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Effect of Hydrothermal Pre-Treatment on Snake Gourd Seed Shelling

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A B S T R A C T

Shelling is a fundamental unit operation during oil extraction of snake gourd seed oil. Lack of proper and efficient method of shelling the seed has been identifying as a major problem in the production and utilization of snake gourd seed oil. Currently manual method is popular which is cumbersome, time consuming and not efficient for the process. Seed pretreatment is required prior to shelling operation for some crops like snake gourd. Effect of hydrothermal pretreatment was evaluated on the shelling efficiency, percentage unshelled and percentage broken of the seed. The evaluations were done using a 2 by 3 by 5 factorial experiment. The two factors and their levels are soaking time (10, 20, 30, 40, and 50 minutes) and seed drying temperature (60, 70, 80, 90, and 100 °C). The result of the experiment shows that the highest shelling efficiency of 82.11% was achieved when the wetting time was 60 minutes and the seed drying temperature was 100 °C while the least efficiency (47.4%) was recorded when the wetting time was 10 minutes and seed drying temperature was 60°C. The highest percentage unshelled (49.1%) was recoded at 10 minutes soaking time and 60°C seed drying temperature. It was observed that the broken percentage decreased from 11.9 to 6.15% as the drying temperature decrease from 100 to 60°C. In conclusion, it was observed that the higher the soaking time and drying temperature the higher the shelling efficiency and the lower the unshell percentage.

Introduction

Snake gourd plant (*Trichosanthes cucumerina* L) is a tropical or subtropical vine that climbs up tree and unfurls the flowers and fruits to hang down to the ground (1). It is very popular in Asia, Africa, Australia, Europe, and South America (2). In Nigeria it is known as snake tomato, pathakaya in India, pakupis in Philippines, buapngu in Thailand, pudalanka in Tamil, paduvalakaayi in kannada and padavalanga in Malayam. The kernels contain soft endosperm which has been proved to be a good source of vegetable oil (3; 4). Postharvest operation is an essential unit operation in an agricultural production and improves the usability of agricultural products. Removal of the seed coat from the kernel is very tedious when manual method is used. Shelling of oil bearing seed before oil expression has been proofed to be of great advantage like better quality and quantity of both raw oil (low wax content) and meal

(higher protein content), and also increases the life span of the oil extraction machine (5; 6 and 7). (8) reported an increase in oil extracted from *Jatropha curcas* seed as the percentage of dehusk seed decreases. The treatment of some seed hydrothermally has been reported to improve their percentage of decortications. Many seeds like melon and sunflower seed decortications were carried out at a certain moisture content to have high decortications percentage (9). Shelling operation was found to depend on moisture content. (1)reported that as moisture content increased from 7 to 10% the shelling efficiency of melon seed shelling machine also increase from 45 to 99 %. Evaluation of shelling process of some industrial crops such as safflower (10) cotton seed (11), sunflower seed (12) and moringa seed (13) has been reported. However, the preliminary research has shown a great opportunity by using mechanical method after a hydrothermal pretreatment of the seed. Hydrothermal treatment involves soaking the seed in water for specific time and then dried it at a specified temperature. This method of pre-treatment with varying degrees has been applied to some crops like millet (14) and rice (15).

In resent time, research work had been done on physical properties of snake gourd (16) and also effect of washing kernel on color and rheological property of snake gourd oil (3) but no work has been done on the effect of hydrothermal pretreatment on snake gourd decortication, hence, the study was done.

Materials and Methods

Material sample collection

The snake gourd seeds used were obtained from the Department of Agricultural Engineering, Ladoke Akintola University of Technology demonstration farm, Ogbomoso,

Nigeria. The seeds were clean to remove immature and damaged seeds before using them for the studies. A snake gourd sheller (Fig. 1) that was developed at the same department was used for the evaluation.

The experimental procedure

5 kg of snake gourd seed was steeped in distil water for a specified time (10, 20, 30, 40 and 50 minutes). The seeds were removed after the specified time and then spread in a steel tray in about 2.5 cm bed thickness and dried in an oven at a specified temperature (60, 70, 80, 90, and 100°C) with uniform drying time of 20 minutes each. The samples were then shelled and separated into shelled, unshelled and broken kernel which was used to calculate the shelling efficiency of the machine.

Evaluation of the machine

The effect of hydrothermal pretreatments of snake gourd seed on shelling was studied under the following headings: Effect of Soaking Time and Seed Drying Temperature on the Shelling efficiency of the machine, percentage unshelled and percentage broken of kernel.

