Automated Salami Wrap Machine

by

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First-Response Robotics LLC. along with Josh McCarty and Professor Ron Singleton have been instrumental in the development of this prototype.
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ABSTRACT

The following report details the work for a machine which will automate the process of creating a salami wrap for caterers or delis to serve as an Hors d’oeuvre. Research was conducted on many existing products in order to examine possible methods which could be used as parts of the end machine, as there was no product or publically available information on a similar product available. A conveyor oven was researched for handling similar food to salami; several patents were researched for possible rolling systems involving a manual mat used for cheese and a multiple conveyor system used for dough. Screw pumps and similar commercial products were looked into for uses or inspirations in the extrusion of cream cheese, as well as handling processes for cream cheese. An interview was also conducted with the president of First-Response Robotics, LLC, Mike Cardarelli, to define the scope of the project.

Following this research, surveys were sent to catering companies to receive customer feedback. Responses showed that ease of operation and ease of maintenance were the most important having received the highest ratings. This feedback was processed into a Quality Function Deployment tool in order to find the most valuable areas for the machine to be designed around. The highest areas of importance were found to be reducing the number of components used, easily ejecting the product after it is made, and having an easy-to-manufacture product (receiving 13.63%, 12.76%, and 11.66% respectively). The requirements for the product were then organized according to their importance based on the customer feedback and a budget and schedule were organized to help facilitate the next steps, design and build.

The design phase of the project started by developing concepts that would perform the task and embody the important aspects found from the customer surveys, which were used to determine the best concepts to be designed. The concepts were then given shape and the stresses were calculated and designed to be safe under normal operating conditions. Building the project started by fabricating the design drawings into physical parts which were later assembled and tested.
PROBLEM STATEMENT AND RESEARCH

PROBLEM STATEMENT

In the current market there is no product which fulfills the needs of automatically making salami wraps. First-Response Robotics has expressed interest in the creation of a product which will squeeze a ribbon of cream cheese onto a sliced piece of salami and roll the combination into a suitable wrap. This machine is to have a high production rate in order to be marketable to catering services as it would allow their chefs to focus on other food preparation rather than a simple Hors d’oeuvre.

PROJECT RESPONSIBILITIES

The Automatic Salami Wrap Machine was produced as a group project; as such the responsibilities were divided between the group members. At the start Josh McCarty was assigned the responsibility of designing the dispensing method, while Ted Oliver was assigned the responsibility of designing the conveyance and the rolling method. Later in the project the support structure was added to Josh McCarty’s responsibilities while the electronics design was added to Ted Oliver’s responsibilities.

RESEARCH

The research for this project was done with the knowledge that there is not a product on the market which does this task already. As a result, methods of producing different aspects of the product were researched:

- Conveyor systems
- Rolling methods
- Extrusion methods for cream-like products

The conveyor system researched was a part of the MPO® Multi-Purpose Oven Cooking System shown in Figure 1 (1). This was chosen due to the fact that it is food-safe conveyor that is capable of handling raw meats, raw meats being similar to salami. The device being designed will likely use a similar method of conveyance; however, there is no need to use a conveyor which will be capable of withstanding such high temperatures. Thus the product’s conveyor will likely be less expensive and also a smaller size.

Following this a process for creating a cheese roll was researched from a patent shown in Figure 2 (2). The rolling process in this case took advantage of a mat, and only required the mat to be pulled over on itself in order to roll the layered cheeses. A similar process to this would be useful if it can be incorporated into the conveyor system, improving the design shown here.
A different rolling method was also researched which did utilize a conveyor system shown in Figure 3 (3). This system used two endless belts to roll two layers of dough into a Swiss-roll-like result. The same usage of this product would apply as the last; however, the improvement would be more in the removal of the end roll in a continuous manner.

From here the methods of extrusion needed to be researched starting with the screw pump shown in Figure 4 (4). Screw pumps are large in size and impractical for a direct use in this application. However, they are an excellent machine to examine due to their hygienic properties and the application in automation.

A similar product to the screw pumps was found later called the Butter Butler shown in Figure 5(5). This product is commercially available and used for applying butter to bread in a ribbon without the need of scraping a stick of butter with a knife. Given the similarities between butter and cream cheese in texture and consistency, this product was a very good example to work off of. However, it would have to be improved by having it incorporated into the automated process in order for it to be used.

Cream Cheese separators were also researched for their ability to readily flow cream cheese (6). They offer several helpful aspects, such as already being FDA approved and already being an automated process. They can be seen in Figure 6 (6).

Additional research was also done on methods of manufacturing cream cheese (7). This was done to foster a better understanding of the product and how it is best handled for application.

In addition to this research, an interview with Mike Cardarelli, president of First-Response Robotics, LLC, was conducted. He is the sponsor for this project and as such had asked for certain requirements to be met, such as a production time of no less than five units per minute and preferably more than thirty units per minute. Also he asked for a simple design that does not require any tools to assemble and disassemble for easy cleaning. Likewise the scope was defined as being for the home or for catering/deli shops (8).

Finally an e-mail correspondence was started with Sandra Walterhouse of McKee Foods Corporation (9). The purpose of this correspondence was to request insight on the process used by Little Debbie® to make Swiss Cake Rolls. However the information was categorized as “proprietary information or trade secret” and could not be divulged. For any additional research information see Appendix A.
MARKET RESEARCH AND CHOSEN SOLUTION

CUSTOMER FEEDBACK

After more than 50 surveys were sent out individually and several online catering forums were asked to complete the same survey over the internet, nine results were returned. The results can be found in descending order of importance in Figure 7.

![Figure 7 – Survey Results](image)

While most of the surveyed features have been shown to have more than average importance, Ease of Operation, Ease of Maintenance, and Safety have consistently been the most important to be focused on. Additional questions from the survey have also shown that the end production rate of the product should be between 10-15 rolls per minute with an end price for the machine being in the area of $300-$400. To find the full survey with results see Appendix B.

