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EFFECTS OF SOME EXPERIMENTAL FACTORS ON THE PERFORMANCE OF AN INTEGRATED OIL EXTRACTION MACHINE

Lawan, I.; Ali, M.A and Abubakar, M. S.
Department of Agricultural Engineering, Faculty of Engineering, Bayero University Kano.
Email: ilawan.age@buk.edu.ng

ABSTRACT

An integrated groundnut oil extraction machine developed at the Department of Agricultural Engineering, Bayero University Kano was evaluated and the effects of some experimental factors were examined. Throughput capacity, extraction rate and extraction efficiency were used as performance indicators, while varieties of groundnut seeds (Manipintar and Ex-Dakar), kneading speeds on the paste (200, 111 and 73 rpm) and quantities of groundnut seeds (24, 16.8 and 12 kg) were used as experimental factors. The experiment was conducted using 2x3x3 factorial in completely randomized design (CRD) in three (3) replications. Thus, a total of fifty four (54) experiments were conducted with the samples at 2.52 and 2.69% (db) moisture content for Manipintar and Ex-Dakar variety respectively. The oil content of the samples obtained were 50.40 and 49.20% for Manipintar and Ex-Dakar variety respectively. Results revealed that the highest throughput capacity achieved was 24.45 kg/hr with combination of Ex-Dakar Variety, kneading speed of 200 rpm and 24 kg of groundnut seeds. The highest extraction rate achieved was 7.90 Lit/hr with combination of Manipintar Variety, kneading speed of 200 rpm and 24 kg of groundnut seeds. Also, the highest extraction efficiency of 78.59% was achieved with combination of Manipintar Variety, kneading speed of 200 rpm and 12 kg of groundnut seeds. Statistical analysis of the results has established that the use of different quantities and varieties of groundnut seeds on the machine is highly significant on all the performance indicators used. While use of different kneading speeds was found to be highly significant on the extraction rate and extraction efficiency. C

KEYWORDS: Integrated machine; Oil extraction; Throughput capacity; Extraction rate; Extraction efficiency.

1.0 INTRODUCTION

Groundnut seed (*Arachis hypogea*), also known as peanut and earthnut, is the most common oil nut grown as an annual crop on about 19 million hectares of land in tropical, sub-tropical and warm temperature regions of the world. It is grown principally for its edible oil and protein rich seeds. The oil content of the seeds is between 45% and 55% depending on the variety (Young, 1982; Woodroof, 1983). To remove the oil content from the groundnut seed, the process known as oil extraction, expelling or expressing is carried out. There are four (4) different methods of extracting oil from groundnut seed namely: traditional; mechanical; chemical and mechano-chemical as explained by Ewaoda *et al.* (2008). The traditional process usually starts with shelling of the dried

groundnut pods to free the seeds. The complete sequence of the process is: shelling, winnowing, cleaning, sun drying, roasting, de-skinning, winnowing, sorting, grinding, primary extraction and secondary extraction (Isiaka, 2005). The collected oil is then deeply fried to separate mixture of fresh groundnut oil and water. This is the process employed by numerous women in the traditional processing of groundnut in Nigeria. Study revealed that 75% of the rural women engaged in groundnut processing used the traditional technologies which are labour intensive and time consuming (Dunmade, 1991). Also, it was found that amongst 436 processors of groundnut oil in three Northern States (Niger, Kaduna and Kano), 74% claimed that they were processing for income generation (Nalumansi and Kaul, 1992). Thus, the processing represents an important economic activity for the women. In recognition of the importance of the activity, as outlined above, many studies were carried out with a view to improving the process. Aliyu (2008) conducted a study to evaluate the traditional groundnut oil extraction process. Results revealed that apart from the drudgery involved, a lot of time is wasted in the activity. A similar study by Ibrahim (2010) in a different location arrived at same findings and recommended improved equipment for small scale groundnut oil extraction. This recommendation prompted different technological intervention in form of developing simple devices for roasting, de-skinning/winnowing and kneading by a number of researchers (Abdussalam, 2013; Abdulaziz, 2014; Bashir, 2014). Despite these developments, the devices still had many aspects desiring modifications. Ibrahim (2015) re-designed these existing devices, developed a milling machine and integrate them together to form an integrated oil extraction machine. This paper therefore, examine the effects of variety of groundnut seeds used, kneading speed used in kneading sub-process and quantity of groundnut seeds used as input for the machine, so as to establish and document the best operating factors for optimum groundnut oil extraction.

