DESIGN AND IMPLEMENTATION OF A BREAD SLICING MACHINE

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Abstract: The need for a bread slicing machine that is cheap, affordable, and efficient for both domestic and industrial applications cannot be overemphasized. The ease of cutting for the bread slicing machine designed and the little amount of bread crumb produced after the entire slicing process shows its uniqueness as compared to other available brands in the market. The blades were able to slice loaves measuring (289 x 102 x 102 mm) into 20 equal parts and produced about 0.02 grams of crumbs. The developed machine is fast, efficient, hygienic, safe, and easy to maintain.

Keywords: Bread, cutting, design, development, slicing

Introduction

Bread is a staple food that is usually baked from a dough of flour and water. Bread is an excellent source of carbohydrate, and there is a recommended amount of carbohydrate the body requires as a source of energy for the brain to function and for other physiologic purposes in human life. Bread contributes about 35% carbohydrate and 17.8% protein to the body. It also contains vitamin B, and some minerals with an appreciable amount of Amino acids (Edwards, 2007; Kilcast, 2004; Whitely, 2006). In Nigeria, bread has become extremely popular and widely eaten food in most homes today, because it is cheap and readily available. Breads are of different types; however, in most countries and especially in Nigeria, the yeast bread is the most common type of baked bread available (Abraham, n.d.).

The first automatically sliced commercial loaves were produced on 6th July 1928, in Chillicothe, Missouri, USA using a machine invented by Otto Rohwedder, an Iowa-born, Missouri-based jeweler. Rohwedder's desire to make the idea of sliced bread a reality was faced with challenges. Fire destroyed his prototype and blueprints in 1917. He was also faced with skepticism from bakers, who thought factory-sliced loaves would quickly go stale or fall apart. In 1928, Rohwedder rebuilt a "power-driven, multi-bladed" bread slicer which was put into service at his friend, Frank Bench's Chillicothe Baking Company (Nix, 2018).

Figures 1 – 4 showed some examples of the improved bread slicing machines available for both domestic and commercial purposes as compared to the earlier slicers produced.

Fig. 1: Benchtype bread slicer

Fig. 2: Industrial bread slicer

Fig. 3: Freestanding bread slicer

Fig. 4: Self-service bread slicer

Bread slicing machine makes it easier to slice bread without going through much stress (Oladejo *et al.*, 2016). Bread slicing machine helps to prevent wastage; it allows for even shearing, packaging, convenience and increase market value for the sliced bread (Oladejo *et al*., 2016). The machine uses the power hacksaw principle of reciprocating motion to achieve its cut. The reciprocating motion of the cutting tool (blade) is made possible by the aid of a rotary pulley powered by a motor. The blades are arranged vertically and reciprocate in a linear motion, and the cuts are achieved by the gravitational feed of the bread in the machine. The cutting technique involves the cutting tool sliding forward and backward along with the bread until the cut is achieved, and the cutting is done on the forward stroke.

Several researchers have studied the principles of slicing and slicing mechanisms. They have made an appreciable improvement over the years with a desire to produce a simple, efficient, functional, and more reliable bread slicing machine.

Several approaches have been made in the past to produce a simple, efficient and reliable bread slicing machine with varying degree of success. Oladejo *et al*. (2016) designed a bread slicing machine with adjustable guides to enhance loaf alignment but encountered such problems as noise, vibration, and high production cost in his attempt to produce a more efficient machine. Various models of slicing machines were developed and which were operated both manually and electrically and utilizes power screws to feed the bread loaves towards the reciprocating blade (Adejugbe *et al.*, 2012; Odior, 2008; Odior, 2012; Oladejo *et al*., 2016; Salaudeen & Awagu, 2012). The slicing machines so developed had some challenges and more prominent was the high cost of production.

In low, medium income countries (LMIC) such as Nigeria; the ownership of a bread slicing machine is a luxury, as it is an expensive machine to acquire for both domestic and commercial purposes.

Therefore, there is need to design and develop an efficient and less expensive bread slicing machine that is affordable and easy to maintain when compared to the already available machines in the market.

Materials and Methods

Design analysis and material selection

The Bread Slicing Machine designed and developed consists primarily of the following key components:

i. A prime mover (Electric Motor) which supplies the power required to drive the pulley and belt system.
ii. The belt drive that transmits power from the electric motor to the shaft.
iii. The bearing which supports and hold the shaft axis line, reduce force dissipation on the shaft due to their low friction coefficient and prevent radial movement of shaft and
iv. The link that transmits rotational motion of the shaft into reciprocating motion of the slider (slider-crank mechanism)

Design calculations

The bread slicing machine was designed in details and the key design parameters tabulated in Table 1; while the mild steel shaft specification for the machine is shown in Table 2.

