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Effects of soaking on moisture: Dependent mechanical properties of some selected grains essential to design of grain drinks processing machine

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The effects of soaking on moisture - dependent mechanical properties of some selected grains essential to design of an automatic continuous grain drinks processing machine was studied. Three grain types were used for the study, they are white maize, white sorghum and large seeded soya beans. The white maize and white guinea corn were soaked for 36 h, while large seeded soya beans was soaked for 12 h in accordance to standard procedure (Gaffa et al., 2003; Gbabo et al., 2012). The result obtained showed that moisture content level of the grains increased with increased in soaking time from 12.4 to 20.5% M.C. for corn when soaked for 36 h, 11.3 to 20.6% M.C for sorghum when soaked for 36 h and 10.9 to 20.5% M.C for soya beans when soaked for 12 h. Soya beans had the highest decreases in rupture force with increase in moisture content level (10.9 to 20.5%) from 197.47 to 89.47 N (54.69% decrease), while corn had the least decreases with increase in moisture content level (12.4 to 20.5%) from 266.67 to 170.23 N (36.17% decrease). Also soya beans had the highest increases in rupture energy with increase in moisture content level (10.9 to 20.5%) from 27.79 to 81.95 N mm (194.89% increase), while corn had the least increase with increase in moisture level (12.4 to 20.5%) from 42.626 to 49.40 N mm (15.89% increase). In addition the expected quantity of drink to be produce from the machine under 8 h operational hours per day were 274.4 L from 34.3 kg of soya beans, 520 L from 65 kg of sorghum and 411.2 L from 51.4 kg of corn . The result thus, obtained will assist in designing of the machine and also ensured its maximum performance.

Key words: Soaking, moisture, mechanical, properties, rapture, force, energy and grain drink.

INTRODUCTION

Background of the study

Food processing is the transformation of raw ingredients into food, or food into their edible forms. Food processing increases shelf life, digestibility, flavour, nutritive value among other benefits (Mbah et al., 2012). According to Rachel (2010) food processing has a lot of benefits which include toxic removal, enhanced preservation, marketing,

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distribution, increased food consistency and increases seasonal availability of many foods.

Food processing sometimes involves mechanical processes that utilize large mixing, grinding, chopping and emulsifying equipment in the production process. For instance wet milling and wet sieving are unit operations in processing grains into drinks. The wet milling separates the seeds into its various components: germ, protein, fiber, and starch (Jasper, 2005; Gana et al., 2013), while the wet sieving separates the filtrate (milk) which is use for various industrial product including drinks from the residue which is useful as animal feed and can be used for other applications (Gaffa et al., 2003). In order to achieve this objective, various types of milling and sieving equipment have been developed. Earle and Earle (1983) enumerated some of this equipment which includes crusher, plate mills, rollers, ball mills, blenders, plate and frame filter press, rotary filters and centrifugal filters. Simonya et al. (2007) reported that the performance of these machines depends on the machine variables and crop parameters. According to Rachel (2010) the performance parameters for food are essential factors that are considered in designing process for food industry.

Knowledge of mechanical properties (properties that have to do with the behaviours of agricultural product under applied forces) such as stress, strain, hardness and compressive strength is vital to engineers handling agricultural product (Chukwu and Orhevba, 2011). Tavakoli et al. (2009) reported that in order to design equipment in handling, processing and oil extraction from grains, there is need to know their various engineering properties as function of moisture content. These properties are important in designing of separating, sizing, grinding and oil extracting machine. The objective of this study was to study the effect of grain soaking on their moisture - dependent mechanical properties that are essential to design of an automatic continuous grain drinks processing machine

MATERIALS AND METHODS

Material preparations

The materials used are of maize (white maize), sorghum (white guinea corn) and soya bean (large seeded). The grains were obtained from Bida central market in Niger state, Nigeria. The grain samples were cleaned, sorted and soaked at recommended duration of 12 h for soya beans and 36 h for sorghum and maize (Gaffa et al., 2003; Gbabo et al., 2012). The soaking softens the grain kernels for milling operation. The selected mechanical properties include rupture force and rupture energy. Also the expected output of the machine was determined.

Determination of some mechanical properties of the selected grains

The mechanical properties of the selected grains were computed using the formula below and the results are presented in Table 1.

Determination of grains moisture content

The grains moisture content were determine using a microprocessor digital moisture meter (MC7821), as reported by Simonyan et al. (2007) and Sobukola et al. (2013), and the results are presented in Table 1.

