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Development and Performance Evaluation of a Groundnut Mixing Machine

O. G. Olajide [a,b*], L. A. S. Agbetoye [b], O. O. Olabinjo [b] and O. S. Lawson [b]

[a] *Department of Agricultural and Bio-Environmental Engineering Technology, Rufus Giwa Polytechnic, Owo, Ondo State, Nigeria.*
[b] *Department of Agricultural and Environmental Engineering, Federal University of Technology, Akure, Ondo State, Nigeria.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Studies that investigated the effectiveness of groundnut mixing as a function of mixing speed and time are scarcely reported. Therefore, the objective of the study is to investigate the main and interaction effects between mixing mixtures and mixing speed on the mixing evaluation parameters, with respect to different mixing proportions of ginger, wheat flour and pepper. The mixing evaluation parameters considered are; final and losses after mixing. Also, the coefficient of variation (CV), Degree of mixing, Percentage loss and mixing efficiency. The components of the mixer consist of frame, the U shaped trough, a central shaft and a helical ribbon agitator. The coating units consists of coating trough, drive shaft and electric motor. The lowest value of CV recorded was 8.94%, while the highest values of the degree of mixing and mixing efficiency recorded were 92.23 and 99.75%, respectively. The effectiveness and efficacy of mixing increases as mixing time increases.

**Corresponding author: Email: olajideaet@yahoo.com;*

Similarly, increased performance in mixing was observed as the mixing speed increases. The main and interaction effects between the mixtures and speed were insignificant (P > 0.05). The highest speed of 60 rpm and mixing time of 15 mins produced the highest mixing efficiency. Therefore, further studies should be carried to determine the optimum speed and mixing time for improved thoroughness in mixing.

Keywords: Groundnut; mixing time; mixing speed; mixtures; mixing efficiency.

1. INTRODUCTION

Groundnut (*Arachis hypogaea* L.) also known as peanut, earthnut and ground bean is a leguminous oilseed crop cultivated in the semi-arid and subtropical regions of the world [1]. Groundnut has a rich nutty flavor, sweet taste, crunchy texture and over and above a relatively longer shelf life. It is an important crop in many countries, including Nigeria [2]. It is a good source of protein (25%-34%), cooking oil (48%-50%) and vitamins. The haulms are a good source of feed for livestock, especially during the dry season when fresh green grasses are not available.

In Nigeria, groundnut is of the importance, the nuts produced and its processing into various products is mostly done by women either for home consumption or for commercial purposes but without value addition [2]. Absence of value addition in the supply value - chain with Nigeria focusing mostly on food production and neglecting the processing and manufacturing thereby losing opportunities for higher earnings and ability to generate employment. Food processing enables the year- round availability of foods that have limited growing seasons [3]; and this include groundnut and many other crops. The processing of groundnut includes various unit operations such as decorticating, cleaning, roasting, mixing, coating and packaging. Mixing, coating and roasting constitute important aspect in the food industry that enhance rapid production in the processing industry.

Mixing is the combination of two or more elements of particles of different components and combining them into a homogeneous mixture [4]. The particles are homogenized when shaken or vibrated [5]. Mixing in the food industry is used mainly to obtain homogeneity with the best possible equipment and the best relation of the power correlations.

Edible films and coatings also play an important role in the quality, safety, transportation, storage and display of a wide range of fresh and processed foods. Food coating is an innovation within biodegradable active packaging concept, which interacts with food to extend shelf life and improve safety and/or functional or sensory properties while maintaining the quality of food packaging. Edible films and coatings based on biopolymers have taken as a major boom in the food industry owing to many factors such as biodegradability characteristics that contribute to reducing environmental pollution, and their potential to prevent the alteration in food mainly preserving physical, chemical and sensory properties. Before mixing, the groundnut mixing components must be thoroughly mixed, which is a function of mixing speed and time. Therefore, the main objective of this study is to evaluate effect of various machine speeds and time on mixing parameters for groundnut coating using a developed groundnut mixing machine.

