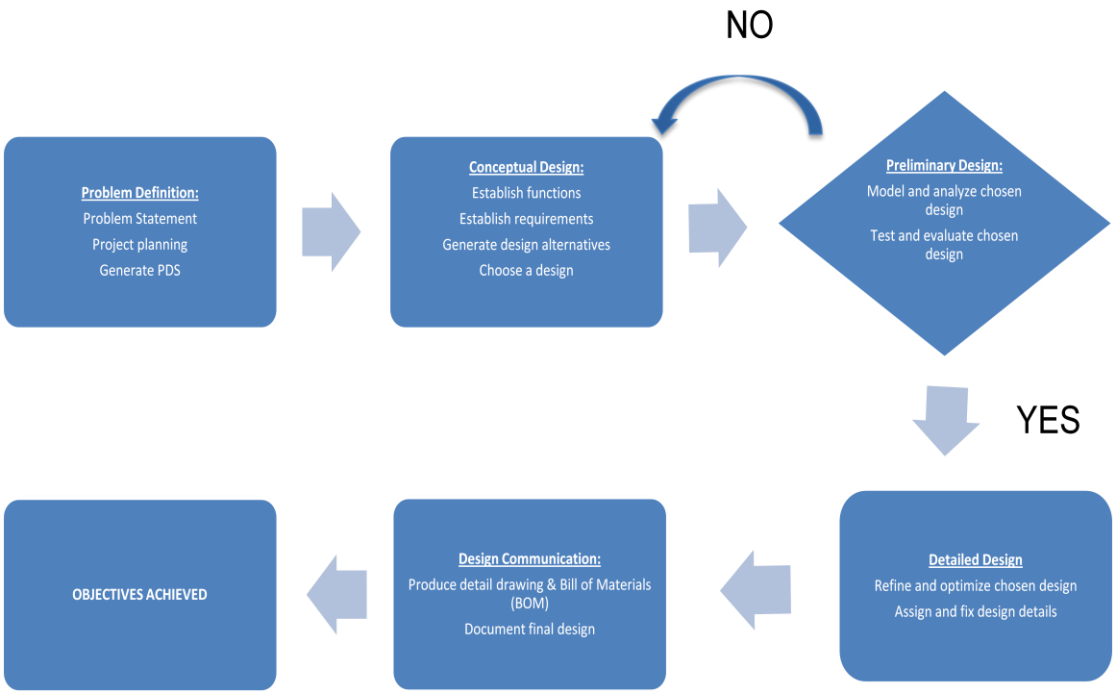

Figure 3.1 : Flowchart of Methodology of The Project

3.2. Project Activities and Key Milestone

The following project activities are derived from the above flow chart.

3.2.1 Problem Definition

- Identify the nature of the problem to be solved. Done through online survey. Develop a problem statement and objectives.
- Plan the whole project flow and tasks to be carried out.

3.2.2 Conceptual Design

- Identify the functions needed to be performed by the product as a whole.
- Identify the constraints and environment in which the product will work.
- Generate a Product Design Specification.
- A few alternative designs must be produced based on the functions to be performed.
- One design must be chosen using morphological chart

3.2.3 Preliminary Design

- Chosen design will be modeled and analyzed using software. (Autodesk Inventor &Simulink)
- Change will be done according to result and if necessary, task 2 need to be repeated.

3.2.4 Detailed Design

- Based on the results from the simulation, design will be refined and optimized so that it can run the required functions under the set of constrains and requirements needed.
- Parameters and specifications will be finalized.

3.2.5 Design Communication

- Final drawing/diagram and necessary reports for the final product will be prepared.

3.3 Tools

The tool required to achieve the objectives of this project are as follow:

- AUTODESK Inventor for solid modeling, analysis, and simulation

CHAPTER 4

RESULT AND DISCUSSION

4.1 Difference between the New Design and Current Product in Market

As written in chapter 2, a similar sandwich vending machine is already available in the market. However, although both machines produce sandwiches, there are a lot of differences that can be pointed out. The table below summarized the differences.

Current Product (TE Model)	New Design
The sandwiches are prepared and pre-packed manually at bakery.	The ingredients for sandwiches are cut, prepared toasted and packed inside the machine.
Limited options, only two types at one time. No customization.	Options depending on the type of fillings loaded into the machine. Customer can customize the type of fillings, number of layers, etc.
Capacity is only up to 140 sandwiches.	Capacity can go up to 300 sandwiches.
Easier maintenance and fewer issues on hygiene as the sandwich is prepared before hand and pre-packed.	Need special maintenance and careful design to avoid hygiene problems.
Less complicated system for food storage. Only chilling in range of 0^{o}C-3^{o}C for storage and a heating device for before dispensing.	Food storage might require different temperatures for freezing, thawing and food preparation.

Table 4.1: Table of Comparison between Existing Product and New Product

4.2 Flowchart of Final Product's Expected Function

Below is the flowchart of the function/work done by the machine in order to prepare a sandwich. Functional decomposition will be done based on this flow chart and corresponding components and systems will be developed based on the functions.

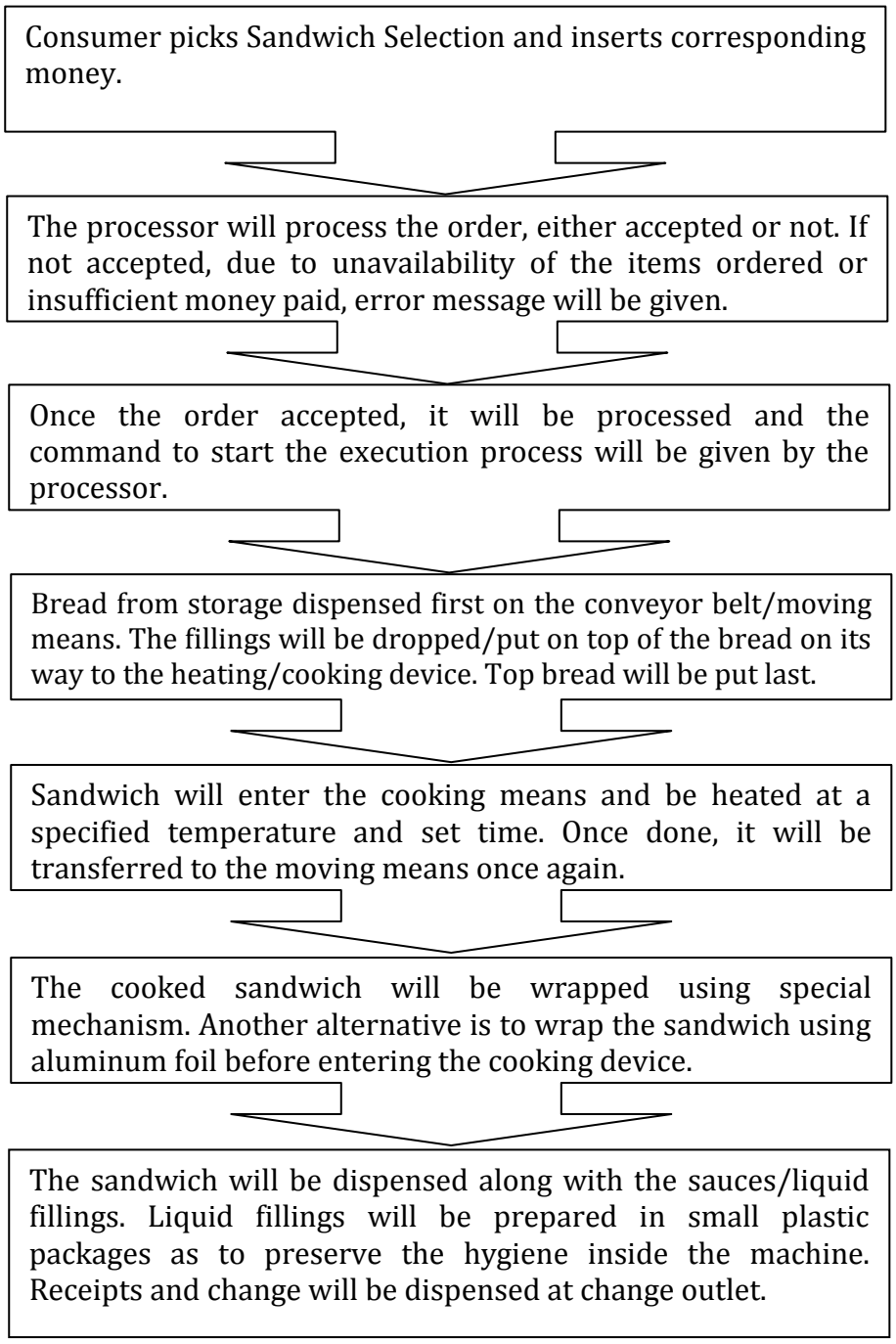

Figure 4.1: Flowchart for Final Vending Machine's Expected Function

4.3 Design Decomposition

Design decomposition is an important process to disassemble the components of an existing product and learn how the components interact to produce the desired result [20]. The vending machine can be divided into the following subsystems illustrated below. Basic conceptual design on each subsystem needs to be completed before the interaction between the subsystems can be established.

