JCBPS; Section B; April 2018 – June 2018, Vol. 8, No. 3; 552-563, E- ISSN: 2249 –1929
[DOI: 10.24214/jcbps.B.8.3.55263.]

Journal of Chemical, Biological and Physical Sciences

An International Peer Review E-3 Journal of Sciences

Available online at www.jcbsc.org

Section B: Biological Sciences

CODEN (USA): JCBPAT Research Article

Test and Analysis main Biomechanical parameters effecting on mechanical harvesting quality of *Alfalfa*

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Received: 02 May 2018; **Revised:** 14 May 2018; **Accepted:** 24 May 2018

Abstract: Purple *Alfalfa* which typically planted in northwest of China were chosen to perform the experiments of tensile and shear by means of 500N electronic universal testing machine. Mechanical properties such as maximum loads of stems or the junctions with *Alfalfa*'s stems and leaves in different harvesting parts were measured, respectively; using the same batch of materials which dry samples were tested crude protein,fiber,acid detergent lignin and pectin contents with Kjeldahl apparatus, *XIH.Починок*, and *colorimetric* methods, respectively; relevant changing trends were analysised. Results showed that average tensile strength of lower parts junctions with *Alfalfa*'s stems and leaves is 0.786N at the Speed of 20 mm/min of load addition, it is higher 26.316% than upper parts; average tensile strength of lower parts with *Alfalfa*'s stems is 56.22N and it is 2.1175 times higher than upper parts. Considering lifetime of cutting edge, the shear strength of tooth edge with 20°slippery cutting is 15.5852-24.762N. Upper average crude protein contents of *Alfalfa* complete stools is up to 24.54% and it is higher 37.63% than lower parts.Testing results of pectin and crude protein contents showed that the average error is 0.01222% compared with the linear equation result with scholar Guo Yan Li; it is

important to remain pectin contents which improve the ratio of nutrition digestion during mechanical harvesting *Alfalfa*.These conclusions are the theoretical foundation to design and develop forage equipment such as separator equipment of stems and leaves to produce different forage products, forage crusher with high quality and harvesting high-protein equipment,It also provides the basic data for development farming database systems coupling biomechanics with forage machinery.

Key words: Mechanical harvesting *Alfalfa*, Biomechanical properties, tensile strength of the junctions with *Alfalfa*'s stems and leaves, Strength of shear, protein and pectin

INTRODUCTION

Alfalfa has the reputation as "Forages Queen" globally. It can grow to 1.7 meters high on the ground and main root grows up to 1.7 meters in the underground, the total value of biomass protein on the ground is significant, the underground biomass is invaluable benefits to the ecological engineering. *Alfalfa* in Arab is referred to as "the father of food. It has the rehabilitation, rich beauty digestible natural fibers that can well condition the intestines and stomach, and help drain the toxins inside the body.

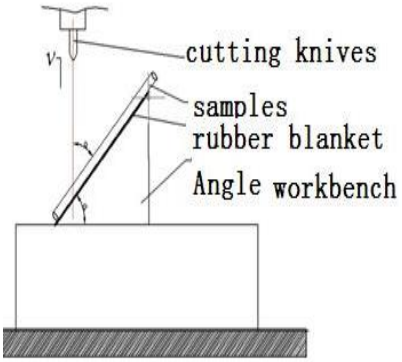


Fig.1.1: Diagram of slippery cutting working platform with different angles (from 10°to 20°, 30°)

Fig.1.2: Testing diagram of shearing strength with different angles

leaf protein in *Alfalfa* is from harvesting *Alfalfa* stems of fresh top or other green plant extracts the cone fluid protein concentrate, Its various amino acid contents are closer to the animal protein and rich in pectin; it is due to the leaves chlorophyll *Alfalfa* protein which belong to plant albumen that also has a food protein composition of the complementarily of the features that provides an alternative to fishmeal and can be added to the briquette fodder. Besides, *Alfalfa* contains a wide variety of minerals and vitamins (such as: *ß-carotene*, vitamin *ß*, vitamin *A*, calcium, zinc, etc.) in the meantime, and its vast territory, adapt to effectively improve physiochemical nature, enhance soil fertility[1,2]. *Alfalfa* has been increasingly using in the forage products, medicine, food, drink, cosmetics, stationery and so on.

