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Cracking Force Estimation for Lecythis Minor Medicinal Nuts

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Abstract

Lecythis minor are medicinal nuts used for obtaining Selenium, an important element for the immunologic system of the human body. This paper presents the statistical procedure for setting a usual (p-value 0.05) interval for the Lecythis Minor nutshell cracking force, so that the nut is separated from the nutshell. Analyzed data was obtained from the software of a SHIMADZU AG-X Plus machine, where the compression test was performed on sample of 25 nuts. Chauvenet´s outlier detection method was recursively applied until a data set of 22 nuts showed no outliers. No previous literature reporting the cracking force for this nut is found. This work is very useful for design engineers since a realistic load value can be assigned to simulations and calculations of nutcracker machines.

Keywords: Lecythis Minor; nutshell cracking force; compression test; Chauvenet

1 Introduction

Low concentrations of Selenium (Se) are required to keep immunologic and circulatory systems functions in human body. Selenium deficiencies in human body might lead to general weakness, hearth diseases and some types of cancer [1, 2]. When there is no Selenium trace on the soil of a region or country, this important element must be taken from dietary supplements, after extracted from the fruit (nuts) of the Lecythidasae trees [3]. Specifically in Colombia country -Magdalena state- there have been found Selenium concentrations in Lecyhtis minor nuts [4]. These nutshells are cracked by hand, before being are exported to other countries where the Selenium is extracted and sold as pill supplements. Some machine designs have been proposed for assisting the nutshell cracking process for diverse type of nuts [5-10], with Romero and Ortegón (2015) [11] having proposed the design of a machine for cracking nutshells of Lecyhtis minor nuts harvested in Santa Marta (Colombia). It was noticed while conducting the study in [11], that there is no information available about the design cracking force of the Lecythis nut. Some related works report experimental data for the walnut) [12, 13]; however, no data is available for Lecythis nut cracking force.

Since no literature is reported about the cracking force for the Lecyhtis minor nut, a sample of 25 nuts were cracked by a compression machine in order to estimate it. This work reports the determination of the cracking force that is needed to separate the Lecyhtis minor nutshell from the nut that is contained inside by applying statistical analysis. This result will serve as the basis for upcoming mechanisms and/or machines that could be designed to crack this important nut for the human body metabolism. For instance, [11] proposed a cracking toothed roll that used a metal plaque for changing its distance with respect to the tooth according with the nut size, see Figure 1. Knowing the nut cracking force F_N in Figure1, will allow setting the simulation parameters for SolidWorks finite element analysis.

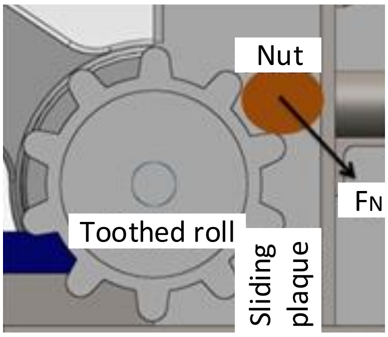

Figure 1. Nut cracking force, F_N, illustrated in a Lecyhtis minor nutcracker machine design proposed by [11]

2 Methodology

2.1 Setup and Initial Data

Each element from a sample of size 25 Lecyhtis minor nuts was subject to compression in a SHIMADZU AG-X Plus machine, as shown in Figure 2.***A***. A zoom of the actual process is depicted in Figures 2.***B*** and 2.***C***. The maximum load capacity of te machine is 100 kN with a +1% resolution. Some cracked nuts are shown in Figure 2.***D***. The performed compression test was simple type at a 100mm/

min speed. Stress-strain plots given by the machine are not taken into account since the specimens do not comply with required elasticity properties. Applied force becomes the only useful output data given by the machine software. Table 1 presents the initial data set.

2.2 Data Analysis

From Table 1, it is apparent the great difference between the smallest (54.6773 N) and the greatest (210.619 N) values. This is explained because of the nut consistency. Data set in Table 1 is checked for outliers detection under the Chauvenet principle, which states an inequality to set the interval for acceptable and outlier data [14]. It is assumed normality of the data, as in the most engineering measurements. Any measurement with less tan 1/(2n) of occurrency probability, with n as the number of the sample, is considered an outlier. Chauvenet´s test follows the two steps presented next.