2. MATERIALS AND METHODS

2.1 Design Considerations

The groundnut processing machine was conceived to reduce the cost of mixing, coating and roasting of groundnut production, alleviate drudgery, time consuming of coating groundnut and attract people into the processing operation. One of the factors considered in the design of the processing plant was the cost of the mixing, coating and roasting peanut that was made affordable by using locally available materials without compromising its effectiveness. The processing plant was designed in a manner that the mode of operation was made easy for the operators with minimum training and the components of the processing plant were easy to fabricate, assemble and maintain. With these considerations, the processing plant should be able to:

a. mix a substantial amount of the additives with the provision of hopper
b. discharge the additives through the provision of outlet at the base of the mixer

c. mix the additives in a short time without wastage of ingredients
d. coat the groundnut effectively in a short period of time with minimum damage through the provision of the coating chamber
e. coat the groundnut with flour and other ingredient
f. help give the groundnut at circular shape with the act of the dish rotating and the groundnut in it with it centrifugal force
g. roasts the coated groundnut in the roasting chamber with minimum loss to the coated groundnut
h. retain the quality of the end product
i. regulate the amount of heat used for roasting the groundnut at a temperature acceptable with minimum breakage.

The calculation of the considered design used for this study is as shown in Table 1.

2.1.1 The mixing units

The machine employed in the mixing unit is a ribbon mixer. Ribbon mixer are principally used for homogenous mixing of two or more powder materials with no or minimum possible wet essential solutions. Ribbon mixers are designed for mixing wide variety of materials with widely varying densities at high mixing efficiency in a remarkable short time. The machine consists of a horizontal U shaped trough containing a central shaft and a helical ribbon agitator. Two counteracting ribbons are mounted on the same shaft, one moving the solid slowly in one direction, the other moving it quickly in other direction. Mixing results from the turbulence induced by the counteracting agitators, not from mere motion of solids through the trough. The ribbon mixer operates on batch wise with the solids charged and mixed until satisfactory. The whole assembly is fitted on rigid frame structure. The trough is located through the opening at the top. Bottom discharge spouts is also provided. The exploded view is shown in the Fig. 1.

2.1.2 Method of mixing

The additives comprise of wheat flour, ginger, pepper and salt formulated using the response surface method. Three level of different formulation A, B, C were used. The mixer was cleaned before starting the experiment. The materials were weighed using top pan balance in a container of known dimensions. As the mixer started to operate, the powder particles were poured into the mixing tank and the materials began to mix.

