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Conceptual Design of Space Food Processor

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Abstract: - The food processor is conceptually designed in order to convert the raw millet powder into edible millet porridge. This equipment can perform various operations like milling, chopping, cooking, fermentation, packing etc., to produce an edible food product in micro-gravity condition. Since there is no gravity in space, the controlled movement of product from one place to another place is difficult which plays a major role in food processing. In this machine the product movement is carried out by creating a pressure difference using high velocity air. The same principle was used over all parts of the equipment to facilitate suction, delivery, holding and other movement of product and water. It can be controlled by micro-controller where in the program can be modified based on the operation. Also the set of programs can be pre-installed in micro-controller to make the various functions. The other design specifications such as food safety, weight, power, water usage also considered while designing.

Keywords: - Processor, Operations, Microgravity, Micro-controller.

I. INTRODUCTION

NASA estimates that 40 different processing equipment's are required to convert crops such as wheat and tomatoes into edible foods like bread, sauce etc. In ISS they tried growing fruits and vegetable on their own using hydroponic and aeroponic technology. It is the technology to grow crops without soil but with nutrient rich water. During the three year mars mission most of the food requirement will be met by growing hydroponically. In such case, raw fruits and vegetables need to be processed to make them edible in different forms. Here we have developed a food processing equipment which will convert the raw materials or crops into the completely processed ones. In general the processed food should be edible, acceptable and safe to consume. The equipment is designed to do different unit operations and it produces a final product as a result by the combination of unit operations. This equipment can be operated in fully automatic or semi-automatic condition. This space food processor is specifically designed for producing edible millet porridge. The concept of this equipment is derived while facing textural change during reconstitution of freeze dried millet porridge. Also the same equipment could be used to process various food products by changing the program stored in the micro-controller. Similar tomato processing equipment is designed and developed by Singh R P et al. [6]

The overall modelling of space food processor is designed using creo parametric 2.0. 3D parts have been designed using creo-part and creo-sheetmetal and have been assembled using creo-assembly. The 2D layout of the design has been drawn in creo-drawing.The electronic circuit of the equipment is designed in the software. The equipment designed has the following parts 1.Outer shell and feeding section, 2.Milling section, 3.Chopping section, 4.Storage section, 5.Cooking section, 6.Delivery section, 7.Hydraulic and pneumatic section and 8.Control panel.

The outer shell is made of Aluminium to reduce the overall weight. The material selection is based on the food contact. The sections which directly come in contact with the food product are usually made of food grade stainless steel. The approximate bill of materials based on the price quoted on the indiamart for the materials/equipment are shown in Table.1

Table1

Material/Product	Unit	Unit price (Rs)	Actual price (Rs)
Aluminium	19 kgs	400	7600
Steel rod	21 kgs	130	2730
Stainless Steel	28 kgs	300	8400

O2 cylinder	1	13500	13500
N2 cylinder	1	7900	7900
Regulator	2	7000	14000
Solenoid valve	7	500	3500
Hoses	5 m	100	500
Processing cost	1	70000	70000
Labour cost	1	20000	20000
Control panel	1	25000	25000
Stepper motor	3	2000	6000
12V DC motor	3	3000	9000
DC servo motor	2	500	1000
Flow control valve	1	5000	5000
Pressure relief valve	1	1800	1800
Nozzle	7	850	5950
Heating coil	1	1000	1000
12 Battery (42 ah)	2	3500	7000
Stone mill	1	3000	3000
		Total	212880

II. EXPERIMENTAL DESIGN AND DISCUSSION

The outer shell is the part which houses all other sections. It is the outer covering and forms the base for the equipment. It consists of air vent on both sides and it has feeding section at the top along with four steel supports.

The feeding section is a 3 axis robot which moves all along the equipment to cover 25% of its total volume. The suction cup is placed in such a way to move in all the three axes but the depth of the feeding section is constrained to 100mm. In order to increase the accuracy DC stepper motor is used to operate the feeding section. Suction cup has a provision for 3-way solenoid valve at the top of it. When air moves through this solenoid valve at a high velocity it creates a pressure difference which will suck the raw material from the storage section in to the suction cup and the raw material will be delivered to any other section by the same principle.

The milling section is used to mill the raw millet into powdered form. It is operated by DC motor with belt drive mechanism to control torque and speed. The inlet port of milling section as in Fig. 2 sucks the product from feeding section using solenoid valve. Here the raw material mixes with air and moves inside the mill and the continuous moving air causes the raw material to move in between the milling plates which produces ground millet. Then the powdered sample is collected through delivery port which is directly connected to the cooking/holding section. The whole section is hold on by steel or aluminium support. The outer covering and inlet port should be made of stainless steel since it has direct food contact. The milling section needs to be maintained at dry condition always for ease of cleaning.