Machine efficiency

The effect of hydrothermal pretreatment on seed shelling efficiency of the machine was calculated from Equation 1 adapted from (18).

$$M_E = \frac{P_k}{K} \times 100 \qquad (1)$$

Where M_E is machine efficiency (%), P_k is percentage kernel recovery,
and K represents the percentage of kernel in seed at the time of shelling.

$$K = \frac{M_S}{M_K} \times 100 \qquad (2)$$

Where k is the percentage of kernel in seed at

time of shelling,
M_s is mass of seed in 100g and M_k is the mass of kernel in 100g
Note: k was found to be 54.3%

Percentage of unshelled kernel

Equation 3 was used to calculate the percentage unshelled.

$$P_{us} = \frac{M_{us}}{M_s} \qquad (3)$$

Where P_{us} is percentage unshelled (%)
M_{us} is mass of unshelled seed (g) and M_s is total mass of seed (g)

Percentage of broken kernel

To calculate the broken percentage Equation 4 was used
This was calculated from Equation

$$T_B = \frac{M_C}{M_C + M_B} \times 100 \qquad (4)$$

Where:
T_B is Percentage shelled
M_B is mass of whole cotyledons
M_C is mass of broken cotyledon

Experimental design

The two factors selected for the hydrothermal pretreatment of seeds before shelling are soaking time (which resulted in differential moisture content) and seed drying temperature. Table 1 shows the five-level two factor that was used for the evaluations. These factors were used in investigating the shelling efficiency of the machine.

Statistical analysis

The Design Expert version 6.0.8 of 2002 was used as statistical tool to evaluate main and the interactive effects of these factors on both

the shelling and breakage percentage of the machine. Response surface methodology (RMS) was used because of its advantages which include reduction of experimental runs needed to give adequate information for statistical acceptability results, also its ability to assess the relationship between the responses and the independent variables and define the effect of the independent variables, alone or in combinations. The advantages also include comprehensive experimental design and mathematical modeling through the partial regression fitting of the mathematical modeling. The software was also used to determine the coefficient of determination for the models. Excel 2013 was used to draw histogram to show the relationship between the two factors.

Results and Discussion

Effect of hydrothermal pretreatment of snake gourd seed on shelling efficiency of an impact snake gourd shelling machine

The results of the effect of soaking time and seed drying temperature pretreatment on shelling efficiency and breakage percentage of an impact sheller, design at Ladoke Akintola University of Technology, Ogbomoso is as presented below.

Effect of Soaking Time and seed drying temperature on shelling Efficiency of the machine

The results of the experiment on the effect of soaking time on the decorticating efficiency of the machine were as shown in Table 2. The decorticating efficiency of the machine was observed to increase as the soaking time and seed drying temperature increased (Fig. 2). The highest decorticating efficiency of 82.11% was observed when the soaking time was 50 minutes, seed drying temperature of 100 °C and machine speed of 461rpm, while

the lowest decorticating efficiency of 47.3% was recorded at 10 minutes soaking time, 60 °C seed drying temperature and 461rpm machine speed. These results follows the same trend as reported by (19), who recorded efficiency of 71% at 7 min. of soaking time and 54% efficiency at 5 min. of soaking time. Also, (12) recorded the highest decorticating efficiency of 70.14% at 20 min. soaking time and lowest decorticating efficiency of 37.87% at 0 min of soaking time. The results of the experiments showed that as the hydrothermal pre-treatment increased the shelling efficiency of the machine also increased

Statistical analysis of the effect of hydrothermal pretreatment on the efficiency of the machine

The results of the experiments were fixed into Design Expert version 6.0.8 software for statistical analysis. The analysis showed that the two factors investigated (soaking time and seed drying temperature) and their interactions were significant ($p < 0.05$) (Table 3) on the shelling efficiency.

The empirical model relating the soaking time and seed drying temperature to predict the shelling efficiency of the machine is as presented in Equation 5.

$$S_E = -0.15186 + 0.10076\ S_T + 0.81685 D_T + 0.3758 \times 10^{-3} D_T S_T$$
$$(R^2 = 0.8435)\quad (5)$$

Where,
S_E is shelling efficiency (%)
D_T *is* drying temperature (° C)
S_T is soaking time (min.)

Effect of drying temperature and soaking time on the percentage seed unshelled

The results of the experiment show that the percentage unshelled varies inversely with seed drying temperature and soaking time.