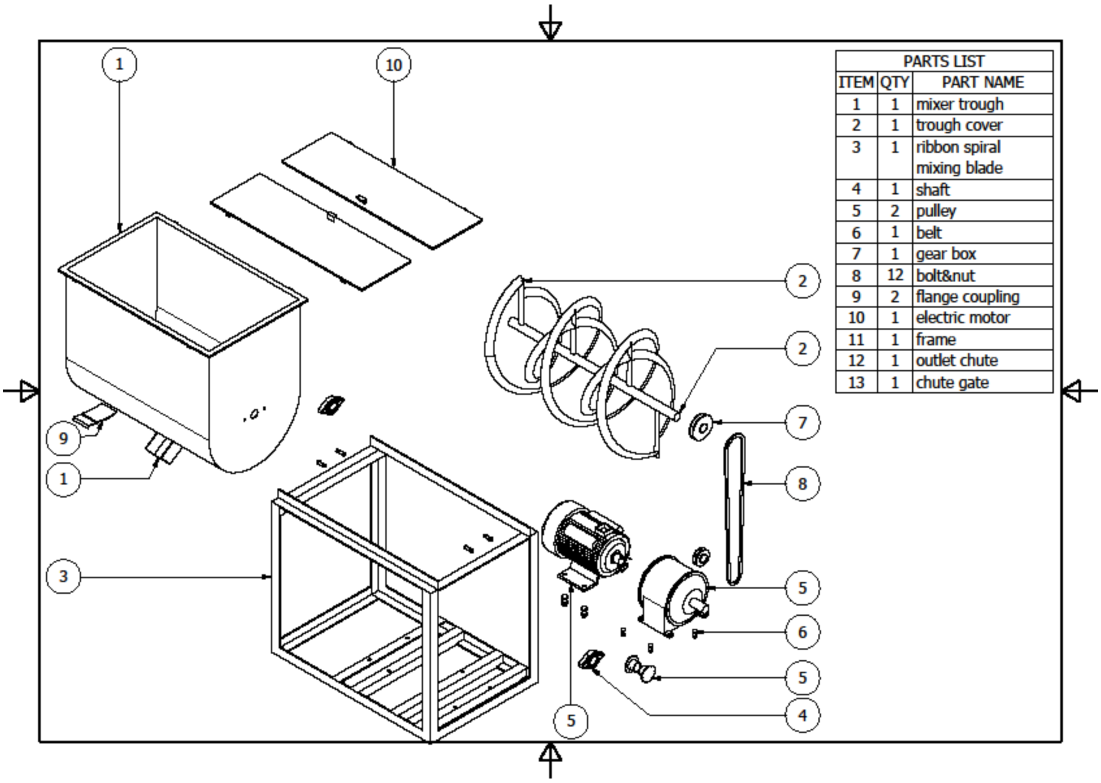

Fig. 1. The conceptual design of the ribbon mixer machine

Table 1. Design Analysis of the components of the machine

S/N	Parameter determined	Equation used	Value obtained	References
1	Mass of egg	$M_e = \rho_e \times V_w$	67.29 eggs	
2	Mass of peanut	**Density formula**	181.97 g	Akcali (2006)
3	average mass of a peanut kernel at 8% moisture	$v_k{}^2 = \frac{W_k}{\rho A_k}$	0.0108891 Kg	Chukwu (2018)
4	Pulley speed	$N_1\emptyset_1 = N_2\emptyset_2$	**15 rpm**	
5	Power rating of the machine	$P_T = P_b + P_p$	**0.031 Kw**	Khurmi and Gupta (2005)
6		$d_s{}^3 = \frac{16}{\pi S_s}\sqrt{(K_b M_b)^2 + (K_t M_t)^2}$	$d_s = 19.9\ mm$	Khurmi and Gupta (2005),
6	Design of the roasting sieve-drum	$V_r = V_p k$	$V_r = 0.126\ m^3$	
7	Determination of optimum roasting speed	$N_r = \frac{30}{\pi}\sqrt{\frac{g}{r}}$	50.2 rpm	Dadang et. al. (2020)
8	Determination of heat energy needed for roasting	$\Delta Q = (m_r C_s + m_p C_p)\Delta T$	$C_p = 3675$ J/kg°C	Gupta (1999)
9	Determination of roasting air flow rate	$cfm = \frac{BTU/hr}{1.08 \times \Delta T}$	1.05 m^3/min	Home barista, 2013
10	Area occupied by the axial fan blad	$A = \pi \frac{\emptyset_f{}^2}{4}$	0.0028274 m^2	
11	$fan\ power$	$\frac{air\ flow\ rate\ \times static\ pressure\ (in.water)}{6320 \times fan\ efficiency}$	0.011 Hp	

2.1.3 Design of the ribbon mixing machine

The ribbon blender is a very efficient and wilder mixing machine for blending dry granules & powders homogeneously. When using a ribbon mixer, to ensure proper mixing, approximately two third of the container volume must be filled. The result of ribbon mixer is best when used for mixing dry powder & granules, this is due to the design and shape of the product container and the mixing ribbon.

2.1.4 Design of the mixing chamber

The mixing chamber, as shown in Fig. 2, has a U-shape trough form. The shape of the mixer is designed to enable homogeneous mixing of the powered material to handle. The volume and weight of the trough can be determined.