2.0 MATERIALS AND METHODS

2.1 Materials

The following materials were used in the current experimental study:

i. Stop watch.

ii. Graduated cylinder.

iii. Sensitive weighing balance (G and G Electronic Scale, 3000g capacity, model: JJ3000Y 0.1g sensitive).

iv. Weighing balance (Camry 150 g capacity, 500 g sensitive).

v. Moisture analyzer (Adam Max. 50 g capacity, 0.001 g sensitive, model; PMB53).

vi. The integrated machine;

The integrated machine consists of four (4) units; roasting, de-skinning/winnowing, milling and kneading units. Thus, groundnut oil is produced by the machine from the just shelled groundnut seeds. The roasting unit consists of roasting chamber, stirrer shaft and the charcoal stove. The shelled groundnut seeds are feed into the roasting chamber and the groundnut seeds got roasted by the heat provided by the charcoal stove. Uniformity in roasting is provided by the stirring action of the stirrer shaft that is manually operated. The roasted groundnut seeds are de-skinned by the rubbing action of the scrubber against the rough surface,

and the de-skinned groundnut seeds are cleaned by centrifugal fan attached below the de-skinning chamber. The cleaned groundnut seeds proceed to the milling unit through a delivering chute inclined at an angle that is greater than the angle of repose of groundnut seeds. The paste produced is conveyed to the kneading unit manually where the paste undergoes the kneading operation by the action of the stirrer shaft that is powered by the prime mover. Plate 1 shows the integrated oil extraction machine.

Plate 1: The Integrated Oil Extraction Machine

2.2 Methods

2.2.1 Experimental factors used

The machine was subjected to three factors during the performance evaluation, namely; variety *V*, quantity of groundnut seeds used *Q*, and kneading speed *K*. Two (2) varieties were used (*Manipintar* and *Ex-Dakar*), three (3) kneading speeds (200, 111 and 73) rpm and three (3) sample sizes of groundnut seeds used (24, 16.8 and 12) kg were also used.

2.2.2 Performance indicators used

The performance indicators used were; throughput capacity (kg/hr), extraction rate (Lit/hr) and extraction efficiency (%). The procedure followed was as reported by Adgidzi *et al*. (2006) and Harmanto *et al*. (2009) as follows;

Throughput capacity: Throughput capacity quantifies the machine's capability in terms of groundnut seeds it can process per unit time. That was obtained using Equation 1 given by Harmanto *et al*. (2009):

$$T_C = \frac{M}{T} \text{.....(1)}$$

Where; T_C= Throughput capacity (kg/hr), M= Mass of seeds processed (kg) and T= Time taken for expelling (hr).

Extraction rate: Extraction rate quantifies the volume of oil that the machine is capable of expelling per unit time. That was obtained as volumetric oil yield per unit time as shown in Equation 2 given by Harmanto et al. (2009):

$$E_R = \frac{Y_O}{T} \text{.....(2)}$$

Where; E_R= Extraction rate (lit/hr) and Y_O= Oil yield (lit) and T= Time taken for expelling (hr).

Extraction efficiency: Extraction efficiency depicts the level of effectiveness of the developed machine comparing the volume of oil extracted to the volume of extractible oil in the processed seeds. That was obtained using according to Adgidzi *et al*. (2006);

$$\eta = \frac{W_d}{W_b} \times 100 \text{.....(3)}$$

Where: η = machine efficiency; W_d= Weight of extracted oil (kg) and Wb= Weight of extractible oil (kg) (% Oil content x Mass of seeds processed (kg).