The highest unshelled (49.1%) was observed when the soaking time was 10 min. at 60 °C drying temperature while the lowest percentage unshelled (6.4%) was recorded at 50 minutes soaking time when the seed drying temperature was 100 °C at 461 rpm hammer speed. The higher the soaking time and seed drying temperature the lower the percentage unshelled of the machine (Table 4). The percentage unshelled increased as the soaking time and seed drying temperature reduced (Fig. 3). This was in agreement with the report of (20) that reported highest unshelled efficiency (13.5%) for canola seeds when soaked in distilled water for 100 minutes followed by hot air drying at 65 °C. Also, (21) recorded the highest percentage of undepulped seed at 9 % at 15 minutes of soaking time, while the lowest percentage of undepulped seed was 1% at 75 minutes of soaking time.

Statistical analysis of the effect of hydrothermal pretreatment on the percentage unshelled of the machine

The results of the experiments were fixed into Design Expert version 6.0.8 software for statistical analysis. The analysis showed that the two factors investigated (soaking time and seed drying temperature) and their interactions were significant ($p < 0.05$) (Table 5) on the percentage unshelled. The empirical model relating the soaking time and seed drying temperature to predict the percentage unshelled of the machine is as presented in Equation 6.

$$P_U = 96.74 - 0.02003 S_T - 0.7731 D_T - 2.4187 \times 10^{-3} D_T S_T$$
$$(R^2 = 0.9925)\ (6)$$

Where,
P_u is percentage broken (%)
D_T *is* drying temperature (°C)
S_T is soaking time (min.)

Table.1 Five-level, two factors hydrothermal pre-treatment on snake gourd decortication

Factors	Levels				
Soaking Time (min.)	10	20	20	40	50
Drying Temperature (°C)	60	70	80	90	100

Table.2 Effect of soaking time and seed drying temperature on the shelling efficiency of   the machine

Evaluation	D_T (°C)	Soaking Time (minutes)				
		10	20	30	40	50
Shelling efficiency	60	47.3	48.8	50.33	51.88	54.56
	70	54.1	55.63	57.1	60.10	60.43
	80	61.70	63.23	64.30	66.54	67.65
	90	68.32.33	69.83	70.32	71.89	74.33
	100	75.18	76.86	78.44	69.88	82.11

Average of three experimental runs

Table.3 Analysis of variance table for response surface model of the effect of the seed hydrothermal pretreatment on shelling efficiency of the machine

Source		Sum of Squares	DF	Mean Squares	F Value	Prob > F
Model		1714.75	3	571.59	4288.62	< 0.0001
	DT	*110.70*	*1*	*110.70*	*830.57*	*< 0.0001*
	SA	*1597.22*	*1*	*1597.22*	*11985.89*	< 0.0001
	DTSA	*1.21*	*1*	*1.21*	9.08	< 0.0146
Residual		1.20	9	0.13		
Cor Total		1715.96	12			

Table.4 Effect of soaking time and seed drying temperature on the percentage unshelled of the machine

Evaluation	D_T (°C)	Soaking Time (minutes)				
		10	20	30	40	50
% Unshelled	60	49.1	47.4	55.4	54.0	41.77
	70	40.13	39.00	37.20	35.3	34.5
	80	32.30	29.10	29.00	26.2	24.44
	90	24.2	23.3	19.5	18.5	15.76
	100	17.6	14.3	11.2	9.07	6.4

Average of three experimental runs

Table.5 Analysis of variance table for response surface model of the effect of the seed hydrothermal pretreatment on percentage seed broken of the machine

Source		Sum of Squares	DF	Mean Squares	F Value	Prob > F
Model		1674.09	3	558.03	1036.40	< 0.0001
	DT	*113.63*	1	*113.63*	*211.04*	*< 0.0001*
	SA	*1551.09*	1	*1551.09*	*2880.77*	< 0.0001
	DTSA	*3.74*	1	*3.74*	*6.95*	< 0.0270
Residual		4.85	9	0.54		
Cor Total		1678.94	12			

Table.6 Effect of soaking time and seed drying temperature on percentage breakage of the machine

Evaluation	D_T (°C)	Soaking Time (minutes)				
		10	20	30	40	50
Breakage percentage	60	6.1	5.8	5.4	5.0	5.0
	70	6.8	6..3	6.0	5.8	5.5
	80	7.5	6.8	6.6	6.5	6.5
	90	9.9	8.3	7.8	7.6	7.5
	100	11.9	10.8	10.6	9.9	9.6

Average of three experimental runs

Table.7 Analysis of variance table for response surface model of the effect of the seed hydrothermal pretreatment on percentage broken of the machine

