DEVELOPEMENT AND PERFORMANCE EVALUATION OF A PNEUMATIC POTATO SLICER

GUIDE: DR PRINCE M V, PROFESSOR, P&FE DEPT.

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DECLARATION

We hereby declare that this project report entitled "**Development and Performance Evaluation of pneumatic potato slicer machine"** is a bonafide record of project work done by us during the course of project and that the report has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title of any other University or Society.

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CERTIFICATE

Certified that this project report ”**Development and performance evaluation of pneumatic potato slicer ”** is a record of project work done by Ms. Ardra C Babu (2015-02-010), Ms. Athira VS (2015-02-014), Ms. Fathima Rasheed (2015-02-020), Ms. Varada Somaraj (2015-02-043) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship.

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DEDICATED TO FOOD ENGINEERING PROFESSION

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SYMBOLS AND ABBREVIATIONS

=	Equal to
/	Divided by
*	Multiplication
+	Plus
-	Minus
:	Ratio
%	Percentage
℃	Degree centigrade
Ø	Diameter
AC	Alternating Current

Cm	Centi meter
et al.	and others
g	Gram
Ha	Hectare
Hp	Horsepower
ie.	That is
in	inches
K.C.A.E.T	Kelappaji College Of Agricultural Engineering and Technology
Kg	Kilogram
mg	Milligram
mm	Millimeter
MS	Mild steel
N	Newton
No.	Number
P & FE	Processing and Food Engineering
pp	Page number
PU	Poly urethane
Rpm	Rotation per minute
Rs	Rupees
s	Second
SI	Serial
SS	Stainless steel
V	Volt
W	Watts

CHAPTER 1

INTRODUCTION

Tuber crops still continue to be major crops contributing significantly to human and animal food apart from finding use in various industrial applications. These crops are adopted to broad agro ecological conditions and yield reasonably well even under marginal environments. Tuber crops fit well into a variety of cropping systems and can be profitably intercropped. In developing countries starchy root and tuber vegetable are the commodity mostly consumed.

The potato is a starchy, tuberous crop from the perennial nightshade Solanum tuberosum. Potatoes were introduced to Europe in the second half of the 16th century by the Spanish. Today they are a staple food in many parts of the world and an integral part of much of the world's food supply. As of 2014, potatoes were the world's fourth-largest food crop after maize (corn), wheat, and rice.

Potato plants are herbaceous perennials that grow about 60 cm (24 in) high, depending on variety, with the leaves dying back after flowering, fruiting and tuber formation. They bear white, pink, red, blue, or purple flowers with yellow stamens. In general, the tubers of varieties with white flowers have white skins, while those of varieties with coloured flowers tend to have pinkish skins. Potatoes are mostly cross-pollinated by insects such as bumblebees, which carry pollen from other potato plants, though a substantial amount of self-fertilizing occurs as well. Tubers form in response to decreasing day length, although this tendency has been minimized in commercial varieties.

In 2016, world production of potatoes was 377 million tonnes, led by China with over 26% of the world total. Other major producers were India, Russia, Ukraine and the United States.

Raw potato is 79% water, 17% carbohydrates (88% is starch), 2% protein, and contains negligible fat. In an amount measuring 100 grams, raw potato provides 322 kilojoules (77 kilocalories) of energy and is a rich source of vitamin B6 and vitamin C with no other vitamins or minerals in significant amount. The potato is rarely eaten raw because raw potato starch is poorly digested by humans. When a potato is baked, its contents of vitamin B6 and vitamin C decline notably, while there is little significant change in the amount of other nutrients.

Storage facilities need to be carefully designed to keep the potatoes alive and slow the natural process of decomposition, which involves the breakdown of starch. It is crucial that the storage area is dark, ventilated well and, for long-term storage, maintained at temperatures near 4 °C (39 °F). For short-term storage, temperatures of about 7 to 10 °C (45 to 50 °F) are preferred. On the other hand, temperatures below 4 °C (39 °F) convert the starch in potatoes into sugar, which alters their taste and cooking qualities and leads to higher acrylamide levels in the cooked product, especially in deep-fried dishes. Under optimum conditions in commercial warehouses, potatoes can be stored for up to 10–12 months. When stored in homes unrefrigerated, the shelf life is usually a few weeks.

PNEUMATICS

In this project we used pneumatic system, 'Pneumatics' from the Greek (pneumatikos, coming from the wind) is the use of pressurized gases to do work in science and technology.

Pneumatics was first documented by Hero of Alexandria in 60 A.D., but the concept had existed before then. Pneumatic devices are used in many industrial applications. Generally appropriate for applications involving less force than hydraulic applications, and typically less expensive than electric applications, most pneumatic devices are designed to use clean dry air as an energy source. The actuator then converts that compressed air into mechanical motion. Pneumatic cylinders are generally less expensive than hydraulic or electric cylinders of similar size and capacity

It is a branch of engineering that makes use of gas or pressurized gas. Pneumatic systems used in industry are commonly powered by compressed air or compressed inert gases. A centrally located and electrically powered compressor powers cylinders, air motors, and other pneumatic devices.

Pneumatic control systems are widely used in our society, especially in the industrial sectors. Many factories have equipped their production lines with compressed air supplies and movable compressors. There is an unlimited supply of air in our atmosphere to produce compressed air. Moreover, the use of compressed air is not restricted by distance, as it can easily be transported through pipes. After use, compressed air can be released directly into the atmosphere without the need of processing. Pneumatic components are extremely durable and cannot be damaged easily.

The designs of pneumatic components are relatively simple. Compared to the elements of other systems, compressed air is less affected by high temperature, dust, corrosion, etc. Pneumatic systems are safer than electromotive systems because they can work in inflammable environment without causing fire or explosion. Apart from that, overloading in pneumatic system will only lead to sliding or cessation of operation. Unlike electromotive components, pneumatic components do not burn or get overheated when overloaded. The speeds of rectilinear and oscillating movement of pneumatic systems are easy to adjust and subject to few limitations. The pressure and the volume of air can easily be adjusted by a pressure regulator. The operations of pneumatic systems do not produce pollutants. The air released is also processed in special ways. As pneumatic components are not expensive, the costs of pneumatic systems are quite low, moreover pneumatic systems are very durable, and the cost of repair is significantly lower than that of other systems.

Applications

- Air brakes on buses, trucks or trains
- Air compressors
- Air engines for pneumatically powered vehicles
- Cable jetting , a way to install cables in ducts
- Dental drill
- Inflatable structures
- Pneumatic air guns etc.

Gases used in pneumatic systems

Pneumatic systems in fixed installations, such as factories, use compressed air because a sustainable supply can be made by compressing atmospheric air. The air has moisture removed and a small quantity of oil is added at the compressor to prevent corrosion and lubricate mechanical components .Smaller or stand-alone systems can use other compressed gases which has asphyxiation hazard, such as nitrogen (oxygen-free nitrogen).Portable pneumatic tools and small vehicles are often powered by carbon dioxide ,because containers designed to hold it such as soda canisters and fire extinguishers are readily available and the phase change between liquid and gas makes it possible to obtain a larger volume of compressed gas from a lighter container than compressed air requires.

SLICING

Prior going to other processing operations like boiling, blanching, drying, grading etc. a significant unit operation is slicing. Slicing is carried out to reduce the size of product to suit processing consumer needs. In past this was done manually. But it’s tedious process and have lots of drawback. Threat to the operator, lack of uniformity in the size of sliced potato, increased time consumption, reduction in quality etc.

The conventional method of potato slicing practised by the farmers is carried out by placing the potato tubers on a chopping board and cut with a sharp knife through desired thickness estimated by their eyes only. This method is injurious, laborious, unhygienic, and produces non uniform slices, and thereby giving poor end products. Due to uneven thickness of slices arising from improper tools, a lot of wastage of vegetables is happening leading to loss of productivity and other miscellaneous damages to vegetables.

There are a number of mechanical slicers available for different fruits and vegetables. Though the slices obtained are of uniform thickness, the process is tedious and power consumption is too high. Also, the equipment is complicated with more moving parts, motors, pulleys, belts and speed reduction systems. A cost effective, simple mechanical device, which is fast and safe with less moving parts need to be designed. Therefore an attempt was made at KCAET, Tavanur to use pneumatics for slicing of potatoes with following objectives.

1. Development of pneumatic operated potato slicer.
2. Performance evaluation of pneumatic potato slicer.

CHAPTER II

REVIEW OF LITERATURE

This chapter reviews the research and developments that had taken place in pneumatic technology and related activities, machineries for slicing potatoes.