Table 1: Determination of critical design parameters of the bread slicing machine

Parameter	Mathematical Formulation	Value
The power required (P)	The power required (P) = Torque (T) x angular velocity (ω) $P = T\omega$ (Bhandari, 2016)	751 W
Shaft diameter	$D = \sqrt[3]{\frac{16T}{\pi\tau}}$ (Bhandari, 2016)	28.608 mm
Effective belt length	$K = 4L_p - 6.28\,(D_2 + D_1)$ **where** L_p= belt pitch effective length, therefore, $L_p = \frac{k+6.28(D_2+D_1)}{4}$	L_p = 0.664 m or 664 mm A standard length of 710 mm 13 c belt was adopted from the manufacturer's catalogue (“Transmission Belts - Belt Drives,” n.d.).
Mass of the pulleys	Dimension of $P_1 = 165x20\ mm, P_2 = 54x20\ mm,\ density = 2705$ $V_1 = \pi(0.0825)^2 0.02 = 0.0004278\ m^3$ $V_2 = \pi(0.027)^2 0.02 = 0.000458\ m^3$ Volume of pulleys = $V_1 + V_2 = 0.00008858\ m^3$ Mass of pulleys = $\frac{0.00008858 m^3 x 2705 kg}{m^3} = 0.2398\ Kg$	0.2398 Kg
Center distance between the motor and machine pulley	The Center distance (C) = $\frac{k+\sqrt{k^2-32(D-d)^2}}{16}$ Where D = pitch diameter of machine pulley, d = pitch diameter of motor diameter and k = service factor Given that D = 0.15 m, d = 0.05 m and k = 1.4 (Khurmi, 2005)	Center distance between pulleys is 168 mm
Angle of Lap	$\theta = 180 - \frac{60\,(D_2+D_1)}{C}$ **where** D_1 is the motor pulley pitch diameter, D_2 is the machine pulley pitch diameter, C is the Center distance between pulleys	2.975 rad
The cutting time analysis	Time for one stroke, t = $\frac{L}{NF}$ **Where** *L = Length of stroke (mm)* *N = revolution of the driven pulley (rev/min).* *F= feed* Length of stroke = 103 mm Feed per stock = 2 mm Bread thickness = 102 mm Number of the stroke to cut the bread = $\frac{102mm}{2mm}$ = 51	The time required to cut the bread of 102 mm thick = 5.05s
Bread cutting strokes	The cutting speed of the slicing machine was determined by the application of the standard bread dimension*(given as x 102 x 102 mm)* and assuming that the saw feed per stroke = 2 mm Therefore, the number of strokes that would successively cut the bread through is = $\frac{bread\ dimension}{feed\ per\ stroke}$	26 strokes

Table 2: Mild steel shaft specification for the machine

Parameter	Value
Young's modulus (E),	2.76 kN/m^2
Density (ρ)	7846 kg/m^3
Modulus of rigidity (G)	7.9 kN/m^2
Tensile strength (τ)	480 N/mm^2
Factor of Safety	5
Allowable stress (without keyways)	96 N/mm^2
Allowable stress (with keyways)	72 N/mm^2

Detailed CAD model and assembly drawing of the bread slicing machine

The detailed Computer Aided Design of the Bread Slicing Machine developed from SolidWorks is shown in Figs. 5 – 20.

