
A study of some hydro-aerodynamic properties of snake gourd (*Trichosanthes cucumerina L*) seed, kernel and chaff

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The design of pneumatic conveying systems, fluidized bed dryer and cleaning of the agricultural product from foreign materials requires the knowledge of aerodynamics properties of the product. With the increase in the importance of snake gourd as a source of nutrients, oil and industrial material, mechanization of the seed production and processing is currently needed to provide information for the proper design of the handling equipment. Terminal velocities and drag coefficient of snake gourd seed, kernel and chaff were experimentally measured at four moisture content (6.8, 8.6, 12, and 14 %) by suspending the snake gourd seed, kernel and chaff in air stream. A wind tunnel purposely designed for this experiment was used for the measurement of the terminal velocity. The result shows that an increase in moisture content from 6.8 to 14 % db increased the terminal velocity from 2.45 to 3.98 m/s for seed, 2.21 to 3.09 m/s for kernel and 1.35 to 1.77 m/s for chaff. While the increase in the moisture content in the same range increased the drag coefficient of seeds from 2.24 to 13.95 and 2.35 to 9.00 for kernel. The result of the experiment was statistically analyzed using two-way ANOVA. Effect of moisture content was found to be significant over all the parameters investigated at 0.05 % probability. For air separation/cleaning of snake gourd seed the air speed should be less than 2.4 m/s while for designing the cleaning chamber of a snake gourd decorticating machine to separate chaff from kernel after dehauling process, the air speed should be less than 2.2 m/s but higher than 1.77 m/s.

Keywords: Aerodynamic, terminal velocity, drag coefficient, decorticating, snake gourd

Introduction

Snake gourd (*Trichosanthes cucumerina L*) commonly called snake tomato is generally believed to have originated from India (ECHO, 2006). The wild species could still be found in India and other parts of South East Asia and portions of Australia. This crop is presently cultivated in India, parts of South

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East Asia, Australia, West Africa, Latin America and the Caribbean (ECHO, 2006). ECHO (2006) also reported that the snake gourd is known by different names in different parts of the World. In Nigeria it is known as snake tomato, *pathakaya* in India, *pakupis* in Philippines, *buapngu* in Thailand, *pudalankaai* in Tamil, *paduvalakaayi* in kannada and *padavalanga* in Malayam.

Snake gourd can be grown twice in a year. The first cultivation is between April to July, while the second is August to November (Oloyede and Adebooye, 2005). Irrigation may be needed in climates with seasonal droughts. The crop can thrive on sandy, sandy loam and light clay soils (Huxley, 1992). However, the soils should be well drained. Oloyede and Adebooye (2005) noted that plant spacing of one metre between rows and one metre within row is adequate for snake gourd. Seeds planted two per hole and three weeding during the life of the crop are recommended.

The snake gourd pulp is used as a substitute in soup to *solanaceous* tomato because of its sweet taste, aroma and deep red endocarp colour when fully ripe (Adebooye *et al.* 2005). The presence of high ascorbic acid which is higher than that of popular *solanaceous* tomato varieties suggests the possibility of utilizing snake gourd in the industrial production of tomato paste and puree. The snake gourd fruit (Plate 1) comprises essentially the pulp and the seed. Unlike most oil producing crops, both the pulp and the seed are nutritionally useful.

The seed (Plate 2) is a good source of edible oil. Many researchers have observed that the presence of antioxidants, such as, carotenoids, flavonoids, lycopene, phenolics and β -carotene in the oil, helps in protection against diseases like cardiovascular, diabetes, and so on (Wright, 2002; Liu *et al.* 2000; Konak, 2002; Amin *et al.* 2004; Zharg and Hemaury, 2004). Perhaps the most interesting news is that the drug for treating HIV infected patients, Compound Q, is a refined protein called *trichonanthine* which is derived from the *trichosanthes* (snake gourd) family. It has been shown that the protein has the ability to kill an HIV infected cell without affecting surrounding tissue (Tropical data base, 2008).