2.1 POTATO

Potato is a dicot plant belonging to family Solanaceae and the genus Solanum. This is a large genus and contains 2000 species. According to the latest classification, the genus has been divided into two sub geneses, Pachystemonum and Leptostemonum. Pachystemonum has been further divided into five sections i.e. Tuberarium (which includes potato and its relatives), Morella, Dulcamara, Micranthes and Lycianthes **(Thamburaj *et al*., 2001).**

Traditionally it was adopted as valuable commercial food crop in temperate climate, under long day growing condition, mainly in Europe. As a crop of high biological value for its starch, protein and a substantial amount of vitamins, minerals and trace elements, it is undoubtedly a very important crop **(Gebre and Sathyanarayana, 2001).**

The global area under potato cultivation during 1998 was about 18 million hectare with a total production of 295 million tons. Among the major potato growing countries of the world China ranks first, followed by the Russian Federation, Ukraine and Poland. India ranks fifth in the world. As one of the principal cash crops, potato contributes to the national economy in many ways. It gives handsome returns to the growers. On the average, the net returns are about Rs. 4,700.00 ha^{-1}. In other terms; 1 rupee of investment gives a net return of Rs. 1.40 in a short period of 80-100 days. Potato is both a labor and capital intensive crops **(Shekhawat *et al*., 1992).**

Potato is grown in over 130 countries and word's annual crop of potato exceeds 278 million metric tons with an estimated value of around 13 billion Rupees. By the year 2020 potato is expected to reach about 49 million tons **(Shekhawat *et al.,* 1999).**

India produces a total of about 25-28 million tons of potato every year. Each hectare of land generally, produces about 16-19 tons of potato. However, in Europe and American countries the productivity is about 30-40 tons $hectare^{-1}$ **(Thamburaj *et al*., 2001).**

The country recorded an increase in 1950-51 to 1.3 million hectares in 2004-05 with the corresponding increases in production from 1.66 to 23.6 million tons. The productivity also improved from 69.2 quintals hectare^{-1} in 1950-51 to 181.5 quintals hectare^{-1} in 2004-05. Thus, there has been a phenomenal increase in the area, as well as the productivity over this period by 44.2, 13.2 and 16.2% respectively **(Pandey *et al*., 2006).**

Seed tuber quality is an extremely important factor for potato yield. Since it is a vegetatively propagated plant, fungal, bacterial and, particularly viral disease, agents are easily transmitted through the tubers. Conventional propagation of potato is done vegetatively using seed tubers which ensure uniformity of the crop in terms of growth and yield, but results in degeneration of the crop due to virus infection. The rates of degeneration vary from place to place and from one growing season to other growing season **(Biniam *et al.*, 2008).**

Potato cultivars (Solanum tuberosum L.) are threatened by various pests and diseases, including a number of important viral diseases which represent a constraint on potato seed production **(Nasir *et al*., 2010).**

Generally tuber is used as a seed. Due to progressive accommodation of viral disease in potato seed stock availability of good quality seed is a major constraint in potato production, which is approximately 50% of the total production cost. Besides high cost of seed potato the productivity is also influenced by characterized by low multiplication rate of only 4-6 times **(Badoni and Chauhan, 2010).**

Potatoes are classified as “starchy vegetables,” highlighting their predominant macronutrient carbohydrate and predominant type of carbohydrate-starch. Potato starch consists of amylopectin (branched chain glucose polymer) and amylose (straight chain glucose polymer) in a fairly constant ratio of 3:1 **(Woolfe 1987).**

A small proportion of the starch found in potatoes is “resistant” to enzymatic degradation in the small intestine and, thus, reaches the large intestine essentially intact. This “resistant starch” (RS) is extensively fermented by the microflora in the large intestine producing short chain fatty acids which have been shown to lower the pH of the gut, reduce toxic levels of ammonia in the GI tract, and act as pre-biotics by promoting the growth of beneficial colonic bacteria **(Higgins 2004, Brit 2013).**

Potatoes provide one of the most concentrated and affordable sources of potassium significantly more than those foods commonly associated with being high in potassium, such as bananas, oranges, mushrooms, etc. **(Drewnowski *et al.*, 2013).**

Magnesium is another nutrient under-consumed by the majority of Americans. A medium (5.3 oz) potato with the skin provides 48 mg of magnesium and recent research indicates potatoes contribute 5% of the total magnesium intake in the diets of Americans **(Freedman and Keast 2012).**

Total carotenoid content of potatoes ranges widely from 35 μg to 795 μg per 100 g fresh weight. Dark yellow cultivars contain approximately 10 times more total carotenoid than white-flesh cultivars **(Brown *et al.*, 2008).**

Potato is a semi-perishable commodity. Therefore, it needs processing for both short and long term storages. Postharvest losses of potato in Bangladesh are, respectively, 25% and 31% in home storage and cold storage systems **(Hossain and Miah, 2011)**.

To elongate the shelf life of potato, it can be dehydrated in the forms of slices, sticks, cubes or powder instead of fresh form of potato used for making vegetables and curry. Potato chips or wafers are also popular forms of potato consumption. It has high acceptance among all categories and ages of people in present urban, semi-urban and to some extent, the village levels. Quality of potato products has an important role on the acceptance to consumers. Poor qualities of potato products as well as high post-harvest loss of potato often result from the use of low grade processing machineries. Poor end potato slicer produces uneven thickness of slices due to design fault which causes uneven drying followed by fungal infestation. To reduce this huge loss, promotion of small scale potato processing at home, cottage industry and SME level at rural areas would be a substantial opportunity. Usually potato farmers have no other option without selling their potatoes at farm gate prices to the middlemen to get at least minimum return before spoilage. Low return discourages farmers and production per head is greatly reduced in the following years. To overcome this problem, potato farmers can peel, blanch and dry their tubers either in lumps or in slices and store them for better profits **(Ehiem *et al.*, 2011).**

2.1.1 Physical Properties

Engineering properties are the properties which are useful and necessary in the design and operation of various equipment employed in the field of agricultural processing and also for design and development of farm machinery (Sahay and Singh). The determination of engineering properties of different fruits and vegetables followed by various research workers were reviewed for this study.

The physical properties such as size, shape, surface area, volume, etc are important in designing a particular equipment.

Singh and Shukla (1995) conducted the experiment on physical properties of potato viz., length, breadth and thickness to develop a potato peeler. Vernier calipers were used for measuring these properties.

2.2 SLICING

Slicing of fruits or vegetables for canning, shredding sweet potatoes for drying, slicing onion for salad, chopping corn fodder, grinding grain for livestock feed and milling flour are size reduction operations. Reducing the size of food raw materials is an important operation to achieve a definite size range **(Henderson and Perry, 1980).**

Cutting, slicing, dicing, and shredding are non-thermal food operation for size reduction. This process reduces the preparation time by consumers. Cutting removes inedible and discolored portions from foods using knife, chopper and slicer **(Corbo *et al*., 2010).**

Leo and Balogun (2009) reported that in drying of fruits and vegetables, the vegetables and fruits must be sliced into smaller pieces to facilitate heat transfer and removal of moisture from the pieces.

In food processing, injured tissues are removed so that these are unavailable for microbial spread. The cut tissues results in reduced respira-tion and enzymes activity, thus retarding rapid spoilage and increases shelf life **(Chung *et al*., 2011).**

The most common geometric shapes of fresh-cut vegetables and fruits are: disc, baton, cube, shred and slice. The shapes depend on the types of product and their requirement **(Koidis *et al.*, 2012).**

Kachru *et al.*, (1996) observed that during cutting, a cutting edge (knife) penetrated into a material, overcoming its strength and thereby separating it. He further stated that during cutting, various deformations occur in the material, depending on the form of the cutting edge and the kinematics of the process.

Cutting and slicing of agricultural material or product have been a great and difficult task to agriculturist processors. Over the years, efforts have been made to mechanize some operations involved in slicing of agricultural products **(Lhekoronye *et al.*, 1992)**.

The invention of slicing technology can be dated back to the 1900's, with a number of authors studying the principles of slicing and slicing machines. The first slicing machine was invented by an American in 1873 **(Hardin, 2001)**, the machine made use of an oblique knife in a vertical slicing frame for slicing dry beef and it worked the frame holding the meat while slicing against the cutting blade **(Odior *et al.*, 2009).**

Otto Rohwedder designed and manufactured the first slicing machine that would slice and wrap bread in 1925 **(Frank, 2004)**. The machine made use of an oblique knife in a vertical sliding frame for slicing dry beef and it worked with the frame holding the meat while slicing it against the cutting blade. The conventional slicing machine was originally designed to slice meat into pieces of uniform thickness. It was also used for slicing cheese, vegetables, ham, onions green peppers and sandwich ingredients.

In the mid-1980s, the slicing technology has experienced its peak of development, many of the automatic multi-function slicers have been commercialized **(Xie, 1996).** Wire saw, a cutting machine was developed during this period. It had a unique design and was totally different from the traditional slicing technology. It uses a steel wire to coil the four guide wheels to form hundreds of saw bands. When they operate in a high speed, the silicon carbide will be taken to the machine to produce the effect of cutting. Its advantages are to cause less kerf, small deviation, even cut surface, big quantity and less costs.

The comb shape cutting machine in 1980s is not new anymore. It has been replaced by the cutting and rotating one, surface grinding one and the one with an air cushion which can prevent the blade from bending and distorting, which can repair and maintain the blade automatically **(Jiang, 2011)**. The chip material can roll and grind by itself while cutting, which can reduce the bending of the monocrystal.

(Obeng *et al.*, 2004) developed a mechanized plantain slicer for cutting of bulk plantains into chips. The mechanized slicer seeks to reduce the drudgery associated with traditional cutting of large-scale plantains into chips. The machine takes 5-7 seconds to slice a finger of an average-size plantain into chips of 2-3mm in thickness compared to the 40-80 seconds with a kitchen knife, which gives non-uniform thickness of plantain chips. It was found to be very convenient, and the average thickness of plantain chips produced with the slicer compares favourably with commercial standards.

