DOI: 0

International Journal of
Science and Engineering Investigations vol. 4, issue 41, June 2015
ISSN: 2251-8843

Mechanical Properties Characterization of Spineless Cactus (Opuntia FiCus-Indica)

Silvestre Rodrigues[1], Dayanne Pinheiro dos Santos[2], Adilson Machado Enes[3], Maria Nazare Alves Batista Sobrinha[4], Jonathan Gazzola[5], Inacio Maria Dal Fabbro[6]
[1,3,5]Assistant Professor, Department of Agricultural Engineering, Federal University of Sergipe, S. Cristovão, SE, Brazil
[2,4]Undergraduate Student, Department of Agricultural Engineering, Federal University of Sergipe, S. Cristovão, SE, Brazil
[6]Professor, Faculty of Agricultural Engineering, State University of Campinas, Campinas, SP, Brazil
([1]silvestre@ufs.br, [2]pinheiro_dayanne@yahoo.com.br, [3]adilsonenes@gmail.com, [4]nanelegal_batista@hotmail.com, [5]jonathan_gazzola@yahoo.com.br, [6]inacio@feagri.unicamp.br)

Abstract- To collect data about machines operational performance looking for a better efficiency and setup of equipment's in characterization of plant tissue field, is the majority importance in this research work. The engine parts and plants components interaction is the cause of tissue rupture and must be explained by mathematical models. In this present research work the methods knew as linear elasticity or generalized Hooke's law was employed. The main of this research was to characterize mechanically spineless cactus (*Opuntia ficus-indica*) as tensile strength and resistance to penetration. Other mechanical properties were collected as a) modulus of elasticity or Young's modulus, E. b) modulo-v Poisson. c) modulus of transverse elasticity-G. d) bulk modulus - k. The specimens were analyzed in a universal machine strain rate with compression velocity of 0.3 mm / s. The data collection was performed at 10 Hz. The tensile and penetration tests were performed using samples with four water content levels. The first one was 24 hours, the second one was 96 third was 192 hours after harvesting

Keywords- *Mechanical properties, Spineless Cactus, Tensile tests*

I. INTRODUCTION

Spineless cactus belongs to the *embryophyta* division, *angiosperma* subdivision, *dicatyledaneae* class, *archiclamideae* sub class, *opunnteales* ordem and *cactaceae* family. The number of species in that family reaches the number of 200, divided into 180 genders. However the genders *Opuntia* and *Napolea* include the most popular species used as fodder, [2]. The use of the crop is concentrated as cat feed and to its water retention capacity (90-93%) which means it presents a high water extraction capacity from the soil [3]. [5] coments that an importance challenge in the design of farm machinery is close associated in obtaining reliable results to support adequate modeling. At this point, it worth to present the Theory of Elasticity expressed as the Generalized Hooke's Law, involving the four basic elastic constants named as **E, ν, G, K** and known as modulus of elasticity, Poisson's ratio, shear modulus and bulk modulus, respectively which is expressed as

$$\sigma_{ij} = f(\varepsilon_{ij}, E, \nu, G, K) \quad (1)$$

These constants can also be related to stress and strain through other analytical models as Hertz, Boussinesq, Lobo Carneiro or *Brazilian Test* as well as other linear and nonlinear elastic models. [4] mentioning [1], the generalized Hooke's Law for an isotropic, continuous and homogeneous body, involving the Lamé's Constants **λ** and **μ,** will take the form:

$$\sigma_{ij} = \lambda\delta_{ij}\,\varepsilon_{kk} + 2\mu\varepsilon_{ij} \quad (2)$$

However that equation can also expressed stress in term of strain as

$$\sigma_{ij} = \frac{E}{1+\nu}\left(\varepsilon_{ij} + \frac{\nu}{1-2\nu}\delta_{ij}\varepsilon_{kk}\right) \quad (3)$$

or

$$\varepsilon_{ij} = \frac{1+\nu}{E}\sigma_{ij} - \frac{\nu}{E}\delta_{ij}\sigma_{kk} \quad (4)$$

