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Development of an Engine Powered Horizontal Dough Mixing Machine

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ABSTRACT: A horizontal dough mixing machine was designed, fabricated, and tested. This concept was developed with the sole aim of solving the problem of machine halts due to frequent power outages experienced by electricity-powered mixers, the high cost of available conventional mixers, and the drudgery of manual mixing encountered by rural bakers. The machine consists of the hopper, stirring arm, pulley, and frame, and it is powered by a 1500-rpm, 9-hp petrol engine. The machine was tested to ascertain its performance using four portions of flour. The results showed that the machine has the highest capacity of 1600kg working at 8 hours per day using 10kg of flour at the highest speed of 400 rpm, a mixing efficiency of 87%, and a fine dough texture. It is ascertained that the machine performs as efficiently as conventional ones, and it would aid rural bakers by reducing drudgery and also increasing bakery production hours.

Keywords: Design, fabricate, test, dough, mixing

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INTRODUCTION

There is a growing interest in fortifying wheat flour with high-lysine materials, such as dry beans, to improve the essential amino acid balance of baked food products. This is a welcome development, especially in developing countries where such blends could lead to improved utilization of indigenous food crops and a reduction in the importation of wheat flour (Amjid *et al.* 2013). According to Olaoye et al. (2006), when it comes to controlling the expenses related to importation of wheat flour, composite flour technology offers a compelling alternative. The mixing procedure ensures that the fortification agents are distributed properly and uniformly throughout the flour or dough fortification process. Mixing comprises two sequential steps: the first step involves combining the ingredients, and the second step involves kneading them. In general, dough mixing is done to improve the structural development of the flour blend and the consistency of the ingredients (Hwang and Gunasekaran, 2001).According to Banu (2000), kneading the dough is one of the most crucial steps in the production of bread. Getting a homogenous combination of the raw and auxiliary ingredients while also obtaining dough with viscous-elastic properties and structure is the major goal of the kneading process. Additionally, a certain amount of air is added to the dough during kneading, which is crucial for the dough's rheological qualities and the end product's quality (Canja et al. 2013). The goal of the mixing process, as stated by Marsh and Cauvain (2007), is to evenly distribute all of the ingredients so that gluten can develop in the dough and give it the best possible physical qualities, including elasticity, stickiness, extensibility, and resistance to deformation. Since the dough's properties are critical to successful baking, mixing is an important step in the preparation of all bread varieties. Dough development is influenced by the torque applied and the intensity (speed) of mixing (Pastukhov and Dogan, 2010). The flour in the container needs to move and stir in the proper pattern with the necessary force and velocity—horizontally in this case—in order to produce the desired mixed dough (Okafor, 2015). Basically, the two major methods of mixing are manual and mechanical techniques. The manual mixing method either does not guarantee the final product's homogeneity or is highly unlikely to achieve it (Oni et al., 2009). The main drawbacks of manually mixing dough are its extreme slowness and laboriousness, as well as the lack of or very little guarantee of homogeneity in the finished product. Traditionally, blade, hook, ribbon, and pin-type dough stirrers and mixers are used in the dough-making industry (Hwang and Gunasekaran, 2001). Despite the growth in commercial bread and baked food manufacturing, Adeleke et al. (2020) noted that most steps in the process cycle are still done manually, particularly the mixing unit operation. Mechanical mixing can be carried out in a matter of minutes with the aid of different equipment that can quickly replicate the compressing and stretching actions (kneading) that would take place during a hand-mixing process (Marsh and Cauvain, 2007). At present, low-speed, spiral (which permits mixing at both fast and slow speeds), and high-speed mixers (planetary, horizontal, and continuous types) are a few of the commercial equipment frequently utilized. Some research has been carried out on the development of a mechanical kneader in order to address the shortcomings of the manual technique. Adeleke et al. (2020) developed and carried out a performance evaluation of a dough mixing machine. Ojo et al. (2024) developed a dough-kneading machine for small and medium-sized enterprises. In all these and the mixers available on the market, the designs still need to be improved. It is necessary to mix the components thoroughly and rapidly. The machine's cost should also be reasonable. Therefore, this presentation focuses on the development of an engine-powered horizontal dough mixing machine.