Owolarafe *et al*., (2007) developed a manually operated lady's finger (okra) slicing device suitable for on-farm use. It was designed, fabricated and tested based on the engineering properties of the vegetable. The machine, simulates the traditional method of okra slicing, consists of the feeder, slicer and receiver. It was made simple for ease of operation and maintenance. The machine was tested with replicated experimental runs using 100, 200, 300, 400 and 500 g of okra. The thickness of the slices (about 10 mm) corresponds evenly to the spacing of the cutting discs. The machine has a slicing efficiency of about 77.4% and through put of about 8.4 kg/h.

Neidhardt (2008) developed the tomato slicer, equipped with a disposable blade cartridge. Features include Razor-sharp blades cut with trouble-free precision, thanks to a unique self-lubricating track material that resists misalignment problems that cause nick sand broken blades. Vertical handle and protective guards improve user comfort and safety.

Gave (2008) developed a vegetable cutter which uses 40 different cutting discs to replicate most hand-cutting styles. Features include a large hopper opening, ¾-hp gear-driven motor, stainless-steel body and base, removable hopper head, and a food pusher, which has antimicrobial protection.

Azizet *et al*., (2011) developed a Slicing machine for fresh cut Pineapple. Intensive research had been conducted in developing a suitable slicing machine to cater for the needs of the local pineapple processors.

2.3 PNEUMATICS

Most of the earlier pneumatic control systems were used in the process control industries, where the low pressure air of the order 7-bar was easily obtainable and give sufficiently fast response. Pneumatic systems are extensively used in the automation of production machinery and in the field of automatic controllers. For instance, pneumatic circuits that convert the energy of compressed air into mechanical energy enjoy wide usage, and various types of pneumatic controllers are found in industry. Certain performance characteristics such as fuel consumption, dynamic response and output stiffness can be compared for general types of pneumatic actuators, such as piston-cylinder and rotary types **(Sorli *et al.*, 1999)**.

The final decision on the best type and design configuration for pneumatic actuator can be made only in relation to the requirements of a particular application. The pneumatic actuator has most often been of the piston cylinder type because of its low cost and simplicity **(Tablin *et al.*, 1963)**.

The pneumatic power is converted to straight line reciprocating and rotary motions by pneumatic cylinders and pneumatic motors. The pneumatic position servo systems are used in numerous applications because of their ability to position loads with high dynamic response and to augment the force required moving the loads. Pneumatic systems are also very reliable **(Clements and Len, 1985).**

Pneumatic servos have advantages over hydraulics in high temperature and nuclear environments. The actuator, rather than the servo valve, generally limits system response and stiffness. Where simplicity and cost are paramount, the piston cylinder is probably the best choice. But if minimum fuel consumption is desired rotary type of motor is indicated. It is also shown that the rotary servo has nearly twice the band pass of the piston cylinder servo. This result is typical for many applications. In short duration missile applications, the weight of a self-contained solid propellant pneumatic servo may be half that of an equivalent self-contained hydraulic system. Where a pneumatic system is to replace a heavier hydraulic system, maximum dynamic response and output stiffness are essential. The outstanding difference between pneumatic and hydraulic systems arises from the low bulk modulus of the pneumatic working medium. The bulk modulus of a gas is p, where h is the ratio of specific heats for the gas and p is the instantaneous pressure. This is the major obstacle in achieving a high response pneumatic system. Several countries have been investigating and developing active suspension technologies in order to improve both vertical and lateral ride quality of fast train passenger cars**. (Taplin *et al.*, 1963).**

Cho *et al*., (1985) investigated the use of actively controlled pneumatic actuators in parallel with conventional passive suspension to improve vehicle dynamics. The use of pneumatic actuators for vehicle active suspension reduced the rms car body lateral suspension stroke by 34 percent with a power requirement of 5.7 KW per car.

Singh *et al.*, (1985) described the design process by which the air brake control valves of heavy and medium duty trucks were centralized modulus. Truck air brake control systems were reviewed and a floor mounted pneumatic application valve acting on a centrally advanced design was developed using dash mounted electrical controls and a floor mounted pneumatic application valve acting on a centrally located electro pneumatic controller. The system performance was demonstrated on an operational truck and tested to the applicable system requirements of federal brake regulations. Nearly all-modern process plants employ control valves, which use either pneumatic or electric actuators, the choice between the two being normally dictated by the size of the valve, the environment, media and availability of power source.

Clements *et al*., (1985) Have developed dedicated electro pneumatic positioned for a class of process valves. The position uses solid-state electronics to combine the functions of both the electric to pneumatic converter and valve positioner. Such are the savings in size and weight that have been achieved by the use of electronics that the resulting unit is housed in an enclosure small enough to be mounted directly on the actuator, which it is to operate.

Virvalo *et al*., (1988) Showed that electro pneumatic servo systems are viable alternatives to hydraulic systems for control of such machines as robots, but most of the research has been carried out on them using comparatively small cylinders. They have studied the problems involved in using heavier versions and have produced a satisfactory method of coping with the somewhat complex problems involved in designing such systems, since with a few simplifications a nonlinear model of a pneumatic servo system can be built and used to time the regulator.

An interesting pneumatic servomechanism, which employs pulse width modulation driving technique, was reported by **Sano *et al*., (1988).** A new electro pneumatic on- off valve with a disk flapper driven by a pulse motor was developed. Experimental tests showed the positioning accuracy and the output power are tolerable but the speed of the response is comparatively less than those of other pneumatic servomechanisms.

The advantages and limitations of the conventional pneumatic cylinder were discussed by **Bird *et al*., (1985).** Recent developments in the design of pneumatic linear actuators have resulted in the production of more compact and better guided actuators. The author worked on system. Typical applications of such systems are also given.

Vincent *et al.*, (1989) investigated an alternative approach to the design of controllers for positioning damping. To avoid conflicting requirements problem associated with traditional state variable feedback design, the design is based on energy methods and is not a full state variable feedback design. The method is illustrated using a low order spring mass example, and the development of special servo control system and its integration into complete control the results are compared with a linear quadratic design.

Another interesting application to pneumatic actuators is that reported by **Ingold *et al.*, (1988).** An electro pneumatic design was developed and tested to meet the engine characteristics such as start ability, load carrying ability, and engine dynamic performance.

As an application of micro-mechanical actuators a new concept for a micro-pneumatically driven actuator has been developed and realized. This actuation principle has several advantages: high energy density, large achievable displacement, high generated forces, excellent dynamic behavior, usage of various fluids as driving medium, usage as final controlling element with continuous action and high design flexibility **(Sebastian *et al*., 2002).**

A methodology combining theoretical and experimental techniques for characterizing and predicting the friability of granules in a laboratory scale pneumatic conveying systems was developed by **(Pavol *et al*., 2008).**

2.4 MACHINERY

Slicing operation is achieved by cutting, which involves moving, pushing or forcing thin sharp blade or knife through the materials resulting in minimum rupture and deformation of the materials **(Raji and Igbeka, 1994).**

Akomas and Otti (1988) found that sharpness of knife used for potato slicing could reduce the potato tissue damage.

Megan (2008) developed Slicer featuring simplified controls, improved geometry, an enhanced carriage design and other innovations that make it easier to use and clean and deliver improved slice quality. With a 50-degree cutting plane and glass-bead-finished gauge plate and top knife cover, the slicers have a smoother glide against the knife while improving visibility of the sliced product. A lighter tray makes repeated loading and unloading easier.

Onwugharam (1991) had designed a stationary slicing machine which is the most commonly used vegetable or food slicing machine tool. It consist of a glass fibre casing on which is mounted a stainless steel cutter placed at an angle of about 30^0 to the direction of the vegetable movement, to ensure its stability and cutting efficiency. An adjuster, which selects the chip size to be cut is between 1.0 – 50mm, guides the cutter during its cutting action. In this method, the vegetables like tomatoes, pepper, potatoes etc., is held by hand and moved against the surface of the cutting edge, producing regular and sized chips or cut of the vegetable. Through the operator’s hand becomes endangered as the food size diminishes. This method can produce an average of 20 slices per minute.

Raji and Igbeka (1994) designed, fabricated and tested a pedal-operated chipping and slicing machine for tubers and it was reported that the machine performed satisfactorily with production of slices of uniform thickness ranging from 1 mm to 13 mm thickness and a throughput of about 376 kg/h at an efficiency of about 83%.

Awili *et al.*, (1992) designed the manual vegetable slicing machine it is operated by the rotating lever. In this design, vegetables are fed into slicer through hoper, which is made of stainless steel. By rotating the handle with hand, cutting blades will rotate. Due to rotation of blades, vegetables will cut into pieces. Pieces of the vegetables will come down due to gravitational force. He also said that, it only suitable only for small quantity of vegetables slicing.

Karthika *et al*., (1995) developed a potato slicer. In this slicer, there is no complex mechanism. It designed in such a way that safety is more compare with existing one. In addition, it can operate by unskilled labour.