2.2 Design of the Ribbon Spiral Mixing Blade

The mixing blade, as shown on Fig. 3, of the ribbon mixer is in spiral form. This made ribbon mixer a very efficient mixer as the material to be mixed in the mixer is turned spirally by every part of the flight of the mixing blade. To design the flight of the ribbon mixing auger, we consider the pitch (p_1), smaller diameter (ϕ_i) and bigger diameter (ϕ_o) of the outer flight and the pitch (p_2), smaller diameter (φ_i) and bigger diameter(φ_o) of the inner flight.

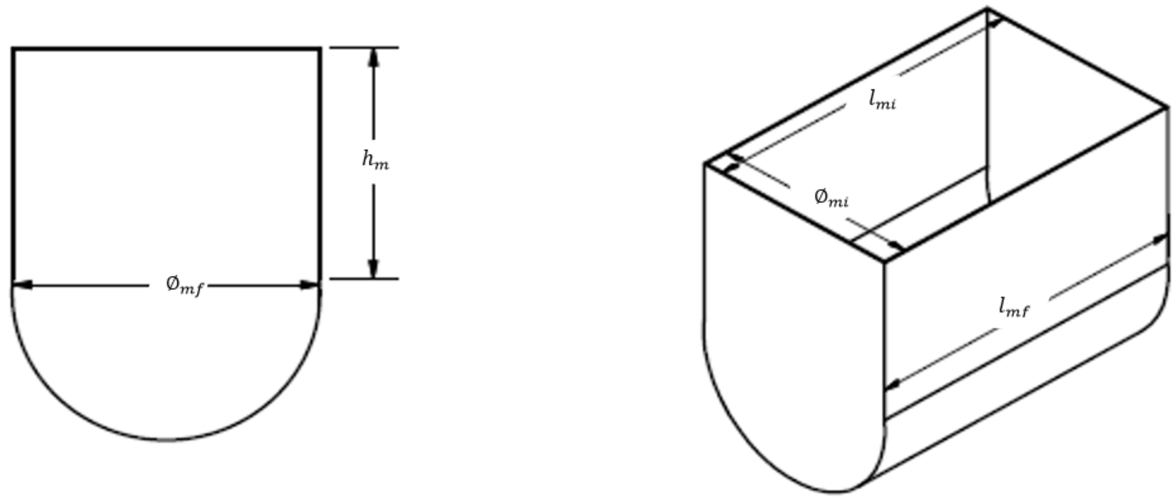

Fig. 2. The mixing chamber

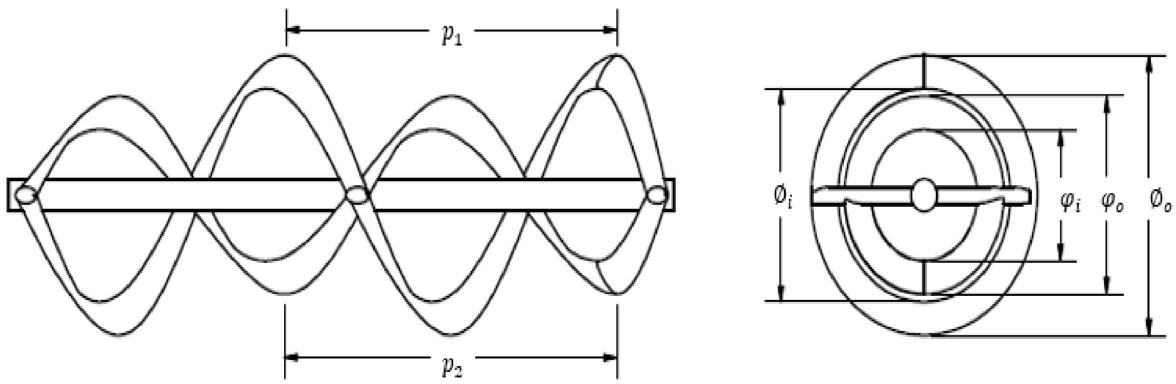

Fig. 3. Schematic diagram of the ribbon spiral blade

2.2.1 Determination of the ribbon mixer capacity

The capacity of a screw conveyor is defined as the weight or volume per hour of a bulk material that can be safely and feasibly conveyed. According to KWS [6], the ribbon mixer capacity can be determined from the formula in Equation 1:

$$R_c = 32036.907 \times \frac{L_t}{\rho_f} \times C_f \qquad \text{(Equation 1)}$$