2.2.3 Experimental design used

The experiments were conducted using 2*3*3 factorial in completely randomized design (CRD). Two (2) varieities of groundnut seeds (V_1 and V_2), three (3) different quantities of groundnut seeds (Q_1, Q_2 and Q_3) and three (3) kneading speeds (K_{S1}, K_{S2} and K_{S3}) were used. That resulted to a total of eighteen (18) treatments. Each of these treatments was subjected to three (3) replications, thus making the number of experiments conducted to be fifty four (54).

2.2.4 Sample preparation

A total of 316.8 kg of groundnut seeds was required for the whole experiments, therefore, 160kg each for the two varieties (*Manipintar* and *Ex-Dakar*) were obtained from *Dawanau* Market, Kano. Thereafter, dirt, foreign materials and immature seeds were removed manually. Moisture analyzer was used in determining moisture content of the groundnut seeds. The moisture contents were found to be 2.52 and 2.69% dry basis for *Manipintar* (*Mai Bargo*) and *Ex-Dakar* respectively. Percentages of oil (extractible oil) in each of the varieties were also determined using Soxhlet Apparatus found at Fortunes Oil Mills Nigeria Limited, *Tokarawa* Hadejia Road, Kano. The oil contents were; 50.40 and 49.20% for *Manipintar* (*Mai bargo*) and *Ex-Dakar* respectively.

2.2.5 Experimental procedures

The stove of the roasting unit was filled with charcoal (5.88 kg) and fire was ignited and it was given some time to circulate throughout the stove. Groundnut seeds were emptied into the roasting chamber and the crank handle was operated until the roasting time elapsed (15 Minutes). The roasted seeds were allowed to go out to the de-skinning/winnowing unit through an exit gate of the roasting unit. The crank handle of the scrubber was also operated and the de-skinned groundnut was cleaned by the centrifugal blower. The clean seeds were milled and the groundnut paste was manually placed inside the kneading chamber. The kneading unit was activated by switching on the bevel gear box and the stirrer shaft rotate and carryout the kneading operation. During the kneading operation, specified quantity of warm water (6.25, 4.25 and 3.25 kg for 24, 16.8 and 12 kg groundnut seeds respectively) was added to the

paste as recommended by Ola (2000). The added water facilitated the leaching process. The extracted oil was collected through the one way valve using a container. The total time spent for each experiment, weight of seeds processed, and volume of oil collected, weight of oil collected and weight of cake obtained were measured and recorded accordingly. The data recorded were used in the computations of the performance parameters (Throughput capacity (kg/hr), Extraction rate (lit/hr) and Extraction efficiency (%)) as outlined above.

It should be noted that the following conditions were strictly adhered to during the experiment:

i. The quantity of charcoal in the stove was maintained at maximum (5.88 kg) throughout the experiments.

ii. The average human cranking speed of 50 rpm at the roasting unit was kept constant throughout the experiments.

iii. Roasting time was evaluated for the three different quantity of groundnut used (24, 16.8 and 12 kg). It was established that there was no significant difference between the roasting times obtained. 15, 13 and 12 minutes respectively for 24, 16.8 and 12 kg respectively. Therefore, roasting time of 15 minutes was used throughout the experiments.

iv. The average human cranking speed of 50 rpm at the de-skinning unit was kept constant throughout the experiments.

v. The setting of the grinding plates was maintained at clearance of 3 mm throughout the experiments.

vi. 12 minutes kneading time was kept constant throughout the experiments as recommended by Ewoada (2006).