Kachru *et al*., (1994) at Central Institute of Agriculture Engineering ,Bhopal developed a multiple string banana slicer to avoid the drudgery and any injury to workers and enhance the capacity and maintain quality gadgets with stainless steel string arrangement was developed in order to study the performance of banana slicing.

Nnanna (2014) has designed a vegetable cutting machine to eliminate the difficulties associated with knife cutter. This project was designed and developed in A.I.F.U. It consists of a galvanized steel cutter secured into a chamber on a flexible coupling. The chamber serves as a passage for sliced food or vegetable materials. The transmission elements were made of galvanized steel, to reduce weight and cost. The shaft rotates the cutter and the vegetable is fed through a pyramid chute. During slicing operation, the shaft is rotated by an electric motor and the transmission element with the cutter. The machine operates at a rate of about 60 slices per minute. A major limitation or set back of this project or machine is that it speed cannot be adjusted and the materials used do corrode and as well contaminates the food.

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the material used methodology opted for the development and evaluation of pneumatic potato slicer. A conceptual design was conceived and then the machine was developed and fabricated in the workshop of Kelappaji College of Agricultural Engineering and Technology, Tavanur.

Important physical and mechanical properties of potato which are necessary for development of pneumatic potato slicer were studied before fabrication. The required parameters, cutting force etc. were experimentally found out at PFE laboratory.

3.1 Raw material

Fresh and matured potato (*Solanum tuberosum*) were procured from local market in Tavanur. Prior to fabrication various experiments were carried out to find out best working principle for the machine.

3.2. Determination of engineering properties of potato

To design and develop some specific crop production and processing equipments, engineering properties are essential. Therefore, there is a need to determine engineering properties of potato for promoting better utilization of potato and its products.

3.2.1 Physical properties

The size of the product is useful in designing pneumatic potato slicer. The principle dimensions (length, width and thickness) were measured using a digital Vernier caliper of least count 0.01 mm and its average value was calculated. Geometric mean diameter was calculated from the length, breadth and thickness using the formula $(abc)^{1/3}$.

3.2.2 Mechanical properties

The cutting force was found out using texture analyser. Cutting force determination is necessary in order to understand the force with which the cutting tool slices the potato. This is important for determining the dimension and material of construction etc of the blades.

3.3 COMPONENTS AND GENERAL LAYOUT OF THE MACHINE

The pneumatic potato slicer consists of the following components;

1. Frame assembly
2. Pneumatic cylinder
3. Compressor
4. Solenoid valve
5. Regulator
6. Pneumatic pipes/tubes
7. Pneumatic pipe fittings
8. Timer
9. Cutting tool

3.3.1 Frame assembly

The main frame was made to house and support the various components and subassemblies of the slicer unit. It is used to provide support to bear the load and minimize vibration and ensure stability to the machine. The frame assembly is fabricated using stainless steel. This section hold the pneumatic system.

Frame consists of 8 stainless steel L angles, cut and welded. The frame has a dimension of height 750 mm, length 680 mm, width 680 mm. 4 angles were welded on the frame to provide support, at a height of 60 mm above the ground.

Plate 3.1. Frame assembly

3.3.2 Pneumatic cylinder

Pneumatic cylinders or air cylinders are mechanical devices which uses the power of compressed gas to produce a force in a reciprocating linear motion. In pneumatic cylinder compressed air is used as working fluid and convert it into kinetic energy as the air expands in an attempt to reach atmospheric pressure. This air expansion forces a piston to move in the desired direction. The piston is a disc or cylinder and the piston rod transfers the force it develops to the object to be moved. Since the operating fluid is a gas, leakage from a pneumatic cylinder will not drip out and contaminate the surroundings.

A standard pneumatic cylinder consists of five modules / parts.

1. Cylinder barrel
2. Bearing cap
3. End cap
4. Piston
5. Piston rod

The air cylinder model that has been used is of bore diameter 50 mm and it is double acting with adjustable cushioning. Working pressure is 0.5-10 bar. Medium temperature is 5-60℃. Other features of this model includes:

- Available in magnetic and non-magnetic version.
- Adjustable cushioning at both ends.
- Threaded end cover- hence direct mounting on the machine is possible.
- Piston rod made of non-corrosive stainless steel.

Table 3.1. Output forces for various working pressures

Cylinder bore diameter (in mm)	Rod diameter in mm	Stroke (N)	Working pressure in bar					
50	20		2	3	4	5	6	7
		Extend	353	530	707	883	1060	1237
		Retract	297	445	594	742	891	1039

Plate 3.2 Pneumatic cylinders

3.3.3 Compressor

An air compressor is a device that converts power using an electric motor, diesel or gasoline engine etc. into potential energy stored in pressurised or compressed air. An air compressor forces more and more air into a storage tank increasing the pressure. When tank pressure reaches its upper limit the air compressor shuts off. The compressed air then is held in the tank until called into use. The energy contained in the compressed air can be used for a variety of application, utilising the kinetic energy of the air as it is released and the tank depressurizes. When tank pressure reaches its lower limit, the air compressor turns on again and re-pressurizes the tank.

An air compressor with power 1 hp, voltage 220 V and speed 2850 rpm was used for working of the developed system.

Plate 3.3. Compressor

3.3.4 Solenoid valve

Solenoid valves are devices designed to allow the passage of air or fluid through a chamber and govern the strength of its flow. These devices are different from normal valves in the way that they have fewer working parts and acts upon the receipt of electric current. The model that has been used within experiment was a single solenoid pilot operated valve. Some of the features of this valve are;

- Diaphragm operated poppet seat type.
- Wide range of coil voltages.
- Low temperature of operation.
- Noiseless performance.
- Good flow characteristics.
- The medium is filtered compressed air.

Solenoid valve have some accessories like pneumatic valves and silencers. It may be of button, conical type with flow control unit.it ensures good flow and silencing characteristics. Pneumatic valves are one of an array of components responsible for controlling the pressure, rate and amount of air as it moves through a pneumatic system.

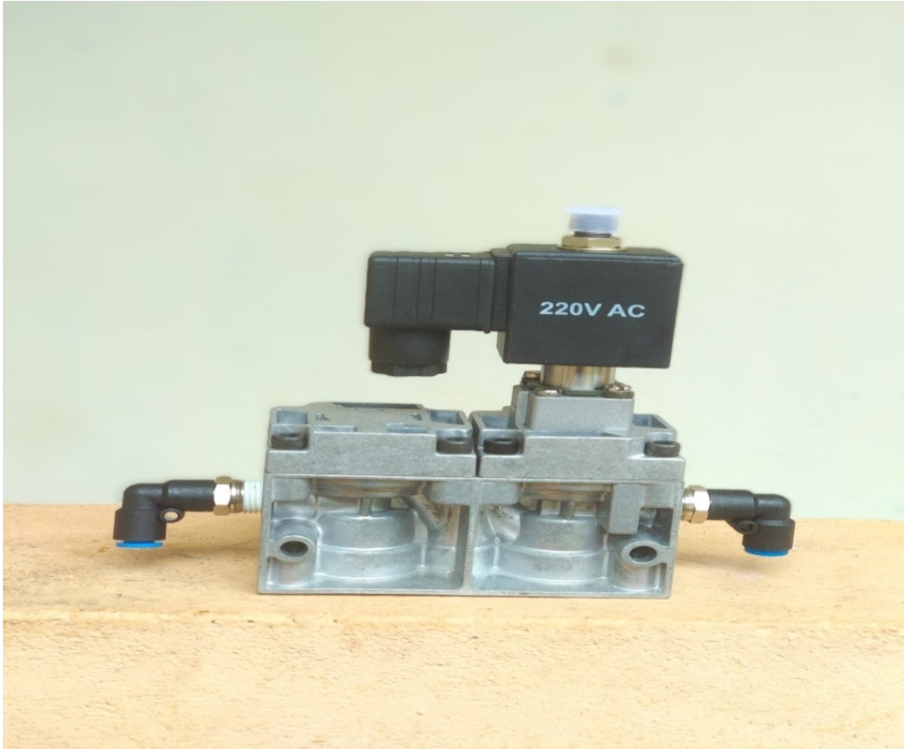


Plate 3.4. Solenoid valve

3.3.5 Regulator

In automatic control, a regulator is a device which has the function of maintaining a designated characteristics. It performs the activity of managing or maintaining a range of values in a machine. The measurable property of a device is managed closely by specific conditions or an advanced set value or it can be a variable according to a predetermined arrangement scheme. The pressure regulator maintains its output at a fixed pressure lower than its input.

It enables us to get the required pressure for the proper working irrespective of the input pressure from the compressor. A pressure gauge is attached along to adjust the incoming pressure.

Plate 3.5. Regulator

3.3.6 Pneumatic tubes / pipes

A pipe is a tubular section or hollow cylinder, usually but not necessarily of circular cross section, used mainly to convey substances which can flow liquids and gases, slurries, powders, masses of small solids. It can also be used for structural applications. The tube is often specified by outside diameter or inside diameter and wall thickness.

Coloured polyurethane tubes of 4 mm outside diameter has been used. The tube was cut using tube cutter instead of blunt tools and clean the edge to ensure leak tight joints. It was also ensured that the tube was fully inserted into the fittings.