Fig. 1. Snake Gourd Fruit (LAUTECH Agric. Engr. Farm)



Fig. 2.Snake Gourd Seeds

The snake gourd seed oil contains 26.2-26.6% crude protein, 44.6-57.7% fat, 7.8-8.15% phosphorus and 0.012-0.026% anti-nutritional oxalate (Adebooye *et al.* 2005). The oil content compared favourably with that of most seed oil. They noted that its anti-nutritional oxalate is low and safe for humans but the seed has not been exploited as there is dearth of information on the aerodynamics properties of the seed which will be used in the design of machine that will clean and separate the seed, the kernel and chaff during dehauling of the crop.

Undesirable materials can be parked with the snake gourd seed during handling. Also there is need to separate the chaff from the kernel after shelling of snake gourd seed. With the increase in the utilization of snake gourd seed as source of industrial raw material the greatest challenges to the crop is designing of the decorticating machine to remove the kernel from the seed. In the design of the cleaning chamber of a snake gourd decorticating machine, an accurate knowledge of the aerodynamic properties of the seed, the kernel, and the chaff is very important. For example if the air speed is lower than the terminal velocity of the chaff, the kernel and the chaff will not be separated, but if the velocity is too high both the kernel and the chaff would be blown to the chaff outlet which will increase the seed loss. In addition, agricultural materials are routinely conveyed using an air stream in pneumatic conveyors. A proper design of this equipment requires the aerodynamic knowledge of the seed and kernel. Inadequate knowledge of this property may result in using higher than required air speed which will result in grain damage and waste of energy while low air speed may cause stagnation in the system. The terminal velocities of many seeds have been measured but that of the snake gourd is still not in literature. Caman (1996) used a dropping tube at various heights. The duration of the fall was plotted as a function of vertical distance. The slope of the linear portion of the distance versus time curve indicated the terminal velocity of the seed. He found that the terminal velocity of the lentil seed increased with increase in moisture content. Bilansk and Lal (1965) used wind tunnel to measure the terminal velocity of wheat kernel and straw. They found out that the terminal velocity of wheat kernel is between 8.8 and 9.2 m/s. Shellard and Macmillan (1978) also used wind tunnel to determine terminal velocity of the Olympic wheat kernel. They found out that the terminal velocity is between 7.50 to 8.50 m/s.

The main objective of this study is to determine the terminal velocity of snake gourd seed, kernel and chaff in order to find the effect of moisture content on it and provide useful data in designing the separating chamber of a decorticating machine.

1.2 Theoretical Background of Aerodynamic Properties

The air velocity at which an object remains in a suspended state in a vertical pipe under the action of the air current is called terminal velocity of the object. Thus in free fall, the object attains a constant terminal velocity, V_t , when the gravitational accelerating force, F_g , is equal to the resisting upward drag force, F_r .

$$\text{Hence } F_g = F_r \text{-----} \quad (1)$$

When $V = V_t$

$$W \left[\frac{\rho_p - \rho_t}{\rho_p} \right] = \frac{1}{2} C_{ap} \rho_t V_t^2 \text{-----} \quad (2)$$

$$Vt = 2W(\rho_p - \rho_t) / \rho_t \rho_p C_d a_p \text{ ----- (3)}$$

Where: Vt = terminal velocity, m/sec

W = weight of the material, kg

$\rho_p \rho_t$ = mass density of the particles and fluids

a_p = projected area of the particles perpendicular to the direction of motion, m^2

If ρ_p is larger than ρ_t the particle motion will be downward when the particle is in steady state condition. If the fluid is denser than the particle, that is ρ_t is larger than ρ_p the particle will rise during the steady-state condition.