As it is said before, these equations are valid for homogeneous, continuous and isotropic bodies. An experimental uniaxial test as governed by the one dimensional Hooke's Law, i.e., ($\sigma_{ij} = E\varepsilon_{ij}$). When the testing body experiences a uniaxial loading it also experiences a longitudinal and transversal deformation which expressed *strain*, which expressed by the the Poisson's ratio (ν). [1] The relations among the remaining elástica constants are:

$$K = \frac{E}{3(1-2\upsilon)} \quad (5)$$

In

$$G = \frac{E}{2(1+\upsilon)} \quad (6)$$

II. MATERIALS AND METHODS

The uniaxial tests were carried in a *Time Group* universal testing press bench model wdw-20e – 2 tonf – 2000 kgf holding a deformation rate of 0.3 mm/s. The experimental tests included a 2mm diameter indenter with round top to impose high stress concentration and small deformation to the material under analysis. Data were collected at a frequency of 10 Hz. Force application was ceased at the point of maximum stress which was coincident with material yielding. Testing material was considered continuous, isotropic and homogeneous which are the conditions imposed by the continuum mechanics. Collected data was organized in excel program. Tests carried at 3 different water content were divided into three categories, i.e., 24, 96 e 192 hours after harvesting. Poisson's ratio tests were carried with a constraining dye in order to control the lateral deformation, forcing the Hooke's Law to yield the Poisson's ratio value.

III. RESULTS

A. *Elastic constants*

The Tables I, II, III and IV, display the modulus of elasticity, Poisson'ratio and bulk modulus values, obtained from the experimental tests as interpreted by the Generalized Hooke's Law. These data are noticed to hold close agreement with the literature. The bulk modulus is defined as the ratio between the volumetric stress and the volumetric strain which was calculated from Equation 05.

TABLE I. RESULTS OF MODULUS OF ELASTICITY CARRIED ON SPINELESS CACTUS (OPUNTIA FICUS-INDICA) SAMPLES AT 24, 96 AND 192 HOURS AFTER HARVESTING DISPLAYS THE MODULUS OF ELASTICITY, POISSON'RATIO AND BULK MODULUS VALUES

Modulus of elasticity (MPa)					
24 h	4,18	4,18	4,18	4,18	4,18
96 h	3, 69	3, 69	3, 69	3, 69	3, 69
192 h	3,26	3,26	3,26	3,26	3,26

TABLE II. RESULTS OF POISSON'S RATIO OF CARRIED ON SPINELESS CACTUS (OPUNTIA FICUS-INDICA) SAMPLES AT 24, 96 AND 192 HOURS (H) AFTER HARVESTING DISPLAYS THE MODULUS OF ELASTICITY, POISSON'RATIO AND BULK MODULUS VALUES

Poisson's Ratio					
24 h	0, 39	0, 39	0, 39	0, 39	0, 39
96 h	0, 57	0, 57	0, 57	0, 57	0, 57
192 h	0, 136	0, 136	0, 136	0, 136	0, 136

TABLE III. RESULTS OF BULK MODULUS OF CARRIED ON SPINELESS CACTUS (OPUNTIA FICUS-INDICA) SAMPLES AT 24, 96 AND 192 HOURS AFTER HARVESTING DISPLAYS THE MODULUS OF ELASTICITY, POISSON'RATIO AND BULK MODULUS VALUES

Bulk Modulus (MPa)					
24 h	-0,18	-0,18	-0,18	-0,18	-0,18
96 h	-0,36	-0,36	-0,36	-0,36	-0,36
192 h	- 0,52	- 0,52	- 0,52	- 0,52	- 0,52

TABLE IV. RESULTS OF SHEAR MODULUS CARRIED ON SPINELESS CACTUS (OPUNTIA FICUS-INDICA) SAMPLES AT 24, 96 AND 192 HOURS AFTER HARVESTING DISPLAYS THE MODULUS OF ELASTICITY, POISSON'RATIO AND BULK MODULUS VALUES

Shear Modulus (MPa)					
24 h	0, 393	0, 393	0, 393	0, 393	0, 393
96 h	0, 571	0, 571	0, 571	0, 571	0, 571
192 h	0, 136	0, 136	0, 136	0, 136	0, 136

B. *Indentor test.*

Tukey test did not indicate significant difference among the samples which might be associated to the short time interval kept between sample tests which were not large enough to observe any alterations on the tissue structure. SANTOS (1998) reported that no difference in the structure of spineless cactus in a period of 16 days storage. NERI et al (1992) reported that young cladodes (rackets) did not present quick reserve polymers degradation as it occurs on the plants $\mathbf{C_3}$ and $\mathbf{C_4}$ after harvesting. Same authors noticed that physiological interchanges that follow the senescence are retarded when the storage is kept under excess of light exposure.