Plate3.6. Pneumatic tubes

3.3.7 Pneumatic pipe fittings

Pneumatic fittings are parts used to connect sections of pipe, tube and hose in pneumatic or pressurised gas systems. Compared to hydraulic fitting pneumatic fittings are typically characterised by tighter seals and lower pressure requirements. The other features are;

- Attractive design
- Compact size
- Threaded nipples of L, T and Y fittings enable plastic portion to turn by 360 degree
- Bubble tight sealing of tubes
- Suitable for both nylon and PU tubing
- Easy and quick push-in connection of tube and easy removal of tube by simply

pressing of collet cap

- Maintenance free and long life
- The fitment and function of tubes are not affected by vibrations due to positive gripping of the tube by collet.

Plate 3.7. Pneumatic fittings

3.3.8 Timer

Timer is a specialised device used for adjusting specific time interval. Timers are used in pneumatic system when there is a need to delay the air signal coming in or going out of the air component. Depending on the model chosen the air time delay may be adjusted from 0.5 to 60 seconds. The input port is indicated by a yellow dot.

Plate 3.8. Timer

3.3.9 Cutting tool

The material used for the cutting tool was 5 mm mild steel. An array of blades were arranged in circular as well as square shape and was used to slice the potatoes. Blades were typically made from materials that are harder than those they are to be used on. The cutting tool could be replaced according to the shape of the slices required. The piston rod of the cylinder pushes the potatoes against the cutting tool. The speed of the piston, pressure from the compressor and the extending and retracting forces of the piston are the determining factors for the efficient slicing of potatoes. The cutting tool for this pneumatic operated potato slicer was fabricated in workshop of KCAET, Tavanur.

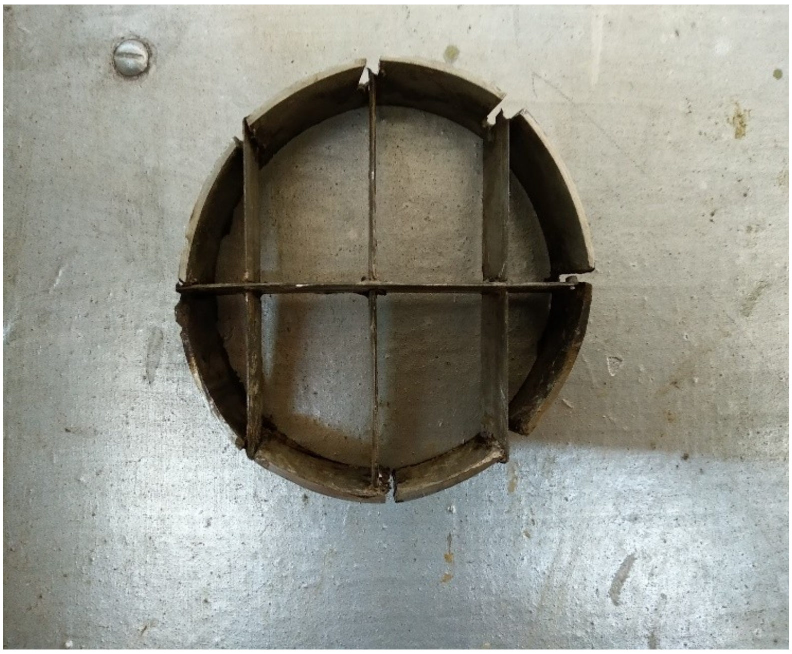


Plate 3.9. Circular cutting blade

Plate 3.10. Square cutting blade

3.4 OPERATIONAL PROCEDURE

The machine works on single phase AC electricity, 220 – 230 V voltage. A pneumatic system is a system that uses compressed air to transmit and control energy. Pneumatic control systems can be designed in the form of pneumatic circuits. A pneumatic circuit is formed by various pneumatic components, such as cylinders, directional control valves, flow control valves, etc. Pneumatic circuits have the following functions:

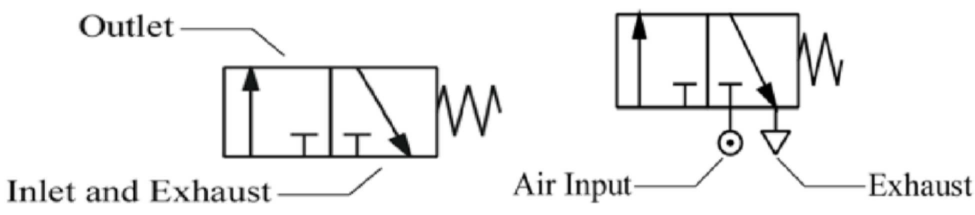
1. To control the injection and release of compressed air in the cylinders.

2. To use one valve to control another valve.

Pneumatic circuit diagram:

A pneumatic circuit diagram uses pneumatic symbols to describe its design. Some basic rules must be followed when drawing pneumatic diagrams.

1. A pneumatic circuit diagram represents the circuit in static form and assumes there is no supply of pressure. The placement of the pneumatic components on the circuit also follows this assumption.
2. The pneumatic symbol of a directional control valve is formed by one or more squares. The inlet and exhaust are drawn underneath the square, while the outlet is drawn on the top. Each function of the valve (the position of the valve) shall be represented by a square. If there are two or more functions, the squares should be arranged horizontally.



3/2 directional control valve 3/2 directional control valve

Fig 3.1

3. Arrows "↓↖" are used to indicate the flow direction of air current. If the external port is not connected to the internal parts, the symbol "┬" is used. The symbol

"⊙" underneath the square represents the air input, while the symbol "▽" represents the exhaust. Fig 2 shows an example of a typical pneumatic valve.

4. The pneumatic symbols of operational components should be drawn on the outside of the squares. They can be divided into two classes: mechanical and manual.
5. Pneumatic operation signal pressure lines should be drawn on one side of the squares, while triangles are used to represent the direction of air flow.

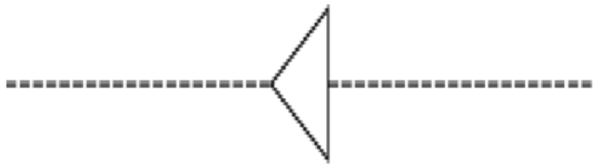


Fig 3.2. Pneumatic operation signal pressure line

Basic principles:

Figure shows some of the basic principles of drawing pneumatic circuit diagrams, the numbers in the diagram correspond to the following points:

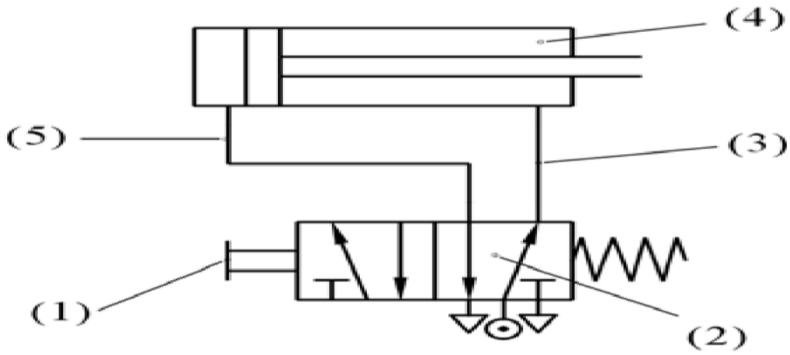


Fig 3.3. Pneumatic circuit

i) When the manual switch is not operated, the spring will restore the valve to its original position.
ii) From the position of the spring, one can deduce that the block is operating. The other block will not operate until the switch is pushed.

iii) Air pressure exists along this line because it is connected to the source of compressed air.
iv) As this cylinder cavity and piston rod are under the influence of pressure, the piston rod is in its restored position.
v) The rear cylinder cavity and this line are connected to the exhaust, where air is released.

The pressurized gas from the compressor is fed to the solenoid valve through the regulator. The regulator adjusts the incoming pressure to the suitable range required for the operation. From the solenoid valve there is a parallel connection to the timer where the time interval for extending and retracting of piston is being adjusted. From the solenoid valve connections are provided to the pneumatic cylinder. At the end of the extended length of piston rod, a cutting tool is fixed, against which the potatoes are being pushed.

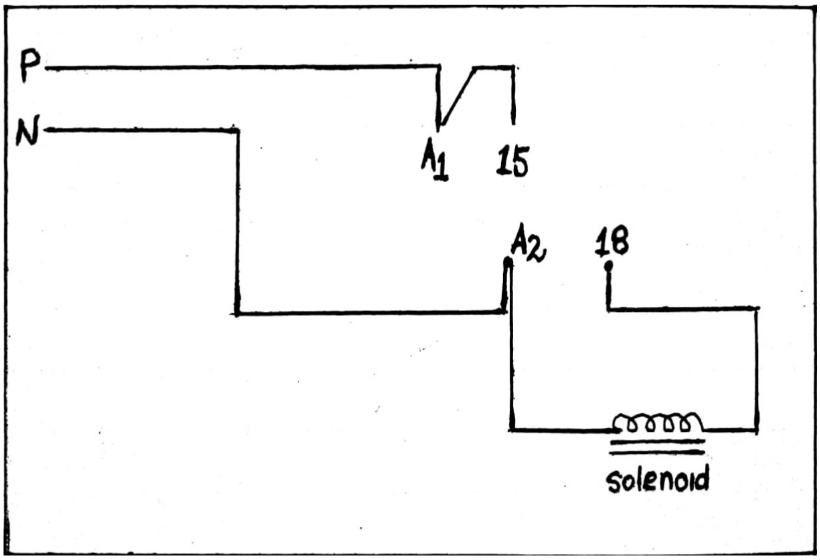


Fig 3.4. Circuit diagram of timer

The connection of the timer to solenoid as well as to the electrical supply should be completed properly as per the figure given above. Even a slight change in the connections may damage the entire system.