MATERIALS AND METHODS

Machine description

The machine consists of the following components;

Mixing Bowl

The mixing chamber consists of a shaft to which a mixing arm is attached, and it performs the function of properly mixing the dough by means of the rotary power supplied to the shaft by the gasoline engine. The shaft and mixing arm are constructed using a stainless-steel material in order to prevent material corrosion.

The mixing arm

The mixing arm is a long piece of metal, circular in cross-section, in the machine that turns and transmits rotary motion that helps in mixing the dough. The shaft is equipped with mixing arms at opposite ends. The power transmitted by the gasoline engine is transferred to the shaft by means of the pulley system.

The frame

This carries all the components of the machine. It is made of a mild steel called angle iron, and it was chosen because of its ability to resist externally applied force without breaking and its high resistance to deformation under stress (stiffness). It was constructed from 1.5 inches (thick) mild steel angle iron (Figure 1, Plate 1).

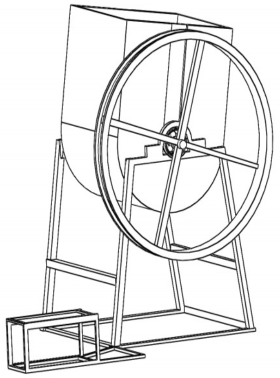

Figure 1: AutoCAD Drawing of machine.

Plate 1: The developed engine powered horizontal mixing machine.

Power transmission unit

The gasoline engine is used to power the machine by means of the pulley system. The pulley helps transmit power to the mixing chamber at reduced speed and increased torque. This enables the shaft to exhibit rotary motion, thereby mixing the dough efficiently.

Bearing

It is a machine element that permits relative motion between the contacting surfaces while carrying the loads. They reduce the friction and transmit the motion effectively. Bearings were used to hold the shaft to the frames and allow the relative motion of the shaft.

Machine's mode of operation

Power generated from the gasoline engine is transmitted to aid the rotation of the mixing arms via the belt and the pulley systems. The machine is turned off, and the flour and ingredients are introduced into the bowl. This is done to prevent possible spillage of material if the machine is still running. The rotation of the mixing arms helps to mix the flour and its additives, causing them to blend together, which gives a homogeneous mixture. This process of blending forms the dough. The bowl is then tilted to ensure adequate discharge of the dough from the mixer (Plate 2).

Plate 2. Dough mixing using the fabricated machine.

Design calculations

Fundamental design analysis and calculations were carried out in order to determine and select materials of appropriate strength and sizes for the equipment component parts.

Determination of the dimension of the mixing bowl and the base arc of the mixing bowl

The volume of the mixing basin was calculated so that the dough would not overflow during mixing, and the base arc of the mixing bowl was determined in order to get the desired shape of the mixing bowl. They were calculated as follows:

$$V = \frac{M_D}{\rho_d} \qquad (1)$$

$$L_a = 2\pi r\left(\frac{\theta}{360}\right) \qquad (2)$$

Where, V is the volume of the mixing bowl (m^3), M_d is the mass of blend flour to be mixed (kg),
ρ_d is the dough density (kg/m^3), L_a is the length of the arc, r is the radius (m), θ is the angle of arc

Determination of shaft diameter

The diameter of the shaft was calculated in order to know the size of shaft that will be needed to efficiently stir the dough. It was determined as reported by Khurmi and Gupta (2005).

$$d^3 = \frac{16}{\pi \varsigma_s} \times \sqrt{(K_b M_b)^2 + ((K_t M_t)^2} \qquad (3)$$

Where, d is the diameter of shaft, ς_s is the maximum permissible shear stress for the shaft, K_b is the combine shock and fatigue factor for bending moment, M_b is the maximum bending moment, K_t is the combined shock and fatigue factor applied to twisting moment, M_t is the twisting moment (Torque)

Determination of Mass of mixer shaft

The mass of the mixer shaft was calculated in order to know the power required to turn the shaft. It was determined is reported by Gana (2016).

$$M_s = \rho_s \times \frac{\pi d^2 l}{4} \qquad (4)$$

Where, M_s is the mass of shaft (kg), ρ_s is the density of shaft (kg/m^2), d is the diameter of shaft (m), l is the length of shaft (m)