Fig. 5: Blade assembly

Fig. 6: Blade frame support

Fig. 7: Blade tensioning member

Fig. 8: Blade tensioning nut

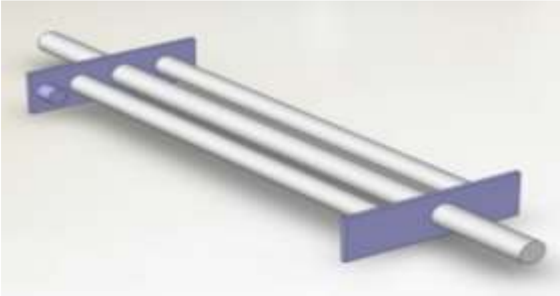

Fig. 9: Brackets assembly

Fig. 10: Cutting blade

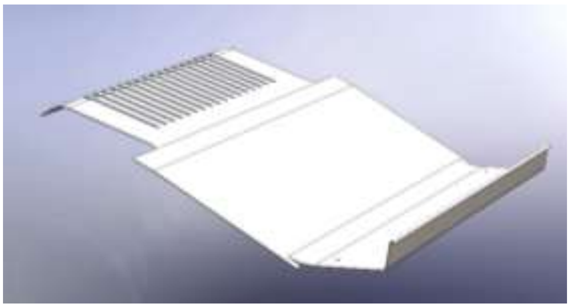

Fig. 11: Exit tray

Fig. 12: Feeder tray

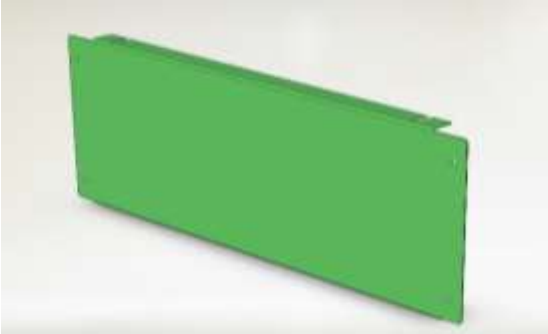

Fig. 13: Front plate

Fig. 14: Rear plate

Fig. 15: The main frame

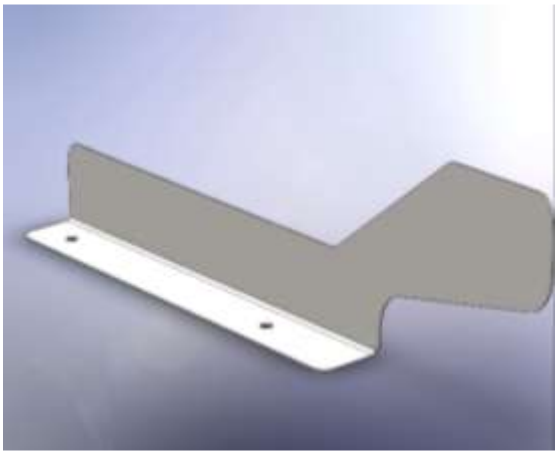

Fig. 16: Guide plate

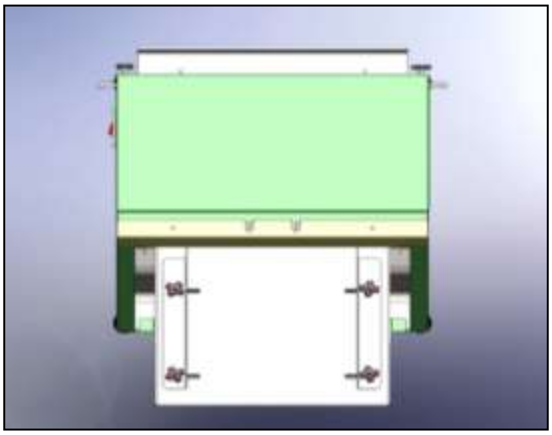

Fig. 17: Top view of the bread slicing machine

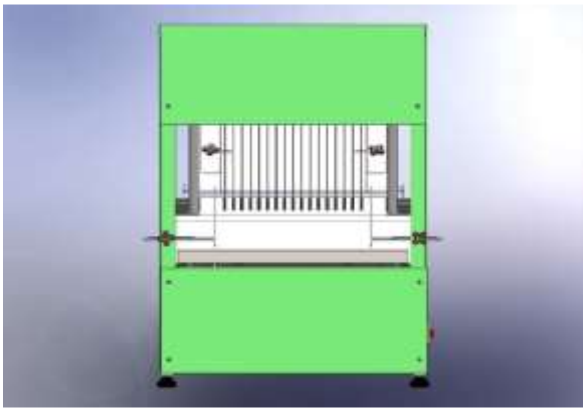

Fig. 18: Back view of the bread slicing machine

Materials selection and description

Operational principle (slider-crank mechanism)

The designed bread slicing machine, as shown in Fig. 21, has a slider-crank mechanism connected to the electric motor. The slider-crank results in the reciprocating motion of the blades as the electric motor is activated. The blades are arranged vertically and mounted correctly on the blade frame. The cuts are achieved on the forward stroke as the bread is fed gravitationally on a 60-degree base plate.

Frame

The frame of the bread slicing machine is made of a mild steel angle bar with a dimension of 40 x 40 x 5 mm thick and stands at 530 x 460 x 754 mm in height after construction. Four dampers are attached to its stands to absorb any form of vibration that may occur during operation.