3.5 PERFORMANCE EVALUATION OF THE DEVELOPED MACHINE

The connections are completed as shown in the figure given below. Make sure the connections are intact. The machine was fabricated as per the conceptual design and the operational procedure as discussed in the section 3.1. Performance of the machine was evaluated in terms of capacity, power and efficiency.

3.5.1 Power requirement

The power consumption of the developed machine was found using a watt meter. The details of the connection of the watt meter to the machine are shown in the figure 3.6

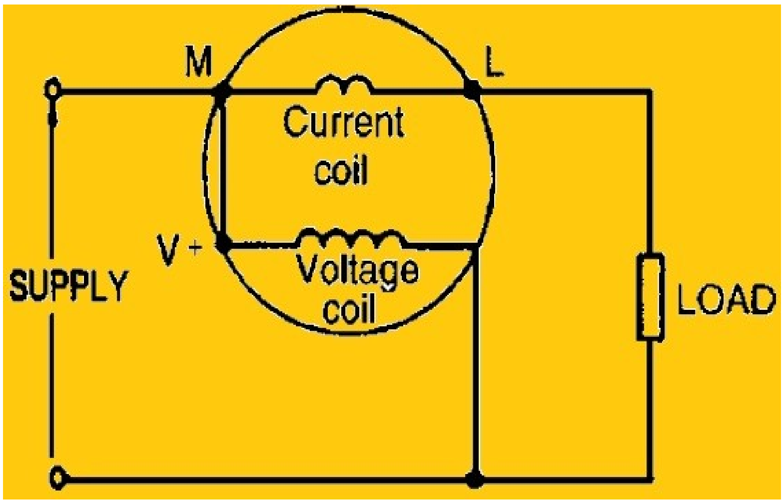


Fig 3.5. Watt meter circuit

The dial shows the readings directly. The machine is connected as the load and the AC input is provided as the supply.

3.5.2 Capacity Measurement

The capacity of the pneumatic slicer is the weight in kilograms of potatoes that can be sliced by the machine in 1 hour. It was found out by noting the weight of potatoes sliced in 60 seconds. Capacity of the machine was found out using the formula given below.

$$\text{Capacity} = \frac{weight\ of\ potato\ slices(kg)}{Time(hr)}$$

3.5.3 Efficiency Measurement

The efficiency of the machine was measured by taking into consideration the attributes of the potato slices. The potato slices were inspected for damages, that is whether there is any broken or non-uniform slices.

The efficiency was calculated using the formulae given below;

$$\text{Efficiency} = \frac{No.\ of\ good\ slices}{Total\ no.\ of\ slices} \times 100$$

