

Development of a Meat Slicing Machine Using Locally Sourced Materials

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ABSTRACT

In an attempt to facilitate the processing of meat which is a daily nutritional food requirement of man, a meat slicing machine has been developed. The machine consists of a cutting blade, a meat feeder, a meat tray, a meat clamp, the crank mechanism and a control unit. The machine was designed to enhance the hygienic slicing of meat for both domestic and commercial consumption and it can accommodate from one to six cutting blades which are spaced 6.5mm from each other to give a meat slice thickness of 5mm per slice. It takes an average of 4 seconds to cut a slice and one hour for 2.673 tonnes.

Keywords: *Meat Slicing, Slicing Machine, Hygienic Slices, Slice Thickness.*

1. INTRODUCTION

Meat is the flesh of animals consumed for food and it is a very important food delicacy that has been eaten since the existence of man. The consumption of meat along with other basic food is very important as it enriches both the nutritional content of the food and also acts as important delicacies. It is a nutritious food containing some quantities of essential amino acids, in the form of proteins and also contains group of vitamins. Animal meat is composed of muscles, bones, fats and connective tissues, and the main edible and nutritional part of the meat is the muscle or lean meat [1]. Therefore the meat has to be cut into large chunks, and then into bits and pieces so as to bring out the flavour and make it in edible form.

Meat is cut using various sharp instruments such as matches, knives and meat saw. These implements are only efficient in cutting the meat into chunks and de-boning but cannot cut the meat into small bits and as a result of this, different machines have been developed over time for slicing meat [2]. The principles of slicing machine is based on the action of shearing by blades and other types of cutters with same principles as the slicing which include the impact-type cutter, the mower cutter bar and the knife drive system.

A number of authors have studied the principles of slicing and slicing machines. Otto Rohwedder designed and manufactured the first slicing machine that would slice and wrap bread in 1925 [3]. The first meat slicing machine was invented by an American in 1873. 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 [4]. 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 [5]. There are basically

three types of slicer; the gravity slicer, the horizontal slicer, and the bacon slicer and these three groups of slicer have their own shortcoming. The slicing machine for slicing food, such as meat, cheese, sausage and vegetable consists of a conveying device, a rotating blade and a knocking-off mechanism for transferring the slices from the conveying device to deposit area. [6] studied a vegetable slicing machine and divided the operations into four stages, consisting of material intake, material transmission, material slicing and material ejection. He also stated that the vegetable slicing machine mechanism is simply the action of shearing by the blades just like that of meat slicing machine.

2. PARTS AND OPERATION OF MACHINE

The developed meat slicing machine was designed to slice meat in frozen form. It can accommodate one or more cutting blades as required by the user. Fig. 1 shows the assembly of the meat slicing machine which works on the principle of a normal slicing machine. It is made up of a frame on which are mounted, electric motor, the tray carriage, the meat feeder, the meat clamp, the slide way which carries the slider in which a set of cutting blades are arranged. The cutting blades are spaced 6.5mm from each other to give a meat slice thickness of 5mm. Fig. 2 shows the cutting blades arrangement and the cross – section of the meat hopper.

The machine is designed to produce smooth and hygienic slices with a total mass of about 3.125 tonnes in one hour. This machine slicing capacity is anticipated with the assumption that the meat being sliced is boneless and in frozen form. It consists of the following main components; the rotating disc cutter, the tray-carriage, the meat feeder, the meat clamp and the control unit

2.1 THE ROTATING DISC CUTTER

The rotating disc cutter is a flat disc made of stainless steel material. It is 240mm in outside diameter with a bore of 15mm diameter and is coupled to an AC electric motor. The blade rotates at a speed of 1200 revolutions per minute and it is shown in Fig. 3.

2.2 THE TRAY – CARRIAGE

The tray - carriage is the component that carries the meat to be sliced to the slicing point. It consists of a framed part

known as tray carriage made of stainless steel that is used to carry and move the meat towards the blade for slicing. It exhibits a reciprocating to and fro motion towards the blade for cutting to take place and this is shown in Fig. 4.

