GLOBAL JOURNAL OF ENGINEERING RESEARCH VOL. 4 NO. 1&2, 2005: 75 - 78
COPYRIGHT(C) BACHUDO SCIENCE CO. LTD. PRINTED IN NIGERIA. ISSN 1596-292X

EFFECT OF MOISTURE CONTENT ON ENERGY OF COMMINUTION OF SOYBEAN

M. A. ODUH, F. B. OKOKON and D. S. ZIBOKERE

(Received 25 October 2004; Revision accepted 24 November 2004)

ABSTRACT

The energy of comminution of soybean using a single disc attrition mill was determined by experimental method and the use of Headley and Pfost equation. The soybean seeds at 4, 5,6,7,8 and 9% w.b were comminuted and size analyses were performed using ASAE S319. 1988. The result by experimental method shows that the effective energy c' comminution was found to increase from 12.7-35.7x10^{-3} k w.h as the moisture content increased from 4-9% w.b. A significant linear relationship ($P<0.05$) does exist between the moisture levels and effective energy of comminution. The estimated energy of comminution by Headley and Pfost equation decreased from 1.04x10^{-3} k W.h at 4%w,b to 0.51x10^{-3} k W.h at 6% w.b: and then increased sharply to 0.98x10^{-3} k w.h at 9%w.b. No significant linear relationship ($P<0.05$) exist between the moisture content and estimated energy of comminution. Therefore, a conditioning chamber designed to reduce the moisture between 4-6% w.b is desirable for uniform product and minimum energy of comminution.

KEYWORDS: soybean. moisture content. comminution energy and particle size.

INTRODUCTION

Soybean *(glycine max)* comminution is achieve through size reducing devices by conversion of mechanical energy into strain energy and finally into heat during which the critical strain is exceeded and the material is broken (Hansen and Stewart 1965, Oduh M. A. 2004). This process aids the extraction of desirable constituent, drying operations, heat transfer operations, mixing and blending by increasing the surface area (Okoro, 2001; Onwuka 2003).

The process of commiuntion has been found to be a very inefficient one. The energy of comminution is used to overcome friction in the bearing and other moving parts of the devices; the toughness of food materials accentuated by the intrinsic moisture content and the varying particle size. These make the determination of the minimum energy required for a given reduction process of biological materials practically difficult and unobtainable by the various comminution theories (Brennan et al, 1969; Earle, 1983; Onwuka, 2003).

OBJECTIVE OF STUDY

This study is to determine and compare the energy of comminution of soybean experimentally and that estimated by the Headley and Pfost equation (Hendley and Pfost, 1968) for food systems at different moisture levels.

MATERIALS AND METHODS

Sample preparation:

Soybean seeds were obtained from the market. The cleaned, whole soybean seeds were soaked in 0.5% bicarbonate solution in a closed container for 2 days, rinsed in tap water and allowed to drain at room temperature for 30 minutes. The seeds were further cooked for 30 minutes, drained and dried at 4% moisture content. A calculated amount of water was added to 5kg of each sample of soybean seeds at 4% w.b in a plastic container to obtain samples at 5, 6, 7, 8, and 9% moisture levels. The seeds were turned several time for 3 days for moisture equilibration. After 3 days, the moisture content for each sample was confirmed using the air oven method (AOAC, 1990) in triplicates.

Determination of Energy of Comminution of Soybean

A single disc attrition mill (Numex Pep grinding Mill) adjusted to 1mm burgap was used to comminute the seeds. Electrical instrumentation consisting of an ammeter and voltmeter were connected to the mill as shown in Fig.1. The mill was run for 5 minutes to attain steady speed. The ammeter and voltmeter readings (I_0, V_0) respectively were taken at no load. One kilogram of the soybean seeds were used in each operation. The time (sec) of stabilized comminution was read by a stopwatch. the Voltmeter (v) and ammeter readings (I) were noted. The energy of comminution was calculated from the readings of the stopwatch, ammeter and voltmeter. Three replicate runs were made at each moisture content level.

M. A. ODUH, Agricultural and Food Engineering Department, University of Uyo, Uyo, Nigeria.
F. B. OKOKON, Agricultural and Food Engineering Department, University of Uyo, Uyo, Nigeria.
D. S. ZIBOKERE, Agricultural and Environmental Engineering Department, Niger Delta University, Yenagoa, Nigeria.