Determination of power requirement by the machine

Power requirement of the machine is a function of the entire load the engine will carry; this is the power which the petrol engine must develop to drive the mixer shaft efficiently. It was calculated as reported by Khurmi and Gupta (2005).

$$P = 2 \times \pi \times N \times \tau / 60 \tag{5}$$

$$\tau = F \times r_d \tag{6}$$

$$F = M \times r_s \times \omega^2 \tag{7}$$

$$\omega = 2 \times \pi \times N / 60 \tag{8}$$

where, P is power required by the machine (watts), F is the total force (N), τ is the torque generated (Nm), M is total mass of the bowl and its content (kg), ω is angular speed (rpm), π is constant, r_s is radius of the shaft (m), N is revolution per minute

Determination of the diameter of pulley

The diameter of the shaft pulley was determined as reported by Khurmi and Gupta (2005)

$$n_1 d_1 = n_2 d_2 \tag{9}$$

Where; n_1 is the speed of the petrol engine pulley (rpm), d_1 is the diameter of the petrol engine pulley (m), n_2 is the speed of the shaft pulley (rpm), d_2 is the diameter of machine pulley (m).

Determination of belt length

The length of pulley belt was calculated using the following formula as reported by Khurmi and Gupta (2005).

$$L_T = \frac{\pi}{2}(D_2 + D_1) + 2C\left(\frac{D_2 + D_1}{4}\right)^2 \tag{10}$$

where L_T is length of belt required in m, D_1 is diameter of electric motor pulley = 0.05m, D_2 is diameter of machine pulley (m), C is the centre to centre spacing of the machine and electric motor pulley (m)

Determination of the Velocity of the Belt

The velocity was used to determine the coefficient of friction acting on the belt. The velocity of the belt was therefore determined using the expression below.

$$V = \frac{\pi N_1 D_1}{60} \tag{11}$$

Where, V is the velocity of the belt (m/s), N_1 is the speed of the petrol engine pulley, D_1 is the diameter of engine pulley (mm)

Design analysis of belt tension

The belt tension was calculated using the following formula as reported by Khurmi and Gupta (2005).

$$\frac{T_1}{T_2} = e^{\mu\theta} \tag{12}$$

$$\theta = (180 - 2\alpha) \times \frac{\pi}{180} \tag{13}$$

To obtain α; $$\sin \alpha = \frac{r_1 - r_2}{x} \tag{14}$$

Where; T_1 is the tight side of belt tension (N), T_2 is the slack side of belt tension (N), μ is the coefficient of friction between material of the belt and pulleys, θ is the angle of wrap (rad), α is the angle of wrap, x is the distance between pulley, R_1 is the radius of large pulley (m), R_2 is the radius small pulley (m)

Testing of the machine

The machine was first run empty (no load) using a petrol engine with a power rating of 9 hp and a speed rating of 200 rpm for 2 minutes. This was carried out to be sure that no parts of the machine were in contact with or sliding against each other.

Design of experiments

The experimental was designed as a function of feed rate (A) and machine speed of operation (B) using the central composite rotatable design (CCRD) of response surface methodology (RSM). In order to obtain the required data, the range of values for each of the two variables (k) was determined as reported by Gana et al. (2017) and is presented in (Table 1). For two variables (k = 2) and the five levels (-α, -1, 0, 1, and +α) of experiments, the total number of runs was obtained as 13, and the design is shown in (Table 1).

Experiments set up

Fifty kilograms of wheat flour were obtained from the Minna central market. It was mixed with additives (sugar, yeast, salt, and oil) and then divided into thirteen samples, as shown in (Table 1), after mixing in the ratio of flour to water of 2:1. The mixing was carried out based on the design matrix shown in (Table 1). The experiment was carried out at the Department of Agricultural and

Table 1. Results of effects of feed rate and mixing speed on machine capacity and efficiency