2.3 MEAT TRAY

The meat tray is the basin which collects the sliced pieces of meat during the slicing operation. It is made of stainless steel to avoid corrosion and contamination of the sliced meat. The meat tray is shown in Fig. 5.

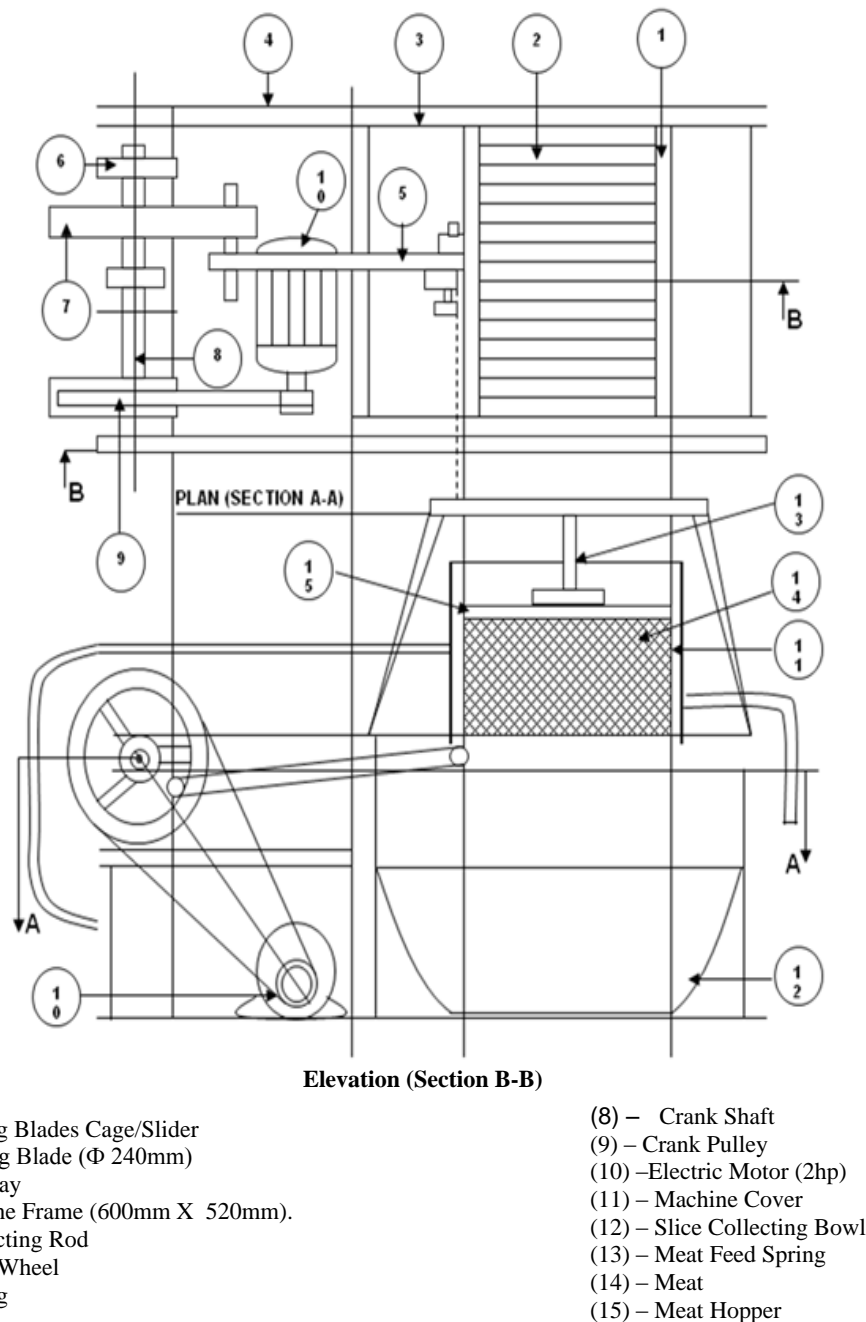


Figure 1. Plan and front view of the meat slicing machine.