CUSTOMER/ENGINEERING ANALYSIS

Engineering characteristics were assigned to the machine and related to the features listed on the survey using the QFD tool. Some features such as Ease of Maintenance and Size were found to have numerous and strong relationships with the engineering characteristics. Size of Machine and Ease of Assembly both had a strong relationship with Reduced Number of Components; however, Product Ejection Method and Manufacturability had only a weak or moderate relationship with these. Product Ejection Method and Manufacturability did however have a strong relationship with Precision and Ease of Operation (Figure 7 shows Ease of Operation as the top Customer Feature).

In short, the QFD tool showed that the most important areas of focus should be on having the fewest number of components and a well designed method for ejecting the product to the customer, as shown in Figure 8 below. For the full QFD see Appendix C.
**CHOSEN SOLUTION**

The process for the final solution was decided using the survey results. The process will utilize a manually fed, clearly marked conveyer. The entire process will be automated from that point using electronic sensors and continuous motion processes. Following placement on the conveyor, the sliced salami will have cream cheese extruded onto it and then be rolled. In order to complete ease of maintenance and assembly, the whole design will not need specialized tools. It will also utilize guards over pinch points and moving parts. The size of the machine will be made to fit easily on the average counter-top.

**PRODUCT OBJECTIVES**

The product objectives are the goals that are set to prove the design and are listed below in order of customer importance.

**Ease of Maintenance**

1. Any replaceable components shall utilize quick disconnects.
2. Off-the-shelf components will be used wherever possible.

**Safety**

1. Guards shall be placed over pinch points and motors.
2. An on/off switch will be put onto the main power.
3. Easily accessible and visible E-stop will be incorporated.

**Durability**

1. All electronic components shall be water tight incase of spills in the kitchen.
2. Guards shall be designed for impact loading (N=12) (Mott, Mechanics of Material).
Precision
1. The rolled diameter of the snack shall be 0.75” ± 0.25”.
2. The machine will dispense ½-1 teaspoon of cream cheese onto the salami (Referenced via www.cooks.com “Salami Roll-Ups” recipe).
   • Assumed 5” diameter salami piece

Ease of Assembly
1. The machine will have a “snap-together” design with pictorial instructions.
2. No tools (i.e. screw drivers or wrenches) shall be required for assembly or disassembly.

Operation Speed
1. The machine shall produce an output of 5-15 products per minute.

Low Noise
1. The machine will be designed to operate below 70 dB (the high rating of a normal conversation).

Appearance
1. The exterior of the machine will have color.

Dishwasher Safe
1. All material in contact with food will be dishwasher safe (excepting electronic devices, i.e. sensors and motors, which will be cleanable using alcohol swabs or other such sterilizing methods).

Reliability
1. The component life and design criteria will follow the spec sheets of said components (i.e. motor spec sheets, controller spec sheets, and conveyor spec sheets).
2. The machine shall have no bare wires exposed.
3. Snap joints will be designed based on standards or fatigue calculation estimates.

Ease of Manufacturing
1. All drawings shall use standard datum.
2. Tolerance on drawings shall be ± .010 for .XX and ± .005 for .XXX dimensions.

Chemical Resistance
1. All components used will be resistant to chemical damage and stain.

Return on Investments
1. To lower cost, standard parts shall be used wherever possible.
2. The machine shall operate at or below 450W (Based on the Kitchen Aid Commercial 5-Series).
User Friendly
1. Instructions for the intended method of operation will be included.
2. The machine will be sized to allow easy transfer from the counter to a cart for transportation.
3. Loading areas will be clearly marked and referenced in instructions.

Compact Design
1. The machine size and weight will be suitable for use on a countertop and for transportation on a cart.

DESIGN

DESIGN ALTERNATIVES AND SELECTION

Conveyance
For conveying the salami through the process, two alternatives were drawn up. The first was to have a straight, flat conveyor (Figure 9) for the salami to be placed on and moved through the process. The second was to have the salami placed onto a rotating plate (Figure 10) and be moved along in that fashion. In the end it was decided that the rotating plate would be too complex and require too much space for the design, so the straight, flat conveyor was chosen.

Figure 9 – Flat Conveyor Concept

Figure 10 – Rotary Conveyor Concept

Rolling
The rolling of the salami was a much more ambiguous problem. As such four different concepts were drawn up.

Static Roller:
The static roller (Figure 11) was a curved plate that was meant to be fixed at the end of the conveyor or rotating plate in such a way to catch the leading edge of the salami guiding it as the conveyor then drives it up and over onto itself. However during testing it was found that this design was not feasible due to there not being enough friction between the salami and the belt to provide sufficient pushing force.

Figure 11 – Static Roller Concept

Powered Roller:
This powered roller (Figure 12) method was similar to the static roller. However, instead of relying on the conveyor a separate device was used to control the salami through constant contact between two counter rotating rollers, in order to move the salami through a guide used to roll the salami back onto itself.

Figure 12 – Powered Roller Concept
Belt Roller:
A third method considered was to have the belt of the conveyor roll back onto itself (Figure 13). However, after a meeting with the custom belting company F.N. Sheppard, it was found that the back bend radius of the belt would not allow for the tightness of diameter that was required for the salami roll, so this concept was no longer viable.

Two Belt Roller:
The final concept that was conceived was to have two belts used to pick up the leading edge of the salami and drive it back on itself (Figure 14). This method was not chosen because of the results of the decision making model (Table 1).

Selection:
Using a weighted decision matrix the different concepts were ranked and designers assigned scores based on their best judgment. The results are shown in Table 1, the Static Roller scored highest; however, it was not a feasible design, and so the next highest ranking concept, the powered roller, was chosen.