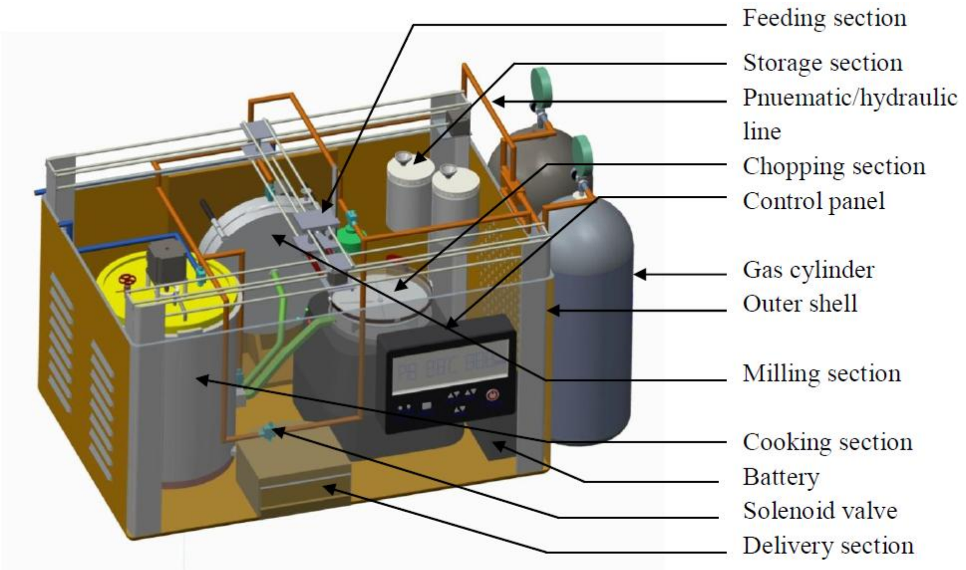


Fig. 1 Overall design of space food processor

The chopping section as in section Fig. 3 is used to cut or chop the products such as onion, tomato, carrot etc. The product can be fed manually or through the feeding section to the inlet port. The chopping blade continuously chops the product and slices into pieces. The thickness and shape of the slices are based on the rpm of blade, cutting section and feed rate. The slices at bottom of the chopping blade are guided by the sweeping blade to the delivery port which is connected directly to the cooking/ holding section through rectangular pipe. The chopping and sweeping blades should be made up of food grade stainless steel.

