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Impact of Processing Method on Compressive Strength of Dried Yam Chips for Yam Flour Production

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ABSTRACT: In the yam flour production, energy required for milling operation is of great importance to a flour miller. This work therefore, determines the effect of some selected processing parameter, on the compressive strength of yam chips prepare for making yam flour. To study the effect of these selected production variables on the compressive strength of dried yam pellet, a 5-level factorial response surface methodology (RSM) of design expert version 6.0.8 of 2002 was used to identify the relationship between the response function (compressive strength) and the selected process variable of the dried yam chips. The factors considered are soaking time 5, 10, 25, 40 and 55 minutes, soaking temperature (40, 60 ,80, 100 and 120, drying temperature 45, 60, 75, 90 and 105 °C and chips sizes in volume 20, 50, 90, 160 & 230 in the determination of compressive strength of the yam chips. The experiments were replicated six times. The RMS was used to get the functional relationships between the processing factors and the empirical model. The results were then validated using the coefficient of determinant (R2) from the design expert software. The compressive strength was observed to increase from 98.15 to 104.15 kN when the soaking time increased from 5 to 55 minutes. It was also observed that as volume increases from 20 to 160 cm3 the compressive stress also increases from 28.14 to 128.82 kN. Varieties was found to be insignificant on the mechanical compressive force of dried yam chips. The study concluded that in the selection of equipment and power equipment for milling dried yam for yam flour production the selected processing parameter should be taking into consideration for selection of accurate energy needed during milling of yam flour.

Keywords: Compressive strength, yam pellet, soaking time, soaking temperature, drying temperature and chips sizes

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INTRODUCTION

Yam, *Dioscorea* (spp.) is one of the oldest known recipes to man. It is a member of the mono cotyledonous family and a staple food in most West Africa, Southeast Asia, and the Caribbean regions (Ijabo *et al*., 2019). This staple crop (yam) is majorly grown in sub-Saharan Africa, especially in the Northern and Western parts of Nigeria, with some fewer productions from the Eastern part. Nigeria is the largest producer of yam (Joyce et al., 2014) and it produce 50 million tones making 70% of global yam production and valued at $13.6 billion (Ayoola, 2022). It is a tuber crop, which belongs to the class of carbohydrate (Ayodeji *et al*., 2017). Yam tubers have various bioactive components, namely, mucin, dioscin, dioscorin, allantoin, choline, polyphenols, diosgenin, and vitamins such as carotenoids and tocopherols. It is grown on free draining, sandy and fertile soil, after clearing the first fallow as reported by Akissoe *et al.* (2013). Land is prepared in the form of mound or ridge or heap of 1 metre (3 ft. 3 in) height. It is a semi perishable class of food diet due to its high moisture content (Adejumo *et al.,* 2013). For Nigeria to achieve the Sustainable Development Goal 12 (SDG12) he must be able to produce enough food and reduce post-harvest losses (Ahungwa and Ahungwa 2020). Yam flour production is a significant means of preserving the crop in its more stable products. In the production of yam flour, the two major unit operations are drying and milling (Idowu and Adewumi, 2021). The drying of the chips is a major intermediate unit operation between blanching and milling in the production of yam flour. Most yam grinder do not take into consideration energy required for milling the dried yam chips, therefore, excess energy are often used during milling operations because the required dried yam chips strength were not considered during design. Idowu and Ige, (2011) reported that for effective design of machines such as miller, sheller, harvester etc the knowledge of the force and pressure required to perform the desired operation must play a significant role. Compressive strength is the capacity of a material or structure to withstand loads tending to reduce its size. The important of compressive properties in the design has been reported (Sunmonu *et al*., 2015).

The compressive properties of crops are influenced by several intrinsic and extrinsic factors. The intrinsic property is moisture content while the extrinsic is the processing factors (Varst 2021). The measurement of the effect of some selected processing methods on the compressive strength will provide information to the machine designer who may want to design the flour milling machine for the production.

MATERIALS AND METHOD

Fresh yam was sourced from a local market in Ibadan, Oyo State capital, Nigeria. The fresh yams were sorted to remove defective and damaged ones. Two local varieties of white yam (“Aamula” and Abuja) were selected for this study. The selection of the varieties was based on its availability.