Source		Sum of Squares	DF	Mean Squares	F Value	Prob > F
Model		47.10	5	9.42	104.19	< 0.0001
	DT	*3.03*	1	*3.03*	*33.49*	*< 0.0007*
	SA	*33.01*	1	*33.01*	*365.09*	< 0.0001
	DT2	*0.26*	1	*0.26*	*2.92*	< 0.1313
	WT2	*3.34*	1	*3.34*	*36.91*	< 0.0005
	DTSA	*0.36*	1	*0.36*	*3.98*	< 0.0802
Residual		0.63	7	0.09		
Cor Total		47.73	12			

Fig.1 The snake gourd sheller

Fig.2
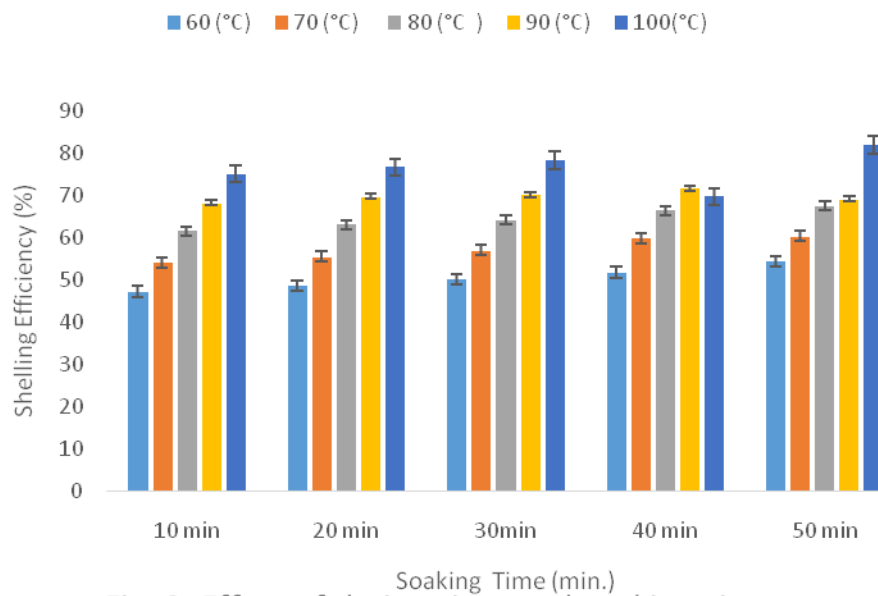
Fig. 2: Effect of drying time and soaking time on the shelling efficiency of snake gourd seed

Fig.3

Fig. 3: Effect of drying time and soaking time on the percentage unshell of snake gourd seed shelling machine
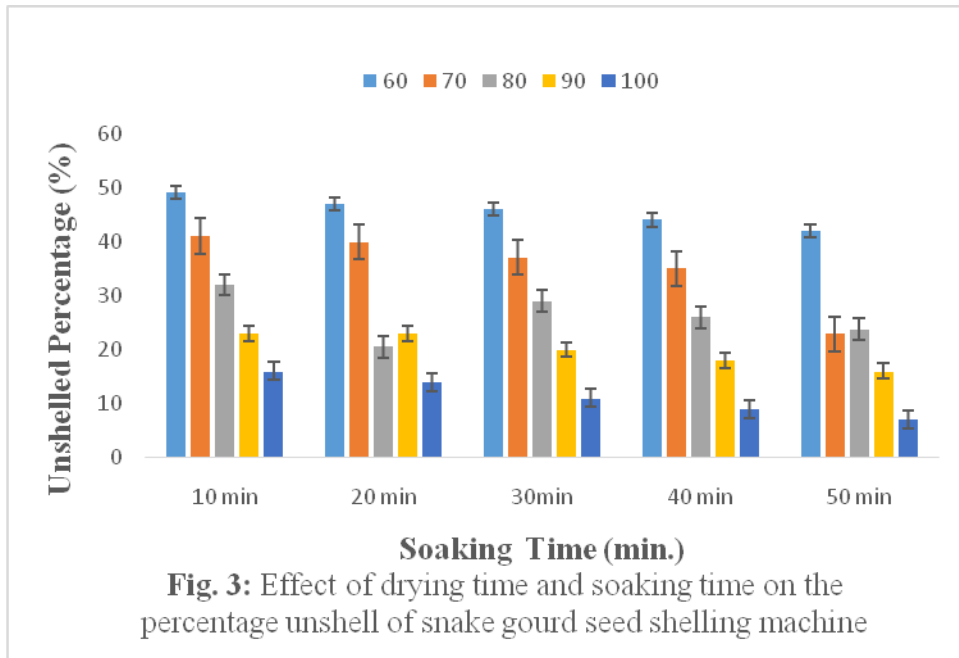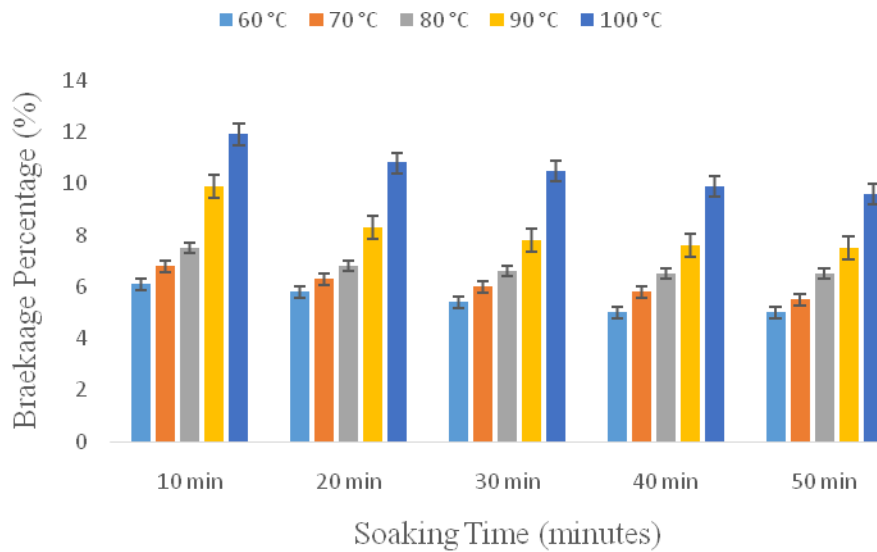
Fig.4