3.0 RESULTS AND DISCUSSION

3.1 Effects of Variety, Kneading Speed and Quantity of Groundnut seeds on Throughput Capacity

The mean values of throughput capacity, extraction rate and extraction efficiency computed from the experimental data obtained from the experiments are presented in table 1. The values were subjected to analysis of variance (ANOVA) and result shown in Table 2 revealed that effects of variety and quantity of groundnut seeds used were found to be highly, while kneading speed was not significant. All the first and second order interactions were statistically not significant. Further analysis using LSD revealed that the mean throughput capacity was found to be statistically higher with V_2 (*Ex-Dakar* Variety). These differences can be attributed to the lower oil content in V_2 (Ex-Dakar Variety) which resulted to easier de-skinning/winnowing and milling operations, thus spending less time. In case of V_1(*Manipintar* Variety) more time is utilized as a result of higher oil content that resulted to more difficult and time consuming de-skinning/winnowing and milling operations.

Also, further analysis using LSD revealed that the mean throughput capacity was found to be higher with higher quantity of groundnut seeds. This shows that throughput capacity increases with increase in quantity of groundnut seeds used from 12 kg to 24 kg. This trend was in line with what was obtained by Arowosaiye (2002), Ewoada (2006), and Salawu (2013). Comparing the throughput values of the integrated machine with that of the traditional, as given by Aliyu (2008),

shows the highest throughput capacity (24.45 kg/hr) of the integrated machine compared with 3.75 kg/hr from the traditional represents a 552% increase in throughput capacity.

Table 1: Mean Values of Throughput Capacity, Extraction Rate and Extraction Efficiency

Treatment	Mean Values of Performance Parameters		
	Throughput Capacity (kg/hr)	Extraction Rate (L/hr)	Extraction Efficiency (%)
$V_1Ks_1Q_1$	23.23	7.9	64.44
$V_2Ks_1Q_1$	24.24	6.6	63.94
$V_1Ks_2Q_1$	23	5.5	48.91
$V_2Ks_2Q_1$	24.45	4.2	48.02
$V_1Ks_3Q_1$	23.2	3.5	36.79
$V_2Ks_3Q_1$	24	2.5	36.98
$V_1Ks_1Q_2$	16.2	5.55	71.34
$V_2Ks_1Q_2$	17	4.96	60.9
$V_1Ks_2Q_2$	16.11	3.6	50.68
$V_2Ks_2Q_2$	17.65	3.1	43.8
$V_1Ks_3Q_2$	16.35	2.5	31.85
$V_2Ks_3Q_2$	17.25	2.2	22.09
$V_1Ks_1Q_3$	11.5	3.99	78.59
$V_2Ks_1Q_3$	12.25	3.54	71.42
$V_1Ks_2Q_3$	11.6	2.6	43.39
$V_2Ks_2Q_3$	12.25	2.5	28
$V_1Ks_3Q_3$	11.7	2.4	38.75
$V_2Ks_3Q_3$	12.6	2.1	16.15

3.2 Effects of Variety, Kneading Speed and Quantity of Groundnut Seeds used on Extraction Rate

Tables 1 shows the mean values of the extraction rate obtained. The values were subjected to analysis of variance (ANOVA) and result shown in Table 2 revealed that all the main effects were statistically significant at 1% probability level. On the first order interactions, variety and kneading speed was not significant at 5% probability level, while that of variety and quantity of groundnut seeds, and kneading speed and quantity of

groundnut seeds were found to be significant at 1% probability level.

Further analysis using LSD revealed that the mean extraction rate using V_1 (*Manipintar* Variety) was found to be significantly different from the mean extraction rate using *V2* (*Ex-Dakar* Variety). This difference can be attributed to the difference in oil content of the varieties. Also, further analysis using LSD revealed that the mean extraction rate increases as the kneading speed increases. Similar trend has been reported by Maduoko *et al*. (2004). More so, for the quantity of groundnut seeds used, further analysis using LSD revealed that the mean extraction rate was found to increase as the quantity of groundnut seeds used increases. This can also be attributed to the fact that the more the quantity of groundnut seeds the more the oil obtained, since volume of oil is a function of percentage of oil content of seeds and quantity of seeds handled. This finding was in line with what was obtained by Ewoada (2006).