Experimental design

Response Surface Methodology (RSM) was employed. Five independent variables were used which include volumes of sliced yam, soaking time, soaking temperature, drying temperature and yam varieties at five levels as shown in (Table 1). These factors were selected from literature (Hwabin *et al*., 2018, Idowu and Adewumi, 2021). The effects of these factors were investigated on compressive strength of the dried yam chips.

Samples preparation

Yam tubers were washed, peeled and sliced into various volumes of 10 by 1 by 2; 10 by 2.5 by 2; 10 by 4.5 by 2; 10 by 8 by 2 and 10 by 11.5 by 2 (20, 50, 90,160 & 230 cm^3). Then samples were soaked in water of 40, 60, 80, 100 and 120^oC at different soaking times of 5, 10, 25, 40, and 55 minutes. Samples were drained before drying at 45, 60, 75, 90 and 105^oC and then subjected to compressive test using Universal Testing Machine at the Department of Agricultural and Environmental Engineering, University of Ibadan, Ibadan, Oyo State, Nigeria.

RESULTS AND DISCUSSION

The breaking Force (CF) of the Yam samples obtained using Universal Testing Machine (UTM) ranges from 24.70 to 176.25kN. The results of the experiment on the effect of some selected processing variables on the compressive force on dried yam chip for making yam flour is as presented in (Table 2). The effect of each processing variables is as discoursed below.

Effect of drying temperature and volume on cracking force

The compressive strength of dried yam chips increased from 28.14 to 128.87 kN as the volume increased from 20 to 160 cm^3. Figure 1 shows a graph comparing the effect of drying temperature and chips volume on the breaking force of dried yam chips. The effect of chips volume was significant, while the effect of drying temperature was not significant ($P< 0.05$). The increase in compressive force was consistent with the findings of Ilori *et al*. (2017).

Effect of soaking time and soaking temperature on breaking force

The compressive strength was observed to increase from 98.15 to 104.15KN when the soaking time before drying increased from 5 to 55 minutes but observed compressive force was increases from 102.10 to 108.34 KN, as the soaking temperature increased from 20 to 40 °C. The interaction effect of soaking time and the soaking temperature on the compressive properties is as presented (Figure 2). The effect of both the soaking time and soaking temperature were found to be significant ($p< 0.05$) on compressive force of dried yam chips.

Effect of variety on cracking force

The two varieties respond to effect of drying temperature and size differently (Figure3a and b). It was observed that the variety has little effect on the compression force of the dried yam chips (Figure 3c). The effect of variety on compressive force was found not to be significant ($P< 0.05$). Though the results were not in agreement with Sunmonu *et al*. (2015), Ilori *et al*. (2017) and Nyorere and Iweka (2019) who reported great difference in compressive force of different varieties of almond and cassava respectively. This may due to the present experiment considering dried chips while they work on fresh crop.

Table 1: Processing Factors and their Levels.

Volume(cm^3)	Soaking time (mins)	Soaking temp (^{0}C)	Drying temp (^{0}C)	Yam variety
20	5	40	45	Amula
50	10	60	60	Abuja
90	25	80	75	
160	40	100	90	
230	55	120	105	

Table 2: Result of Effect of Selected Processing Methods on Compressive Properties Using Box – Behnken 5 Factor Experimental Design.

S/N	ST (min.)	STT (°C)	DTT (°C)	Vo cm^3	Va	CS(KN)
1	25	80	75	230	y2	162.71
2	40	60	90	160	y1	175.25
3	40	100	60	160	y2	128.87
4	25	80	75	90	y1	108.34
5	25	80	105	90	y1	99.85
6	10	60	90	20	y1	35.55
7	40	60	60	20	y2	43.46
8	40	100	90	160	y1	99.58
9	25	120	75	90	y2	106.10
10	25	80	75	90	y2	110.80
11	25	120	75	90	y1	118.40
12	25	80	75	90	y1	126.95
13	25	40	75	90	y2	150.00
14	25	80	105	90	y2	102.95
15	25	80	75	90	y2	45.27
16	10	60	60	20	y1	112.08
17	25	80	45	90	y1	156.44
18	25	40	75	90	y1	145.04
19	10	100	90	160	y1	101.46
20	40	100	60	160	y1	116.98
21	25	80	75	90	y2	112.36
22	10	60	60	160	y2	136.42
23	10	60	90	160	y1	124.56
24	40	60	90	160	y2	89.17
25	10	100	60	160	y1	48.59
26	25	80	75	90	y1	121.56
27	10	100	90	20	y2	45.12
28	40	100	90	160	y2	115.61
29	10	100	60	20	y2	58.73
30	10	100	90	20	y1	98.12
31	25	80	75	50	y1	93.48
32	25	80	75	90	y2	92.77
33	25	80	75	90	y1	42.40