Fig 4: Effect of soaking time and seed dring temperature on percentage brakage

Fig.5 Complexity plot of NADH
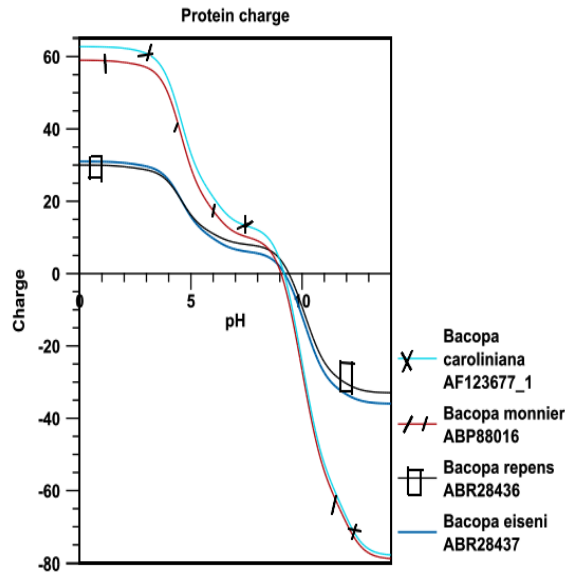
Effect of drying temperature and soaking time on the percentage seed brakeage

The results of the experiment on the effect of hydrothermal pretreatment on the broken percentage of shelled snake gourd seed was as presented in Table 6. The pecentage broken kernel decreases as the soaking time increases. The least broken percentage was achieved when soaking time was 50 minutes and drying temperature was 60°C while the highest broken percentage was recorded when the soaking time was 60 minutes. This result was in agreement with the report of (22) for Jatropha fruit decortications and (23) for shea butter craking they both reported decrease in broken percentage with increase in moisture. It was observed that the higher the seed drying temperature the higher the broken percentage (Fig. 4).

Statistical analysis of the effect of hydrothermal pretreatment on the broken percentage of the machine

The results of the experiments on the effect of drying temperature and soaking time on the broken percentage during shelling of snake gourd were fixed into Design Expert version 6.0.8 software for statistical analysis. The analysis showed that the two factors investigated (soaking time and seed drying temperature) and their interactions were significant ($p < 0.05$) (Table 7).

The regression model representing the relationship between wetting time and drying temperature is as shown in Equation 7.

$$P_B = 16.669 - 0.0258W_T - 0.3569D_T + 8.4829 \times 10^{-4}W_T^2 + 3.1691 \times 10^{-3}D_T^2 - 7.5 \times 10^{-4}D_TS_T$$

$$(R^2 = 0.9867) \quad (7)$$

Where,
P_B is percentage broken (%)
D_T *is* drying temperature (°C)
S_T is soaking time (min.)

In conclusion, the effect of seed pretreatment on shelling efficiency and broken percentage was evaluate using hydrothermal pretreatment (soaking time and seed drying temperature). The result shows that both the soaking time and the drying temperature were very

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