TABLE V. INDENTOR TESTS RESULTS CARRIED ON SPINELESS CACTUS (OPUNTIA FICUS-INDICA) SAMPLES AT 24 HOURS AFTER HARVESTING. TABLE SYMBOLOGY: SAMPLE NUMBER - NUM; DIAMETER OR THICKNESS MM2 - Θ; USEFULL LENGTH (MM) - LENGTH; MAXIMUM LOAD (KN) - LOAD; RESISTING STRESS (MPA) - STRESS; SECTION AREA (MM) - AREA ; MAXIMUM DEFORMATION (MM) - DEFOR

Numb.	θ (mm)	Length (mm)	Load (KN)	Stress (MPa)	Area (mm)	Strain (mm)
1	10	120	0.125	0.63	200	13.612
2	10	115	0.162	0.95	170	15.707

TABLE VI. INDENTOR TESTS RESULTS CARRIED ON SPINELESS CACTUS (OPUNTIA FICUS-INDICA) SAMPLES AT 96 HOURS AFTER HARVESTING. TABLE SYMBOLOGY: SAMPLE NUMBER-NUM; DIAMETER OR THICKNESS MM2-Θ; USEFULL LENGTH (MM)-LENGTH; MAXIMUM LOAD (KN)-LOAD; RESISTING STRESS (MPA)-STRESS; SECTION AREA (MM)-AREA ; MAXIMUM DEFORMATION (MM)-DEFOR

Numb.	θ (mm)	Length (mm)	Load (KN)	Stress (MPa)	Area (mm)	Strain (mm)
1	25	55	0.047	0.16	300	4.048
2	10	50	0.091	0.54	170	7.039

TABLE VII. INDENTOR TESTS VALUES OBTAINED FROM TESTS CARRIED ON SPINELESS CACTUS (OPUNTIA FICUS-INDICA) AT192 HOURS AFTER HARVESTING. TABLE SYMBOLOGY: SAMPLE NUMBER - NUM; DIAMETER OR THICKNESS MM2 - Θ; USEFULL LENGTH (MM) - LENGTH; MAXIMUM LOAD (KN) - LOAD; RESISTING STRESS (MPA) - STRESS; SECTION AREA (MM) - AREA ; MAXIMUM DEFORMATION (MM) - DEFOR

Numb.	θ (mm)	Length (mm)	Load (KN)	Stress (MPa)	Area (mm)	Strain (mm)
1	19	80	0,10	0,35	283,53	7,14
2	18	68	0,096	0,45	216,00	8,526

C. *Traction Test*

Traction tests are carried with testing body, observing the elongation up to failure in which the specimen dimension should obey specific norms; otherwise data could not be compared. In this research work the maximum stress can be observed at the times of 24, 96 and 192 hours, as seen on Tables 5 to 7. Results did show time influence, which can be associated to the fact the material do not obey the ideal conditions as mentioned before. The testing material is fixed in the testing press and the traction is carried in the longitudinal direction, up to failure.