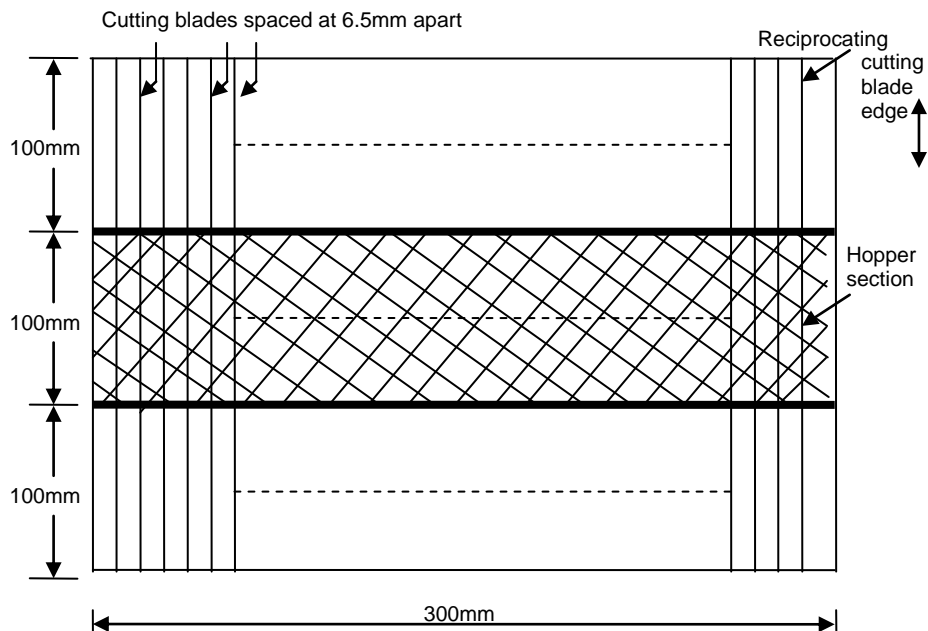


Figure 2. Cutting blades arrangement and cross – section of meat hopper

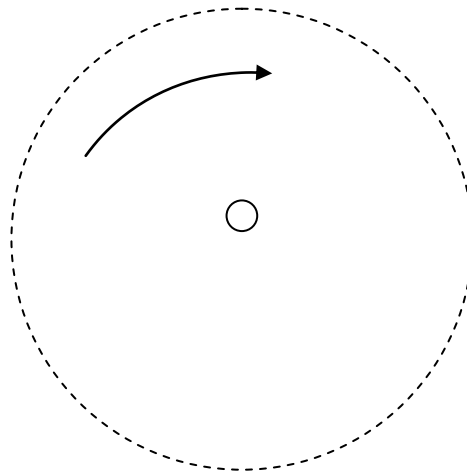


Figure 3. Cutting blade

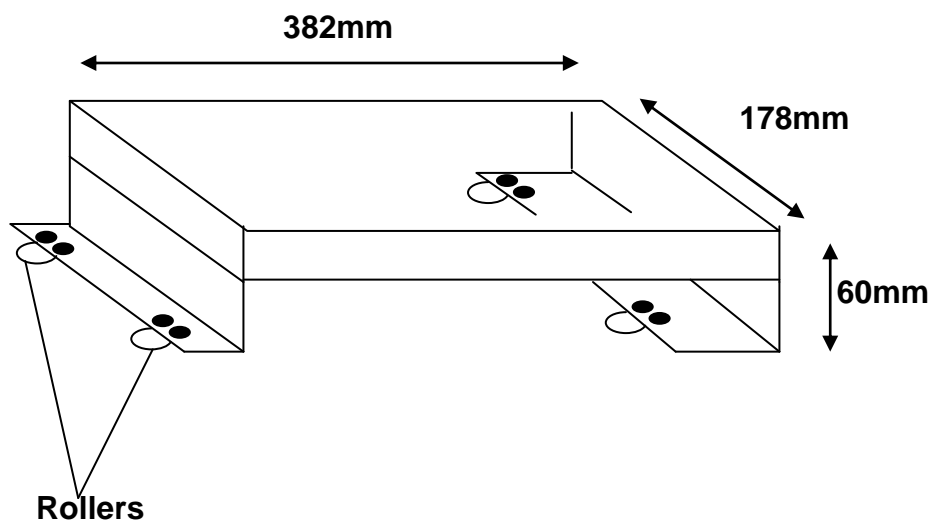


Figure 4. Tray – carriage

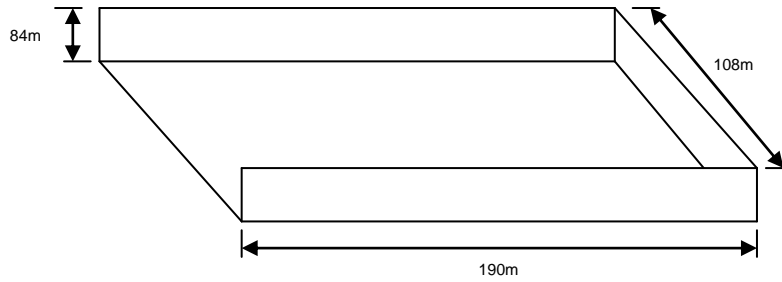


Figure 5. Meat tray.

2.4 Meat Feeder

The meat feeder feeds the meat to be sliced towards the blade by pushing the meat out of the tray towards the blade. The meat feeder consists of a pusher and threaded screw length as shown in Fig. 6.

2.5 Meat Clamp

The meat clamp is a device that holds the meat to be cut in place. As the meat is fed out by the meat feeder, the clamp is activated to hold and clamp the meat in position for slicing. This is shown on the assembly of meat feeder, meat clamp and tray carriage in Fig. 7.

