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RESEARCH PAPER

Performance Evaluation of a Conductive Rotary Dryer for Peanut Roasting

Rotimi Rufus Dinrifo[1*], Lateef Ayodele Sanni[2] and Boluwatife Adewole[2]

[1]Department of Agricultural and Biosystems Engineering, Lagos State University of Science and Technology, Ikorodu, Lagos Nigeria
[2]Department of Agricultural and Environmental Engineering, Obafemi Awolowo University, Ile Ife, Osun State Nigeria

*Corresponding author: rdinrifo@yahoo.com (**ORCID ID:** 0000-0002-1385-0173)

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ABSTRACT

Roasting is a critical step in the preparation of peanuts for use as snacks and in processing of the nuts into oil, butter and flour. A rotary dryer developed at Sandel Engineering, Ile-Ife, Osun State Nigeria, for roasting peanuts, was evaluated. Using the Taguchi experimental design method, nine experiments were conducted to evaluate the effects of four operational parameters: quantity of peanuts, drum speed, airflow rate and drum temperature on the quality of roasted peanuts. The moisture content of the roasted samples ranged from 1.13% to 3.22%. The Taguchi method revealed signal to noise ratios of 4.05, 2.26, 0.37, and 5.41 for the four parameters respectively, their contributions were 30.34%, 7.87%, 1.85%, and 59.95%. Drum temperature emerged as the most critical parameter, followed by peanut quantity, drum speed, and airflow rate. The optimal roasting conditions were identified as a peanut quantity of 5 kg, drum speed of 60 rpm, airflow rate of 0.9 m^3/hr, and drum temperature of 150°C. The machine's roasting efficiency ranged between 68.55% and 88.46% across the nine experimental runs. The sensory evaluation revealed a preference for the sample which had a final moisture content of 1.78%, scoring the highest in colour, taste and overall acceptability.

HIGHLIGHTS

- Drum temperature is the most critical factor affecting roasting of peanuts in the assessed rotary dryer.
- Acceptable roasted samples have 1.13% to 3.22% moisture content.

Keywords: Peanut, roasting, rotary drier, Taguchi method, quality

Peanuts or groundnuts (*Arachis hypogaea*) are quite popular worldwide due to their numerous and valuable products such as oil, butter, flour. They are rich in protein, oil and fibres (Arya *et al*. 2016, Girish and Shiv, 2020) and are eaten as roasted or cooked nuts (Aliyu *et al.* 2023). The world peanut industry was valued at USD 90.05 billion in 2023 (Pradeep, 2024) and boasts of an annual worldwide production of about 35.6 million tons, grown on 26.4 million hectares. Nigeria currently ranked third in peanut production (Aliyu *et al.* 2023). with predominant cultivation occurring in the northern part of the country, specifically in states such as Kano, Kaduna, Taraba, Bauchi, Borno, and Adamawa (Tobin-West and Baraka, 2018). Groundnut holds a pivotal role in Nigeria as a major source of edible oil and a livelihood for small-scale farmers, particularly in Northern Nigeria.

Peanut can be added to a variety of food products without causing tremendous change in colour and flavour; however, when roasted, it develops a pleasant aroma, nutty flavour and smooth texture which is generally accepted (Bindhya and Anita 2015). Roasting of peanut is essential to enhance quality, easy handling, safe storage, further

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processing, and value addition of the product. The traditional roasting of peanut involves boiling dried or fresh peanut seeds with salt, followed by a light drying. Subsequently, the seeds are roasted in an earthen pot or a frying pan with coarse sand (Abdullahi *et al*. 2014). The challenges associated with traditional peanut roasting, such as tediousness, drudgery, and unhygienic circumstances are being addressed through the use of mechanical roasters.

Efforts have been made by many researchers to develop groundnut roasting machines, to enhance the groundnut roasting process, and to address various issues associated with the traditional methods. In a study by Aliyu *et al.* (2023) a peanut roasting machine was developed, which achieved a roasting efficiency of 70%, at a constant speed of 4.55 rpm, while the temperature varied between 140°C to 180°C over a duration of 10 minutes. However, bulk feeding of peanuts into the hopper resulted in the auger conveyor getting clogged, leading to an increased breakage ratio. There was also a need to increase the length of the roasting chamber to enable the roasted peanuts to come out easily before the roasting time is complete at the specified speed. Alao *et al.* (2020) also reported the design, fabrication and performance evaluation of groundnut roasting machine. Raw groundnuts were roasted with the fabricated machine and parameters such as weight of raw groundnuts, weight of roasted groundnuts, weight of seeds damaged were used to evaluate the efficiency of the machine. Average roasting efficiency of 94.11% was achieved. However, roasting efficiency was determined as the ratio of the weight of the roasted groundnut not damaged to the total weight of the roasted groundnut, and not of the effectiveness of energy usage. Musa *et al.* (2022) modified and optimized a groundnut roasting machine using Response Surface Methodology (RSM). The roasting efficiency of the machine was in the range of 55.15 – 76.50% at a feed rate of 240 kg/h and roasting temperature of 120°C.