Plate 3.11. Front view of pneumatic potato slicer

Plate 3.12. Side view of pneumatic potato slicer

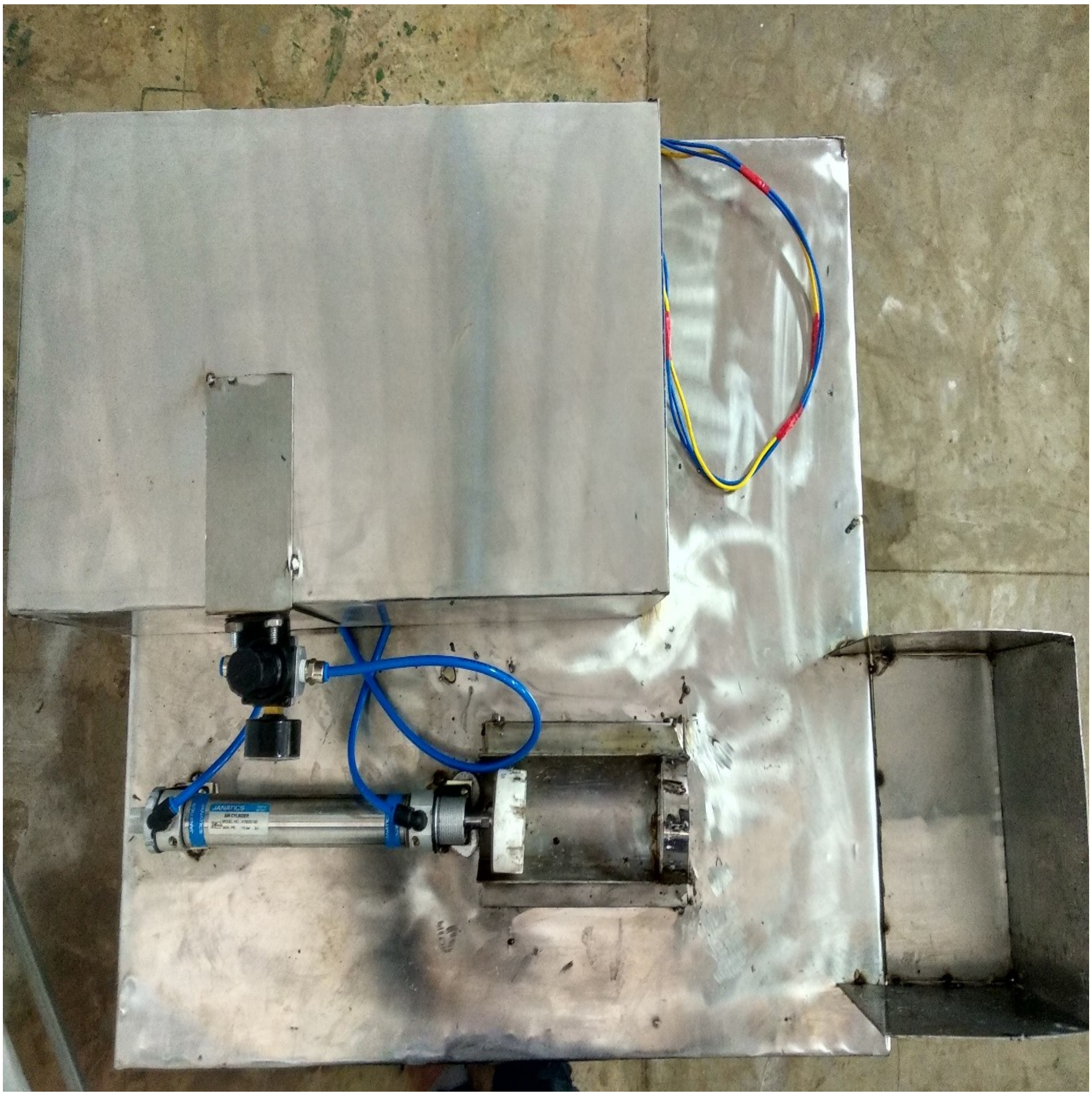


Plate 3.13. Top view of the pneumatic potato slicer

Plate 3.14. Schematic isometric view of pneumatic potato slicer

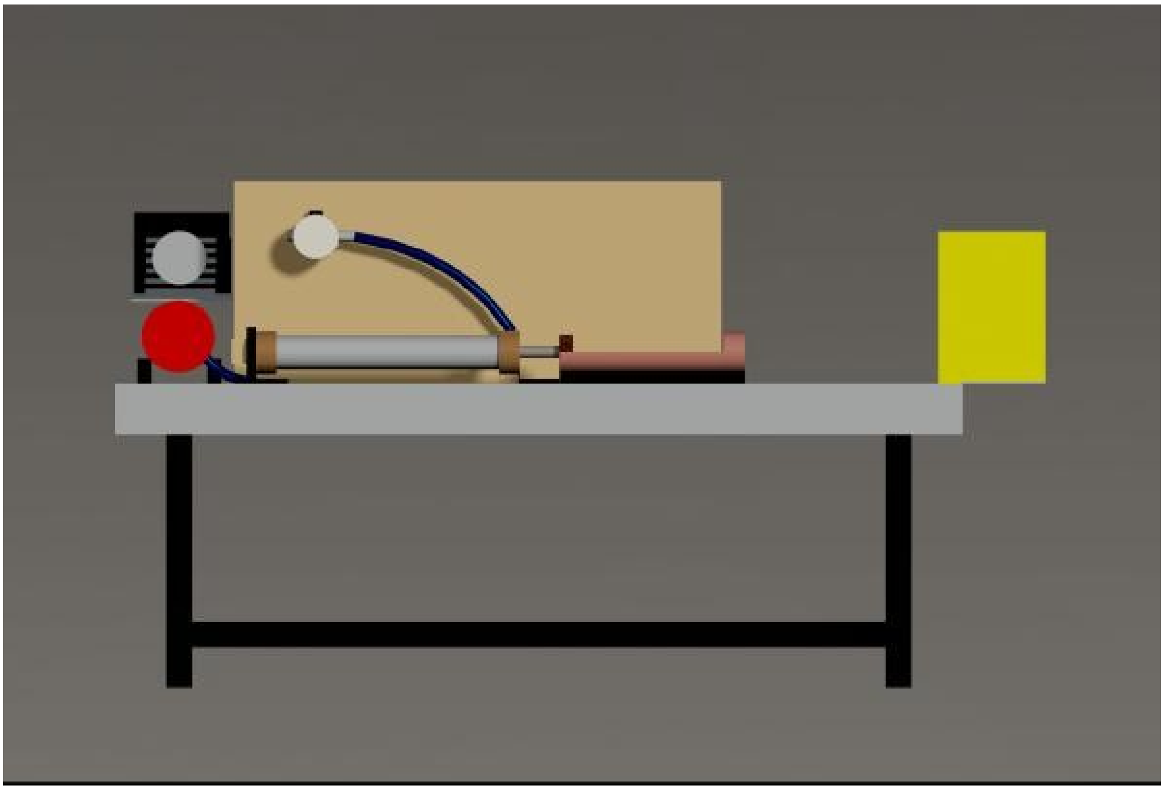


Plate 3.15. Schematic front view of pneumatic potato slicer

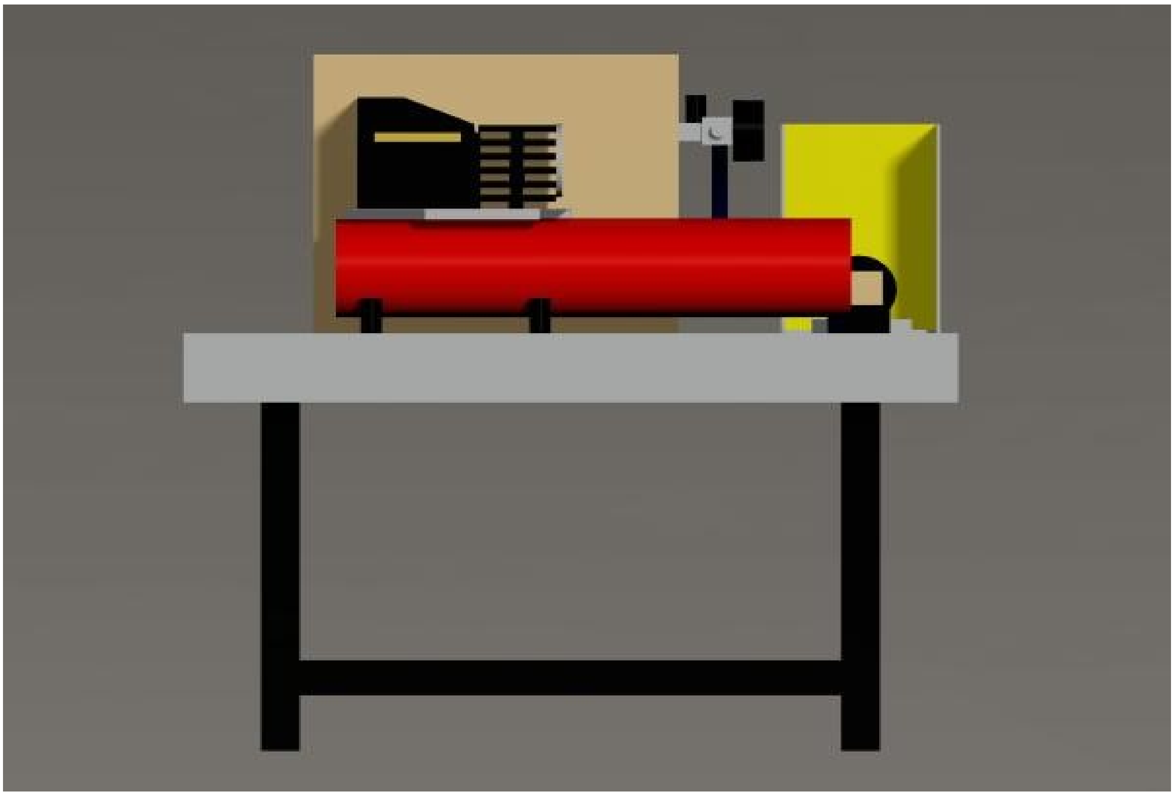


Plate 3.16. Schematic side view of pneumatic potato slice

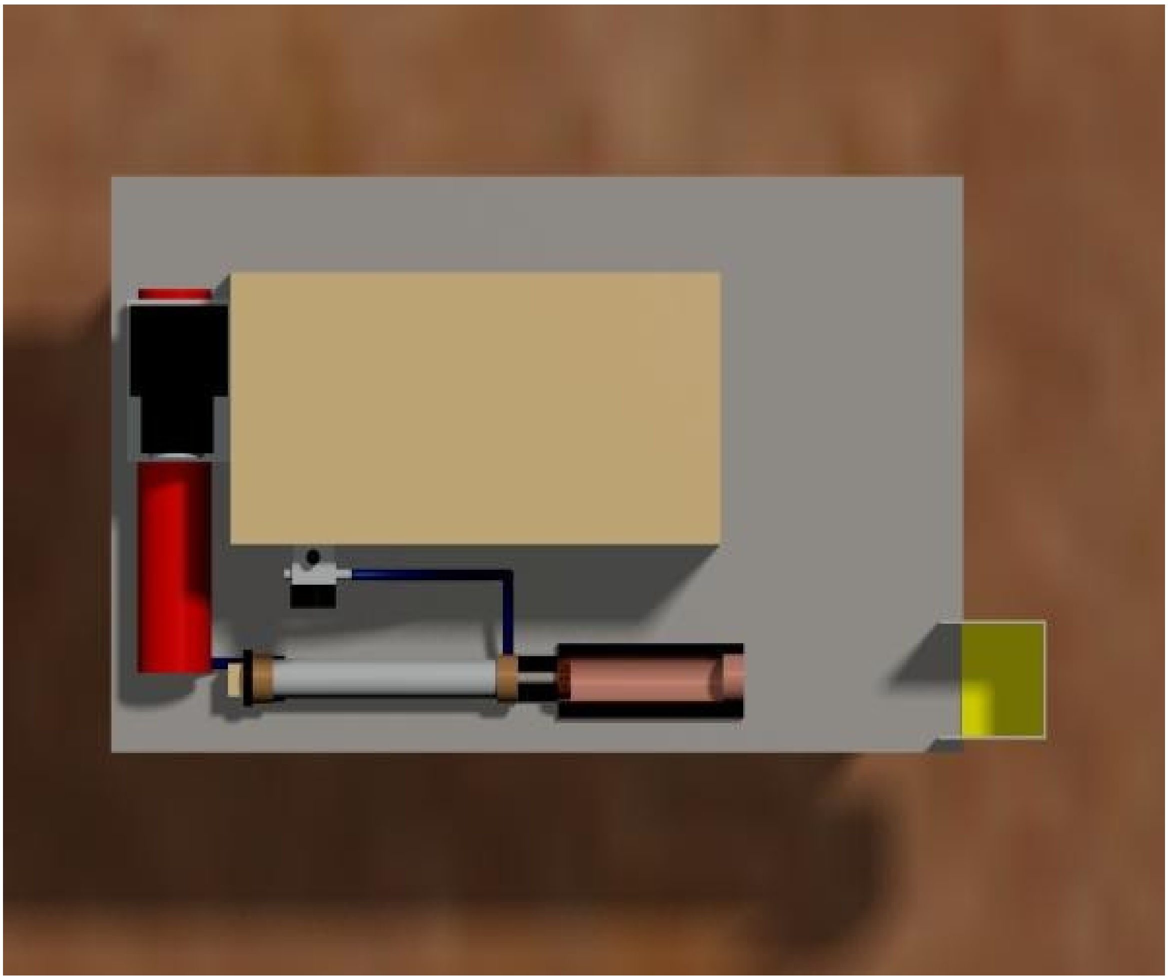


Plate 3.17. Schematic top view of pneumatic potato slicer.

CHAPTER 1V

RESULT AND DISCUSSION

4.1 Selection of potatoes

It was found that the machine worked efficiently for medium sized good quality potatoes with an average weight of 130 gram. If very small sized potatoes were used, it couldn't be pressed against the cutting tool efficiently. Preferred texture for the potato is stiff with very low moisture content.

4.2 Size of the potatoes

Potato having different size and maturity has been collected and its length, breadth and thickness were measured.

Table 4.1. Specifications of the potatoes chosen

Length (mm)	**Breadth (mm)**	**Thickness (mm)**	**Geometric mean diameter (mm)**
75.22	68.98	43.12	60.70
78.50	72.12	47.17	64.39
69.19	60.02	41.05	55.44
80.02	75.10	48.80	66.43

It was found that the average length, breadth and thickness of potatoes are 75.73 mm, 69.05 mm and 45.03 mm respectively. The average geometric mean diameter was calculated as 61.74 mm.

4.3 Cutting force

The cutting force measured using texture analyser was 164.5 N.

4.4 Capacity of the machine

Table 4.2. Capacity of the machine

Weight (g)	Time required (sec)	Capacity (kg/hr)
90	6	54
108.2	6	64.8
95.8	8	43.11
88.71	8	39.91

Machine had a capacity of 50.4 kg per hour provided that there is constant supply of compressed air and electricity without any kind of interruptions.