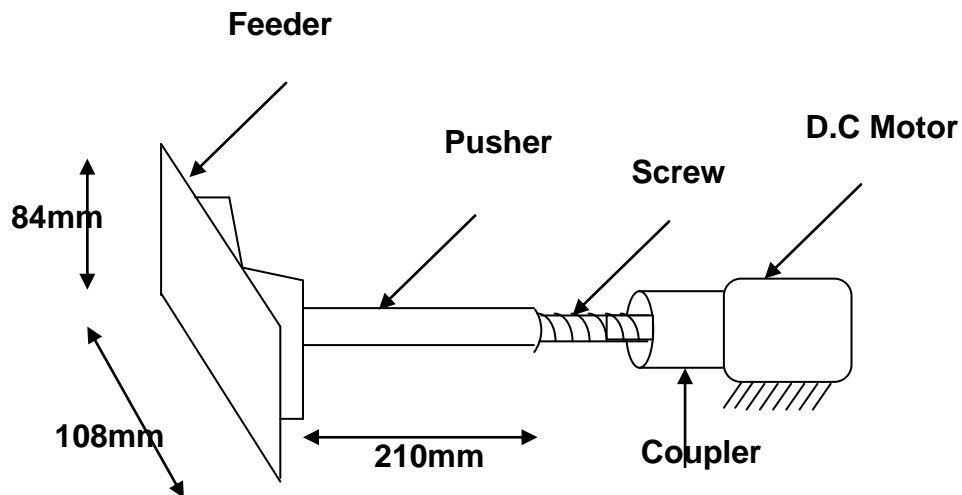


Figure 6. Meat feeder

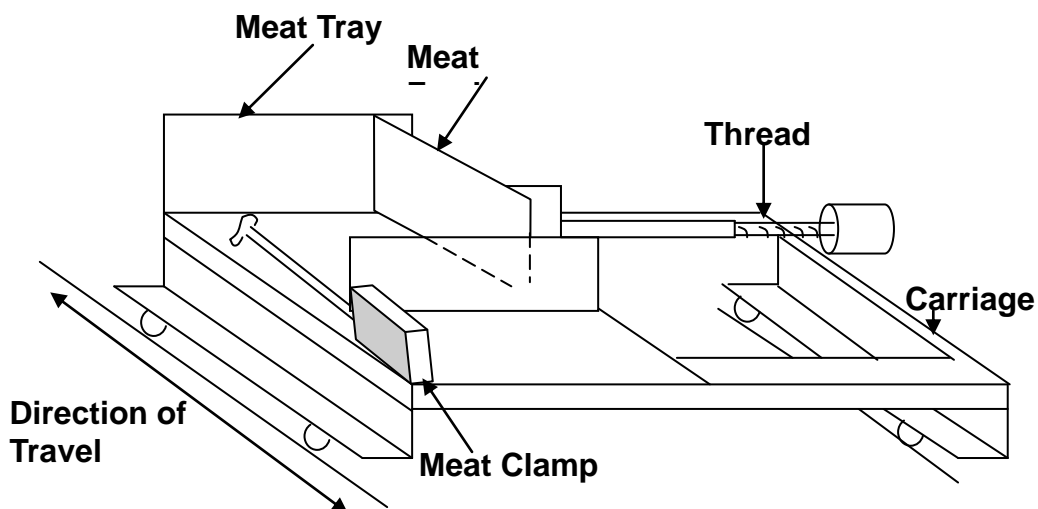


Figure 7. Assembly of meat feeder, meat clamp and tray on the carriage

2.6 Operation of the Machine

The meat to be sliced is loaded on the tray placed on the tray-carriage which moves the tray with the meat towards the blade for cutting. The meat feeder then moves the meat through a pre-set distance before the meat clamp is activated to hold the meat in position for cutting. When the power source is switched on, the cutting blade begins to rotate while the required size of the meat to be cut is selected for the slicing. The meat feeder then feeds the selected size of the meat towards the cutter and stops automatically

A signal is then set to the meat clamp to hold the meat to be sliced and the tray mechanism moves quickly to the rotating blade which then cuts the meat into the pre-set slice sizes. After that the tray returns to its original position and as it stops, another signal is set to the meat clamp to release the meat by pushing it towards the blade. It takes on the average about 4 seconds to cut a slice. The process continues until the whole meat is completely cut into the required slices.

3. DESIGN ANALYSIS

3.1 Power Required for Slicing Operation

In cutting processes, the power required for slicing is [7],

$$P_m = P_e \eta_m \quad (1)$$

$$\text{or } P_m = P_s Z_w \quad (2)$$

$$\text{while } Z_w = f_a a_c v \quad (3)$$

where P_m = cutting power.

P_e = electric motor rating,

η_m = overall drive system efficiency,

P_s = specific cutting energy

Z_w = material removal rate,

f_a = feed per stroke of cutter,

a_c = undeformed meat thickness,

v = cutting speed.

3.2 Cutting Speed

The cutting speed required for slicing is given by,

$$V = \frac{\pi D n}{60} \quad (4)$$

Where V = cutting speed of blade,

n = rotational speed of blade (rpm),

D = cutter diameter.

The speed of cutter is obtained from equation (4) as,

$$n = \frac{60V}{\pi D} \quad (5)$$

3.3 Crank Mechanism of the Tray-Carriage

Fig. 6 shows the crank mechanism which produces the reciprocating motion of tray-carriage that carries the meat and moves to and fro relative to the disc cutter. The displacement, velocity and acceleration of the slider are now evaluated.