There have also been manually operated peanut roasting machines. The roaster developed by Kabri *et al*. (2010) used charcoal as the source of heat and incorporated a blower to supply constant air to maintain the temperature while roasting. Ahanmisi *et al*. (2019) and Unguwanrimi *et al.* (2020) developed similar manually operated machines. In the three cases, very high values of efficiencies were claimed, based solely on the percentages of seeds that were not burnt during the roasting process. Roasting efficiency encompasses maximizing desirable qualities while minimising energy, time and defects (Mwena *et al*. 2025).

A rotary dryer was developed for roasting peanut by Sandel Engineering Services Limited, an industrial machinery manufacturing firm located in Ile-Ife, Osun State, Nigeria. This study evaluated the rotary dryer's performance for peanut roasting under various factors. The effects of the variation in the speed of the drum, quantity of peanuts, airflow rate, and temperature within the drum were analysed to show how these factors affected the roasting process.

MATERIALS AND METHODS

Description of the Sandel Engineering Rotary Dryer

The rotary dryer (Fig. 1) consists of a rotating cylindrical drum of diameter (0.308m) and length (1.05m), made of corrosion-resistant stainless steel. The drum is horizontally supported on two (2) roller bearings at each end is slightly tilted to ensure the peanut's downward fall due to gravity. The surface of the drum is heated continually using a gas burner during roasting. When a batch of peanuts is introduced into the cylindrical drum through the hopper; the peanut, being in contact with the hot surface of the rotating drum takes in the sensible heat from the heated drum.

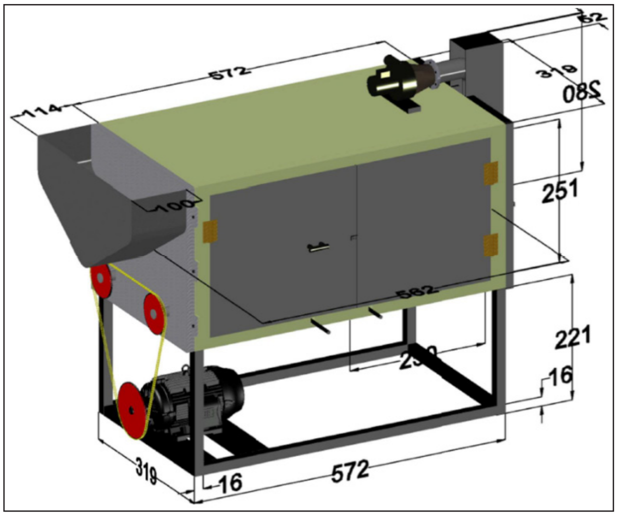

Fig. 1: The rotary dryer

Two (2) cartridge heating elements (220V, 75W) held in place at equal distances from the drum, ensured even transfer of heat within the drum. Controlling the airflow within the drum was achieved through a 2-inch gauge value fitted along the 2-inch pipe linked to the blower. The gauge valve operated at 3 different levels namely: full opening, half opening and quarter opening. A thermocouple (K-type: (-200 to +1250 ^{o}C; +/- 2^{o}C) was fitted into the cylindrical drum through the 2-inch pipe to measure the temperature within the drum.

Unlike Full Factorial Design (FFD), which requires running all possible experiments, the Taguchi method reduces the number of necessary experiments to a minimum without affecting the authenticity of the experimental results.