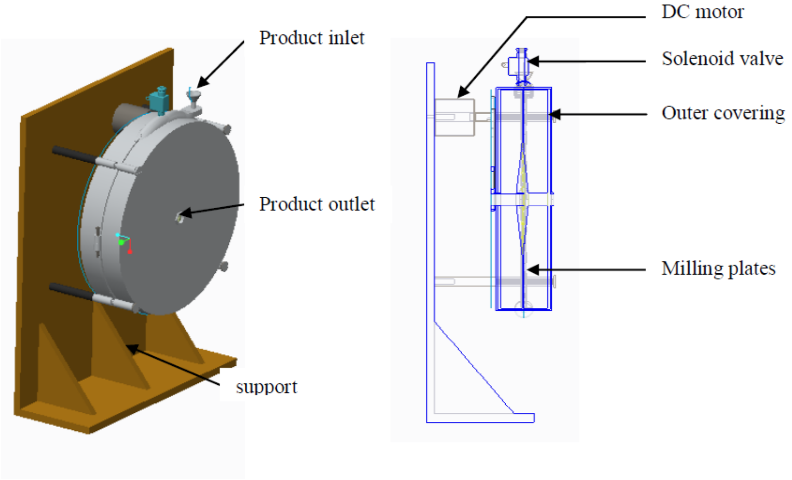


Fig.2 Isometric and cross-sectional view of milling section

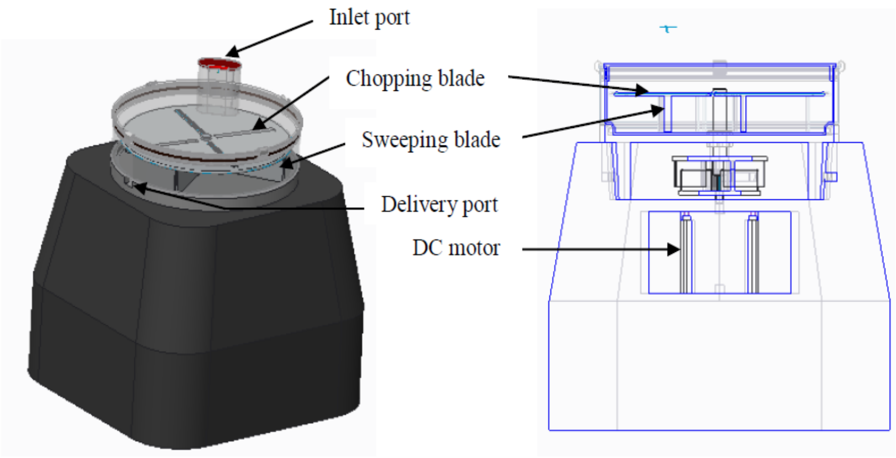


Fig.3 Different views of chopping section

The cooking section forms the major part of the equipment which can involve in multiple operations such as fermentation, holding, mixing, cooking etc. It consists of seven main parts i.e., main cylinder, top lid, movable middle lid, rotor blade, drive system, heating coil and valves. The main cylinder gives the way for every operation listed above; it should be made of stainless steel. The top lid gives place for DC motor which is attached to the rotor blade. The one more important part is the middle lid as in Fig. 4 which divides the main cylinder into two halves. Cooking takes place in the lower half which has fixed volume (2.0 L). However the middle lid can move to provide extra volume when the product enters. The rotor shaft facilitates the movement for the middle lid and for the rotor blade. The middle lid opens up the inlet port when the rotor shaft rotates anti-clockwise by moving upward. The middle lid closes the inlet port when the rotor shaft rotates clockwise by moving downward upto the lower limit i.e., 50mm from the bottom of the main cylinder. The middle lid also holds solenoid valve for water or oil inlet and pressure relief valve which passes the excess pressure from the lower half of the cylinder to the upper half of the cylinder. The products from milling section and chopping section enter into the cooking section through the inlet port by means of Bernoulli's principle. The rotor blade driven by the DC motor provides mixing, kneading and agitation during cooking and fermentation. The rotor blade and middle lid should be made of stainless steel. The cooking is carried out by means of induction heating or ohmic heating where the only AC source required to operate. However ohmic heating suits for the best application in space food development.

The water or oil is sprayed into the cooking area through the nozzle at middle lid. There is a delivery port which operates by servo and it directly connects to the delivery section. The cleaning of this section is done by delivering hot water into the cylinder and rotates the rotor at high speed and the waste water collected at delivery point will send for waste water recovery unit. The most of the air used in this equipment is send back to the flow control unit which facilitates air recovery.

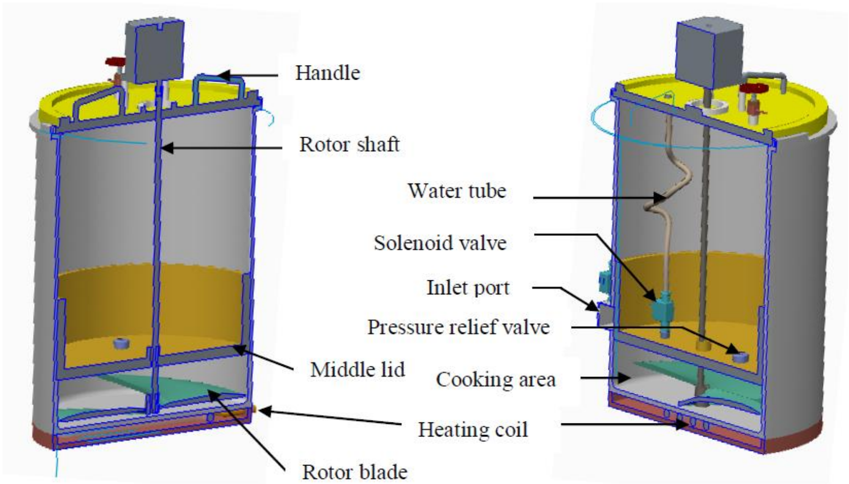


Fig.4 Cross-sectional view of cooking section

The delivery section is an air tight container; it has a retractable tray which needs to be operated (open/close) manually. The food from cooking section falls into the tray when solenoid valve positioned at top of the delivery section triggers on. We can manually clean the tray by taking it out or by connecting the section directly to the waste water recovery; the excess water drawn from cooking cylinder is used to clean this section automatically.