Mohsenin (1978), explain that if an object is dropped from a sufficient height, the force of gravity will accelerate it until the drag force exerted by the air balances the gravitational force. It will then fall at a constant velocity called the terminal velocity.

$$C_d = \frac{2Mg}{\rho_a V_a^2 A_f} \text{ ----- (4)}$$

$$Mg = \frac{1}{2} \rho_a V_a^2 C_d A_f \text{ ----- (5)}$$

Where C_d is the drag coefficient, M the mass of the seed (g), ρ_a the density of air (kg/m^3), V_a the air velocity (m/s) and A_f the frontal (projected) area of the seed in the direction of the airflow (m^2) and g is the acceleration due to gravity (m/s^2).

Material and methods

The seeds were collected from the Department of Agricultural Engineering demonstration farm of Ladok Akintola University of Technology, Ogbomosho, Nigeria. These seeds were manually cleaned to remove all foreign matters before they were conditioned.

Moisture Content Determination

The moisture content of the seed was determined by using oven drying method as adopted by Ogunsina *et al.* (2009); and Ozguven *et al.* (2005). A weighed sample of the seed was kept in an oven at a temperature of $105^\circ C$ for 6 hours. The sample was weighed again at the end of the period to determine its final weight. This experiment was replicated five times and the average weight was recorded. The relationship below was used in calculating the moisture content.

$$\text{Moisture content} = (W_i - W_f) / w_i \times 100 \text{ ----- (6)}$$

Where W_i = initial weight and

W_f = final weight

Moisture Conditioning of the Seed

As the natural moisture content of snake gourd seed was not the same as the one used, the wetting techniques adopted from Shepherd and Bhardwaj (1986); Carman (1996); Deshpande *et al.* (1993); and Aydin (2007) was used in achieving different moisture content used in studying the effect of moisture content on the aerodynamic properties of snake gourd seed, kernel and chaff. The desired moisture levels were prepared by spraying calculated amounts of distilled water on the sample using the equation below.

$$W_w = [(M_2 - M_1) \div 100] M_0 \text{ ----- (7)}$$

Where: M_w = mass of added water (g), M_2 required moisture content %, M_1 : initial moisture content (%),

After the spraying of water, the seeds were kept in air tight containers and kept at low temperature in a refrigerator for the sample to equilibrate. Before starting a test, the required quantity of the sample was taken out of the refrigerator and was allowed to warm up to room temperature.

Determination of Aerodynamic Properties of Snake Gourd Seeds

Terminal velocity was measured by using an air column made up of a vertical wind tunnel as shown in Plate 3 which was designed and fabricated for the research. This consists of transparent plastic upper gourd (pear peck), screen (wire mesh), axial fan, frame and blower housing. Each sample of the seed at the required moisture was dropped into the air stream from the top of the air column and the air velocity adjusted until the seed is suspended in the air stream. The air velocity near the location of the grain suspension was measured by an anemometer having accuracy of 0.1m/s. Measurement of the air velocity was replicated five times for each treatment.



Fig. 3. Wind Tunnel for Measuring the Terminal Velocity

Measurement of Effect of Moisture Content on Drag Coefficient of Snake Gourd Seed and Kernel

The drag force of small particles (like grain seed) cannot be measured directly by wind tunnel thus it was calculated from its terminal velocity which is experimentally measured and used via this formula.

$$M.g = \frac{1}{2} \rho V^2 C_d A \quad \text{----- (8)}$$

$$\text{Where } C_d = \left(\frac{2M.g}{\rho V_t^2 A} \right) \quad \text{----- (9)}$$

And M= Mass of object (kg), g=gravitational acceleration (m/s²)

l= Air density (kg/m³), A= projected area (m²), V_t= Terminal velocity (m/s)

Results and discussions

The terminal velocity and the drag coefficient of snake gourd seed, kernel and chaff were obtained as a function of moisture content at four moisture levels. The result of the experiments is as reported below.