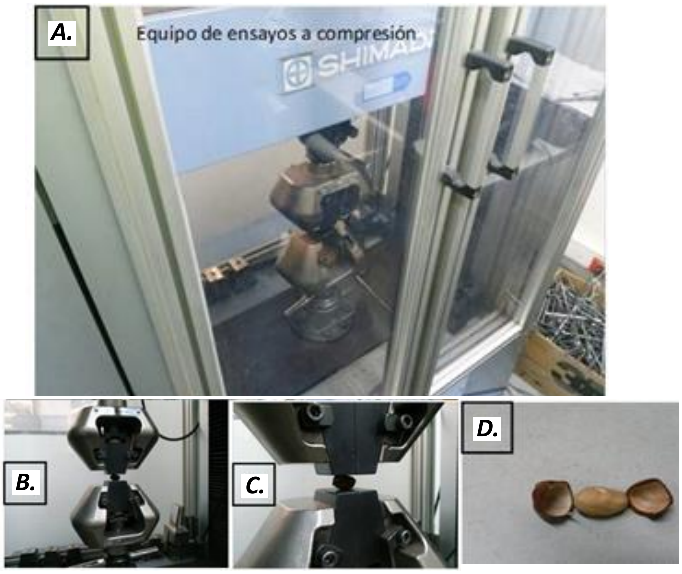

Figure 2. ***A***. Compression test of Lecythis nuts in SHIMADZU AG-X Plus machine. ***B***. & ***C.*** Test zoom. ***D***. Aspect of cracked nuts

Table 1. Initial data from the compression test.

No.	**Force [N]**	**No.**	**Force [N]**	**No.**	**Force [N]**	**No.**	**Force [N]**	**No.**	**Force [N]**
1	108.782	6	54.677	11	151.698	16	160.79	21	158.374
2	114.552	7	81.889	12	157.563	17	162.077	22	143.067
3	120.608	8	151.857	13	176.732	18	190.226	23	173.632
4	65.835	9	141.7	14	138.156	19	159.82	24	210.619
5	185.617	10	134.118	15	148.265	20	187.063	25	196.139

Step 1: Find the z score, z_i, for the measurement x_i with Equation (1), where $\bar{x}$ is the average of the data set, and s is the standard deviation of the data set.

$$z_i = \frac{|x_i - \bar{x}|}{s} \quad (1)$$

Step 2: x_i is an outlier if,

$$1 - 2P(z_i) < \frac{1}{2n}. \quad (2)$$

The initial data set information is: s=39.125 N, $\bar{x}$=146.954 N, n=25, and 1/(2n)= 0.02. Table 2 shows the two-step procedure values in Equations (1) and (2). Measurement No. 6 in Table 2 complies with Equation (2), then it is taken out of the data set, leading to the new data set in Table 3.

Table 2. Chauvenet´s values, initial data set.

No.	Force [N]	z_i	1-2P(z_i)	No.	Force [N]	z_i	1-2P(z_i)
1	108.782	-0.976	0.329	14	138.156	-0.225	0.822
2	114.552	-0.828	0.408	15	148.265	0.034	0.973
3	120.608	-0.673	0.501	16	160.79	0.354	0.724
4	65.835	-2.073	0.038	17	162.077	0.387	0.699
5	185.617	0.988	0.323	18	190.226	1.106	0.269
6	54.677	-2.359	0.018	19	159.82	0.329	0.742
7	81.889	-1.663	0.096	20	187.063	1.025	0.305
8	151.857	0.125	0.9	21	158.374	0.292	0.77
9	141.7	-0.134	0.893	22	143.067	-0.099	0.921
10	134.118	-0.328	0.743	23	173.632	0.682	0.495
11	151.698	0.121	0.903	24	210.619	1.627	0.104
12	157.563	0.271	0.786	25	196.139	1.257	0.209
13	176.732	0.761	0.447				