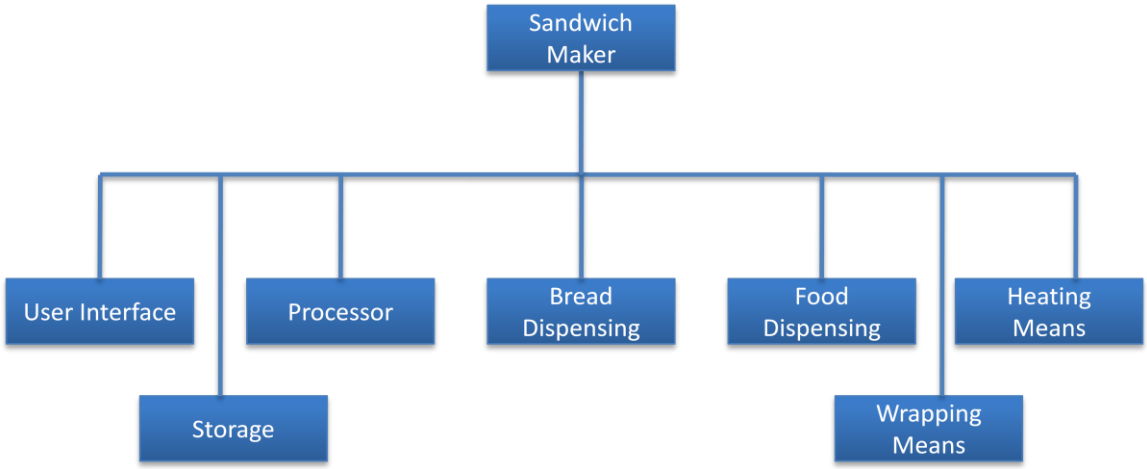

Figure 4.2: Design Decomposition of A Sandwich Making Vending Machine

Storage inside a vending machine is a crucial issue. Optimum storage size and condition is important as to ensure that the food products contained in the vending machine are sufficient and in good condition. If the amounts were insufficient, it would be hard for the operator to always refill the vending machine before the stipulated time. However, if the condition such as the storage temperature and food handling were not suitable, it would be dangerous for the consumer if food degradation happened before the expected time. Another thing for consideration is the time needed for food to be moved out from the storage and to be prepared before dispensed, especially for food stuff that are frozen. Thawing the frozen food will need sometime and if not done right way, it will be consuming a lot of time for the process.

4.4 Pairwise Comparison Chart – Priority of Features

A number of features as in list below have been set. Next, the priority is decided based on the comparison of each of the features, against all other features, in which the more important feature will be given a score of one, while the less important will be given a zero. The scores will be summed up and the feature with the highest score will be regarded as the most important [20]. The lowest scoring feature is the least important.

The features set are;

1. Cost – The cost to build up the designed system, based on early estimation.
2. Size – The overall size of the designed system.
3. Durability – The number of operation hours served until the system fail, estimated based on the moving parts.
4. Food Freshness – The ability to retain food taste, condition and avoid food contamination.
5. Ease of Maintenance – The procedures/cost that might be needed in the case of failure.
6. Moving Parts – The number of moving parts in the system, based on early sketches/drawings.

	Cost	Size	Durability	Food Freshness	Ease of Maintenance	Moving Parts	**Score**
Cost	xxx	0	0	0	0	0	0
Size	1	xxx	0	0	0	1	2
Durability	1	1	xxx	0	0	1	3
Food Freshness	1	1	1	xxx	1	1	5
Ease of Maintenance	1	1	1	0	xxx	1	4
Moving Parts	1	0	0	0	0	xxx	1

Table 4.2: Pair-wise Comparison Chart for Features

4.5 Conceptual Design

Based on the manual sandwich preparation that is shown in appendix, it can be deduced that food-dispensing system will be the main mechanical part in the sandwich making process. Therefore, three conceptual designs had been produced to illustrate the process. The first design, Design A is as illustrated below. It comprises of two conveyor belts moving in opposite directions, one microwave oven and two sets of static food dispenser. The conveyor belt on the right hand side will move in the direction of the microwave oven. The first slot on the said food dispenser will be dispensing bread. The conveyor belt then will then move towards the oven and selected food items/fillings will be dropped on the bread. During the dispensing of each filling, the conveyor belt will stop for a few seconds. The bread and fillings will then enter the microwave for certain period of time, and pushed to the left side conveyor belt. This conveyor belt will move away from the oven and along the way receive fillings if any. The furthest slot from the oven will be dispensing the second bread.

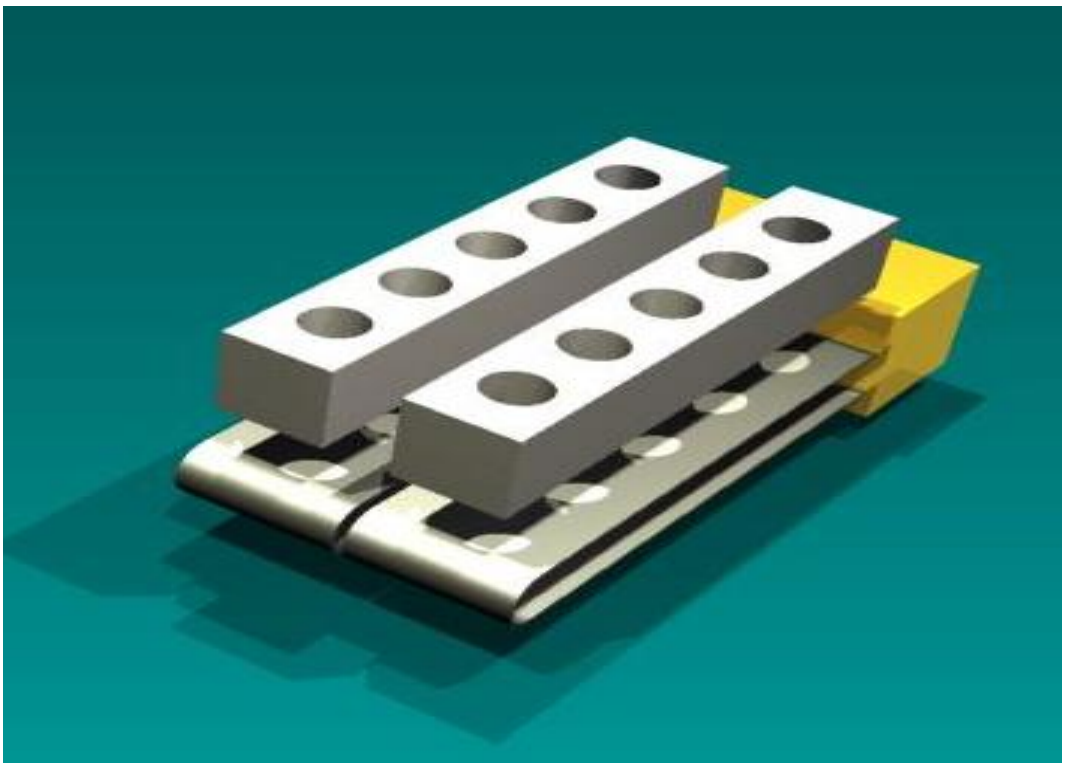

Figure 4.3: Initial Design A

Figure 4.4: Initial Design B

Design B as illustrated above will have the same set of conveyor belts and microwave oven. However, the food dispensing units have been changed to rotary mechanisms. With this, the number of food selection can be increased significantly compared to design B.