From the results obtained, the highest extraction rate of the integrated machine (7.9 Lit/hr) compared with 0.11 Lit/hr and 0.83 Lit/hr from the traditional method using pestle/ mortar and improved technology (using manually operated machine) represents 7, 082 and 852% increase in extraction rate respectively.

3.3 Effects of Variety, Kneading Speed and Quantity of Groundnut Seeds Used on Extraction Efficiency (%)

Table 1 shows the mean values of the extraction rate obtained. The values were subjected to analysis of variance (ANOVA) and result shown in Table 2 revealed that all the main effects were statistically significant at 1% probability level. On the first order interactions, variety and kneading speed was found to be significant at 5% probability level. While variety and quantity of groundnut seeds used, and kneading speed and quantity of groundnut seeds used was found to be significant at 1% probability level. The effect of variety on the extraction efficiency was found to be statistically significant at 1% probability level.

Further analysis using LSD revealed that mean extraction efficiency obtained using V_1 (*Manipintar* Variety) was found to be higher than the mean extraction efficiency obtained using V_2 (*Ex-Dakar* Variety). This difference can be attributed to the difference in percentage of oil content within the varieties used. Also, further analysis using LSD revealed that mean extraction efficiency increases with increase in kneading speed.

Table 2: Analysis of Variance for the Performance Parameters and their Interaction

Sources of variation	**Degree of freedom**	**Calculated F**		
		Throughput Capacity (kg/hr)	**Extraction Rate (L/hr)**	**Extraction Efficiency (%)**
Replication	2	6.37*	0.01^{NS}	1.52^{NS}
Variety, *V*	1	52.91^{**}	146.82^{**}	271.62^{**}
Kneading speed, *Ks*	2	0.30^{NS}	994.94^{**}	1779.57^{**}
Quantity, *Q*	2	2554.97^{**}	564.80^{**}	31.12^{**}

Interactions:				
VxKs	2	0.77^{NS}	1.79^{NS}	4.94^{*}
VxQ	2	0.62^{NS}	27.42^{**}	45.90^{**}
KsxQ	4	0.44^{NS}	73.02^{**}	69.52^{**}
VxKsxQ	4	0.50^{NS}	0.71^{NS}	11.45^{**}
Total	53			

Key: NS = Not significant; * = Significant at 5% probability level; ** = Significant at 1% probability level.

More so, the effect of variation in quantity of groundnut seeds used was found to be statistically significant at 1% probability level. Further analysis using LSD revealed that there is significant difference between the mean extraction efficiency obtained using 24kg of groundnut seeds and the mean extraction efficiency obtained using the 16.8kg of groundnut seeds, but there is no significant difference between the mean extraction efficiencies obtained using 12kg of groundnut seeds and other quantities of groundnut seeds (24 and 16.8 kg). Comparing the highest extraction efficiency achieved with the integrated machine (78.59%) with the extraction efficiency achieved with the traditional method (65%) given by Aliyu (2008) represents 21% increase in extraction efficiency.

4.0 CONCLUSIONS

The following conclusions were made;

i. The effects of variety, kneading speed and quantity of groundnut seeds used were examined on throughput capacity, extraction rate and extraction efficiency.

ii. The effects of variety of groundnut seeds used were found to be highly significant on throughput capacity, extraction rate and extraction efficiency.

iii. The effects of kneading speed were found to be highly significant on extraction rate and extraction efficiency.

iv. The effects of quantity of groundnut seeds used were found to be highly significant on throughput capacity, extraction rate and extraction efficiency.

v. The effects of the interaction of variety of groundnut seeds used and kneading speed was found to be significant on extraction efficiency.

vi. The effects of the interaction of variety and quantity of groundnut seeds used were found to be highly significant on extraction rate and extraction efficiency.

vii. The effect of the 3-factor interaction of variety of groundnut seeds used, kneading speed and quantity of groundnut seeds used was significant on extraction efficiency.

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