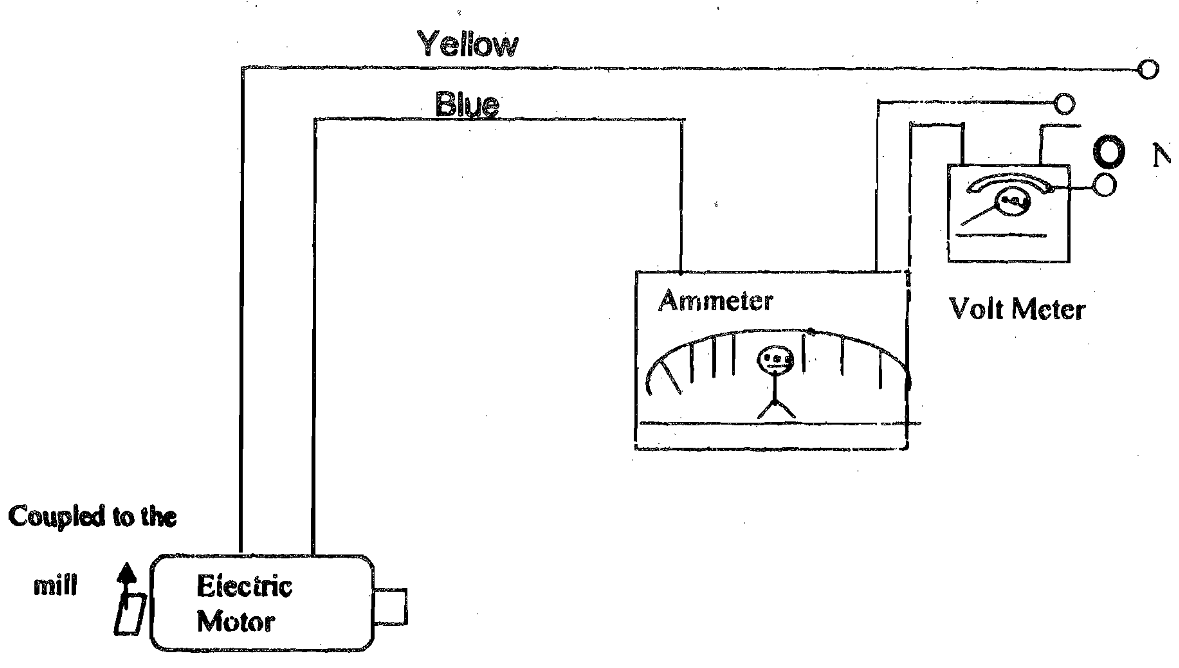

Fig. 1 Power Measuring Winning Diagram.

Particle size measurement

From the 4, 5, 6, 7, 8 and 9% w.b samples, the whole and complement soybean were subjected to particle size analysis by the ASAE S319, 1988. British standard sieves and Ende-cott type sieve shaker were used. 100g of each sample were placed on top of a set of eleven sieves in order of size. The sieves were shaken for 10 minutes until a constant weight was achieved on each sieve. The weight of the material retained on each sieve was obtained. The logarithmic normal distribution parameters, namely: the Geometric Mean diameter (d_{gw}) and the geometric standard deviation (S_{gw}) were determined for the whole and complement soybean at each moisture level.

Calculations:

(1) The effective energy of comminution (E_e) by experimental method is obtained as:

$$E_e = \frac{E_m t(P_r - P_n)}{3600} \quad \text{.........................(1)}$$

Where:

E_e	=	effective energy of comminution (kWh)
t	=	time of stabilized comminution (Sec)
E_m	=	efficiency of the mill (80%)
P_r	=	power input to the mill during comminution $(V \times I) \times 10^{-3}$kw
P_n	=	power input at no-load $(V_0 \times I_0) \times 10^{-3}$ KW

(b) The estimate energy of comminution ($\bar{E}$) (Headley and Pfost, 1968) is expressed as

$$\bar{E} = f\,\Delta P \quad \text{...................................(2)}$$

ıen

$$\Delta P = \frac{S^c_{gw}\ \log_e (S^c_{gw})\ ^1/_2}{d^c_{gw}} - \frac{S^h_{gw}\ \log_e (S^h_{gw})\ ^1/_2}{d^h_{gw}} \quad \text{.....(3)}$$

Where Ê = Energy consumed per unit weight of material ground (kW - h)

\P = Represents the change in log-normal distribution parameters as shown in equation (3)

F ( ) ="a function of "

s^{c}_{gw}, s^{h}_{gw} are the geometric standard deviations of the complement and whole soybean respectively in each case as:

$$\text{Log } S_{gw} = \sqrt{\frac{\sum wi\,(\text{logdi} - \text{logdgw})^2}{\sum wi}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

d^{c}_{gw} and d^{h}_{gw} are the geometric mean diameter of particle size of complement and whole soybean respectively calculated as:

$$\text{logd}_{gw} = \frac{\sum \text{wilogdi}}{\sum wi} \quad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where:

wi	=	weight of sample on each sieve (g)
di	=	(do x du) $^{1}/_{2}$
do	=	size of sieve on which particles are retained
du	=	size of sieve through which particles will pass.

RESULTS AND DISCUSSIONS

The energy of comminution results computed from values of voltmeter, ammeter and stopwatch readings are shown on Table 1. The table shows that energy required for comminuting soybean increased with increased moisture content of the soybean. The energy consumed by the attrition mill with 9% w.b (35.7×10^{-3} kW.h) has about three times the energy consumed at 4% w. b (12.7 x 10-3 kW. h). This indicates that the moisture content level of the seeds confers toughness on soybean by increasing the "yield point" or critical strain of the materials.