Std	Run	Speed of mixing (rpm)	Weight of Flour Fed (kg)	Machine Output (kg/hr)	Efficiency (%)	Texture
9	1	325	17.5	1127.1	67.84	Coarse
11	2	325	17.5	1135.09	65.04	Coarse
6	3	360	17.5	1573.56	86.81	Fine
4	4	350	20	1343.75	80.57	Fine
5	5	290	17.5	683.97	41.12	Coarse
13	6	325	17.5	1134.23	66.39	Coarse
10	7	325	17.5	1122.69	68.67	Coarse
3	8	300	20	728.45	56.5	Coarse
7	9	325	14	1280	54.62	Coarse
8	10	325	21	988.76	72.61	Coarse
12	11	325	17.5	1126.67	60.09	Coarse
1	12	300	15	901.44	45.97	Coarse
2	13	350	15	1530.31	75.65	Coarse

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Statistical analysis

An analysis of variance (ANOVA) was carried out to estimate the influence of the main variables and their likely effects on the responses (Gana et al., 2017).

Determination of effects of the independent variable on the machine performance

The overall performance of the harvester was evaluated on the basis of machine capacity and efficiency by varying feed rate and speed. The parameters measured and tested in determining the performance of the mixer are consistency and texture, mixing efficiency, and machine capacity.

Dough consistency and texture

The consistency or texture was determined by the hand feel (sensory feeling) obtained by touching the mixed dough, and it was expressed as fine, medium, and coarse.

Determination of mixing efficiency

The efficiency was determined by the performance of the machine, i.e., how well the machine was able to mix the dough. This is the ratio of the mass of flour before mixing to the mass of flour after mixing, expressed in percentage. The formula for calculating efficiency is as follows, as reported by Ojo et al. (2024)

$$E = \frac{M_a}{M_b} \times 100 \qquad (15)$$

Where, M_a is the mass of flour before mixing (kg), M_b is the mass of flour after mixing (kg).

Determination of machine output/capacity

The capacity of the machine was determined by the quantity of dough that was mixed at a given time. It is the practical capacity obtained from the machine during testing after fabrication, and it is expressed in kg/hr or kg/8 hrs/day.

$$C = \frac{M \times T}{t} \qquad (16)$$

Where, M is the mass of flour per batch (kg), T is the time (hrs), t is the time used (mins)

RESULTS AND DISCUSSION

The results of the effects of the feeding rate and speed on the machine's performance are shown in (Table 1). The machine's capacity ranged from 1573.56 to 683.97 kg/hr. The highest value of 1573.56 kg/hr was obtained from the combination of a mixing speed of 360 rpm and a weight of 17.5 kg, while the interaction between a mixing speed of 290 rpm and a weight of 17.5 kg yielded the lowest value of 683.97 kg/hr. The machine's efficiency

Table 2: Regression analysis of response of machine capacity.

Source	Coefficient Estimate	df	F-value	p-value	
Model	1128.92	1	6912.09	< 0.0001	significant
A-Speed of mixing	312.78	1	12624.3	< 0.0001	
B-Weight of Flour Feed	-96.43	1	1199.88	< 0.0001	
Lack of Fit	506.78	6	2.99	0.1546	not significant
R^2	0.9993				
Adj. R^2	0.9991				
Pred. R^2	0.9985				
Adeq Precision	233.8916				
C.V. %	0.6975				

ranged from 41.12% to 86.81%. The highest value of 86.81% was obtained from the combination of a mixing speed of 360 rpm and a weight of 17.5 kg, while the interaction between a mixing speed of 290 rpm and a weight of 17.5 kg yielded the lowest value of 41.12%. The consistency and texture of the dough at varying speeds vary from coarse to fine.

Effects of independent variables on machine capacity

The result of the statistical analysis of variance (ANOVA) of the machine capacity presented in (Table 2) showed that the model is significant with an F-value of 691.09 and a P-value probability > F less than 0.0500. In this case, both the mass of the flour and the speed had a significant effect on the machine's capacity. The R-square value of 0.9993 was very close to 1, as recommended by Gana et al. (2017). The lack of fit F-value of 2.99 implies that the lack of fit is not significant relative to pure error. There is a 15.46% chance that a lack of fit F-value this large could occur due to noise. A non-significant lack of fit is good because if it is significant, then the model will not be able to predict the response.