Table 1: Experimental design using Taguchi L9 orthogonal array

Experiment	Quantity (kg)	Speed (rpm)	Airflow rate (m^3/hr)	Temperature (°C)
1	5	20	0.45	110
2	5	40	0.9	150
3	5	60	1.8	130
4	7	20	0.9	150
5	7	40	1.8	110
6	7	60	0.45	130
7	9	20	1.8	130
8	9	40	0.45	150
9	9	60	0.9	110

Performance Evaluation

A batch of peanuts (95kg) was purchased from the local market at Sabo, Ile-Ife, Osun State and was stored in a cool place. Three levels of quantity, labelled as low (5kg), medium (10kg) and high (15kg), three levels of rotational speeds - low (20 rpm), medium (40 rpm), and high (60 rpm), three (3) temperature levels within the drum labelled low (110°C), medium (135°C), and high (150°C), were adopted. Three (3) airflow levels in m^3/hr as low, medium and high: 0.0075, 0.015, 0.03 m^3/hr. The airflow rate was controlled by the gauge valve, which allows for adjustments and measurement with an anemometer. A digital tachometer (Peak Tech 2790, LCD 5-digits display) was used to record the speed. For the performance evaluation of a rotary dryer for peanut which used 4 factors and 3 levels, L9 orthogonal array is suitable requiring 9 experiments as shown in Table 1. The total quantity of peanut used was 63kg.

The roasting performance was assessed primarily through measuring the moisture content of roasted peanuts and a sensory evaluation panel. The moisture content of the peanuts was determined at a regular time interval of 10mins from the start of the experiment to the end by taking 15g of samples, using oven drying method of ASABE D245.7 (ASABE, 2021). A twelve (12) member panellist consisting of six (6) male students and six (6) female students of the Obafemi Awolowo University were selected based of experience and familiarity with roasted groundnut for sensory evaluation. The organoleptic properties investigated are colour, aroma, taste, mouthfeel (smoothness), crunchiness and overall acceptability as recommended by (FAO, 2002). Each attribute was rated on a 3-point hedonic scale of 1 to 3 representing good, 2 for satisfactory and 3 for poor. The throughput capacity of the rotary dryer for peanut roasting was determined as quantity of sample after roasting per time. The efficiency of the rotary dryer was evaluated by measuring the moisture content of peanuts at regular intervals during the roasting process.

RESULTS AND DISCUSSION

Results

Table 2 presents the average moisture content at these intervals. The moisture content decreased steadily in all experimental runs, with the most significant reduction occurring within the first 30 minutes of roasting. Higher temperatures (130°C, 150°C) significantly expedited the roasting process, resulting in lower moisture content within shorter periods.

Fig. 2 shows the time at which each of the nine roasted sample of peanut reached their final moisture content which ranged from 1.13 to 3.22% wet basis for 60mins. The low standard deviation values across the experimental runs indicate a high degree of consistency in the roasting process. This consistency is critical for scale-up operations in industrial settings, where uniformity in product quality is essential. The calculated averages further support the conclusion that higher temperature is key to achieving optimal moisture content in roasted peanuts.

Table 2: Average moisture at different time intervals

Sl. No.	Experiment Factors				Average Moisture content @10 min	Average Moisture content @20 min	Average Moisture content @30 min	Average Moisture content @40 min	Average Moisture content @50 min	Average Moisture content @60 min
	Q_p	S_d	A_f	T						
1	i	i	i	i	7.85	6.82	4.88	4.30	3.83	2.72
2	i	ii	ii	ii	8.79	7.20	5.22	3.04	2.47	1.78
3	i	iii	iii	iii	8.33	6.33	4.39	2.79	1.93	1.13
4	ii	i	ii	iii	8.24	7.07	5.32	4.11	2.59	1.66
5	ii	ii	iii	i	8.68	7.98	6.21	5.12	4.18	3.22
6	ii	iii	i	ii	8.99	7.67	5.94	4.19	2.89	1.69
7	iii	i	iii	ii	9.52	7.87	6.84	5.29	4.19	2.97
8	iii	ii	i	iii	8.33	7.27	6.17	4.48	3.61	2.32
9	iii	iii	ii	i	9.07	7.89	6.63	4.99	3.99	3.22

**Note that Q_p, S_d, A_f, T represents the peanut quantity, drum speed, airflow rate and the temperature respectively while i, ii, iii represent the three levels that each experimental factor has.*
Under temperature T; the values i, ii, iii represents 110 °C, 130°C and 150°C respectively,
For peanut quantity P; the values i, ii, iii represents 5kg, 7kg and 9kg respectively,
For airflow rate Am; i, ii, iii represents 0.45m³/hr , 0.9m³/hr and 1.8 m³/hr respectively, and
For drum speed; i, ii, iii represents 20rpm, 40rpm and 60rpm respectively.