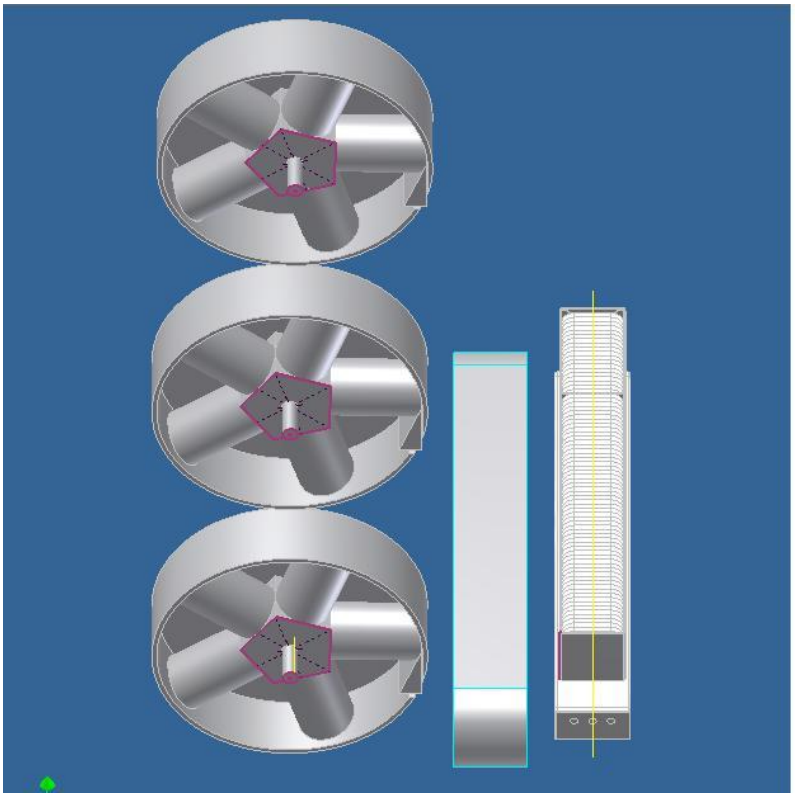

Figure 4.5: Initial Design C Front, Upper View

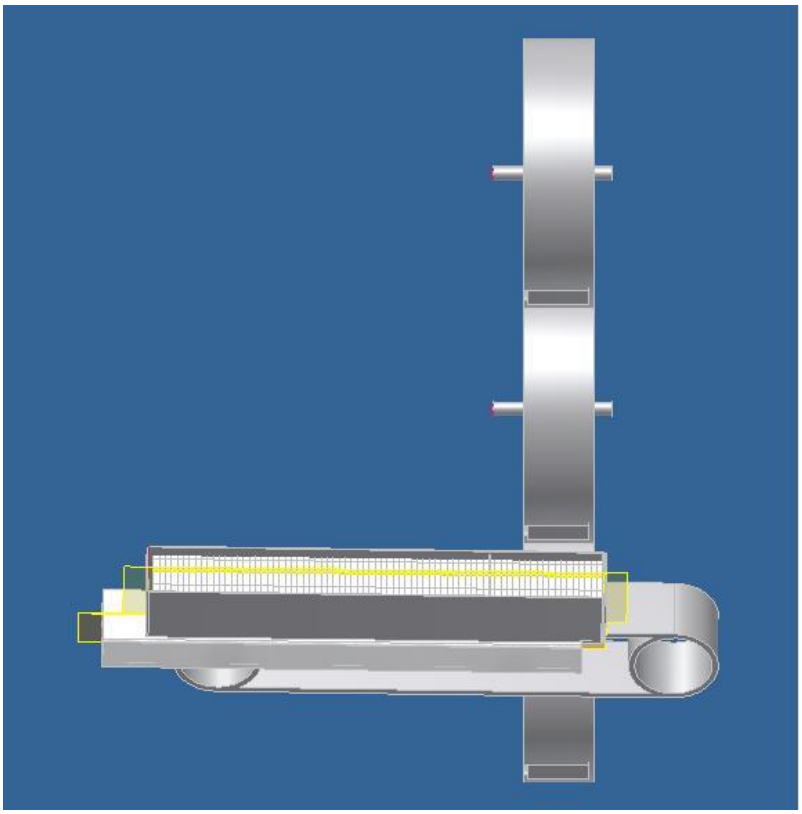

Figure 4.6: Initial Design C, Left, Upper View

Design C have lot of differences compared to Design A and B. It comprises of 3 main compartments which are; Bread Storage and Dispenser Unit, Conveyor Unit, and Meat Storage and Dispenser Unit. The first unit will store bread (in this case only toast is possible). Once receiving command for bread dispensing, a motor will rotate a power screw, thus pushing the whole row of bread to the back of the unit. At the most back end of the unit, a component will push a slice of bread down on a chute (not in the picture) that leads the bread to the conveyor unit. The conveyor unit is able to move forward and backward. The final component is the Meat Storage and Dispenser Unit. The unit is cylindrical in shape and consists of an outer part and an inner part. The outer part is equipped with a blade and will be static in operation. The inner part comprised of five cylindrical tubes containing meat and a spring mechanism that will always push the cylindrical-shaped meat outward. The inner part will be rotating during operation. Whenever the meat comes in contact with the blade of the outer part component, it will be sliced and ejected from the meat storage and send to conveyor unit through a chute (not shown in the picture). The meat is supposed to fall on top of the dispensed bread. Each rotation of the inner part of the inner part of the Meat Storage and Dispenser Unit will produce 5 slices of meat.

4.6 Design Selection

The three design alternatives that had been generated are compared with each other to select the best design. The selection criteria are based on the features set on the previous table, in which the most important feature will be given the highest weight. Each of the design alternatives will then be compared according to each feature. The design which is the best according to the particular feature will be given the score of three while the worst be given one. The score will then be multiplied with the weight of that feature. In the end the scores of each feature for each design will be summed up and the design with the highest score will be considered as the best design and will be developed further. [20]

Features	Design A	Design B	**Design C**	Weight
Cost	2	1	**3**	1
Size	1	2	**3**	3
Durability	3	2	**1**	4
Food Freshness	1	1	**3**	6
Ease of Maintenance	2	1	**3**	5
Moving Parts	3	2	**1**	2
Score	2+3+12+6+10+6 = 39	1+6+8+6+5+4 = 30	**3+9+4+19+15+2 = 52**	

Table 4.3: Table of Initial Design Comparison and Selection

Based on the chart, the design that will be developed further is design C.

4.7 Detailed Design

The detailed design was drawn using Autodesk Inventor Professional 2009. The techniques to draw were studied step-by-step using a textbook by Autodesk, Bethune, J.D (2009) [21]

Sandwiches to be produced by the system consisted of two slices of bread and slices of meat. Therefore the sizes of both items must be considered first before the design of the system. The following are the pictures and size of both items.

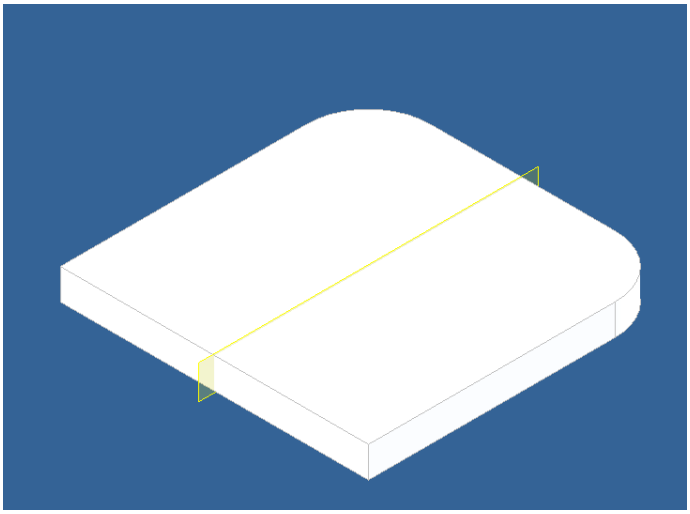

Figure 4.7: Bread Slice

Each slice of bread has a cross section of 10mm x 10mm and 1 mm thickness. The bread will be the basis used for the bread dispenser unit.