Mechanical properties of the selected grains

Mechanical properties of the selected grains were evaluated using California Bearing Ratio (CBR) equipment. The equipment was adapted for the test with some of its parts modified to suit the purpose. The CBR is a machine for determining the strength of the soil. It has a loading with a dial gauge attached for measuring the load and a second dial gauge that measure the deformation.

Test procedure

The compressive tests were carried out following the American Society of Agricultural Engineers Standard 368.1 (ASAE, 2004). The device was equipped with a load cell of 50 KN, the accuracy of measurement for force and deformation was ±0.001 N and ±0.001 mm, respectively. The seed was loaded between the machine plunger heads, compressed at the pre-set condition until rupture occurred. Deformation of the material samples and the force causing the deformation were monitored on the dial gauges attached to the loading. The loading was discontinuous after observing a continuous reduction in the load with increase in deformation which signifies that rupture has occurred. The rupture force, deformation and energy used for rupture were measured at a fixed crosshead speed of 2 mm/min.

Force deformation

The grain samples were placed between the plunger head of the machine and the base supporting unit, and force-deformation curves were obtained (ASAE, 2004). The amount of force and deformation at rupture point for various grain samples were directly obtained and the result is presented in Table 1.

Absorbed (rupture energy)

Absorbed (rupture) energy by the grains samples at rupture point was determined by calculating the area under the force-deformation curves from the follow equation given by Ardebili et al. (2012)

$$E_a = FD/2 \quad (1)$$

Where E_a = the rupture energy (Joules), F = the rupture force (N), D = the deformation at rupture point (mm)

Expected output of the machine

The expected output of the machine is critical in planning for a business and it will also help in quantifying the amount of drink to be produce in a day. It can be determined using the following equation:

$$L_E = L_K M_T \frac{T_{De}}{T_{TP}} (2) \quad (2)$$

Table 1. The effects of change in moisture content levels of soya beans, sorghum and corn on their mechanical properties.

Parameter	Soya beans (10.9 M.C)	Soya beans (20.5 M.C)	Sorghum (11.3 M.C)	Sorghum (20.6 M.C)	Corn (12.4 M.C)	Corn (20.5 M.C)
Rupture force (N)	197.56±3.6	89.47 ±7.46	189.23 ±7.56	114.44 ±3.38	266.67 ±5.58	170.23 ±4.684
Deformation (mm)	0.281±0.038	1.83 ±0.108	0.231 ±0.017	0.689 ±0.107	0.32 ±0.0223	0.579 ±0.1499
Rupture energy (N mm)	27.79 ±4.208	81.95 ±9.74	21.91 ±2.441	39.46 ±5.891	42.626 ±2.13	49.403 ±13.309

Table 2. The expected quantity of drinks to be produced by the machine when processing soya beans, sorghum and corn.

Type of grain	Soya beans	Sorghum	Maize
Initial moisture content (%)	10.9	11.3	12.4
Steeping duration (hours.)	12	36	36
Final moisture content (%)	20.5	20.6	20.5
Volume of grains before soaking (m^3)	8.72×10^{-4}	9.03×10^{-4}	8.75×10^{-4}
Volume of grains after soaking (m^3)	2.24×10^{-3}	1.22×10^{-3}	1.43×10^{-3}
Initial mass of grain that after soaking will expand to 0.0016 m^3	0.5	0.94	0.75
Expected litres of drink (time) (litres)	4	7.52	6
Mass of grain to be process (day) (kg)	34.3	65	51.4
Expected litres of drink (day) (litres)	274.4	520	411.2

$$\text{where,}\quad M_T = \frac{\frac{V_C}{6} R_g}{V_f} M_i (3) \qquad (3)$$

Where, L_E is expected litres of drinks to be produce in a day (8 h/day), L_K is litres of drink that can be produce from 1 kg of grains (before steeping), M_T is mass of grains (before steeping) to be process at a time, T_{DP} is the operating time in a day (480 min), T_{TP} is the processing time at a time (7 min), V_C is the volume of the retaining cylinder (m^3), $R_g$is the ratio of grains to water to use for blending, $M_i$is the initial mass of the grain before soaking, $V_f$is the volume of the grain at the highest moisture level.

RESULTS AND DISCUSSION

Effect of increase in moisture level on rupture force of the grains

The results obtained from effect of increased in moisture level on rupture force of the grains is presented in Tables 1 and 2, corn with 12.4 M.C had the highest rupture force of 266.67 N while soya beans with 20.5 M.C had the least rupture force of 87.47 N.