Table 1 – Weighted Decision Matrix

<table>
<thead>
<tr>
<th>Factors</th>
<th>weight</th>
<th>Static</th>
<th>Belt</th>
<th>Powered</th>
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<td></td>
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</table>

LOADING CONDITIONS
A fundamental portion of every design is the forces that it must endure. The following section details the forces, or loading conditions, that were accounted for in the design phase of this project.

Conveyor
For the conveyor the dominant loading condition will be the tension in the belt. This tension will be transmitted over the shaft and into the structure where it will be held in static equilibrium. The only other loading condition on the conveyor are the points where forces are transferred into the shaft and out of the shaft, this being the motor driving the conveyor and the transfer of the power from the conveyor to the rolling system respectively.

Roller
In the case of the rollers the salami itself is only a matter of grams which has negligible effect on the loading of the rollers. Also, since the contact between the sprockets is so small relative to the strength of the material the forces produced by them are negligible.
DESIGN ANALYSIS

Conveyor
The design of the conveyor was started by finding a food-safe belt. This is because the main loading condition to the conveyor was the tension on the belt. Once this was selected the conveyor shafts were designed at the belt’s max tension using the process taught in the Design of Machine Elements class for Mechanical Engineering Technologies students at the College of Applied Science. This yielded the reactions that would be resisted by both the side plates and the tension links. The pins holding the system together were then calculated in double sheer for the worst case scenario to ensure their safety. Full calculations can be found in Appendix G. For picture see figure 15.

Figure 15 – Conveyor Model

Roller
As previously stated the loading conditions for the rollers were considered negligible. This is because the material strength for Acetal Delrin was found to be 9800 psi (10). Likewise the strength for the PTFE Fluoropolymers guides was found to be 4000 psi (10). Both of these strengths greatly exceeded any forces that would be acting on them in normal operation. For pictures see figures 16 and 17.
Electrical
The electrical design was started with the oversight of Professor Ron Singleton. With his advice, the system was designed at 12V DC for simplicity and predictability. From here the torque needed for each component’s operation was used to find motors that appeared as though they would fit both the 12V DC and the torque requirements. Once the method used by the project to roll salami was analyzed, it was determined that relays would be needed for the protection of particular circuits. At this point a timer circuit was designed with tremendous help from Prof. Singleton and the circuits’ fuses were calculated to maintain safe usage, yet still account for voltage peeks in operation. For full calculations see Appendix G.

COMPONENT SELECTION
Conveyor
The first component which needed to be selected for the conveyor was the belting, because it was the most source of the loading condition and critical to the design. Once a food safe belt was selected the max tension of the belt was used to design for the loading conditions in the conveyor shafts and their supports. Aluminum was used for its low weight relative to strength for shafts, supports, and tensioning links. The links and supports were attached using steel cotter pins for convenience of purchasing and fabrication.

Roller
The most important aspect which had to be met in the roller system was that the material contacting the salami be food safe, because of this Delrin was chosen for its high strength and food safe approval. Also thanks to its high strength the forces acting on the rollers were negligible in comparison. As for the supports, aluminum was chosen for the sake of purchasing. This was because no new line item had to be added a previous one only had to be changed from the material for the conveyor. The guide also used a carbon fiber and a
Fluoropolymers Teflon® PTFE for the food safe portion of the guide, with the supports also being made out of the same previously ordered aluminum.

**Electrical**
Selection for the electrical components was advised by Prof. Ron Singleton. The first step to this was to decide on power source for the system, 12V DC current was chosen for the sake of simplicity in design. From here the motors and components were sized based on the calculations for the required torque needed to run the system. Next the fuses were sized for the system based on the specifications of the components. Finally variable resistors and components for the timer circuit were selected with the over-sight of Prof. Singleton in order to have the variability required for a prototype.

**BILL OF MATERIALS**

**Conveyor**
Cost for the conveyor system was far below what was planned at the outset. This is due to the conveyor being designed from scratch rather than bought off-the-shelf, due to size constraints. There were very few parts purchased off-the-shelf, namely the belt and the cotter pins. Most components were fabricated from raw stock Aluminum rods and plates; this raw stock held the bulk of the cost for the conveyor.

**Roller**
The roller, as well as the guide, had only one major item that was purchased off-the-shelf. Instead most of the materials used for this were manufactured from materials that were ordered along for the conveyor; those materials being the aluminum stock and the cotter pins. The only major components that could be purchased directly were the spur gears used to transfer the movement of the shafts. The plastic materials for the rollers and the guides, Acetal Delrin and PTFE Fluoropolymers respectively, were the only components that had to be bough specifically for this component. None of these components however had a particularly high cost relative to the rest.

**Electrical**
At the beginning of the project the electronics were not planned to be as complicated as they became; because of this, there was never a set amount allotted for the electronics. However it was not an insubstantial portion of the budget, the largest portion of the budget going to the electronic motors used for the system. Besides these, the components were inexpensive and could be found at most local electronics stores.

**FABRICATION AND ASSEMBLY**

**Fabrication**
Most parts of the Automatic Salami Wrap Machine were fabricated rather than bought off-the-shelf. First-Response Robotics, LLC. fabricated the conveyor plates, conveyor links, roller guide supports, rollers and roller supports, and the dispensing system. Ted Oliver fabricated the conveyor shafts, and roller guides. Finally the support structure was handled by Josh McCarty. Electrical components and custom belting were purchased parts.
**ASSEMBLY**

The following details the specialized assembly methods used for the Automatic Salami Wrap Machine. Full drawings for all components can be found in Appendix H.