Effect of Moisture Content on Terminal Velocity of Snake Gourd Seed

The results of the experiments on the terminal velocity of the snake gourd seeds at different moisture contents is presented in Fig.1. As the moisture content increased from 6.80 to 14.00 %, the terminal velocity also increased from 2.45 to 3.98 m/s for seed, 2.21 to 3.09m/s for kernel and 1.35 to 1.77 m/s for chaff. The results were similar to those reported by Aydin and Ozcan

(2006), Kural and Carman (1999). The increase in terminal velocity with increase in moisture content can be attributed to the increase in weight of individual snake gourd seed per unit frontal area presented to the air stream. The regression equations relating the moisture content and terminal velocity of the snake gourd seed, kernel and the chaff are presented as equation 10, 11 and 12 respectively.

$$V_t (k)= 0.271Mc + 1.935 \quad R^2= 0.956 \text{ -----(10)}$$

$$V_t (s)= 0.549Mc + 1.83 \quad R^2= 0.956 \text{ -----(11)}$$

$$V_t (ch)= 0.144Mc + 1.17 \quad R^2= 0.96 \text{ -----(12)}$$

Where: $V_t (s)$ = terminal velocity of seed, $V_t (k)$ = terminal velocity of kernel
 $V_t (ch)$ = terminal velocity of chaff. Mc = moisture content

The statistical analysis of the effect of moisture content on the terminal velocity is as presented in Table1 which indicated that the effect of moisture content on the terminal velocity was significant ($p < 0.05$). This implies that in the design of processing equipment where aerodynamic properties are needed the effect of moisture content must also be considered.

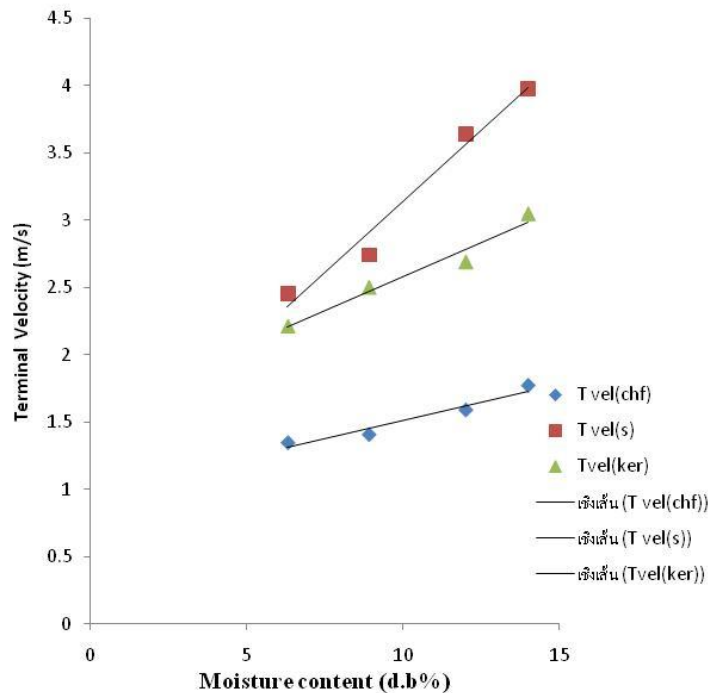


Fig. 1. Effect of Moisture Content on Terminal Velocity of Snake Gourd Seed, Kernel and Chaff

Effect of Moisture Content on Drag Coefficient of the Seed, Kernel and Chaff of Snake Gourd

The result of the experiment on the effect of moisture content on drag coefficient is as shown in Fig 2. However, the drag coefficient of snake gourd chaff was found to be higher than that of seed and kernel due to its lighter weight which the air is easily dispersed. The relationship between the moisture content and the drag coefficient is as presented in the regression equations below:

Drag coef f. (chaff) = $0.132Mc - 0.642Mc + 10.12$ $R^2= 0.843$ ----
 ----- (13)

Drag coef f. (seed) = $0.22Mc + 1.144Mc + 3.565$ $R^2= 0.920$ ---
 ----- (14)

Drag coef f. (kernel) = $1.085Mc - 1.523 + 3.565$ $R^2= 0.985$ ----
 ----- (15)

The result of the statistical analysis on the effect of moisture content on the drag coefficient shows that the effect was significant on the drag coefficient of the seeds at 0.05 significant levels on the kernel and the chaff.