From Figure 1, the values of rupture force of soya beans decreases with increase in moisture level (10.9 to 20.5%) from 197.47 to 89.47 N (54.69% decrease), and that of corn also decreases with increase in moisture level (12.4 to 20.5%) from 266.67 to 170.23 N (36.17% decrease), and sorghum had a decrease with increase in moisture level (11.3 to 20.6%) from 187.23 to 114.44 N (39.52% decrease). It was noted that the lower rupturing force were obtained at higher moisture contents for all the grains. This might have resulted from the fact that the grains might have soft texture at high moisture content. Mohammed (2010) and Altunas and Yildiz (2005) reported similar report for corn (*Sc. 704*) and faba been. The lower the moisture content of the grains the more force is required to rupture the grain seeds and this indicates higher cost of operation. On the other hand the more the moisture content (longer duration of soaking) the less force required to rupture the grain seeds. This indicated that soaking of the grains which resulted in increase in moisture content of the grains will reduce the cost of operation in terms of selection of power requirement of the machine. This is in line with similar results obtained by Karaj and Muller (2010).

Effect of increase in moisture level on rupture energy of the grains

The results obtained from effect of increased in moisture level on rupture energy of the grains is presented in Table 1, corn had the least increased in rupture energy of 6.8 N mm with increased in moisture content level while soya beans had the highest increased in rupture energy of 54.16 N mm with increased in moisture content level.

From Figure 2, the values of rupture energy of soya beans increases with increase in moisture level (10.9 to 20.5%) from 27.79 to 81.95 N mm (194.89% increase), and that of corn also increase with increase in moisture level (12.4 to 20.5%) from 42.626 to 49.40 N mm (15.89% increase), and sorghum had an increase with increase in moisture level (11.3 to 20.6%) from 21.91 to

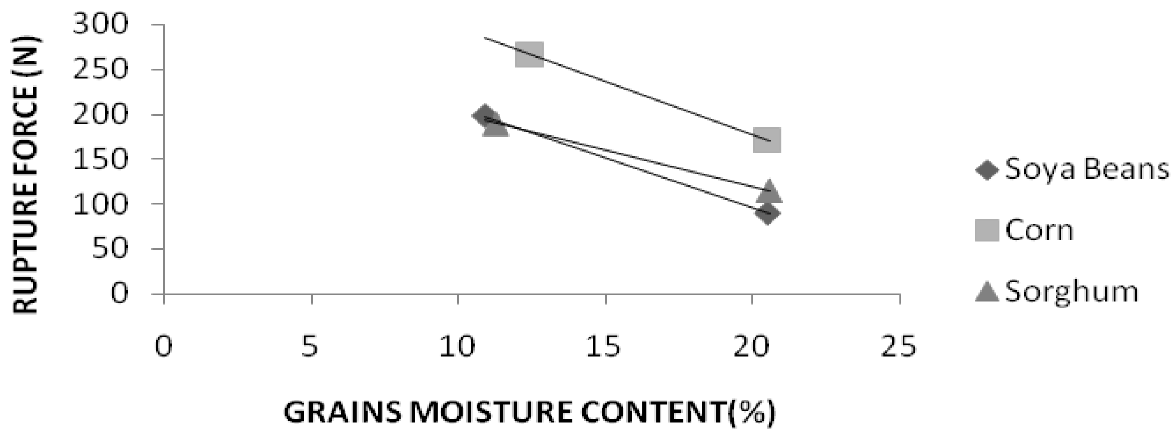

Figure 1. Relationship between increased in moisture content and rupture force of the grains.