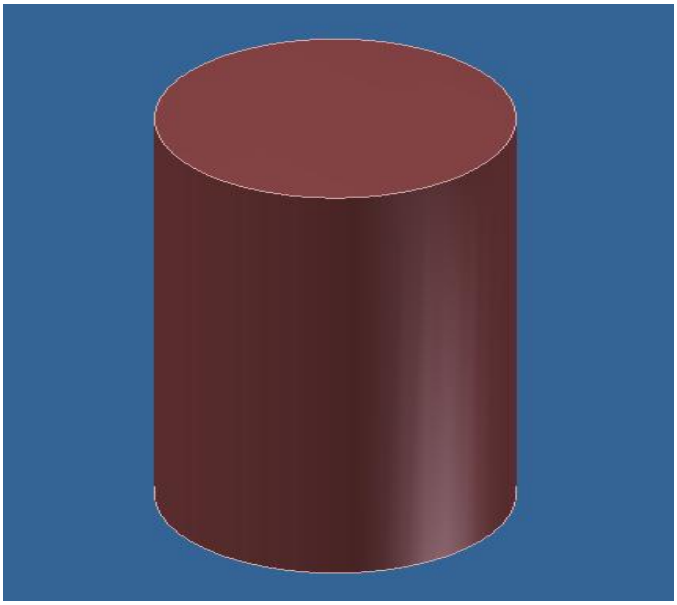

Figure 4.8: Meat/Fillings Cylinder

The sandwich fillings are stored in as cylinders with cross section having the diameter of 9mm and 150 mm height. Meat is considered as the sample filling. The cylinder will be sliced; producing 3 mm thickness layered meat. The sliced meats are called salamis. The reasons why fillings are made into cylinders are for maximum use of storage space and ease of dispensing.

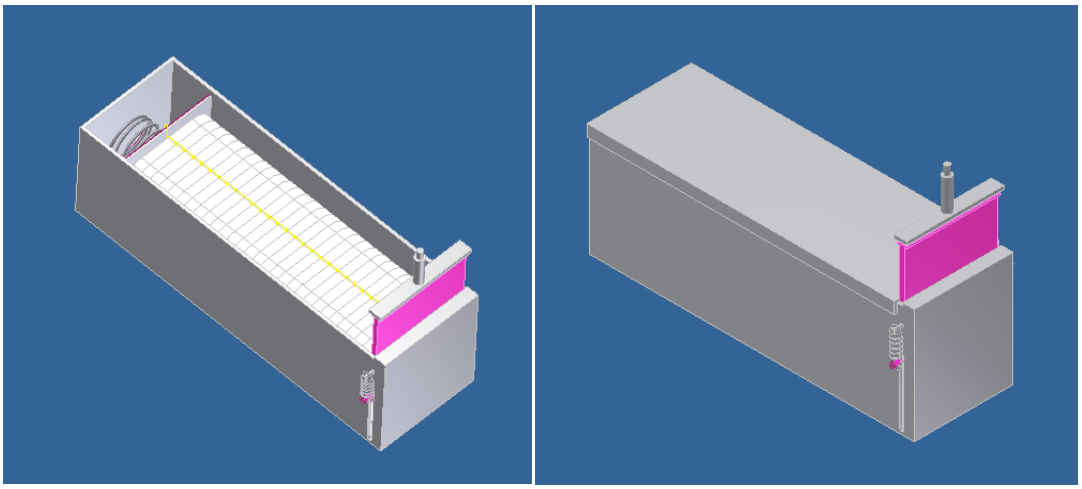

Figure 4.9: Bread Dispenser Unit

The bread-dispensing unit, each can hold up to 30 slices of bread. The bread is pushed to the front using a compressed spring. A plunger is located at the front of the bread dispenser, and will be controlled using a solenoid. Once and order is placed, the solenoid will push down the plunger, which in turn, will be pushing down a slice of bread to the conveyor belt. The solenoid will be retracted back upwards, leaving the plunger pushed upwards by a pair of springs. Vacancy will be left at the place of the pushed down bread. This will lead to the expansion of the spring located at the back of the bread-dispensing unit, which will push all the bread in the container to the front.

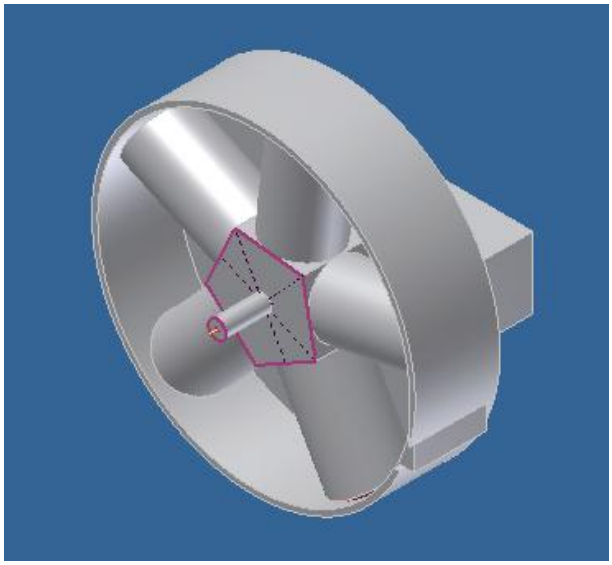

Figure 4.10: Fillings Dispenser with Motor Unit (In box)

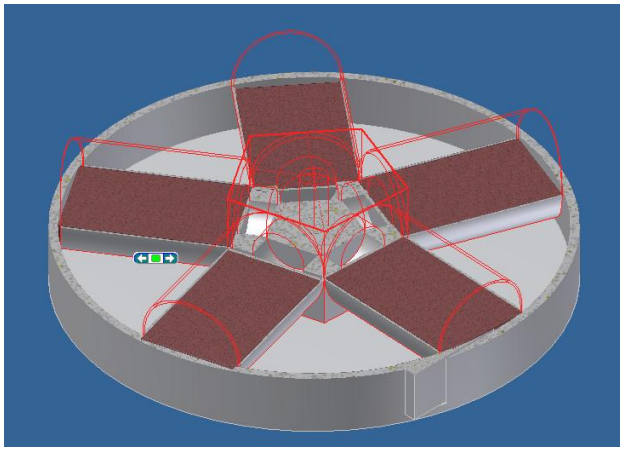

Figure 4.11: Fillings Dispenser Unit (Cross-sectioned)

The filling/meat dispenser consisted of two mating cylinders and a motor. The outer cylinder is called the slicer. The slicer will remain static and is equipped with a blade to cut meat. The inner cylinder is called meat storage. Meat storage has 5 hollowed bores, which are used to store the cylindrical shaped fillings/meat discussed above. The meat will be always pushed outwards by means of compression springs. Motor will be used to spin the meat storage. At one point, the meat will come in contact with the blade of the slicer and will be sliced into 3mm-thick salami before pushed down on top of the dispensed bread on a conveyor belt.

The system was inspired by the mechanism to produce cubed chicken shown in Berk (2009) [23]