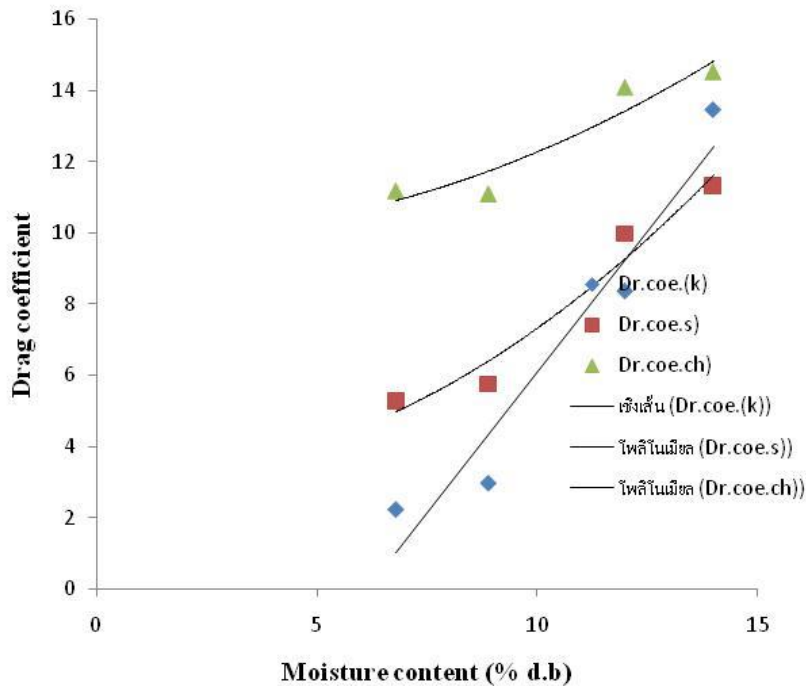


Fig. 2.Effect of Moisture Content on Drag Coefficient of Snake Gourd Seed

Table1. Summary of statistical Analysis of Variance on the effect of moisture content on the terminal velocity and drag coefficient of snake gourd seed and kernel (significant at 0.05)

Source of Variation	SS	MS	F	P-Value	F-Critical
Ter.V(S)	25.33604	8.445346	2.350274	0.250547	9.276619
Ter.V(K)	20.97404	6.991346	1.504806	0.372573	9.276619
Ter.V(C)	19.202	6.400667	1.24317	0.431123	9.276619
Drag(K)	104.9993	34.99975	13.46964	0.030196	9.276619
Drag (C)	37.15124	12.38375	9.886597	0.045937	9.276619

Conclusion

The statistical analysis indicated that the effect of moisture content on the aerodynamic properties of snake gourd studied were significant. It is therefore mandatory that for effective design of cleaning and separating equipment for snake gourd seed, kernel and chaff, moisture content of the seed must be considered. It is then recommended from the result of this experiment that in the design of separating or cleaning chamber of a snake gourd seed decorticator the terminal velocity should be more than 1.35 m/s (terminal velocity of chaff), but less than 2.21 m/s (terminal velocity of kernel).