Modelling the effect of the variables on the compressive force of dried yam chips

The relationship between the Compressive Strength and other variables are presented by the Equation 4. This equation will be of good help to the yam flour millers in the selection of an apprioprate power required for milling dried yam given chips volume, drying time, and soaking temperature. This equation will predict compressive force required to 82.0% confidence level.

$C_s = 6.94 - 0.12S_T + 0.04S_{TT} - 0.42D_{TT} + 0.62V_v - 2.05V_A$ ($R^2 = 0.8200$)

Where:

C_s = Compressive Strenght
S_T = Soaking Time
S_{TT} = Soaking Temperature
D_{TT} = Drying Time
V_v = Volume
V_A = Variety

Practical application

This study provides a basement line information on effect of the selected processing methods on compressive force

Table 2 continued

34	40	80	45	90	y2	38.90
35	40	60	60	20	y1	138.48
36	10	60	90	20	y2	24.60
37	10	100	60	160	y2	94.46
38	10	60	90	20	y2	28.14
39	10	100	60	20	y1	30.96
40	5	80	75	90	y1	98.15
41	40	100	60	20	y2	28.14
42	40	100	90	20	y1	30.96
43	5	80	75	90	y2	98.15
44	10	100	90	160	y2	143.86
45	40	100	60	20	y1	32.48
46	25	80	75	230	y1	176.25
47	40	100	90	20	y2	42.75
48	40	60	90	20	y1	42.22
49	40	60	60	160	y1	115.61
50	55	80	75	90	y2	104.12

ST =Soaking times, STT = Soaking temperature, DTT = Drying Temperature, Vo = Volume, Va = Variety, R=Response.

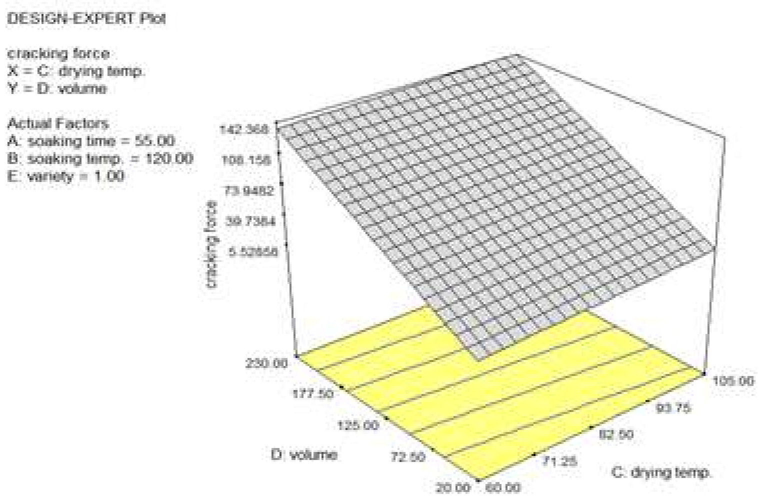
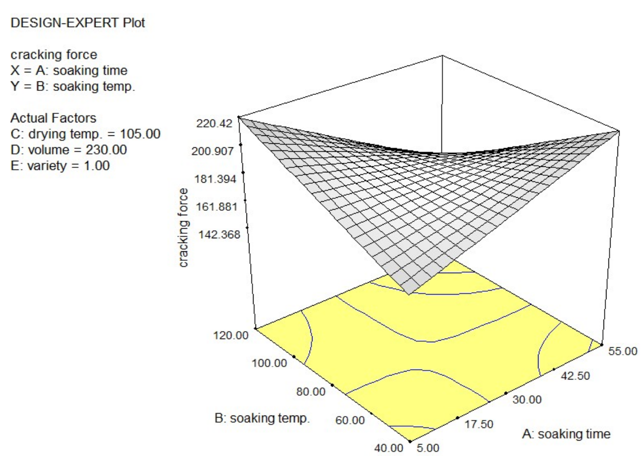


Figure 1: Effect of drying temperature and volume on cracking force.



of dried sliced yam for yam flour production. The results from this research will be of great help in selecting appropriate machine power required for milling sliced yam into yam flour.