Sensory Evaluation

A sensory evaluation was conducted to assess the quality of the roasted peanuts using four organoleptic properties: colour, taste, mouthfeel, and crunchiness. The sensory evaluation results reveal a significant variation in the panellists' ratings across different samples. Samples with lower final moisture content generally received higher ratings, particularly in attributes such as crunchiness and taste, which are closely linked to moisture levels.

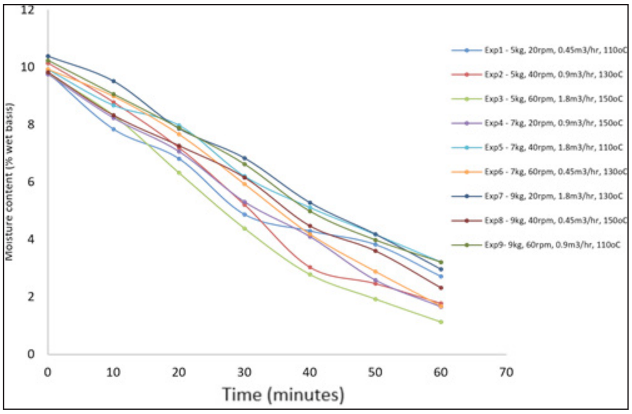

Fig. 2: Drying curves

Table 3 and Fig. 3 present the overall sensory evaluation results, summarizing the ratings for each sensory attribute across all nine samples. Achieving an optimal balance of roasting parameters can significantly enhance the sensory qualities of roasted peanuts, making them more appealing to consumers. Sample 2, which had a low final moisture content (1.78%), exhibited the highest acceptability rate of 91.7%.

Table 4 presents the moisture content attained during roasting. Moisture content plays a crucial role in determining the texture and overall acceptability of roasted products (Young *et al.* 2012). This result underscores the importance of controlling moisture levels to produce a high-quality, consumer-accepted product. Achieving the right balance between these factors is crucial for ensuring that the final product meets both quality standards and consumer expectations.

The sensory evaluation data was further analysed based on the gender of the panellists, providing a nuanced understanding of how different demographics perceive the quality of roasted peanuts. The male panellists displayed a preference for samples with more uniform roasting, particularly valuing attributes like crunchiness and taste while female panellists showed a strong preference for samples with optimal moisture content, particularly valuing colour and mouthfeel. It is crucial for product development, to aim for balanced sensory qualities that appeal to a broad demographic.

Table 3: Compound standard deviation and average moisture content

Sl. No.	E	Experiment Factors			Moisture content of the peanut after roasting of replicate A	Moisture content of the peanut after roasting of replicate B	Standard deviation	Average of Moisture content of the peanut after roasting of replicate A and B
	P_Q	*DS*	*AR*	*TR*				
1	i	i	i	i	2.98	2.45	0.37	2.72
2	i	ii	ii	ii	1.90	1.65	0.18	1.78
3	i	iii	iii	iii	1.25	1.00	0.18	1.13
4	ii	i	ii	iii	1.72	1.60	0.08	1.66
5	ii	ii	iii	i	3.23	3.20	0.02	3.22
6	ii	iii	i	ii	1.39	1.99	0.42	1.69
7	iii	i	iii	ii	3.11	2.83	0.20	2.97
8	iii	ii	i	iii	2.26	2.37	0.08	2.32
9	iii	iii	ii	i	3.13	3.31	0.12	3.22

Table 4: Final moisture content of roasted peanut for 60 minutes in the rotary dryer of the L9 experimental design

Experiment No	Quantity of peanut	Speed of drum	Air flow rate	Drum temp	Final MC
1	I	i	i	i	2.72
2	I	ii	ii	ii	1.78
3	I	iii	iii	iii	1.13
4	Ii	i	ii	iii	1.66
5	Ii	ii	iii	i	3.22
6	Ii	iii	i	ii	1.69
7	Iii	i	iii	ii	2.97
8	Iii	ii	i	iii	2.32
9	Iii	iii	ii	i	3.22

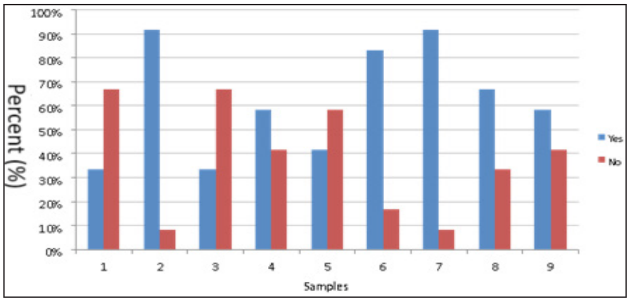

Fig. 3: Overall acceptability of panellists for sensory evaluation of roasted peanut