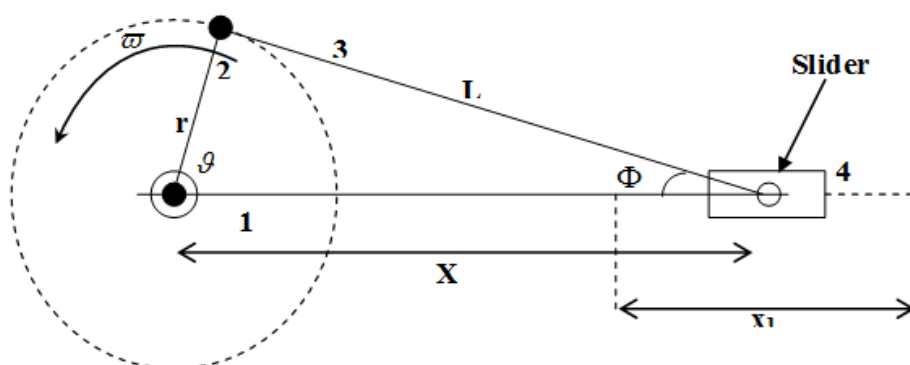


Figure 6. Crank Mechanism for the Tray Carriage

$$x = R(1 - \cos \theta) + \frac{R^2}{2l} \sin^2 \theta \quad (6)$$

$$a = \frac{d^2 x}{dt^2} = R\omega^2 \left(\cos \theta + \frac{R}{l} \cos 2\theta \right) \quad (8)$$

$$v = \frac{dx}{dt} = R\omega \left(\sin \theta + \frac{R}{2l} \sin 2\theta \right) \quad (7)$$

Where

x = distance moved from maximum end of dead centre,

v = velocity,
 a = acceleration
 l = length of connecting rod,
 R = crank length,
 ω = angular velocity of the crank,
 θ = crank angle,
 ϕ = connecting rod angle.

$$\begin{aligned} M_m &= V_m \times \rho_m \\ &= 40.5 \text{ cm}^3 \times 1100 \text{ g/cm}^3, \\ &= 44550 \text{ g} \\ &= 44.55 \text{ kg per minute.} \end{aligned}$$

The mass of meat sliced in one hour,

$$\begin{aligned} M_m &= 44.5 \times 60 \text{ kg.} \\ &= 2673 \text{ kg or 2.673 tonnes.} \end{aligned}$$

3.4 Turning Moment and Axial Load on Meat Feeder

The turning moment and axial load on the meat feeder is obtained from the relationship,

$$T = w \left[r_m \left(\frac{\tan \alpha + \frac{f}{\cos \theta}}{1 - f \frac{\tan \theta}{\cos \theta}} \right) + f_c r_c \right] \quad (9)$$

Where

T = torque applied to turn the meat feeder,
 w = load parallel to screw axis,
 r_m = mean thread radius,
 r_c = effective radius of rubbing surface,
 f = coefficient of friction at collar,
 α = helix angle at mean radius,
 θ = angle between tangent to tooth profile and a radial line.

4. THE THROUGHPUT OF THE MACHINE

The machine capacity is determined from the mass of the sliced meat per unit time. From the performance of the machine, the time taken for the carriage to move to and from the blade is 4 seconds and the thickness of each slice is 5mm, while the length of the slice is 108mm. Thus the cross – section of the meat sliced by the blade is

$$A_m = 10.8 \times 0.5 \text{ cm}^2 = 5.4 \text{ cm}^2$$

The stroking rate of the to and from the blade is $S_f = 15$ strokes per minute,

The feed rate of cutting the meat is $f_m = 0.5 \text{ cm /stroke}$.

Therefore, the height of meat cut in one minute is $H_m = S_f \times f_m = 7.5 \text{ cm}$.

Thus, volume of meat sliced in one minute is

$$V_m = A_m \times H_m = 40.5 \text{ cm}^3$$

The density of meat (at 75 percent moisture content), $\rho_m = 1100 \text{ g/cm}^3$.

Thus, the mass of the meat cut per minute,

5. CONCLUSION

Over the year, the traditional process of slicing meat has always been slow, tedious, boring, time consuming and in some cases unhygienic. The possibility of mechanizing the process of meat slicing becomes very necessary. A meat slicing machine was therefore designed to mechanize the process of slicing meat for both domestic and commercial consumption.

The manufacture of the meat slicing machine involves the design and fabrication of some principal components which include the tray-carriage, the disc cutter, the meat feeder, the meat clamp and the control unit. Each part was carefully designed to meet the functional requirement of the machine, and different sizes of slices are obtainable by activating the meat feeder to give the desired sizes of sliced meat. The efficiency of the machine is quite encouraging as very smooth and hygienic slices are obtained and it takes on the average, about 4 seconds to cut a slice, while the mass of meat sliced in one hour is about 2.673 tonnes.

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