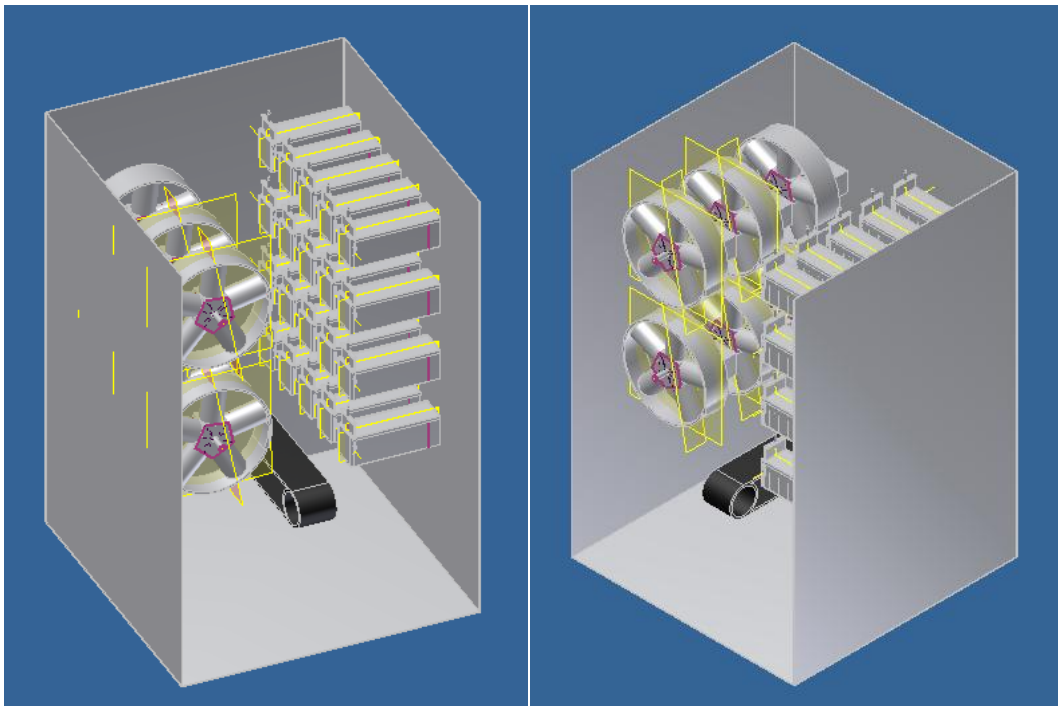

Figure 4.12: Arrangement of Units inside Vending Machine

The picture above showed how the meat dispenser, bread dispenser and conveyor belt are placed inside a 1200 mm x 1200 mm x 1800 mm space. This is the size of a general canned drinks vending machine. The size is used as constraint for the sandwich vending machine and to estimate the capacity of sandwich that can be stored and produce. The machine can store up to 6 meat dispenser and 20 bread dispensers. In the system design, the cleanliness and easy of refilling are considered. Each array of filling dispenser and bread dispenser can be taken out as in bringing out a drawer.

4.8 Related Calculations

4.8.1 Machine Estimated Capacity

Bread capacity = $\frac{\text{20 bread dispenser x 30 units}}{\text{2 breads per set}}$ = 300 sets

Filling/Meat Capacity = 5 cylinders x 6 dispenser = 30 cylinders

Each cylinder can produce 150mm/3mm = 50 slices of salamis.

Therefore, maximum slices of salamis = 50 x 30 cylinders = 1500 slices.

4.8.2 Torque Needed to Slice Meat

To ensure that meat will be successfully sliced, enough torque has to be applied by motor to produce enough slicing force. An acceptably tender meat sample of 10mm x 10mm cross-section needs 6 kgfforce to be sliced. [23]

1 kgf = 9.8 N

6 kgf = 9.8 N x 6

= 58.8 N

The cross-section area of the meat cylinder $= \pi r^2$

$$A = \pi(45mm)^2$$

$$= 6362mm^2$$

$6362mm^2/100mm^2 = 63.62$ times

Force needed to slice through meat = 58.8N x 63.62

= 3740.86N

Torque = Force x Level Arms

= 3740.86N x Radius of Food Storage Cylinder

=3740.86N x 0.217m

=811.77 N.m

Using the factor safety of 2, Motor and Gear Head must be able to produce minimum 811.77 N.m x 2 = 1623.54 N

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Based on the result and discussion in the previous chapter, various findings, design, and analysis that are relevant towards the accomplishment of the project. The results produced are;

i. Comparison of the designed system compared to the existing product
ii. Final product expected functions
iii. Design Decomposition
iv. Priority selections for the features of the product
v. 3 Alternative designs
vi. Final design selection
vii. Related Calculations

From the results stated above, it can be said that the two objectives, which are to develop the architecture of the system for food production and preparation and to validate the designed system using simulation and mathematical calculations.

5.2 Recommendation

The overall objective for the project has been achieved. However, looking at the completion of the final intended product – a vending machine capable of producing

customized sandwiched, there are still a lot of works to be done. These can be divided into several sections.

5.2.1 Mechatronic/Electronic System

For the overall system to run, a complete mechatronic system to control and run the movements and the relationships between subsystems is needed. A suitable PLC system can be applied to act as the control or 'brain' of the vending machine as well as various sensors and actuators that will collect information and produce actions so that the intended product – sandwiches, can be delivered satisfactorily to the users. The correct selection of sensors and actuators needed to be done and placed at the right places as to ensure smooth operations. Among the sensors/actuators that might be useful are;

i. Various switches
ii. Thermistor
iii. Hall effect sensor
iv. Motor
v. Solenoid

5.2.2 Further Refinement of the Mechanical System for Food Dispenser

The food dispenser design in this project can be greatly upgraded to maximize the storage capacity, as well as increasing the number of food suitable to be dispensed by the system. As for now, the system is only capable of dispensing simple, solid food that can be easily sliced such as chicken, beef, mutton, etc. Upgraded system might be able to dispense other, hard to handle foods (for various issues) such as eggs, vegetables, or liquid food items. Refined system will also make maintenance and cleaning easier.

5.2.3 Thermodynamics and Heat Transfer

The vending machine will contain refrigerating elements to ensure that food can be frozen or chilled, thus preserving the nutrient, and condition and preventing any microbial growth and food degradation. Besides, there will also be heating elements for cooking/toasting the sandwiches before dispensing to the user. The refrigerating/heating elements will involve the transfer of energy from one place to another. Maintenance of the systems also need to be considered as any failure to either of the systems will made the vending machine as a whole to be malfunction. Food produced in the event of failure will be dangerous and hazardous.

5.2.4 Engineering Economics

To ensure that the final product is financially viable, a study on engineering economics application has to be done. The materials to be used, the capacity, breakeven analysis, as well as manufacturing and maintenance cost have to be studied thoroughly. These are to ensure that any future investment to be made to develop such product will generate profit, thus enabling an establishment of good businesses centered on the product.

5.2.5 Recommended specification of the Final Product

Item	Description
Product Name	Sandwich-Making Vending Machine.
Purpose	Vending machine that can prepare and sell custom-made sandwiches as and when ordered.
New/Special Features	An array of bread types, fillings

	(meat/chicken/fish/vegetables) and sauces to select. Sandwiches prepared hot, when ordered, not pre-packed. Serving time per sandwich is 2 minutes.
Competition	Will compete against pre-packed foods sold at convenient stores and fast food outlets.
Intended Market	Universities (1.1 million student in Malaysian higher learning institutions), Public transport users (156,084 users per day for Kelana Jaya Line LRT only).
Service environment	Outdoor or indoor with temperature range of 10 to 50^{o}C, 20 to 100 percent relative humidity.
Product Name	Sandwich-Making Vending Machine.
Purpose	Vending machine that can prepare and sell custom-made sandwiches as and when ordered.
New/Special Features	An array of bread types, fillings (meat/chicken/fish/vegetables) and sauces to select. Sandwiches prepared hot, when ordered, not pre-packed. Serving time per sandwich is 2 minutes.
Competition	Will compete againts pre-packed foods sold at convenient stores and fast food outlets.
Intended Market	Universities (1.1 million student in Malaysian higher learning institutions), Public transport users (156,084 users per day for Kelana Jaya Line LRT only).
Service environment	Outdoor or indoor with temperature range of 10 to 50^{o}C, 20 to 100 percent relative humidity.

Table 5.1: Recommended Specification of Final Product

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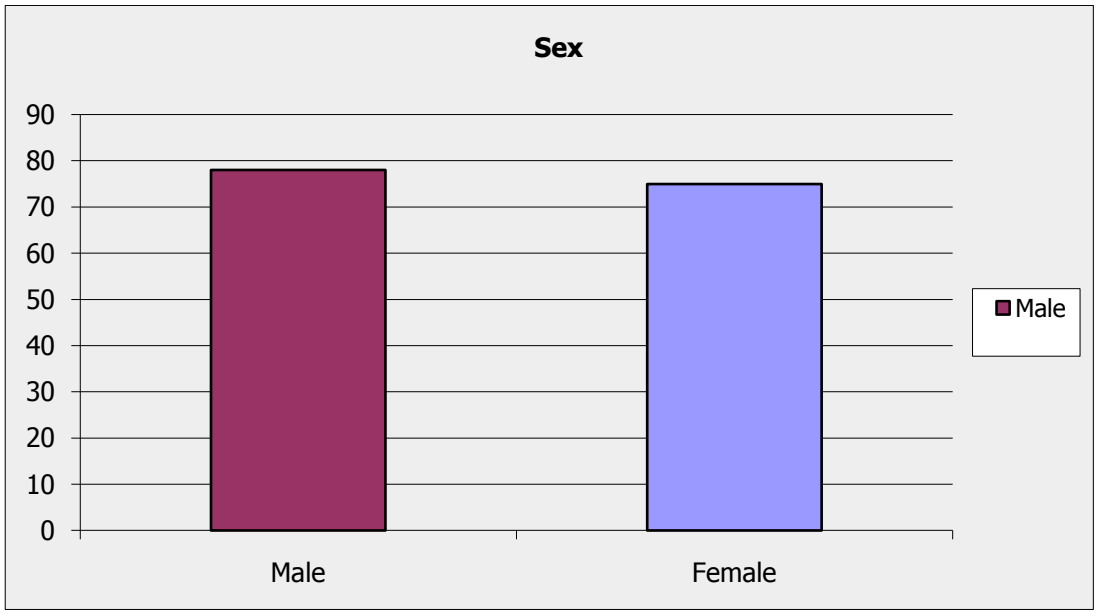
APPENDIXES