*Conveyor*

The side plates and the shaft holders are assembled together using cotter pins. Separately, the links are assembled with the mover rod; these are used to tension the belting later. These two assemblies are then put together using cotter pins. Next this full assembly is assembled into the slots with the stop blocks between the two side plates on each side. It is important that the stop blocks be between the plates because they are used to hold the links in tension just over center while the side plates are tightened down.

The sleeve bearings are then slid onto the shaft and held in place with retaining rings to reduce the friction on the shafts while in operation. Then three locking collars are put onto the two shafts’ ends, to keep it from sliding while in operation; the end that should not have a locking collar is the mount for the motor which will turn the conveyor.

The assembled shafts are then placed into the belt and put into the non-tensioned side plates. The mover rod is then pushed down against the stop blocks and the side plates are tightened down, putting the belt in tension. The motor shaft is later placed into the mounting section of the conveyor shaft and tightened down.

*Roller*

The rollers are first placed into their supports, putting the bladed roller on top in order to keep the cream cheese from sticking to the roller and having the system bind up. The spur gears are then placed onto the transfer shafts and tightened down. This assembly is then slid onto the full machine.

Next the guide is assembled, first by mounting the guides to their respective plates using set screws, after this the plates are then put together using cotter pins. This assembly is then slid onto the main assembly. Finally the separator is attached to its mount which is then screwed into the main board as to allow the guide to open when it is pulled back.

*Electrical*

The electrical system begins with the terminal blocks. Here the main power is put into the system and the secondary terminal blocks are wired in. Also the motors and solenoid are wired into the main block with a variable resistor placed between them to use as a speed controller. The roller motor and the conveyor motor are then wired into their individual fuses which lead back into the secondary terminal blocks. However, the solenoid and the cream cheese motor are wired into relays before they are wired into their fuse and finished in the secondary terminal block.

Relays are used to protect the more delicate switches and circuitry that are beyond them. For the cream cheese motor it is simply a limit switch which controls the motor’s activation. The solenoid on the other hand is wired with a timer circuit which utilizes a variable resistor in order to control the amount of time the solenoid is active as well as a switch to trigger the circuit. These individual sections have their own separate circuits that connect to the secondary terminals; this is to keep a low current through these delicate components.
TESTING AND PROOF OF DESIGN

Testing Methods

Once the project was fully assembled unanticipated problems arose from the motors, namely that they did not provide enough torque for the application. Due to time constraints, the problem could not be addressed, and testing needed to be done manually. Each component was run manually on an individual basis to show proof of concept.

Results

The results of running each component individually showed that the concepts of the process were almost all correct. The conveyor was able to hold the tension of the belt and move the belt with the rotation of only one shaft. The electrical system operated as it was wired when the power supply was attached and the motors were not mounted to the system. However, the roller system was not able to work properly due to the salami not following the guide; instead it would meet with resistance in the guide and roll on top of the guide once inside. This would cause a jam in the finished system. Figure 18 shows the final assembly.

Figure 18 – Final Assembly

PROJECT MANAGEMENT

Project Budget

Table 1 shows the actual budget compared to the initial proposed budget:

<table>
<thead>
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<th>Component</th>
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<td>Total</td>
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There is a drastic difference between the proposed and actual budget due to several
major changes from the initial assumption and the actual results. In the case of the conveyor, the original assumption was that a premade conveyor would be purchased and used; however, due to the size constraints the system had to be designed from scratch, causing the drastic change. In the case of the roller, a motor was assumed in the cost of the system at the start. In the actual budget, this was taken up by the electrical system, which also included the cost of the motors from the dispenser and the conveyor. The full budget can be viewed in Appendix E.

**PROJECT SCHEDULE**

The following schedule, Table 2, is the listing of key dates comparing the original proposal to the actual finished dates. The concept development was finished earlier than expected. However, the design took longer than anticipated due to difficulties finding a working concept for the rolling of the salami. Due to this setback the build session was pushed back and was not completed for testing until the night before Tech Expo. The project was, however, presented to the public on time at Tech Expo on May 7th. The full schedule can be found in Appendix D.

<table>
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<tr>
<th>Task</th>
<th>Proposed date</th>
<th>Actual date</th>
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<tr>
<td>Concept Development</td>
<td>Dec. 20</td>
<td>Dec. 13</td>
</tr>
<tr>
<td>Design</td>
<td>Feb. 7th</td>
<td>Mar. 2nd</td>
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<tr>
<td>Build</td>
<td>Apr. 11th</td>
<td>May 6th</td>
</tr>
<tr>
<td>Tech Expo</td>
<td>May 7th</td>
<td>May 7th</td>
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</table>

**CONCLUSIONS AND RECOMMENDATIONS**

As with any machine, this is not a perfect device. The Automatic Salami Wrap Machine has several areas that can be improved; this section is meant to detail the proposed improvements to be made.

**Conveyor**

The first problem with the conveyor stems from the motors having been sized too small. Factors of resistance were not taken into account during the design portion, and the shafts have too much mechanical resistance for the selected motors to turn them. To help alleviate this, a switch should be made from sleeve bearings to sealed roller bearings; this will help reduce friction at the supports.

Likewise, the motor may still need to be resized; this could result in a change to the mating hole on the shaft to the motor. To help remove the need for possible tooling, the current method of a set screw could be changed with a flat ended hole (Figure 19) that was made to fit the motor shaft. A belt or chain system could also be used; however it would need to be tensioned which may or may not include tooling to tension belt or chain while the motor is fixed in place.

Another area where tooling was used for convenience was in the slot for the base. The ¼-20 bolts and mating slide could be replaced with specialized mating slides. These needed to be tightened down on either side of the belt to ensure full tension for operation. To help
alleviate the need for tooling, mating slots could be machined into the side plates and into slides (Figure 20). To address the tensioning issue, the links could have tighter tolerances or the belt could be made shorter; however, these solutions will increase the cost of the machining. To avoid this, a device could be made to lift the plate in the slot similar to how the bolting does now.