Information for the modified data set in Table 3 is: s=34.809 N, $\bar{x}$=150.799 N, n=24, and 1/(2n)= 0.0208. It is evident from measurement No. 4 in Table 3 that Equation (2) condition is met, then this is an outlier. After removing this measurement, the new data set is presented in Table 4. Information for the modified data set in Table 4 is: s=30.403 N, $\bar{x}$=154.493 N, n=23, and 1/(2n)= 0.0217. After looking at Table 4, measurement No. 5 is an outlier according with the condition in Equation (2). Then, a new data set in Table 5 is obtained. For this data set, the information is: s=26.570 N, $\bar{x}$=157.793 N, n=22, and 1/(2n)= 0.0227. Occurency probability for each measurement in Table 5 does not comply with the condition in Equation (2), then there are not outliers in this data set. Finally, the data set for analyis have been reached.

In order to propose a value for the nutshell cracking force, F_N, it will be created an interval. Since there is no previous report of the Lecythis nutshell cracking force so that information about the population mean or standard deviation might be taken, it will be used the t-Student distribution. The sample size is less than 30, and if assumed that the 25 nuts from the sample were randomly taken [15], then Equation (3) is used, where $t_{\nu,\alpha/2}$ is the t-Student coefficient, ν is the degrees of freedom of the sample, and α is the significance (p-value) associated to the estimation.

Table 3. Chauvenet´s occurrency probablity, second data set.

No.	**Force [N]**	**1-2P(z_i)**	**No.**	**Force [N]**	**1-2P(z_i)**	**No.**	**Force [N]**	**1-2P(z_i)**
1	108.782	0.227	9	134.118	0.632	17	190.226	0.257
2	114.552	0.298	10	151.698	0.979	18	159.82	0.796
3	120.608	0.386	11	157.563	0.846	19	187.063	0.298
4	65.8353	0.015	12	176.732	0.456	20	158.374	0.828
5	185.617	0.317	13	138.156	0.716	21	143.067	0.824
6	81.8888	0.048	14	148.265	0.942	22	173.632	0.512
7	151.857	0.976	15	160.79	0.774	23	210.619	0.086
8	141.7	0.794	16	162.077	0.746	24	196.139	0.193

Table 4. Chauvenet´s occurrency probablity, third data set.

No.	**Force [N]**	**1-2P(z_i)**	**No.**	**Force [N]**	**1-2P(z_i)**	**No.**	**Force [N]**	**1-2P(z_i)**
1	108.782	0.133	9	151.6	0.927	17	159.82	0.861
2	114.552	0.189	10	157.5	0.920	18	187.06	0.284
3	120.608	0.265	11	176.7	0.464	19	158.37	0.898
4	185.617	0.306	12	138.1	0.591	20	143.06	0.707
5	81.8888	0.017	13	148.2	0.838	21	173.63	0.529
6	151.857	0.931	14	160.7	0.836	22	210.61	0.065
7	141.7	0.674	15	162.0	0.803	23	196.13	0.171
8	134.118	0.503	16	190.2	0.240			

It is to say, before the absence of reported data for Lecythis minor nutshell cracking force, this interval will provide the machine designer a range for choosing the design force, depending on the design criteria and standpoint: conservative or non-conservative. After using Equation (3) with n=22, ν=n-1=21, with a p-value α=0.05 (95% confidence), reading from t-Student table [15] $t_{21,0.025}$=2.0796, it yields that the cracking force is within the interval (146.02, 169.58) N. However, for an extremely conservative design, the designer migt consider the greatest measurement value x=210.619 N in Table 1.

$$F_N = (\bar{x} - t_{v,\frac{\alpha}{2}} \frac{s}{\sqrt{n}}, \bar{x} + t_{v,\frac{\alpha}{2}} \frac{s}{\sqrt{n}}) \quad (3)$$

Table 5. Chauvenet´s occurrency probablity, final data set.