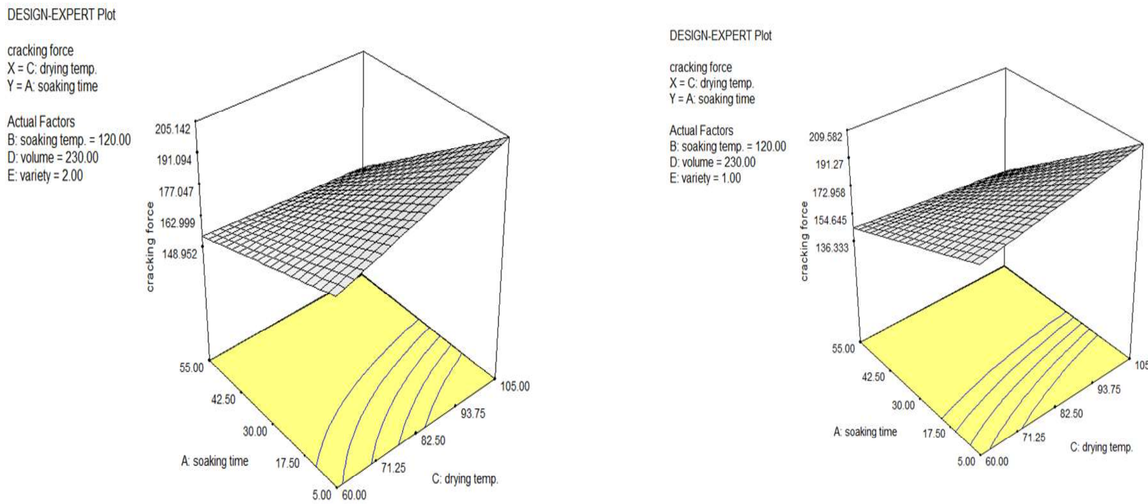


Figure 3: Effect of Drying Temperature on breaking Force of Yam Pellet of: a.) Aamula and b.)

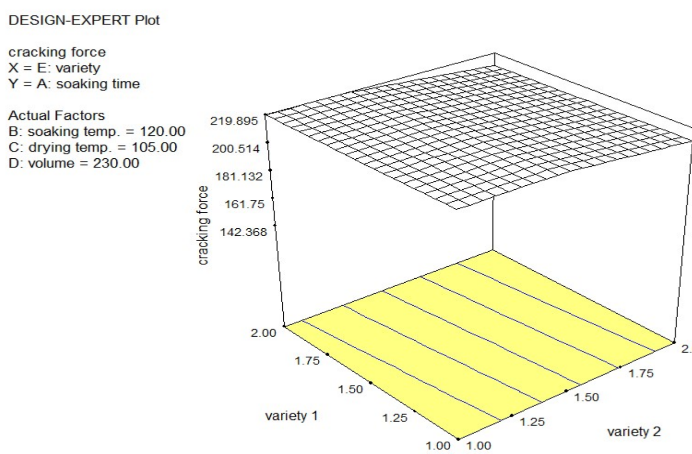


Figure 3c: Effect of variety 1 and variety 2 on cracking force

Conclusion

The study has established that the yam chips size, drying temperature, soaking temperature and soaking time have significant effect on the mechanical compressive breaking force of the two yam varieties studied. The mechanical compressive breaking force increases with increase in chips size and drying temperature of dried yam chips while varieties has little effect on the compressive breaking forces. Thus, these processing methods must be given a serious attention in the design and development of efficient and economical dried yam chips milling machine.

Competing interests

The authors have no competing interests.

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