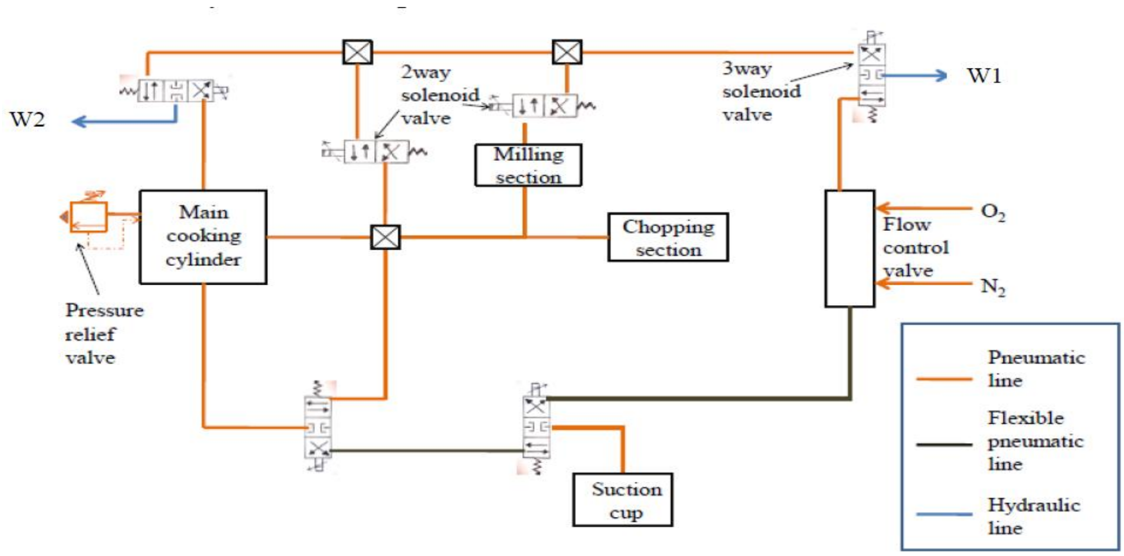
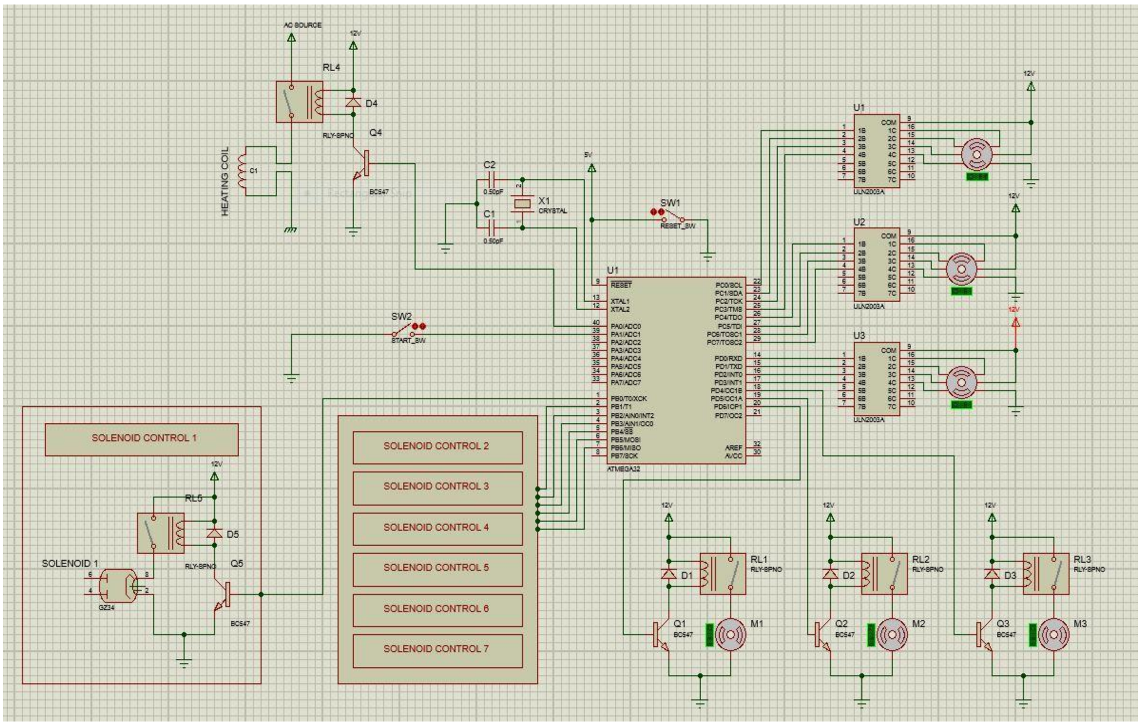