**Roller**

Rolling was the most difficult problem in this project, due to the unpredictability of the salami slice. Several different concepts were developed and tested with various results. The static plate design started the roll the best; however, the salami never had enough force to continue through on the roll. Likewise the powered roller which gripped the salami, kept control, and forced it through, but the guide did not operate properly because the salami was still not controlled as it entered it. The next step in finding the solution is to compile what was learned from these into a single design that utilizes rollers to grip the salami and push it into a guide which is located above the belt, the purpose for that being that the belt will control the point where the salami enters the guide. To better understand this concept see Figure 21. The guide itself should be either a two-part guide similar to the final design produced here, or another possibility is a flexible sheet that is on a moving mount in order for it to be able to eject the rolled salami.

**Electrical**

The recommendations for the electrical system are most dependent on the changes which need to be made to the motors. It is possible that to have enough required power for this system an increase in voltage would be needed; this would require that the relays be changed to account for that new voltage.

Likewise any major change will require new fuses for the motors and solenoid due to the change in current. An additional recommendation is to add a fuse in the main power supply before the terminals for the whole system as an added safety feature. Also for convenience an LED light could be added in line with the fuses to show when they need to be changed if one were to go bad, this would avoid the customer having to worry about testing multiple fuses.

Another change that could be made for the customer’s convenience would be to recalculate the resistance needed in order to have the system speed set by a single resistor or speed controller. This would require testing with the variable set up that is currently designed to find the optimum settings, likewise the cream cheese might still be best to have on a separate resistor to be able to vary the amount of cream cheese dispensed for a given wrap.

**Final Remarks**

In conclusion, the task of creating the Automatic Salami Wrap Machine was a more complicated endeavor then was anticipated. However, this is a prototype; one that has produced several useful designs and tested several concepts. This work can still be taken and advanced farther; this, though, is the decision of First-Response Robotics, LLC. as owners of the Automatic Salami Wrap Machine.
REFERENCES
APPENDIX A: SALAMI WRAP MACHINE REFERENCES

<table>
<thead>
<tr>
<th>Diagram</th>
<th>Description</th>
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</table>
| ![Diagram](image1.png) | Apparatus for Producing a Dough Roll by Rolling up a Dough Piece.  
US Patent #5,078,585  
Sept. 26, 2008 |
| ![Diagram](image2.png) | Process for Producing a Rolled Cheese.  
US Patent #4,588,597  
Sept. 26, 2008 |

An apparatus is provided for producing a dough roll by rolling up a dough piece. The apparatus has a moving means that includes a holding roller and an endless belt supply device, and a rolling up mechanism having upper and lower endless belt devices. The belt of the upper endless belt device moves rearwardly, and the belt of the lower endless belt device moves forwardly at a speed higher than that of the upper endless belt device. When a dough piece is fed to the apparatus the leading end begins to be rolled at the upstream ends of the upper and lower endless belt devices while its trailing end stays between the belt of the endless belt supply device and the holding roller. Therefore, the leading end moves at a speed which equals the difference between the speeds of the upper and lower endless belt devices while the trailing end moves at the same moving speed as that of the belt of the endless belt supply device.

A rolled cheese and a process for making the cheese is described. The cheese comprises a layer of fresh cheese curd coated with flavoring such as herbs, which is rolled into a spiral. The fresh cheese curd is neither cooked nor kneaded, and the resulting rolled cheese has two distinct layers which each contain a distinctive taste.
The MPO’s unique cooking process preserves more of the original moisture content and flavor of foods. Precisely control the interaction between cooking temperature and moisture to achieve rapid heat transfer without dehydration. And you can develop the ideal surface texture while maintaining valuable yield.

* **Non-Contaminating:** As the pump being used for HYGENIC application, all parts in contact with the liquid is in Smooth Stainless Steel finish eliminating the product retaining Pockets, subsequently avoiding the bacterial & chemical contamination. Further the stator is also made of non-contamination rubber.

* **Non retaining pockets:** All internal contours are designed to be swept by the fluid flow or by detergent during in line cleaning, thus eliminating products retaining pockets, which can cause chemicals or bacteriological contamination.

* **Low NPSH (R):** High suction lift can work against high vacuum, ideal for pumping viscous fluids from vacuum pan.

* **Gentle handling of fluids:** Low fluid Velocities ensures gentle handling of shear sensitive fluids without aeration or damage.

* **Non-clogging:** Ability to handle solids in suspension or mixtures containing high percentage of solids.
This amazing new machine dispenses and spreads butter for you. Simply slide in your favorite butter or margarine, pop on the top, and twist. The Butter Butler X-Press dispenses a paper-thin ribbon of butter like magic. $21.95

<table>
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<tr>
<th>Useful dispenser method</th>
<th>Low cost @ $21.95</th>
<th>Requires user labor</th>
<th>FDA approved</th>
</tr>
</thead>
</table>

Separators, Inc. has pioneered the conversion of two Alfa Laval dairy separators to fully functioning cream cheese separators. Flow rate is equal to an O.E.M. cream cheese separator but the cost is dramatically lower.

**MRPX 418-TGV-Cream Cheese Separator**
- Capacity: 20,000 Lbs./Hour
- Operation: C.I.P. Solids Ejecting Bowl
- Motor: 50 HP Wye-Delta
- Drive: Direct Drive

<table>
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<tr>
<th>Already used w/ cream cheese</th>
<th>Automated process</th>
<th>Useful for dispensing</th>
<th>FDA approved</th>
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The present invention is directed to methods for utilizing, frozen concentrated milk fat to manufacture cream cheese. Generally in accordance with the method, frozen concentrated milk fat which has been stored in a solid state is comminuted and mixed with a dairy fluid prior to melting of the milk fat, and the frozen concentrated milk fat is melted while in contact with the dairy fluid to provide a cream cheese mix, which is subsequently fermented, separated from whey and packaged to provide a cream cheese product with excellent keeping quality without oxidized off flavors.