Blades

The blades are made of AISI 410 stainless steel material to prevent food contamination that may arise due to rust and wear. The blades are 280 mm long, 15 mm wide and 1 mm thick and are spaced 12 mm apart (Fig. 19). The slicer blades are fastened on the blade holder using M6 x 5 mm bolts and nuts.

Fig. 19: The blade assembly

Electric motor

The power required to drive the blade was determined and based on the manufacturer's catalogue, a single phase 2 horsepower electric motor was selected that can run up to 1800 rev/min.

Bread tray

The bread tray is made of AISI 410 stainless steel material of 580 mm length and 520 mm wide and 2 mm thick. This material was selected because of its excellent corrosion resistant property in other to avoid food contamination that may arise due to rust.

Shafts

Five shafts were used in the construction of the bread slicing machine namely, Driving, driven, transverse and two bracket shafts and are all made of mild steel because of such properties as having excellent tensile strength, toughness, and machinability. The bracket shafts are 280 mm long and 18 mm in diameter each. The bent shaft is 20 mm in diameter and 530 mm long while the machine and motor shafts are 330 mm long and 180 and 20 mm in diameter, respectively.

Link bar

It is made of mild steel measuring 200 mm in length, 30 mm in width and 3 mm thick (Fig. 20).

Fig. 20: The link and pulley assembly

Fig. 21: The bread slicing machine

Results and Discussion

Performance test

Evaluation of the bread slicing machine performance was done using loaves of bread measuring 289 x 102 x 102 mm and having a gross weight of 865 g. As a result of the gravitationally feed positioning of the bread on the feeding tray, the bread slide towards the cutting blades. The time for the bread to be completely sliced through was recorded, and the number of crumbs that was generated from the cutting process was also recorded. It was observed that the cutters successfully sliced the bread into 20 equal stripes measuring 12 mm with minimal crumbs less than 0.13-gram weight. The following performance parameters were obtained for the bread slicing machine: the percentage weight loss, average time for slicing a loaf of bread and efficiency of the bread slicing machine (Table 3).

Table 3: Performance parameters evaluated for the bread slicing machine

S/N	Parameter Evaluated	Mathematical Formula Used	Result Obtained
1	The percentage weight loss of the bread	$\%\, weight\ loss = \frac{weight\ of\ the\ bread\ before\ slicing}{weight\ of\ the\ bread\ after\ slicing} x\ 100$	13%
2	Average time for slicing	$\bar{T} = \frac{\sum T}{n}$	5.05 seconds
3	The efficiency of the bread slicing machine	$\eta_{bread\ slicing\ machine} = 100 - \%\, weight\ loss$	87%

The percentage weight loss of the bread

The percentage weight loss is obtained as the ratio of the difference in weights of the bread before and after slicing to the weight of the bread before slicing. It is expressed mathematically as:

$$\%\, weight\ loss = \frac{weight\ of\ the\ bread\ before\ slicing}{weight\ of\ the\ bread\ after\ slicing} x\ 100 \quad (1)$$

Average time for slicing

The average time taken for the bread slicing machine to slice a loaf of bread was obtained as the average time to slice a loaf of bread for repeated recordings. In our study, it was found to be 5.05 seconds. This is a significant improvement as compared to the already existing bread slicing machines in the market.

$$\bar{T} = \frac{\sum T}{n} \quad (2)$$

Where $\bar{T}$ is the average time for slicing a loaf of bread, $\sum T$ is the total time recorded for the slicing of each loaf of bread, n is the number of times of slicing.

The efficiency of the bread slicing machine

The efficiency of the machine is the capability of a machine to convert inputs to outputs efficiently without waste. In this study, the efficiency of the bread slicing machine is obtained from the percentage weight loss as:

$$\eta_{bread\ slicing\ machine} = 100 - \%\, weight\ loss \quad (3)$$

Conclusion

The design and construction of a Bread Slicing Machine that is simple, efficient, and easy to operate for both domestic and industrial applications were achieved, as shown in Fig. 19. The Bread slicing machine so designed is cost effective and simple to maintain with minimum vibration observed due to the dampers installed at its base stand. The performance parameters obtained showed that the efficiency of the bread slicing machine is 87%; the average time to slice a loaf of bread was 5.05 seconds; and the percentage weight loss after slicing of the bread is 13% as shown in Table 3. The machine designed was found to be extremely fast as a result of the double reciprocating motion of the slider crank mechanism adopted for the cutting.

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Conflict of Interest

Authors declare that there is no conflict of interest reported in this work.

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