Fig.5 Hydraulic and pneumatic circuit

Fig. 5 shows the schematic circuit diagram of the hydraulic and pneumatic lines which are connected across various parts of the equipment. Flexible pneumatic lines are made of flexible rubber tube as they are subjected to movement all over the equipment. High pressure gas stored in cylinder first reaches flow control valve which regulates the flow based on the operation and then it reaches spring retractable solenoid valve. Inside the valve, velocity of the gas is increased by passing through a nozzle. This increases the pressure difference and the high pressure difference causes desired movement to take place in the equipment. Hydraulic line ‘W1’ supplies water to all the sections of the equipment for the cleaning purpose, whereas ‘W2’ supplies water or oil into the cooking cylinder.

The control panel controls all the motors, heating coil and valves by the use of micro-controller. Micro-controller separately triggers each motor and valve based on the input given. Generally the input will be given to the micro-processor through the program and also we can give manual input through control panel module; the program depends on the operation corresponding to the product formation. We can store multiple program into the micro-processor based on the variety of product we are going to cook. In this equipment, 3 stepper motors, 3 DC shunt motors, 7 solenoid valves and 1 heating coilare used. All of these items are controlled using Arduino mega 32 (ATMEGA32) micro-controller, which is simple and reliable. Fig. 6 shows that the wiring connections between various parts. We have chosen ATMEGA32 board for this equipment because of its number of output pins. It has 40 pins out of which 32 is given for outputs. It is easy to control and easily programmable. The 8 pins from port C and 4 pins from port D is used to control3 Stepper motors i.e., U1, U2 and U3 in fig. 6 which are used as 3 axis robot for feeding section. It gives precise movement and increases the accuracy. The 3pins from port D controls the 3 DC shunt motor M1, M2 and M3 in Fig. 6 which is used for milling, chopping and mixing. The port B controls all the 7 solenoid valves which are responsible for the hydraulic and pneumatic circuit. We can take control over each and every motor and solenoid valves using this circuit. The port A controls the heating coil which is operating under AC source. Out of 32 outputs we are using 24 outputs still some sensors needs to be included to display speed and temperature in LCD display. It is easily programmable using any of the arduino IDE recognized software such as USBasp and the input can also be given manually. All the DC circuits have a voltage rating of 12 V which can be easily managed by using a set of 2x12V (48ah) rechargeable battery. The battery can be continuously recharged by means of solar panel or thermoelectric generators.



III. CONCLUSION

We have planned to develop a probiotic rich product for astronauts but unfortunately during processing and packaging most of the LAB count decreased also the texture of the reconstituted sample was not as good as freshly cooked sample. To overcome this problem we have designed a space food processor which produces the fresh probiotic millet porridge in space. Also this equipment is designed in such a way to produce many other foods based on the input we are feeding. Since this equipment works using micro-controller, it is very easy to take control over the operations.

Here, we have proposed the conceptual design whereas in future the same model may be prototyped and analysed in various aspects to determine the capability of the equipment to do the desired job. Based on the analysis the equipment could be modified in terms of materials used, power consumption, range of operation, water usage, and overall efficiency.

REFERENCES

[1]. Castro S. L., Ott C. M., and Douglas G. *L Probiotics in the Space Food System:Delivery, Microgravity Effects, and the Potential Benefit to Crew Health*. 2004

[2]. Lyndon B, *Space Food. NASA Facts*, FS-2002-10-079-JSC, 2002

[3]. Nor ArinaBt Adam , *Microcontroller (M68HC11) for fluid flow control*. Universiti Malaysia Pahang Institutional Repository, 1, 109. 2006.

[4]. Perchonok M., Swango B., Toerne M E, *The Challenges in the Development of a Long Duration Space Mission Food System. NASA Scientific and Technical Information*, 20030003738, 2003.

[5]. ReetamM., Arumay M., Debdoot B Embedded system of DC motoe closed loop speed control based on 8051 microcontroller. *Procedia Technology* 10, 2013, 840-848.

[6]. Voit DC., Santos MR., Singh RP, Development of Multipurpose Fruit and Vegetable Processor for a manned mission to mars. *Journal of Food Engineering*, 77(2), 2006, 230-8.

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