No.	Force [N]	1-2P(z_i)	No.	Force [N]	1-2P(z_i)	No.	Force [N]	1-2P(z_i)
1	108.782	0.065	9	157.563	0.993	17	187.063	0.271
2	114.552	0.104	10	176.732	0.476	18	158.374	0.983
3	120.608	0.162	11	138.156	0.460	19	143.067	0.579
4	185.617	0.295	12	148.265	0.720	20	173.632	0.551
5	151.857	0.823	13	160.79	0.910	21	210.619	0.047
6	141.7	0.545	14	162.077	0.872	22	196.139	0.149
7	134.118	0.373	15	190.226	0.222			
8	151.698	0.819	16	159.82	0.939			

4 Conclusions and Recommendations

An interval for the usual values of the Lecythis minor nutshell cracking force is presented in this report. Chauvenet's method for outlier detection was recursively applied on the data set, until no strange value was detected. T-Sudent distribution was used for setting the cracking force interval, before the lack of available data. Machine designer can now choose the design force for simulations and calculations, when performing finite element analysis simulations or formula calculations in the design of a machine to assist in the cracking of Lecythis minor nuts.

References

[1] L. Clark, Effects of Selenium supplementation for cancer prevention in patients with carcinoma of the skin. A randomized controlled trial. Nutritional Prevention of Cancer Study Group, *The Journal of the American Medical Association*, **276** (1996), no. 24, 1957-1963.

[2] R. Mckenzie, J. R. Arthur, S. M. Miller, T. S. Rafferty, G. J. Beckett, Selenium and the immune system, in *Nutrition and Immune Function*, P. Calder, P. Field, and H. Gill, CABI Publishing, 2002, 229-250. https://doi.org/10.1079/9780851995830.0229

[3] S. Mori and G. Prance, *Flora Neotropica*, The New York Botanical Garden: New York, 1990.

[4] J. Lafont, E. Calle and L. Durango, Composición química del aceite de almendras producidas por el árbol Olleto (Lecythis minor DC), *Revista Información Tecnológica*, **24** (2013), no. 1, 59-68. https://doi.org/10.4067/s0718-07642013000100008

[5] USPTO. Power-operated nut cracker having knives for cracking or splitting end of nuts. Inventores: Judson S. Swearingen; John R. Barton. Int. CL.: 146-10. Application date: 5, October, 1951. USA, patent of invention. US2690196. 28, September, 1954.

[6] USPTO. Nut cracker. Inventors: Judson S. Swearingen; John R. Barton; Richard Mollison. Int. CL.: A47j 43/04. Application date: 5, January, 1967. USA, patent of invention. US3422865. 21, January, 1969.

[7] USPTO. Electric powered nut cracker. Inventors: George H. Burdette; George Spector. Int. CL.: A23N 5/00. Application date: 11, August, 1988. USA, patent of invention. US4848220. 18, July, 1989.

[8] USPTO. Nut cracking machine. Inventors: Wilfred C. Frederiksen; Sun Y. Kim. Int. CL.: A23N 5/00. Application date: 8, May, 1992. USA, patent of invention. US005247879. 28, September, 1993.

[9] USPTO. Nut cracking mechanism for variable-sized nuts. Inventor: Sun Y. Kim. Int. CL.: A23N 5/00. Application date: 16, Auguts, 2005. USA, patent of invention. US7717033 B1. 18, May, 2010.

[10] M. Dasso, *Design, Construction, and Testing of a Walnut Cracker*, Technical Report, California Polytechnic State University, San Luis Obispo, USA, 2012.

[11] C. Porto-Romero and F. Bolívar-Ortegón, *Diseño de Una Máquina Descascaradora de Nueces Medicinales Para la Obtención de Selenio*, Proyecto de Grado, Ing. Mec. Universidad del Atlántico, Barranquilla, Colombia, 2015.

[12] F. Sharifian and M. Haddad, Mechanical behavior of walnut under cracking conditions, *Journal of Applied Sciences*, **8** (2008), no. 5, 886-890. https://doi.org/10.3923/jas.2008.886.890

[13] O. Joshua and E. Babatunde, Predicting cashew nut cracking using hertz theory of contact stress, *Journal of the Saudi Society of Agricultural Sciences*, (2017), 11. In Press https://doi.org/10.1016/j.jssas.2017.04.002

[14] R. Figliola and D. Beasley, *Theory and Design for Mechanical Measurements*, Dooner, 5ed, John Wiley & Sons, Inc.: USA, 2010.

[15] M. Triola, *Elementary Statistics*, 13ed, Pearson: New York, 2017.

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