The coefficient of variation (C.V.) of 0.697% obtained was low, below the threshold value of not greater than 10%. This indicated that the deviation between experimental and predicted values was low, as reported by Gana (2016). The coefficient of determination R value of 0.9965 indicated that the model was able to predict 99.65% of the variance, and only 0.35% of the total variance was not explained by the model. The coefficient of correlation R-squared value of 0.9993 was very close to 1, as recommended by Xin et al., (2008). But as further reported, a large value of R2 does not always suggest that the regression model is a good one because it will increase when a variable is added, regardless of whether the additional variable is statistically significant or not. Hence, predicted and adjusted R^2 were suggested to be used to check the model's adequacy. It was also observed that the predicted R-Squared of 0.9985 was in reasonable agreement with the adjusted R-Squared of 0.9991, which indicated that the experimental data fitted well. The value of adequate precision of 233.89 obtained was above the minimum value of 4 reported by Gana (2016). This indicated an adequate signal, which showed that the model can be used to navigate the design space.

Effects of independent variables on machine efficiency

The result of the statistical analysis of variance (ANOVA) of the machine capacity presented in (Table 3) showed that the model is significant with an F-value of 110.95 and a P-value probability > F less than 0.0500. In this case, both the mass of the flour and the speed had a significant effect on the machine's efficiency. The R-square value of 0.9569 was very close to 1, as recommended by Gana et al. (2017). The lack of fit F-value of 0.62 implies that the lack of fit is not significant relative to pure error. There is a 71.37% chance that a lack of fit F-value this large could occur due to noise. A non-significant lack of fit is good because if it is significant, then the model will not be able to predict the response.

The coefficient of variation (C.V.) of 4.59% obtained was low, below the threshold value of not greater than 10%. This indicated that the deviation between experimental and predicted values was low, as reported by Gana (2016). The coefficient of determination R value of 0.9782 indicated that the model was able to predict 97.82% of the variance, and only 2.18% of the total variance was not explained by the model. The coefficient of correlation R-squared value of 0.9569 was very close to 1, as recommended by Xin et al. (2008). But as further reported, a large value of R2 does not always suggest that the regression model is a good one because it will increase when a variable is added, regardless of whether the additional variable is statistically significant or not. Hence, predicted and adjusted R2 were suggested to be used to check the model's adequacy. It was also observed that the predicted R-Squared of 0.9297 was in reasonable agreement with the adjusted R-Squared of 0.9483, which indicated that the experimental data fitted well. The value of adequate precision of 29.31 obtained was above the minimum value of 4 reported by Gana (2016). This indicated an adequate signal, which showed that the model can be used to navigate the design space.

Table 3: Regression analysis of response of machine efficiency.

Source	Coefficient Estimate	df	F-value	p-value	
Model	64.76	1	110.95	< 0.0001	Significant
A-Speed of mixing	14.80	1	198.25	< 0.0001	
B-Weight of Flour Feed	5.11	1	23.66	< 0.0001	
Lack of Fit	42.60	6	0.6209	0.7137	not significant
R^2	0.9569				
Adj. R^2	0.9483				
Pred. R^2	0.9297				
Adeq Precision	29.310				
C.V. %	4.590				

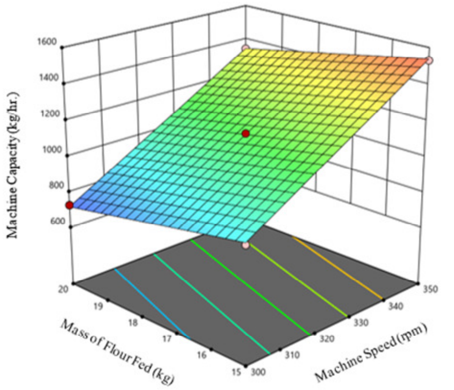

Figure 2. Response surface for effects of feeding mass and mixing speed on the machine capacity

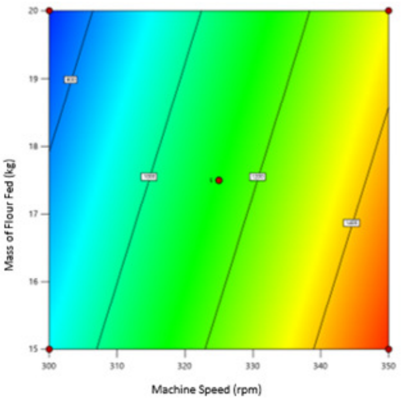

Figure 3. Contour Plot for effects of feeding mass and mixing speed on the machine capacity