Interview with customer, Sept. 17, 2008
Mike Cardarelli, President, First-Response Robotics, LLC.
Wants to automate the making of a cream cheese/salami roll
Min. of 5 rolls per minute (prefer 30+)
Used in-home or for delis and catering services
Simple snap assembly
Easy to clean

E-mail with customer care correspondent, Sept. 30, 2008
Sandra Walterhouse, Consumer Care Correspondent, McKee Foods Corporation

“Dear Mr. Oliver:
Thank you for your interest in LITTLE DEBBIE® Swiss Cake Rolls. We appreciate you taking the time to contact us.
Unfortunately, we will not be able to help you with your request. The information you need would be considered proprietary information or trade secrets that we would not be able to disclose.
We are delighted that you thought of us for your project and we wish you much success in your studies and career in mechanical engineering.
Thanks again for contacting us and visiting our website.
Sincerely,
MCKEE FOODS CORPORATION
Sandra Walterhouse
Consumer Care Correspondent”
*Extra spaces removed for clarity*
APPENDIX B: CUSTOMER SURVEY AND RESULTS

We are two seniors at the University of Cincinnati studying Mechanical Engineering Technology. Our senior design project is to produce an automated machine for which a caterer may produce salami wraps with a slice of salami and cream cheese in large quantities with ease. We would appreciate if you would take a few moments to answer these questions to help us produce a better product.

1) Please rate how important each of the following features are for you as a caterer. Circle your response clearly. 1 = low importance 5 = high importance

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</table>

2) If this machine were to be manually fed, how many wraps would you expect to be produced per minute? Please circle your answer:

- 5-10 (3)
- 10-15 (3)
- 15-20 (1)
- 20-25 (1)
- 25-30 (1)

3) How much would you be willing to pay for this machine? Please circle your answer:

- $50-$100 (2)
- $100-$200 (1)
- $200-$300 (2)
- $300-$400 (3)
- $400-$500 (1)

4) Would you be willing to pay more if the features you have mentioned were met or exceeded? Please circle your answer:

- Yes (6)
- No (3)

Thank you for your time. We appreciate the help your input is giving us.

Appendix B1
APPENDIX C: QUALITY FUNCTION DEPLOYMENT ANALYSIS

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*NOTE: The Improvement Ratio, Modified Importance, and Relative Weight were removed from the QFD because a previous machine is not available for previous satisfaction ratings.*

*The Sales Point column has been filled with a value of "1" because no prior data exists to prove otherwise. By keeping this column, one may insert the necessary data should it arise.*
### APPENDIX D: SCHEDULE

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**Green shows proposed dates, Blue shows actual dates**
## APPENDIX E: ESTIMATED BUDGET

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APPENDIX F: SPONSOR SUPPORT LETTER

University of Cincinnati
College of Applied Science
2220 Victory Parkway
Cincinnati, Ohio 45206-2839

October 20, 2008

Muthar Al-Ubaidi,

First-Response Robotics, LLC would like to thank the University Of Cincinnati College Of Applied Science with the opportunity to work with your team on the salami roll machine project.

Ted Oliver and Josh McCarty have shown an extremely high level of enthusiasm with this project. Since they are the primary design engineers, their contributions will not go without notice. First Response Robotics, LLC would like to donate our team with all manufacturing requirements needed in order to build the salami roll machine. This will include all materials, tooling and assembly work to complete the job. Included with this grant is the financial support needed to purchase necessary materials.

Mr. Oliver and Mr. McCarty along with the University of Cincinnati will not be paid for their research and development. They will be acknowledged as the design engineers on this project but will not be awarded any rights for their designs. All rights and designs will be the property of First-Response Robotics, LLC.

The cost for materials will need to be approved by First Response Robotics, LLC. and assigned a purchase order number. We look forward to Tech Expo 2009 and will support your team with this project with the same amount of enthusiasm.

Sincerely,

Mike Cardarelli
President
First-Response Robotics, LLC.
APPENDIX G: FULL CALCULATIONS

Conveyor:
Conveyor Shaft X direction:

\[ R_A = R_C = \frac{W}{2} = \frac{89.6 \text{lb/\text{in}} \times 6.0\text{in}}{2} = 268.8\text{lbs} \]

\[ M_A = M_C = -\frac{WL}{12} = -\left(\frac{89.6 \text{lb/\text{in}} \times 4.0\text{in}}{2}\right) \times 6.0\text{in} = -179.2\text{in} - \text{lbs} \]

\[ M_B = \frac{WL}{24} = \frac{(89.6 \text{lb/\text{in}} \times 6.0\text{in}) \times 6.0\text{in}}{12} = 134.4\text{in} - \text{lbs} \]