Where;
R_c = Ribbon mixer capacity (ft^3/hr)
L_t = Weight of material per hour (tons/hr)
ρ_f = Bulk density of material (kg/m^3)
C_f = Mixer capacity factor
The amount designed to be mixed per hour is 10 tons, hence;

2.2.2 Determination of the ribbon mixer power rating

The power rating of the mixer is the power required to homogeneously mix the powered ingredients fed into the mixer for a specific period of time. The horsepower required to drive a ribbon mixer is called Total Shaft Horsepower (TSHP). TSHP is a function of the characteristics of the bulk material being mixed and the friction inherent in the mixer. The ribbon mixer is designed with sufficient horsepower in order to prevent downtime and loss of production.

According to KWS [6], the Total Shaft Horsepower for a ribbon screw mixer is given in Equation 2:

$$\text{TSHP} = \frac{FHP+(MHP\times SF)}{e} \ldots\ldots\ldots \qquad \text{(Equation 2)}$$

Where;
FHP = Friction HP (HP required to drive mixer empty)
MHP = Material HP (HP required to mix bulk material)
SF = Special Flight Factors (Ribbon flight factor will be selected)
e = Drive Efficiency (Typical value of 0.88 issued for a shaft mount reducer/motor)

2.3 Statistical Analysis

The homogeneity of the mixture is determined using coefficient of variance (CV) (Equation 3) [7]. The coefficient of mixing was calculated as per equation by [8] and [9]. Analysis of Variance (ANOVA) using One-Way was performed. Also main and interaction effects were performed between the mixing time and speed on the mixing homogeneity.

$$CV(\%) = \frac{Standard\ deviation\ (s)}{mean} \times 100 \qquad \text{(Equation 3)}$$

3. RESULTS AND DISCUSSION

3.1 Mixing of Groundnut Seed Coating Ingredient

The effects of the mixing speed on the mixing time, final mass and losses at mixtures A, B and C are given in Tables 2-4.

Table 2. Influence of speed and different mixtures on the mixing parameters for mixture A

Mixture	Speed (rpm)	mixing time(min)	final mass(g)	losses(g)
A	40	5	996.99a	3.01a
A	50	5	995.50a	4.50b
A	60	5	997.19a	2.81ab
A	40	10	996.35a	3.65a
A	50	10	996.28a	3.72a
A	60	10	996.55a	3.45a
A	40	15	996.46a	3.54a
A	50	15	997.58a	2.42b
A	60	15	998.36a	1.64c
Main effects				
Speed		NS	NS	NS
Wheat flour		NS	NS	NS
Ginger		NS	NS	NS
Interaction effects		NS	NS	NS
Speed*Wheat flour		NS	NS	NS
Speed ginger		NS	NS	NS

Note: Mixture A consisted of 930, 25, 25 and 20g of wheat flour, ginger, pepper

Table 3. Influence of speed and different mixtures on the mixing parameters for mixture B

Mixture	Speed (rpm)	mixing time(min)	final mass(g)	losses(g)
B	40	5	998.12a	1.88a
B	50	5	995.50a	4.17b
B	60	5	997.88a	2.12ab
B	40	10	997.21a	2.79ab
B	50	10	996.28a	3.72a
B	60	10	996.82a	3.18b
B	40	15	998.00a	2.00a
B	50	15	996.48a	3.52b
B	60	15	997.74a	2.26a
Main effects				
Speed		NS	NS	NS
Wheat flour		NS	NS	NS
Ginger		NS	NS	NS
Interaction effects		NS	NS	NS
Speed*Wheat flour		NS	NS	NS
Speed ginger		NS	NS	NS