Effects of mass of flour fed into the machine and mixing speed on machine capacity

From (Table 1), all the samples mixed at low speeds have a coarse texture, while those processed at higher speeds of 1344 and 1574 rpm have a fine texture. This could be due to the fact that higher speed is associated with a high shear force that helps break down any lumps or clusters of solid particles, ensuring uniform dispersion. This agreed with the findings of Sumarji et al. (2019), where in high-speed mixing of composite dispersion, the particles tend to agglomerate with particle clumps. Also, the faster mixing speed results in a more homogeneous mixture compared to the slower speed. Thereby, increases in the mixing speed can allow increases in the homogeneity index. The highest mixing speed (i.e., 1420 rpm) has less variation between the samples. Homogeneity at the highest speed was the most stable in terms of results between the points in the homogeneity index among the other mixing speeds.

Effects of mass of flour fed into the machine and mixing speed on machine capacity

From (Figures 2 and 3), the effects of the mass of flour fed into the machine and mixing speed on machine capacity revealed that increasing the mass of the flour fed into the machine from 15 kg to 20 kg decreased the machine capacity from 1560 kg/hr to 1375 kg/hr.

This is due to the fact that a larger mass of dough takes more time to mix per batch. This is in line with the report by Basinskas and Sakai (2016), where the increase in the powder amount reduces the mixing performance. On the other hand, increasing the mixing speed from 300 rpm to 350 rpm increases the capacity from 1100 kg/hr to 1560 kg/hr. This could be due to the high-speed rotation and powerful stirring that make the materials reach a uniformly mixed state in a short time, thereby improving production efficiency. This agreed with the findings of Basinskas and Sakai (2016), where the increase in the mixing speed not only reduces mixing time but also substantially increases the mixing performance if measured per number of rotations.

Effects of mass of flour fed into the machine and mixing speed on machine efficiency

From (Figures 4 and 5), the effects of the mass of flour fed into the machine and mixing speed on machine efficiency revealed that increasing the mass of the flour fed into the machine from 15 kg to 20 kg increased the machine efficiency from 73.8% to 86%. This could be a

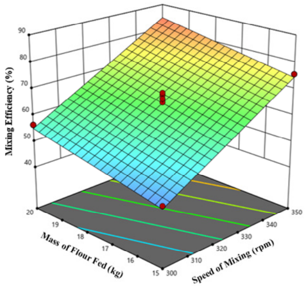

Figure 4. Response surface for effects of feeding mass and mixing speed on the machine efficiency

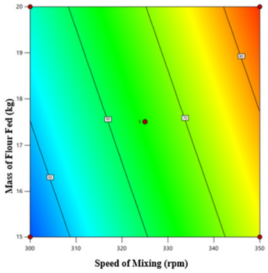

Figure 5. Contour Plot for effects of feeding mass and mixing speed on the machine efficiency

result of the packing density of flour decreasing with an increase in the mixing speed. This agreed with the findings of Jin et al. (2022), where the total contact number of different particles and final mixing degree increased with the increase in fill level and particle density. On the other hand, increasing the mixing speed from 300 rpm to 350 rpm increased the efficiency from 54.5% to 86%. This could be because the high speed of mixing is associated with high shearing action, which breaks down the agglomerates of solid particles and disperses them evenly throughout the liquid medium. This high-speed rotation generates intense shear forces within the mixture. This shear force helps in breaking down any lumps or clusters of solid particles, ensuring uniform dispersion. Additionally, the impact between the particles due to the high-speed mixing action further aids in the dispersion and blending processes. This is in line with the result of Jin et al. (2022), where the rotation speed increasing from a low rotation speed of 60 rpm to a higher 120 rpm can promote the mixing performance linearly.