4.5 Power requirement

The power was found out using a watt meter. It is connected to the machine as mentioned in the above section 3.3.1.

It was found that the average power requirement for the operation of the pneumatic operated potato slicer was 75 W.

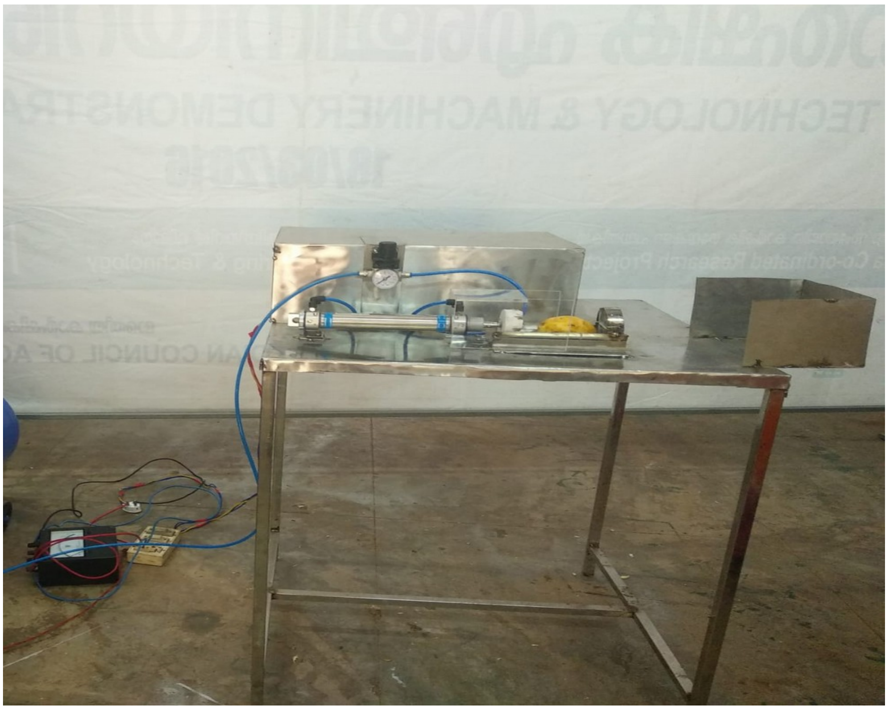


Plate 4.1. Power measurement using watt meter

4.6 Specifications of the Sliced Potatoes

Table 4.3. Specifications of the Sliced Potatoes using square cutting tool

Sample	Average Length	Average Breadth	Average Thickness

1	79 mm	15 mm	8 mm
2	63 mm	12 mm	6 mm
3	58 mm	14 mm	6 mm
4	52 mm	13 mm	5 mm

Plate 4.2. Potato slices cut using square cutting tool

Table 4.4. Specifications of the Sliced Potatoes using circular cutting tool

Sample	Average Length	Average Breadth	Average Thickness
1	85 mm	33 mm	17 mm
2	72 mm	28 mm	15 mm
3	69 mm	30 mm	14 mm
4	65 mm	26 mm	12 mm

The dimensions of the potato slices obtained using two different cutting tools is shown in table 4.1 and 4.2. The result indicated that the slices obtained from square cutting tool was more thin and uniform compared to the pieces obtained from the circular cutting tool . It may be because more number of blades will be in contact with surface of the potatoes when square cutting tool was used. Nevertheless, slices obtained using both the tools were satisfactory. The machine save considerable amount of time and energy.

Plate 4.3. Potato slices cut using circular cutting tool

4.6 Pressure of the compressed air

The machine worked efficiently at a pressure of 3 – 4 bars (3×10^5- 5×10^5 Pa) and about 3 seconds time interval with an average extending and retracting length of piston rod as 600 mm and 500 mm respectively. The time interval could be reduced as per convenience. A time interval of less than 3 seconds is usually not preferred as it interferes with the feeding of potatoes.

4.7. Efficiency

Table 4.5. Efficiency using Square cutting tool

Weight of slices (g)	Weight of damaged slices (g)	Efficiency (%)
92.88	2.9	96.37
105.65	3.8	96.4
118.20	6.03	94.88

Efficiency when square cutting tool was used is 96.05 %.

Table 4.6. Efficiency using Circular cutting tool

Weight of slices(g)	Weight of damaged slices (g)	Efficiency (%)
110.21	8.10	92.65
130.05	11.71	90.99
95.2	4.5	95.27

Efficiency when circular cutting tool was used is 92.9 % .

4.8 Analysis of the Slices obtained

The potato slices recovered had remarkably perfect dimensions with negligible damage. Moreover there is a provision to replace the cutting tool according to the necessities. It was found to be a very effective method to get potato slices of desired shape and size in very less time with least damages.

SCOPE OF FUTURE MODIFICATION

- A peeling unit could also be incorporated.
- A more convenient mechanism for feeding, synchronising with the movement of cylinders could be developed.
- There should be a provision to replace the cutting tools for getting the desired shape and size.
- A fully automatic system with proper conveyance, peeling, feeding, slicing and collecting could be developed.

5. SUMMARY AND CONCLUSIONS

Tuber crops are the major crops contributing significantly to human and animal food.Potato (Solanum tuberosum) is a starchy, tuberous perenial crop which is world's fourth largest food crop. Potatoes yield abundantly with little effort, and adapt readily to diverse climates as long as the climate is cool and moist enough for the plants to gather sufficient water from the soil to form the starchy tubers.

Pneumatic is a branch of engineering that makes use of gas or pressurized gas. Pneumatic systems used in industry are commonly powered by compressed air or compressed inert gases. A centrally located and electrically powered compressor powers cylinders, air motors, and other pneumatic devices.

The traditional method of potato slicing practised by the farmers is done by placing the potato tubers on a chopping board and cut with a sharp knife through desired thickness estimated by their eyes only which was injurious, laborious, and producing non uniform slices. Due to uneven thickness of slices arising from improper tools, a lot of wastage of vegetables occured leading to less productivity.

There are a number of mechanical slicers available for different fruits and vegetables. The slices thus obtained are of non-uniform thickness and the process is too tedious. To compensate for the drawbacks of mechanical slicers, the use of pneumatic system for slicing was put forward.

The pneumatic potato slicer consists of a frame assembly, pneumatic cylinder, air compressor, regulator, solenoid valve, timer, cutting tool and pneumatic pipe and other fittings. The pressurized gas from the compressor is fed to the solenoid valve through the regulator. The regulator adjusts the incoming pressure to the suitable range required for the operation. From the solenoid valve there is a parallel connection to the timer where the time interval for the extending and retracting of piston is being adjusted. From the solenoid valve connections are provided to the pneumatic cylinder. At the end of the extending length of piston rod, a cutting tool is fixed, against which the potatoes are being pushed. The potatoes are being pushed with the help of a circular nylon piece attached to the end of the piston so that it does not smash the potatoes.

The cutting tool used may be of any shape according to our requirements. The pneumatic slicer used square as well as circular shaped cutting tools. The speed of the piston, pressure from the compressor and the extending and retracting forces of the piston are the determining factors for the efficient slicing of potatoes.

A pressure of 3-4 bars where needed for the working of the slicer. The pneumatic operated potato slicer proved to be a great success working with a higher efficiency of 93 %. The power requirement was found to be 450 W. The developed slicer had a capacity of slicing 600 potatoes per hour with a constant supply of air and electricity.

The slices produced were having uniform thickness with an even and smooth surface characteristics. The potato slices had good texture when compared to that of the slices produced from manually or mechanically operated slicing machines.

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APPENDIX I

COST ESTIMATION

Initial Cost (C)

Fabrication cost of Pneumatic Operated Potato Slicer

Including cost of materials = Rs. 18500/-

Average life of machine = 10 years

Working hours per year = 3650

Salvage value = 10 % of initial cost

A) FIXED COST

1. Depreciation

$$= \frac{C-S}{LH}$$

$$= \frac{18500-1850}{10 \times 3650}$$

= 0.456

2. Interest on investment @ 12 %

$$= \frac{(C+S) \times 12}{2 \times H \times 100}$$

$$= \frac{(18500+1850) \times 12}{2 \times 3650 \times 100}$$

= 0.334

Total Fixed Cost = 0.79

B) Variable cost

1. Labour wage = Rs 600 / day of 8 hr
2. Cost of electrical energy

   Unit cost of electricity = Rs 7.5 kwh

   Energy consumption of machine = 0.2

   Cost of electricity = 1.5/ h

3. Repair and maintenance cost

   @ 10 % of initial cost p.a.

$$= \frac{18500 \times 10}{3650 \times 100}$$

= 0.506

Total variable cost = 77.006/h

Total operating cost = 77.796

ABSTRACT

A simple, semi-automatic pneumatic operated potato slicer which is easy to operate and maintain was fabricated. The slicer was found to have a capacity of 50.4 kg/hr with a power requirement of 75 W. The machine worked efficiently at a pressure of 3 – 4 bars. For a wider range of applications, cylinder models capable of withstanding further high pressure of compressed air are available. Cutting tool patterns could be changed based on the requirement. It was observed that uniform slices with least damages were obtained. The capacity could be varied by adjusting the time interval of movement of the piston using the time switch delay mechanism.