Appendix A - Survey Questions

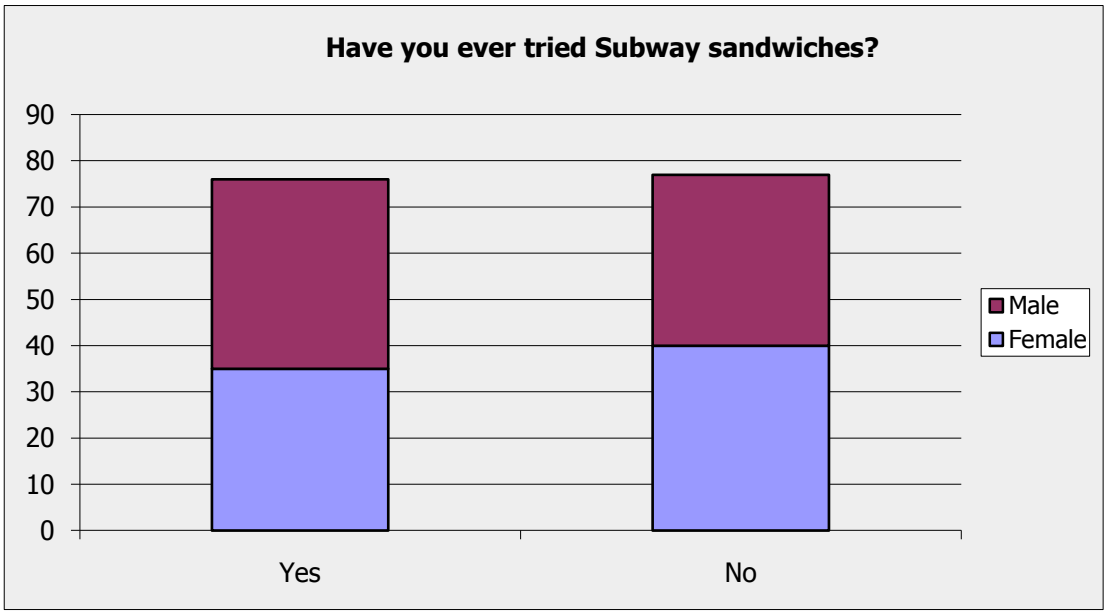
Question 1 – What is your gender?

Sex		
Answer Options	**Response Percent**	**Response Count**
Male	51.0%	78
Female	49.0%	75
	answered question	**153**



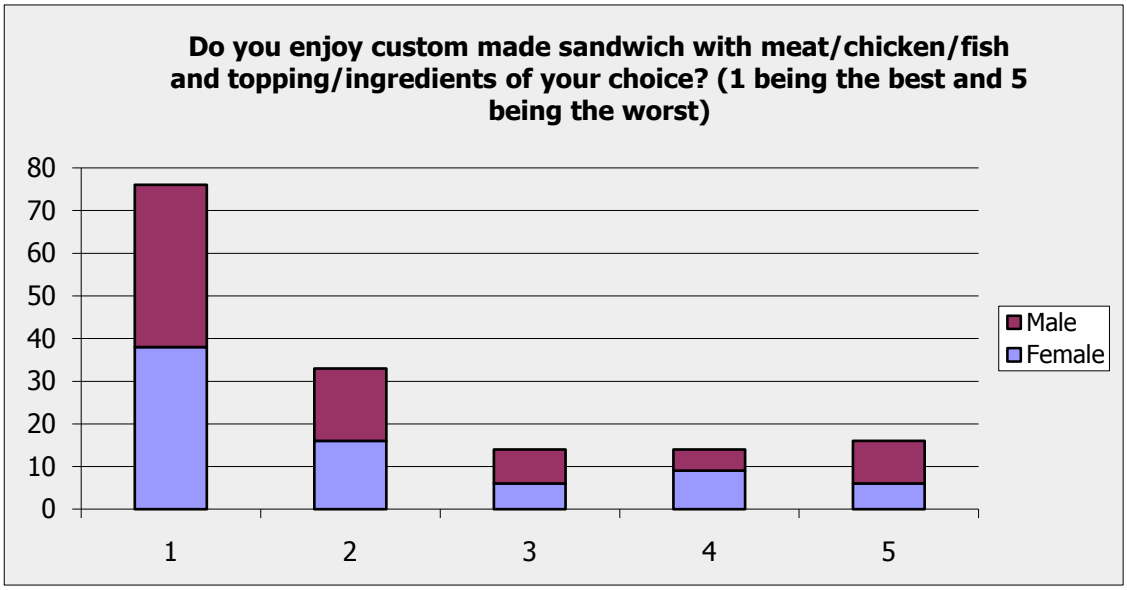
Question 2 – Have you ever tried Subway sandwiches

Have you ever tried Subway sandwiches?		
Answer Options	**Response Percent**	**Response Count**
Yes	49.7%	76
No	50.3%	77
	answered question	**153**



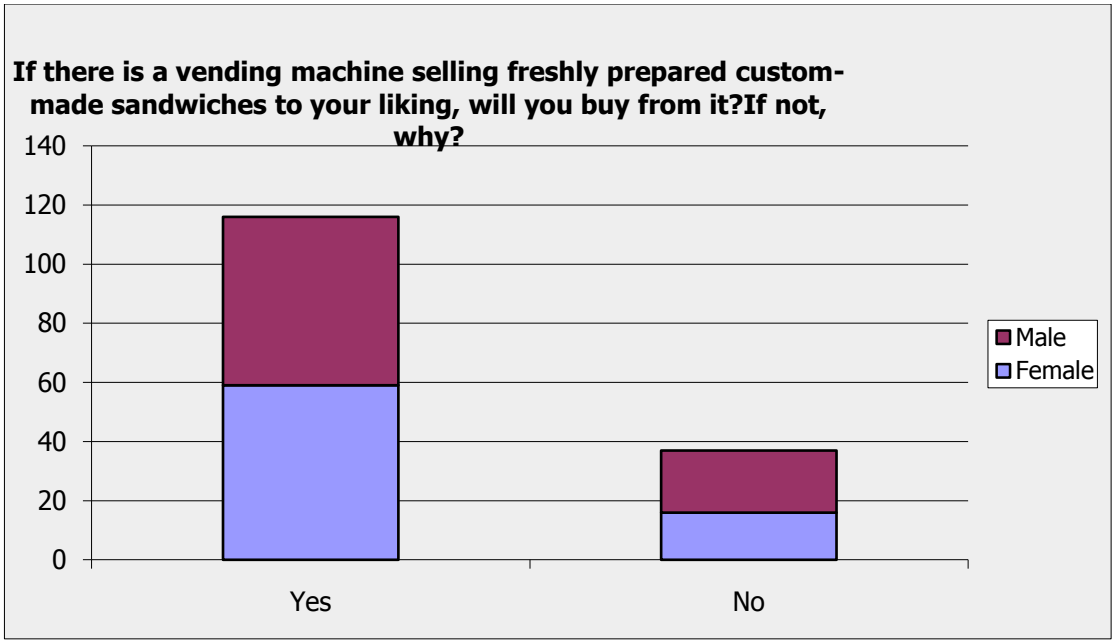
Question 3 – Do you enjoy custom-made sandwich with meat/chicken/fish and topping/ingredients of your choice? (1 being the best and 5 being the worst)

Do you enjoy custom made sandwich with meat/chicken/fish and topping/ingredients of your choice? (1 being the best and 5 being the worst)		
Answer Options	**Response Percent**	**Response Count**
1	49.7%	76
2	21.6%	33
3	9.2%	14
4	9.2%	14
5	10.5%	16
	answered question	**153**



Question 4 - If there is a vending machine selling freshly prepared custom-made sandwiches to your liking, will you buy from it?If not, why?