Conclusion

The machine was designed, fabricated, and tested successfully. It was concluded that the fabricated machine will solve the problem encountered by electrically powered mixers due to frequent power outages with the aid of the petrol engine. The use of locally available materials makes the machine affordable for rural bakers, hence increasing its marketability. From the test carried out, it was discovered that the maximum speed of 400 rpm produced a fine outcome for the mixed dough.

REFERENCES

Adeleke, A.E., Oni, O.K., Ogundana, T. O.,Satimehin, A. A. & Oyelami, S. (2020). Development and Performance Evaluation of a Dough Mixing Machine, UNIOSUN Journal of Engineering and Environmental Sciences. 2(2). Pp-30-40.

Amjid, M. R., Shehzad, A., Hussain, S., Shabbir, M. A., Khan, M. R. & Shoaib, M. (2013). A comprehensive review on wheat flour dough rheology PAK. J. FOOD SCI., 23(2), Pp-105-123.

Banu, C., (2000). Handbook engineer food industry. vol II. (in Romanian). Technical Publishing House, Bucharest.

Basinskas, G.& Sakai, M. (2016b). Numerical study of the mixing efficiency of a batch mixer using the discrete element method. *Powder Technol.* 301: 815–829.

Canja, C. N., Lupu, M. &Tăulea, G. (2014). The Influence of Kneading Time on Bread Dough Quality Bulletin of the Transilvania University of Braşov Series II: Forestry, Wood Industry, Agricultural Food Engineering • Vol. 7 (56) No.1

Gana, I. M. (2016). Development and optimisation of functional parameters of an automated grain drinks processing machine [Unpublished PhD. Engineering Thesis]. Minna: Federal University of Technology; 2016.

Gana, I. M., Agidi, G., Idah, P. A., &Anuonye, J. C. (2017). Development and testing of an automated grain drinks processing machine. Food and Bioproducts Processing, Journal of the European Federation of Chemical Engineering: Part C. Elsevier. 2017;104:19-31. www. elsevier.com/locate/fbp

Hwang, C.H.& Gunasekaran, S. (2001). Determining wheat dough mixing characteristics from power consumption profile of a conventional mixer. Cereal Chem. 78(1): 88-92.

Jin X., Wang, S., & Shen, Y. (2022). Effects of operating conditions and particle properties on mixing performance in an industrial-scale U-shape ribbon mixer, Powder Technology, Volume 411.

Khurmi, R.S., and J. K. Gupta (2005). A Textbook of Machine Design. Eurasia publishing house Ltd, New Delhi.

Marsh, D., &Cauvain, S. P. (2007.) Mixing and dough processing. In: Technology of breadmaking. Springer, Cham, pp 93–140

Ojo, O., Oyerinde, A., Bamisaye, O. S., Adewole, J. & Adepoju, T. (2014). Development of Dough Kneading Machine for Small and Medium-Sized Enterprises. Journal of Applied Research. 5(1): 23-31,

Okafor, B.E. (2015). Design of Power-Driven Dough Mixing Machine. Int'l Journal of Engineering and Technology 5(2): 76-79.

Olaoye, O. A., & Ade-Omowaye, B. I. O. (2011). Composite flours and breads: potential of local crops in developing countries. In V. R. Preedy, R. R. Watson, & V. B. Patel, (Eds.), Flour and breads and their fortification in health and disease prevention. London, Burlington, San Diego: Academic Press, Elsevier. Pp.183- 192.

Oni, O. K., Alakali, J. S. &Akpapumam, M. A. (2009). Design, Fabrication and Performance Evaluation of a Powered Soy-Gari Mixer. Journal of Engineering and Applied Sciences 4(3): 164-169.

Pastukhov, A.S. & Dogan, H. (2010). Effect of kneading speed on thermo mechanical properties of flour doughs. Kansas State University, KS, U.S.A. Cereal Food World, 55: A63.

Sumarji, Ridha, F., Dwilaksana, D., Syuhri, S., & Raihaan. (2019). The Effect of Particle Dispersion due to Mixing Speed on Spent Coffee Ground Composites. Indonesian Journal of Science and Technology, 4(2):188-195.

Xin, J., Imahara, H., & Saka, S. (2008). Oxidation stability of biodiesel fuel as prepared by supercritical methanol. Fuel 87:1807-1813.