TABLE VIII. TRACTION TESTS VALUES OBTAINED FROM TESTS CARRIED ON SPINELESS CACTUS (OPUNTIA FICUS-INDICA) AT 24 HOURS AFTER HARVESTING. TABLE SYMBOLOGY: SAMPLE NUMBER - NUM; DIAMETER OR THICKNESS MM2 - Θ; USEFULL LENGTH (MM) - LENGTH; MAXIMUM LOAD (KN) - LOAD; RESISTING STRESS (MPA) - STRESS; SECTION AREA (MM) - AREA ; MAXIMUM DEFORMATION (MM) - DEFOR

Numb.	θ (mm)	Length (mm)	Load (KN)	Stress (MPa)	Area (mm)	Strain (mm)
1	10	120	0,125	0,63	200	13,612
2	10	110	0,122	0,61	200	14,334
3	10	115	0,162	0,95	170	15,707

TABLE IX. TRACTION TESTS VALUES OBTAINED FROM TESTS CARRIED ON SPINELESS CACTUS (OPUNTIA FICUS-INDICA) AT 96 HOURS AFTER HARVESTING. TABLE SYMBOLOGY: SAMPLE NUMBER - NUM; DIAMETER OR THICKNESS MM2 - Θ; USEFULL LENGTH (MM) - LENGTH; MAXIMUM LOAD (KN) - LOAD; RESISTING STRESS (MPA) - STRESS; SECTION AREA (MM) - AREA ; MAXIMUM DEFORMATION (MM) - DEFOR

Numb.	θ (mm)	Length (mm)	Load (KN)	Stress (MPa)	Area (mm)	Strain (mm)
1	25	55	0,047	0,16	300	4,048
2	10	50	0,091	0,54	170	7,039
3	10	115	0,057	0,38	150	5,821

TABLE X. TRACTION TESTS VALUES OBTAINED FROM TESTS CARRIED ON SPINELESS CACTUS (OPUNTIA FICUS-INDICA) AT 192 HOURS AFTER HARVESTING. TABLE SYMBOLOGY: SAMPLE NUMBER - NUM; DIAMETER OR THICKNESS MM2 - Θ; USEFULL LENGTH (MM) - LENGTH; MAXIMUM LOAD (KN) - LOAD; RESISTING STRESS (MPA) - STRESS; SECTION AREA (MM) - AREA ; MAXIMUM DEFORMATION (MM) - DEFOR

Numb.	θ (mm)	Length (mm)	Load (KN)	Stress (MPa)	Area (mm)	Strain (mm)
1	25	55	0,047	0,16	300	4,048
2	10	50	0,091	0,54	170	7,039
3	10	115	0,057	0,38	150	5,821

IV. CONCLUSIONS.

Based on what on what it has been exposed before the following conclusions can be drawn. Spineless cactus had decreasing modulus of elasticity according to the period after harvesting. The experiments allowed determining the four constants of elasticity, i. e., modulus of elasticity, Poisson's ratio, shear modulus and bulk modulus. Indenter tests indicated that the spineless cactus experienced an increasing resistance to failure as time after harvesting also increases. Traction tests allowed verifying the material potential to resist rupture.

REFERENCES

[1] MASE, G. Continuun Mechanics - 1970. Schaum Collection, Mc Graw Hill, N.Y.

[2] PUPO, N. I. H. Manual de pastagens e forrageiras: formação, conservação, utilização. Campinas: Instituto Campineiro de Ensino Agrícola, 1979.

[3] SANTOS, M. V. F.; LIRA, M. de A.; FARIAS, I.; BURITY, H. A.; NASCIMENTO, M. M. A.; SANTOS, D. C.; TAVARES FILHO, J. J. Estudo comparativo das cultivares de palma forrageira "Gigante", "Redonda" (Opuntia ficus-indica Mill) e "Miúda" (Nopalea cochenillifera Salm-Dick) na produção de leite. Revista da Sociedade Brasileira de Zootecnia, Viçosa, v.19, n.6, p.504-511, 1990.

[4] PIEDADE, S. R. ; RODRIGUES, S. ; PIEDADE, A. C. T. R. ; MISCHAN, M. M. ; DAL FABBRO, I. M. . Estudo da perda da tensão do enxerto de tendão calcâneo bovino. Brazilian Journal of Veterinary Research and Animal Science, v. 45, p. 109-115, 2008.

[5] LAURENTI, R. ; FABBRO, I. M Dal ; VIEIRA, M A P ; RABELO, G. F ; RODRIGUES, S. Determination of Elastic Constants by Diametrical Compression of Cylindrical Specimens. C&T. Ciência e Tecnologia, UNISAL - Campinas, v. 10, n.1, p. 35-40, 2004.