If there is a vending machine selling freshly prepared custom-made sandwiches to your liking, will you buy from it?If not, why?		
Answer Options	**Response Percent**	**Response Count**
Yes	75.8%	116
No	24.2%	37
Why dont you buy from it?		36
	answered question	**153**

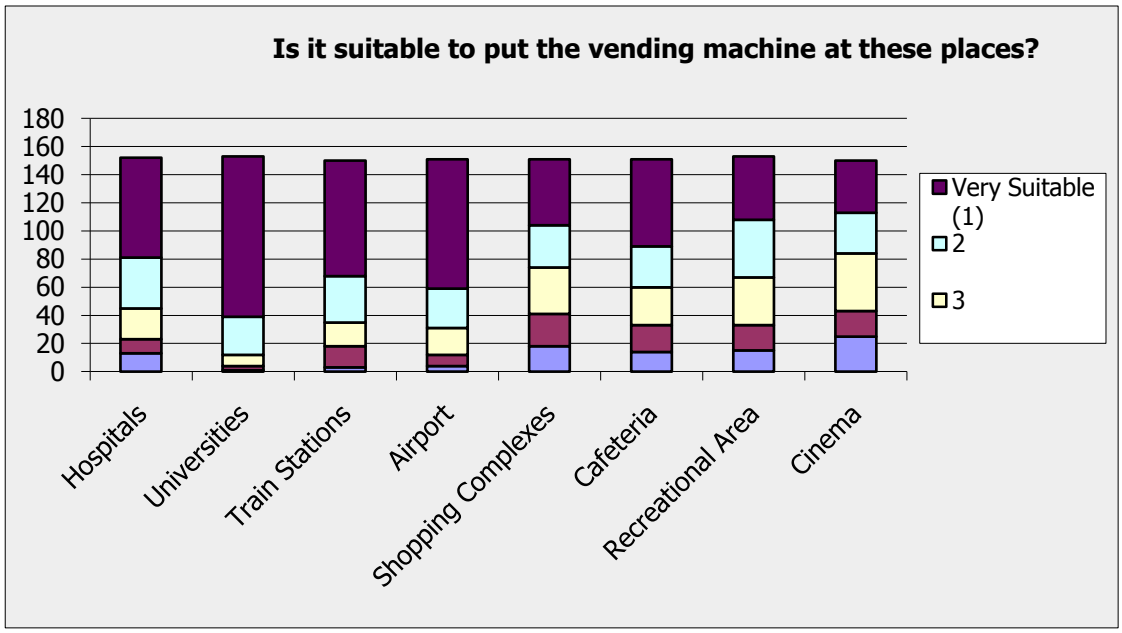


Question 5 - Please rank the most important criteria to least important criteria for the vending machine.(1 being the most important and 5 to be the least important. One rank can only be given to one criteria.)

Please rank the most important criteria to least important criteria for the vending machine.(1 being the most important and 5 to be the least important. One rank can only be given to one criteria.)						
Answer Options	**1**	**2**	**3**	**4**	**5**	**Response Count**
Taste	65	28	25	14	20	152
Hygiene	90	19	12	9	23	153
Price	38	32	31	23	29	153
Freshness	57	28	31	23	14	153
Duration to Prepare Sandwich	41	18	16	27	51	153

Question 6 - Is it suitable to put the vending machine at these places?

Is it suitable to put the vending machine at these places?						
Answer Options	**Very Suitable (1)**	**2**	**3**	**4**	**Not Suitable (5)**	**Response Count**
Hospitals	71	36	22	10	13	152
Universities	114	27	8	3	1	153
Train Stations	82	33	17	15	3	150
Airport	92	28	19	8	4	151
Shopping Complexes	47	30	33	23	18	151
Cafeteria	62	29	27	19	14	151
Recreational Area	45	41	34	18	15	153
Cinema	37	29	41	18	25	150
					answered question	**153**

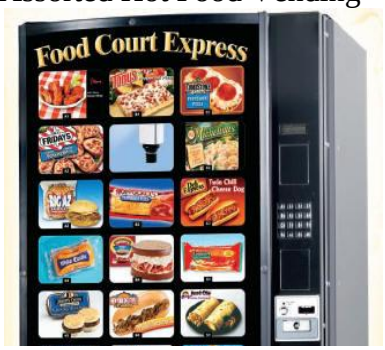


Appendix B – Various Food Vending Machine

Assorted Hot Food Vending

Sandwich Vending

Assorted Hot Food Vending



Assorted Hot Food Vending


Corn Vending Machine

Hot Dog Vending Machine

Ramen Vending Machine

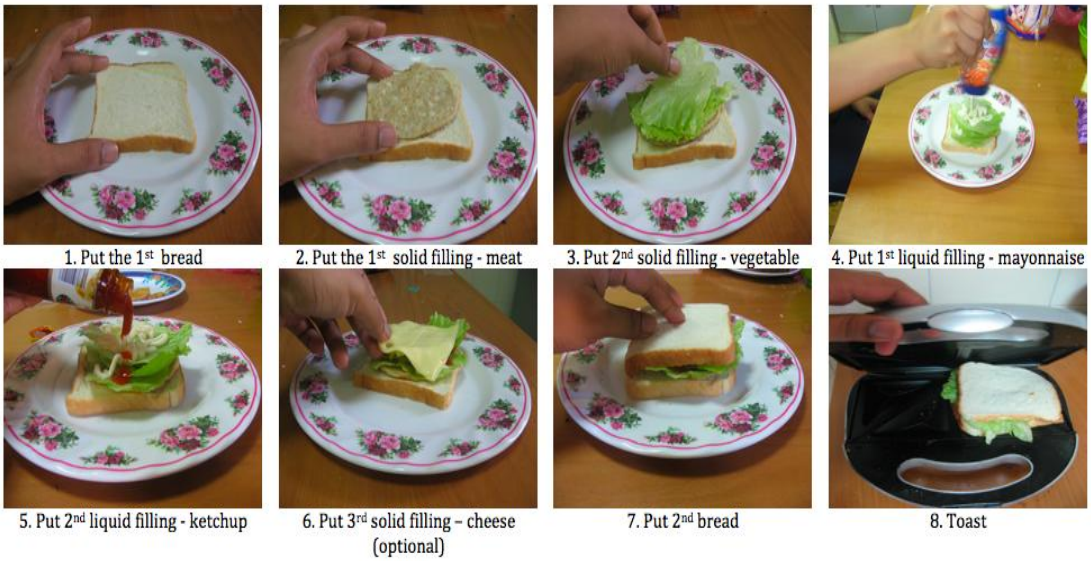
French Fries

Ice Cream Vending


Snack Vending Machine

Rice Vending Machine

Appendix C - Manual Preparation of a Sandwich



Steps to Make Sandwich Manually

Appendix D – Suitable Motor for Filling Dispenser

Closed Loop Stepping Motor and Driver with Built-in Controller (AC Input) [24]