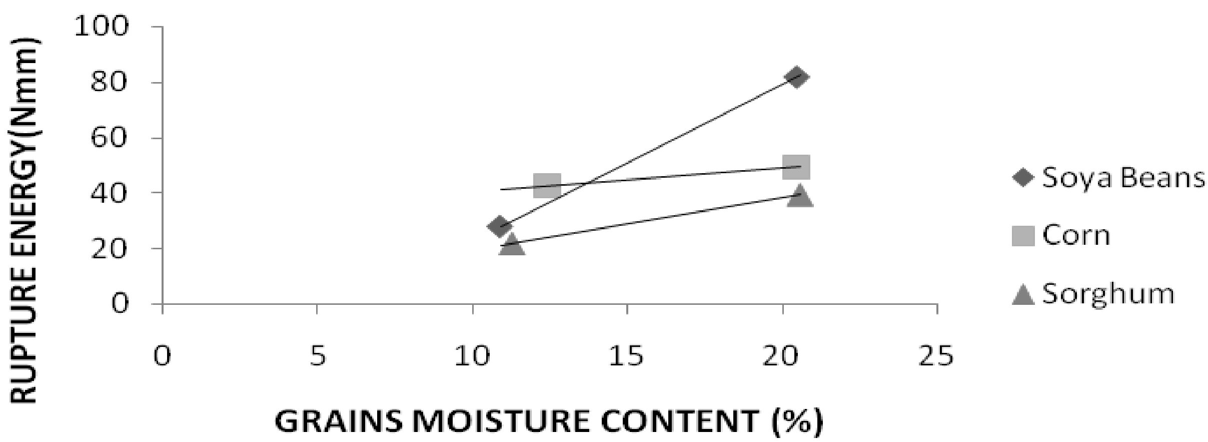

Figure 2. Relationship between increased in moisture content and rupture energy of the grains.

39.46 N mm (80.40% increase). It was noted that the lower rupturing energy were obtained at lower moisture contents for all the grains and vice versa. The rupture or absorbed energy was a function of both rupture force and deformation up to rupture point. It was observed that at low levels of moisture content, the grain seeds required high force to be ruptured and the deformation of the seed at that point was observed to be low. While when the grains were soaked which resulted to increase in their moisture content levels, the rupture force required by the grains was observed to be low and the deformation at that point was high. This results are similar to those reported by Guner et al. (2003) for hazelnut and Altuntas and Yildiz (2005) for faba bean.

Expected output of the machine]

The quantity of drinks to be produced depends on initial moisture content and volume of the grains. The expected quantity of beverages to be produced from the selected grains when processed using the machine is presented in Table 2. The expected quantity of drink to be produced is evaluated based on the volume of the blending chamber 0.0032 m^3, volume of the blending chamber to be occupied by the grains 0.0016 m^3. This is $\frac{3}{6}$ of the volume of the chamber, as water will occupy $\frac{2}{6}$ and the remaining $\frac{1}{6}$ of the volume will be left as safety volume. The litres of beverages to be produced from 1 kg of dry grains are approximately 8 L (Africa Do Business Limited, (ADBL) (2012)). Based on this the quantity of drinks to be produce in one phase of operation of the machine is 4 L from 0.5 kg of dry soya beans (bulk density of 780.44 kg/m^3), and total of 274.4 L from 34.3 kg processed in 8 h operational hours per day. For sorghum (bulk density of 787.17 kg/m^3) is 7.52 L of drink from 0.94 kg of dry sorghum, and total of 520 L from 65 kg processed in 8 h operational hours per day. Also 6 L can be obtain from

0.75 kg of dry corn (bulk density of 768.55 kg/m^3), and total of 411.2 L from 51.4 kg processed in 8 h operational hours per day. The least quantity of soya milk to be produced could be as result of high rate of increase in volume of soya beans seed compared to other grains under the study. It was also observed that soya beans when soaked for 12 h expanded 1.5 and 1.88 times more than corn and sorghum respectively when soaked for 36 h.

Conclusions

The test on the mechanical properties of the grains was concluded. The results obtained were discussed and the following conclusions were made.

(1) Soya beans had the highest decreases in rupture force with increase in moisture content level (10.9 to 20.5%) from 197.47 to 89.47 N (54.69% decrease), while corn had the least decreases with increase in moisture level (12.4 to 20.5%) from 266.67 to 170.23 N (36.17% decrease). In terms of power required the more the soaking duration of the grains the more their moisture content increases and the less the power is required for their rupture.
(2) Rupture energy of soya beans had the highest increases in rupture energy with increase in moisture level (10.9 to 20.5%) from 27.79 to 81.95 N mm (194.89% increase), while corn had the least also increase with increase in moisture level (12.4 to 20.5%) from 42.626 to 49.40 N mm (15.89% increase). The rupture energy of the grains increases with increase in moisture content while rupture force decreases with increase in moisture content (soaking duration) of the grains.
(3) The expected quantity of drink to be produce in 8 h operational hours per day are 274.4 L from 34.3 kg of soya beans (bulk density of 780.44 kg/m^3), 520 L from 65 kg from of sorghum (bulk density of 787.17 kg/m^3), and 411.2 L from 51.4 kg of corn (bulk density of 768.55 kg/m^3).
(4) These are important factor to be considered when designing as they will provide information on the quantity of grains the machine can process at a time in order to avoid over loading and underutilization of the machine due to change in volume of the grains. They are also essential in determination of expected power require by the machine in order to avoid machine failure and to achieve maximum machine performance.

Conflict of Interests

The authors have not declared any conflict of interests.

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