**Actual Belt width was 4in, assumption of 6in was made to simplify equations and safely calculate stresses**

Conveyor Shaft Y direction:

\[ c.g. = \frac{\Sigma(A_t c_i g_i)}{A_T} = \frac{(1.00\text{in}^2 \times .50\text{in}) + (8.00\text{in}^2 \times 3.00\text{in}) + (2.00\text{in}^2 \times 6.00\text{in}^2)}{3.32\text{in}} = 3.32\text{in} \]

\[ R_A = \frac{Pb^2}{L^3} (3a + b) = \frac{48.063\text{lbs} \times (2.68\text{in})^2}{(6\text{in})^3} (3 \times 3.32\text{in} + 2.68\text{in}) = 179.2\text{lbs} \]

\[ R_C = \frac{Pa^2}{L^3} (3b + a) = \frac{48.063\text{lbs} \times (3.32\text{in})^2}{(6\text{in})^3} (3 \times 2.68\text{in} + 3.32\text{in}) = 27.86\text{lbs} \]

\[ M_A = -\frac{Pab^2}{L^2} = \frac{-48.063\text{lbs} \times 3.32\text{in} \times (2.68\text{in})^2}{(6\text{in})^2} = -31.836\text{in} - \text{lbs} \]

\[ M_B = \frac{2Pa^2b^2}{L^3} = \frac{2 \times 48.063\text{lbs}(3.32\text{in})^2(2.68\text{in})^2}{(6\text{in})^3} = 35.232\text{in} - \text{lbs} \]

\[ M_C = -\frac{Pab}{L^2} = \frac{-48.063\text{lbs} \times 2.68\text{in} \times (3.32\text{in})^2}{(6\text{in})^2} = -39.438\text{in} - \text{lbs} \]

Torque for Motor:

\[ T_i = S_y \sqrt{4 \left[ \left( D_i^3 \frac{\pi}{32N} \right)^2 - \left( \frac{K_t M_i}{S_n} \right)^2 \right]} \]

\[ K_t = 2.5 \text{ for sharp corner fillets} \]

\[ N = 2 \text{ Design factor from P.546 from DME book} \]

\[ S'_{n} = S_n C_m C_{st} C_R C_s = 18\text{ksi} \times .6 \times 1.0 \times .90 \times .88 = 4.28\text{ksi} \]

\[ M_i = \sqrt{M_{x_i}^2 + M_{y_i}^2} \]

\[ M_A = 182.006\text{in} - \text{lbs}, M_B = 96.278\text{in} - \text{lbs}, M_C = 183.488\text{in} - \text{lbs} \]

\[ T_A = 866.564\text{in} - \text{lbs}, T_B = 3590.8\text{in} - \text{lbs}, T_C = 876.356\text{in} - \text{lbs} \]

Belt/Conveyor Length

Assumption: 10in travel length for salami

Belt Length: 10in + 10in + 2in × π = 26.283in

1% stretch for tension: 26.283in × .01 = .262in

.262in × .5 = .131in stretch center to center

Center to center distance: 10in + .131in = 10.131in
Conveyor Plates

c.g. of plates:
\[ c.g. = \sum \frac{A_i y_i}{A_T} \]
\[ A_1 = \frac{\pi D^2}{8} = \frac{\pi (0.64in)^2}{8} = 0.161in^2 \]
\[ A_2 = b \times h = 2.165in \times 4in = 8.66in^2 \]
\[ A_T = 8.821in^2 \]
\[ c.g. x = \frac{(0.161in^2 \times 0.136in) + (8.66in^2 \times 1.083in)}{8.821in^2} = 1.066in \]
\[ c.g. y = \frac{(0.161in^2 \times 3in) + (8.66in^2 \times 2in)}{8.821in^2} = 2.018in \]

Assumption: 1 in thick plates

Volume = 8.821in³, \( \rho_{Al} = \frac{1lbm}{in^3}, m = \frac{0.88lbm}{in^3} \)

\[ \Sigma F_x = 0 = 179.2lbs - R_x, R_x = 179.2lbs \]
\[ \Sigma F_y = 0 = -27.862 - (0.88lbm \times 32.2) + R_y, R_y = 56.198lbs \]
\[ \Sigma M_A = 0 = (-179.2lbs \times 3in) + (179.2lbs \times 1.5in) + (27.862lbs \times 2.165in) \]
\[ + (0.88lbm \times 32.2 \times 1.177in) - (56.165lbs \times 1.177) + M_R, \]
\[ M_R = 241.234in - lbs \]

Tension Links

\[ I = \frac{bh^3}{12} - \frac{\pi D^4}{64} = \frac{0.75in(2.54)^3}{12} - \frac{\pi (0.397in)^4}{64} = 1.02in^4 \]

\[ r = \sqrt{I/A} = \sqrt{1.02in^4/0.1875in^2} = 2.33in \]

Slenderness Ratio = \( L/r = 2.54in/2.33in = 1.09 \)

\[ C_c = \frac{2\pi^2 E}{S_y} = \frac{2\pi^2 (10.6 \times 10^6psi)}{8000psi} = 161.723 \]

\[ P_{cr} = \frac{4\pi^2 E}{\pi^2 E} \left( 1 - \frac{S_y (\text{Slenderness Ratio})^2}{8000psi(1.09)^2} \right) \]
\[ = 0.1875in^2 \times 8000psi \left( 1 - \frac{8000psi(1.09)^2}{4\pi^2 (10.6 \times 10^6)} \right) = 1499.97psi = 1.5ksi \]

Pin

Assumption: Material: AISI 301 Annealed Steel

\[ S_u = 110ksi, S_y = 40ksi, S_{ys} = 9S_y = 36ksi \ (P. 102), E = 28 \times 10^6psi, \rho = \frac{0.29lbm}{in^3} \]

\[ A_{net} = 2 \left( \frac{0.25 \times 3in}{8} \right) = 0.1875in^2 \]

\[ F_{net} = 2(179.2lbs) = 359.4lbs \]

\[ \sigma = \frac{F_{net}}{A_{net}} = \frac{359.4lbs}{0.1875in^2} = 1911.47psi = 1.9ksi \]

Electrical:

Timer Operation Time

Appendix G2
$T = 1.1 \times R_{pot} C$

Where:

$T =$ Time solenoid is active
$C =$ Capacitance of Capacitor (10μF used)
$R_{pot} =$ Resistance set for variable resistor

Fuse Sizing:

$I_{Fuse} = 2.5 I_{motor}$

Where: $I_{motor}$ is given in spec. sheet.
APPENDIX H: DRAWINGS

The following are the detailed drawings for the Automatic Salami Wrap Machine.