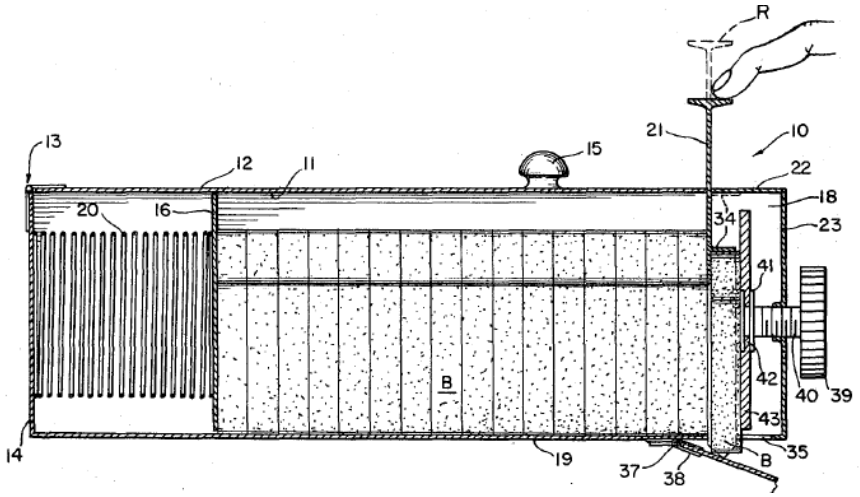
Single-Phase 100-115 VAC Models						
Type		Features	Motor Frame Size		Basic Step Angle	Max. Holding Torque
			w/o Brake	w/ Brake		
Non-backlash	 PN Geared	▪ High accuracy positioning ▪ High permissible/maximum torque ▪ High gear ratios, high resolution ▪ In-line output shaft ▪ Gear Ratios: 50:1, 100:1 ▪ Backlash: 0 arc minute	2.36 in. (60 mm)	2.36 in. (60 mm)	0.0072° ~ 0.072°	30 ~ 70 lb-in (3.5 ~ 8 N·m)
			3.54 in. (90 mm)	3.54 in. (90 mm)		88 ~ 320 lb-in (10 ~ 37 N·m)
	 HG Geared	▪ High accuracy positioning ▪ High permissible/maximum torque ▪ High gear ratios, high resolution ▪ In-line output shaft ▪ Gear Ratios: 50:1, 100:1 ▪ Backlash: 0 arc minute	2.36 in. (60 mm)	2.36 in. (60 mm)	0.0036°, 0.0072°	48 ~ 70 lb-in (5.5 ~ 8 N·m)
			3.54 in. (90 mm)	3.54 in. (90 mm)		220 ~ 320 lb-in (25 ~ 37 N·m)

Closed Loop Step Motor and Driver Systems (DC Input)

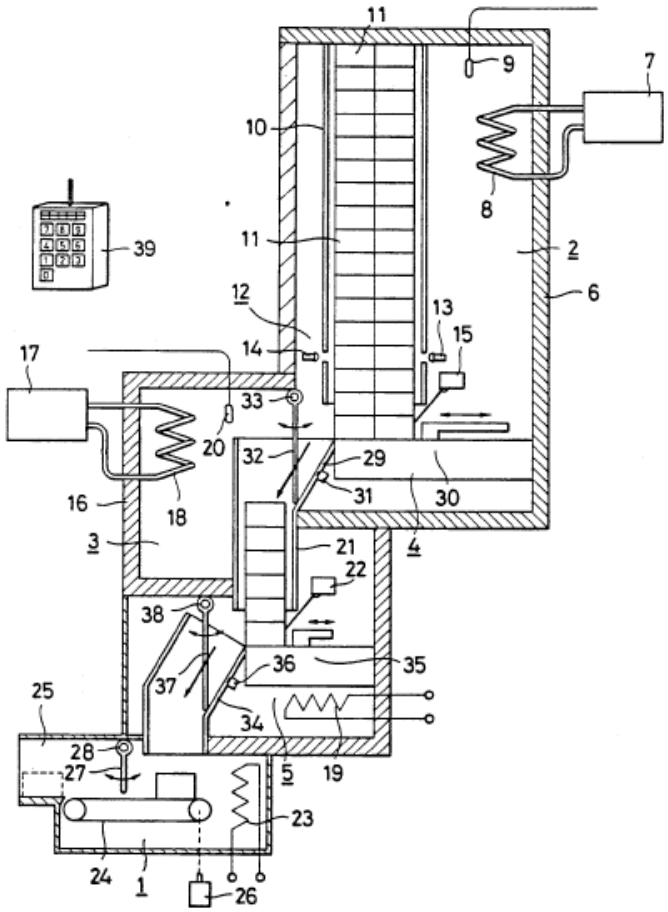
Type		Features	Motor Frame Size	Power Supply		Max. Holding Torque
				Standard	Electromagnetic Brake	
Non-backlash	 Planetary Gear	▪ High speed, high accuracy positioning ▪ High permissible/maximum torque ▪ A wide variety of gear ratios for selecting the desired step angle (resolution) ▪ In-line output shaft ▪ Gear ratios: 5:1, 7.2:1, 10:1, 25:1, 36:1, 50:1 ▪ Backlash: 2 ~ 3 arc minute	1.65 in. (42 mm)	24/48 VDC	24/48 VDC	11.9 ~ 13.2 lb-in (1.35 ~ 1.5 N·m)
			2.36 in. (60 mm)	24/48 VDC	24/48 VDC	30 ~ 70 lb-in (3.5 ~ 8 N·m)
			3.54 in. (90 mm)	24/48 VDC	24/48 VDC	88 ~ 320 lb-in (10 ~ 37 N·m)
	 Harmonic Gear	▪ High accuracy positioning ▪ High permissible/maximum torque ▪ High gear ratios, high resolution ▪ In-line output shaft ▪ Gear Ratios: 50:1, 100:1 ▪ Backlash: 0 arc minute	1.65 in. (42 mm)	24/48 VDC	24/48 VDC	30 ~ 44 lb-in (3.5 ~ 5 N·m)
			2.36 in. (60 mm)	24/48 VDC	24/48 VDC	48 ~ 70 lb-in (5.5 ~ 8 N·m)
			3.54 in. (90 mm)	24/48 VDC	24/48 VDC	220 ~ 320 lb-in (25 ~ 37 N·m)

Appendix E – Pictures From Related Patents

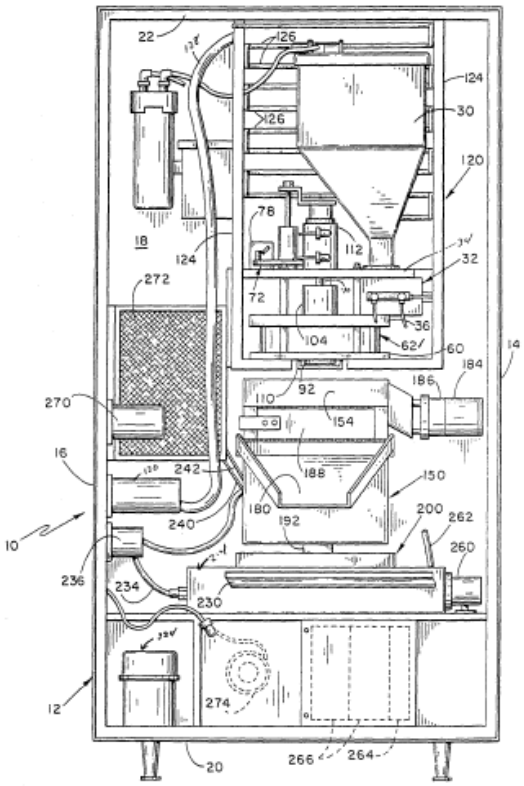
US Patent 3,578,207 – Adjustable bread Dispenser With Ejector-Controlled Closure (Danow, 1971) [25]



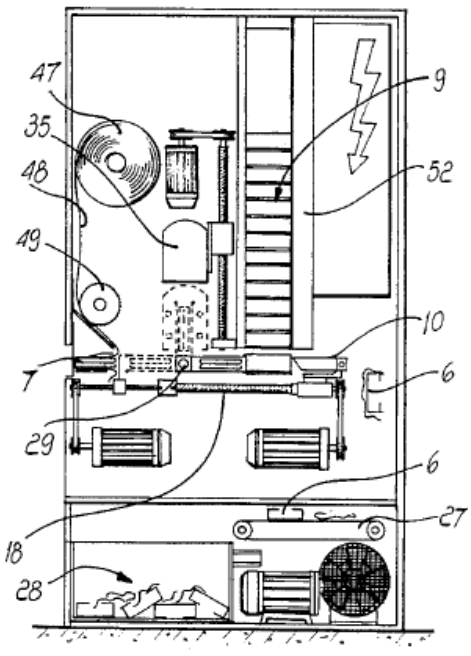
US Patent 5,163,356 – Automatic Food Vending Machine (Chigira, 1991) [26]



US Patent 5,272,961 – Apparatus for Providing French Fried Potato (Campbell et. al, 1993) [27]



US Patent 5,555,793 – Food Vending Machine Particularly Warm Food Such as Toasts, Sandwiches, Pizzas and Briochers (Tochet et. al, 1996) [28]



US Patent 6,383,542 – Method and Apparatus For Preparing and Dispensing A Combination of Food Products In a Vending Machine. (Khodor et. al, 2002) [29]