Effects of Rotary Dryer parameters on the drying kinetics and quality of Roasted Peanut

The four parameters expected to influence the performance of the rotary dryer in effectively roasting peanut were investigated statistically using the signal-to- noise ratio analysis (S/N) and analysis of variance (ANOVA). The S/N analysis (Table 5) helped to determine the parameters which had the strongest effect on the roasting of the peanut and the optimum levels at which the parameters gave the best performance of the rotary dryer. ANOVA helped to determine statistical significance of each parameter and their percentage contribution to the performance of the rotary dryer.

Throughput Capacity

The throughput capacity of the rotary dryer ranged between 4.36 kg/hr to 8.02 kg/hr. Table 6 shows the results of the throughput capacity of the rotary dryer for each of the experiments. The efficiency of the conductive multipurpose rotary dryer as given by was calculated using:

$$\varphi_d = \frac{W_s - W_c}{W_s} 100$$

where W_S (%) is the moisture content of the peanut before roasting and W_C (%) is the moisture content of

Table 5: Responses for moisture content of roasted peanut

Parameter	Symbol	Average S/N Ratio			Parameter Average	Grand mean	Maximum-minimum S/N Ratio	Ranking
		Level i	Level ii	Level iii				
Quantity of Peanut (kg)	Q	-4.92	-6.37	-8.97	-6.75	6.76	4.05	2
		1.88	2.19	2.84	2.3	2.62		
Drum Speed	D	-7.52	-7.49	-5.26	-6.76		2.26	3
		6.32	2.44	2.01	3.59			
Airflow rate	A	-6.85	-6.52	-6.89	-6.75		0.37	4
		2.22	2.44	2.4				
Temperature of Drum	T	-9.67	-6.34	-4.26	-6.76		5.41	1
		3.05	2.15	1.7	2.3			

Table 6: Throughput Capacity of the conductive multipurpose rotary dryer

Experiment No	Quantity of peanut	Speed of drum	Air flow rate	Drum temp	Mass	Time	Throughput
1	I	i	i	i	4.56	60	4.56
2	I	ii	ii	ii	4.38	60	4.38
3	I	iii	iii	iii	4.36	60	4.36
4	Ii	i	ii	iii	5.8	60	5.80
5	Ii	ii	iii	i	6.25	60	6.25
6	Ii	iii	i	ii	6.42	60	6.42
7	Iii	i	iii	ii	8.02	60	8.02
8	Iii	ii	i	iii	7.5	60	7.50
9	Iii	iii	ii	i	7.25	60	7.25

**Note that i, ii, iii represent the three levels each experimental factor has.*
For Temperature; i, ii, iii represents 110°C, 130°C and 150°C respectively,
For Peanut quantity; i, ii, iii represents 5kg, 7kg and 9kg respectively,
For Airflow rate; i, ii, iii represents 0.45m³/hr., 0.9m³/hr and 1.8 m³/hr respectively, and
For Drum speed; i, ii, iii represents 20rpm, 40rpm and 60rpm respectively.

the peanut after roasting. It shows higher efficiency for experiment where high temperature was used.

CONCLUSION

The multipurpose conductive rotary dryer built by Sandel Engineering Limited was evaluated to determine optimal operating conditions based on moisture content and sensory evaluation. The Taguchi method revealed S/N ratios of 4.05, 2.26, 0.37, and 5.41 for the four parameters, respectively, while ANOVA confirmed their contributions as 30.34%, 7.87%, 1.85%, and 59.95%. Drum temperature emerged as the most critical parameter, followed by peanut quantity, drum speed, and airflow rate. The optimal roasting conditions were identified as a peanut quantity of 5 kg, drum speed of 60 rpm, airflow rate of 0.9 m^3/hr, and drum temperature of 150°C. The machine's roasting efficiency ranged between 68.55% and 88.46% across nine experimental runs.

The findings of this study have significant implications for the industrial-scale production of roasted peanuts. By optimizing the key roasting parameters—temperature, airflow rate, peanut quantity, and drum speed—producers can achieve a high-quality product that meets consumer expectations for taste, texture, and overall acceptability. Overall, the research results provide a technology intervention which can help in the industrial processing of peanut in Nigeria.

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