Conveyor Parts H1-H8

Roller parts H9-H18

Assemblies H19-H23

Electrical H24-H26
Appendix H

Drill & Tap for 1/4-20 thread
See SECTION A-A for depth

4 used in assembly
designed for 6061-O aluminum

Size H drill for 1/4 in thru hole
Size X drill for 3/8 in thru hole
Size 1-9/32 dia. for 1-1/4 in fit hole
Material: 6061-O Aluminum
4 used in assembly

∅.266 Size H

Additional View

Size H drill for 1/4 in thru hole
Size 1-9/32 dia. for 1-1/4 in fit hole
Material: 6061 Al
2 Needed for Assembly

SECTION E-E

1/4-20 drill & taptap (thru one side)

thru hole for Motor Shaft (depth)

4x .086
4x .876

φ 1.00

φ .549

5.741

1.645

6.837

UNLESS OTHERWISE SPECIFIED:

DIMS. IN INCHES TOLERANCES:

FRACTIONAL ± .001
ANGULAR: MACH ± 2°
TWO PLACE DECIMAL ± .001
THREE PLACE DECIMAL ± .000

DRAWN
CHECKED
ENG APPR.
MFG APPR.
G.A.
COMMENTS:

TITLE:

SIZE DWG. NO. REV
A Shaft

SCALE: 1:2 WEIGHT: SHEET 1 OF 1

APPLICATION DO NOT SCALE DRAWING

NEXT ASSY USED ON FINISH

PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS
DRAWING IS THE SOLE PROPERTY
OF INSERT COMPANY NAME HERE. ANY
REPRODUCTION IN PART OR AS A WHOLE
WITHOUT THE WRITTEN PERMISSION
OF INSERT COMPANY NAME HERE IS
PROHIBITED.
Material: 6061-O Aluminum
4 used in assembly

Size X drill for 3/8 in thru hole
Material: Designed for AISI 301 Annealed Steel
1 used in assembly
Size H drill for 1/4 in thru hole

Material: Aluminum 6061-O
2 needed in assembly
1/4-20 bolt used with a nut in recess to lock in place

SECTION A-A
Size H drill for 1/4 in thru hole

Material: Acetal Delrin
1 used in assembly
Material: 6061-O Al
2 used in Assembly

Drill & Tap 1/4-20

SECTION A-A

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ±BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:

SIZE DWG. NO. REV
SCALE: 1:1 WEIGHT: SHEET 1 OF 1
Appendix H

Material: 6061 Al
2 used in Assembly

2\(\frac{1}{32}\) drill for
5/8 thru hole

\[ \phi 2\frac{1}{32} \]

5.00

\[ \frac{7}{16} \]

3.00

\[ \frac{7}{8} \]

.50

SECTION C-C

Material: 6061 Al
2 used in Assembly

A Roller plates

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: FRACTIONAL
ANGULAR: MACH 2
TWO PLACE DECIMAL
THREE PLACE DECIMAL

INTERPRET GEOMETRIC
TOLERANCING PER:

DRAWN
CHECKED
ENG APPR.
MPG APPR.
G.A.
COMMENTS:

SIZE
DWG. NO.
REV

SCALE: 1:1
WEIGHT:
SHEET 1 OF 1
Material: Acetal Delrin
1 used in assembly

DETAIL A
SCALE 2:1

Top roller

SCALE: 1:1 WEIGHT: SHEET 1 OF 1
Material: Acetal Delrin

1 used in assembly
Appendix H

Drill & Tap for 8-32 screw

Material: 6061 Al
2 used in Assembly

Size H drill for 1/4 in thru hole

Drill & Tap for 1/4-20 thread
See SECTION A-A for depth

SECTION A-A

Material: 6061 Al
2 used in Assembly

Size H drill for 1/4 in thru hole

Drill & Tap for 1/4-20 thread
See SECTION A-A for depth
**Front plate**

**Material:** 6061 Al

2 used in Assembly

Size H drill for 1/4 in thru hole

---

**Dimensions** are in inches.

**Tolerances:**
- Fractional
- Angular: Machined ± Bend ±
- Two place decimal ±
- Three place decimal ±

**Interpret Geometric Tolerancing Per:**
- Material

**Drawn:**
- Checked
- Eng. Appr.
- Mfg. Appr.
- G.A.

**Title:**

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**Size DWG. No.**

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**Scale:** 2:1

**Weight:**

**Sheet:** 1 of 1
Material: Fluoropolymers 1" tube
1 used in assembly

Drill & Tap for 8-32 thread
See SECTION A-A for depth
Material: Fluoropolymers 1/2" tube

1 used in assembly

Drill & Tap for 8-32 thread
See SECTION A-A for depth
Material: Acetal Delrin
1 used in assembly

Drill & Tap for 8-32 thread
See SECTION A-A for depth

DETAIL A
SCALE 2:1

Material: Acetal Delrin
1 used in assembly

Drill & Tap for 8-32 thread
See SECTION A-A for depth

DETAIL A
SCALE 2:1
Dead Plate

1/4-20 x 1/2" (4 places)

Dead Plate Holder
1 12VDC Battery
2 Potentiometer
3 Motor
4 12VDC DPDT Relay
5 1N4001 Diode
6 1N4001 Diode
7 Limit Switch
1. Limit Switch
2. 1k(ohm) Resistor
3. 10 micro Farad Capacitor
4. Potentiometer
5. 1k(ohm) Resistor
6. 1N4001 Diode
7. 1N4001 Diode
8. .001 micro Farad Capacitor
9. 12VDC DPDT Relay
10. 12VDC Battery
11. 12VDC Solenoid

IC 555 Timer Chip

+12VDC

12VDC

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**Appendix H**

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