References

- Adebooye, O.C., Oloyede F.M., Opabode. J.T., Onagoruwa. O.O. (2005). Fruit characteristics and Nutrient composition of Landrace Morphotypes of Snake gourd. Oklahoma, USA. 11(4).
- Adebooye, O.C. and Oloyede, F.M. (2005). Fruit yield and Quality of Landraces of *Trichosanthes Cucumerinas* affected by phosphorous level. Journal of Vegetable Science. Oklahoma, U.S.A. 11(4).
- Amin, M. N.; Hossain, M. A., and Roy, C. (2004). Effects of moisture content on some physical properties of lentil seeds. Journal of Food Engineering, 65:83-87.
- Aydin, C. (2007). Some engineering properties of peanut and kernel. Journal of Food Engineering, 79:810 – 816.
- Aydin, C. and Ozcan, M. M. (2006). Determination of nutritional and physical properties of myrtle (*myrtuscommunis L.*) fruits growing wild in Turkey. Journal of Food Engineering, 79:453 – 458.
- Bilanski W.K. and Lal R. (1965). Behaviour of threshed materials in a vertical wind tunnel. Transactions of the ASAE, 8 (3):411 – 413.
- Carman K. (1996). Some physical properties of lentil seeds. Journal of Agricultural Engineering Research, 63:87 – 92.
- Desphande, S. D.; Bal, S. and Ojha, T. P. (1993). Physical properties of soybean. Journal of Agricultural Engineering Research, 56:89 – 98.

- ECHO, (2006). Snake Gourd. ESCHO Plant Information Sheet, USA <http://www.echonet.org> (Accessed 2nd may, 2010).
- Faruk, O. and Kubilay, V. (2004). Some physical mechanical and aerodynamic properties of pine (*pinus pinea*) nuts. *Journal of Food Engineering*, 86:191 -1196.
- Huxley, A., (1992). *The New R.H.S. Dictionary of Gardening* Press. ISBN 0-335-47494-5.
- Konak, M.; Carman, K., and Aydin, C. (2002). Physical properties chickpea seeds. *BiosystemEngineering*, 82(1):73 – 78.
- Liu S., M J.E., Lee.I.M., Cole.S.R., S.R., Hennekens.C.H., Willett .W.C., Burning.J. (2000). *American journal of clinical Nutrit.* 72:922 – 928.
- Kural, H., and Carman, K. (1999). Aerodynamic properties of seed crops. In *National symposium on Mechanisation in Agriculture* (pp. 615 – 623). Turkey: Tokat.
- Konak, M., Carman, K., and Ayadin, C. (2002). Physical properties of chick pea seeds, *Biosystems Engineering*, 82(1):73-78.
- Mohsenin N.N. (1978). *Physical Properties of some Plant and Animal Materials* .New York, N.Y: Gordon and Breach Science Publishers.
- Ogunsina, B. S.; Olaoya, I. O.; Opeyemi, O.O., and Adegbenjo, A. O. (2009). Some nutritional, physical and mechanical properties of sponge gourd seeds. *Journal of Proceedings of 3rd International Conference of WASAE and 9th Conference of NIAE, January 25-29, 2009, Ile-Ife, Nigeria.*
- Oloyede, F. M, and Adeboye, O. C. (2005). Effect of season on growth, fruit yield and nutrient profile of *teolandracesw* of *Trichosanthes cucumerinala* *African Journal of Biotechnology*. 10:1040 - 1040.
- Ozguven, M.; Sekin, S., Gurbuz, B., Sekeroglu, N., Ayanoglu, F. and Erken, S. (2005). *Tutuntibbive aromatic bitkiler Uretimiveticareti TMMOB.*
- Shellard, J.E. and R.H. Macmillian R.H. (1978). Aerodynamic properties of threshed wheat materials. *Journal of Agricultural Engineering Research*, 23:273 – 281.
- Shepherd, H., and Bhardwaj, R. J. (1986) Moisture dependent physical properties of pigeon pea. *Journal of Agricultural Engineering Research*, 35:227 – 234.
- Tropical data base. (2008). Internet update on snake Gourd. <Http://www./google.com> (Accessed 2nd may, 2010).
- Zhang .D., and Hamauzu Y. (2004). Snake gourd. *Journal of food chemistry*, 88:503 – 509.
- Wright, K. (2002). *Healing Foods*. Geddes and Grosset, Scotland, Pp. 8-3.

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