Note: The mixture of B consisted of 945, 20, 20 and 15g

Table 4. Influence of speed and different mixtures on the mixing parameters for mixture C

Mixture	Speed (rpm)	mixing time(min)	final mass(g)	losses(g)
C	40	5	995.48a	4.52a
C	50	5	995.81a	4.19a
C	60	5	997.19a	2.81b
C	40	10	997.42a	2.58a
C	50	10	998.48a	1.52b
C	60	10	998.22a	1.78b
C	40	15	997.12a	2.88a
C	50	15	997.45a	2.55a
C	60	15	998.36a	2.03b
Main effects				
Speed		NS	NS	NS
Wheat flour		NS	NS	NS
Ginger		NS	NS	NS
Interaction effects		NS	NS	NS
Speed*Wheat flour		NS	NS	NS
Speed ginger		NS	NS	NS

Note: mixture of C consisted of 955, 20, 15 and 10g for wheat flour, ginger, pepper and salt, respectively

Table 5. Performance of groundnut seed mixer

Mixing time(min)	Coefficient of variation (%)	Degree of Mixing (%)	Percentage loss (%)	Mixer efficiency (%)
5	13.75	85.17b	34.57a	99.62a
10	13.60	86.76b	36.21a	99.64a
15	8.94	92.23a	25.33b	99.75a
speed(rpm)				
40	15.6	84.40a	44a	99.56a
50	13.64	86.36a	36ab	99.65a
60	10.86	89.14a	25b	99.75a

Mixture A consisted of 930, 25, 25 and 20g of wheat flour, ginger, pepper. The mixture of B consisted of 945, 20, 20 and 15g while the mixture of C consisted of 955, 20, 15 and 10g for wheat flour, ginger, pepper and salt, respectively. The total mass of the mixture total 1000g. In all treatments, no obvious effect of mixing speed were observed on the mixing time. The effect was insignificant ($P > 0.05$) on the mixing time, final mass and the amount of the mixture losses. However, the result of the analysis showed that mixing time reduces as the mixing speed increases. The lowest mixing time was achieved at a speed of 60 rpm. Also, the mass of losses mostly reduced as the mixing speed increased. The main effect of all the mixing components and speed were all insignificant ($P > 0.05$) on the mixing time, final mass and losses.

The corresponding coefficient of variability (CV) of 13.75, 13.6 and 8.94 %, were obtained during mixing times of 5, 10, and 15 minutes, respectively. From Table 5, it could be observed that at the mixing time of 15 minutes, the lowest coefficient of variation was recorded, showing that as the mixing time increases, the coefficient of variation decreases, while percentage degree of mixing increases. However, the mixing efficiency increased similarly ($P > 0.05$) with respect to the considered mixing times. The percentage coefficient of variation and degree of mixing of the mixing machine at mixing speeds of 40, 50 and 60 rpm were found to be 15.6, 13.64 and 10.86 %, respectively. From Table 3, it can be seen that, at the mixing speed of 40, 50 and 60 rpm, the mixing degree were 84.4, 86.36 and 89.14%, respectively. Also, the mixing efficiency ranged between 99.56 and 99.75%. The value of coefficient variations obtained at the different mixing time and speed are similar with the result reported by Herrman and Behnke [10,11]. The values of the coefficient of variations (CV) are rated excellent, in terms of uniformity/thoroughness of mixing. Therefore, the mixing uniformity was highest at the combination of mixing speed of 60 rpm and 15 minutes of mixing time.

4. CONCLUSION

On the present work, machines for mixing was designed, fabricated and the performance evaluations were carried out. Different proportions of ginger, wheat flour, salt and pepper were considered in the mixing mixtures. From the research, mixing parameters like mixing speed and the different mixture component do not affect the mixing evaluation parameters. Also, the designed machine evaluation showed that the degree of mixing and mixing efficiency was high.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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