TABLE 2: Estimated energy of comminution by Headley and Pfost equation

Moisture content, %, w. b.	d^{c}_{gw} (::) Microns	s^{c}_{gw}	d^{h}_{gw} (::) Microns	s^{h}_{gw}	Estimated energy of comminution (kW. h) x 10^{-3}
4	518.27	1.82	4279.72	1.16	1.04
5	433.51	1.51	3876.79	1.46	0.65
6	462.24	1.41	4213.38	1.13	0.51
7	479.77	1.63	4465.65	1.17	0.81
8	429.94	1.64	4029.69	1.15	0.92
9	439.31	1.67	4489.52	1.13	0.98

A simple linear regression ($p<0.05$) shows that a significant relationship does exist between the moisture levels and effective energy of comminution with 0.989 coefficient of correlation and 0.98 coefficient of determination. This result is in conformity with other findings. Sitkei (1986) reported that the energy requirement in the hammer mill increased linearly with moisture content in the range of about one and half times when the moisture content increased from 10 - 20% w. b. This was supported by Akubuo and Ezeike (1988). However, Zibokere (1991) reported that the effectiveness of the hammer mill was adversely affected by the increased grain moisture contents and that the burmill was found to tolerate the increased grain moisture contents.

Table 2 shows the computation of estimated energy of comminution of soybean by Headley and Pfost equation from the log-normal parameters The table shows that the estimated energy of comminution decreased from 1.04 x 10^{-3} to kW h to 0.51 x 10^{-3} kW h as the moisture content of soybean increased from 4 - 6% w.b. it then increased sharply to 0.81x 10^{-3} kW h at 7% w.b. The estimated energy increased from 0.81 to 0.98 kw.h as the moisture content increased further from 7 - 9% w.b The result shows that no linear relationship exists between moisture content variation and estimated energy of comminution when calculated by the Headley and Pfost equation.

TABLE 1: Effective Energy of Comminution at each moisture content level by experimental method

Moisture content. %, w. b	Time (Seconds)	Power Input, (p_r) kW	Power Input No load (p_n) kW	Effective energy of comminution (kW.h) x 10^{-3}
4	150	1.04	0.66	12.7
5	231	1.04	0.66	19.5
6	292	1.04	0.66	24.7
7	351	1.04	0.66	29.6
8	403	1.04	0.66	34.0
9	423	1.04	0.66	35.7

(I_o= 3 amperes; V_o = 220 volts)

The energy expended in size reduction and in the production of uniform product size which are dependent on moisture content of the seeds can be minimized by reducing the moisture content level to about 4% w.b. It is worth noting that if the moisture content is higher than 9% w.b clogging in the mill may occur reducing throughput and comminuting efficiency.

CONCLUSION AND RECOMMENDATION

This study showed that the energy consumed by a single disc attrition mill increased linearly with increased moisture level. As the moisture content of the seeds increased from 4 – 9% w.b, the energy of comminution increased about three times. Although the Headley and pfost equation could be used to predict the energy of comminution of grain and cereals, the results of this investigation showed that no linear relationship exist between the estimated energy and moisture levels. Therefore, processors of soybean who desire to obtain uniform product at minimum energy of comminution to reduced cost of production, should control the moisture content by passing it through a conditioning chamber designed to reduce the moisture between 4 -6% w.b prior to the comminution process.

REFERENCES

Akubuo, C. O. and Ezeike, G.O. T., 1988. Performance Evaluation of a free– swing type corn Hammer mill. Paper-proceeding of CIGR, intersectors symposium, Illorin p.239-245.

AOAC, 1980. Official Method of analysis, 13th Edition association of official analytical chemists, Washington D.C.

ASAE S 319: Agricultural Engineering Yearbook, 1988. Method of determining and expressing finness of feed materials by sieving pp. 351-352.

Brennan, J.G., Butler, J. R. Cowel, N. D. and Lilly, A. E. N., 1969. Food Engineering Operations. Applied Science publishers, Ltd. London. p443.

Earle, R. L., 1969. Unit operation in food processing. *Pergamon press*, New York. p207

Hansen, R.C. and Stewart, R.E., 1965. Energy size reduction Relationship in Agricultural grain comminution. *Transaction of ASAE*, 8(2): 230-237

Headley, V. E. and Pfost, H. B., 1968. A comminution equation relating Energy to Surface area by the log-probability method. *Transactions of ASAE* II (3): 332-338.

Oduh, M. A., 2004. Investigation of energy utilization in soybean comminution. Unpublished M.Sc Thesis, Rivers State University of science and technology, Port Harcourt, Nigeria.

Okoro, C.C., 2001. Unit operations in food processing (An integrated approach): New wave Publisher, Lagos p145.

Onwuka, N.D.K., 2003. Essential elements of food related processes engineering. The academic publishers. Nsukka. p669.

Sitkei, G., 1986. Mechanics of agricultural materials. *Elsevier science publishers*, Oxford,

Zibokere, D.S., 1991. Investigation into the energy utilization in the milling of maize. M.Sc Thesis, Obafemi Awolowo University, Ile-Ife, Nigeria.