Studies on the Rice, maize, and mainly focused on crops lodging resistance and their mechanical characteristics were primarily researched by domestic and foreign scholars[3], there are few studies on biomechanics and their harvest crusher [4,-6] .Zhang han [7] comprehensively overviews the cutting characteristics of crop Stalks, Gao Men Xiang, Guo kangquan, etc, have studied the average maximum shearing strength of corn's Stalks when the load speed increasing from 20cm/min to 100 cm/min; Wang Cheng Jie[8] and other scholars have analytical studied the impacts which the mechanical conditioner *Alfalfa* drying speeds and *Alfalfa* hay in the Modulated process moisture contents and rough protein related between analysis.

Harvesting complete stools or different parts of *Alfalfa* above the ground can produce all kinds of forage products, only harvesting fresh stems and leaves of the upper segments *Alfalfa as* raw highly protein materials can produce high-protein products、 harvesting *Alfalfa*'s seeds above the ground were included the mechanized harvesting *Alfalfa*. In the past few years, It was showed that: the strength and rigidity of forage stems are primarily depended on the ratio of quality between the cellulose and lignin, and their links and alignment; The ratio quality fraction of lignin and cellulose in the new varieties of *Erect crown vetch* strain is lower than the *Creeping type crown vetch* and *semi-Creeping type crown vetch* and more vulnerable to scale planting and more easy to mechanization harvesting[9].

Pectin is kind of natural macromolecule compound, structural carbohydrates, and abundant in seedling stage of *Alfalfa,* it can increase the gastric juice PH value of Lymphoma, and can greatly increase the feed nutrients to digestion and utilization rates[10]. Field tests showed that: Basing on practical mechanized harvesting, pectin contents of *Alfalfa* is one of main factors to impacting the cutting forces and cutter's lifetime of harvester (especially to the cutting edge's structure and material effecting on lifetime of the cutter), many nutrients materials such as coarse protein and ß-carotene, etc, are saved by crushed stems, vascular and skin of stems are crushed gently, so as to exposed them to air for drying quickly, organization conduction water resistance and water from lever inside the movement of resistance, dry faster and effective save their Nutritional Substances, significantly increasing the digestible rates of forages[11-14].

The areas of *Alfalfa*'s cultivation in Gansu are divided into four different areas such as *He Xi cool sandy blown by the wind and irrigation areas*, the *Loess Plateau Hills South District are staffed by ravines damp Area and Long Nan Low Mountainous Area*. Until 2015, *Alfalfa* cultivation areas had more than up to 66.667 million hectares. In recent years, with the rapid development of livestock industry, varieties breeds such as *Long Dong Alfalfa and GanNong No.*3 *Alfalfa* are planted in the main regional of northwest China. Today, big database resources including exploitation of biological resources at home and abroad have caused highlight attention, Universal database of biomechanics features coupling with forages machinery would not only set a clear goal for the development of appropriate scale cultivation of high-quality, high-output, resistance to the cold and drought and pest control of pastures new varieties[15] ,but also provides the theoretical basis for design and development of innovation forage machinery products and processes[16].

1. MATERIALS AND METHODS

1.1 Mechanics performance test of *Alfalfa* stems

1.1.1 Test Materials and Methods: *Alfalfa* for random selecting of about 1200 samples in the 2nd harvesting periods on 3-year growth were tested according to the different segments of harvesting *Alfalfa*: Lower parts is 0-100mm

above the ground, upper parts is 0-150mm from top ,and the rest of parts is named as the middle parts as show in **Fig.1.3**; *Alfalfa's* complete stools were tested by electronic universal testing CMT2502 with measuring range of 500N,resulation of 0.001N and accurately of ±0.5% and self-made apparatus for stems tensile and cutting experiments. To prevent stem slipping from clamp systems when tensile test, two ends of clamps were knotted with a width of 10 mm soft rubber for making samples soft tightening, the samples shall be fitted at each end of the clamps to test with the speed of 100 mm/min, selecting the different diameter samples as three groups (short\medium\long), the same length with similar diameter as the same group are measured to the strain-stress ensuring consistency. When load increases, broken everywhere stems folder when both of tensile test results are valid; Shearing test with self-made slide switch (slippery cutting working platform with different angles from 10°to 20°, 30°)were carried out, as shown in **Fig.1.**1. For each of its different parts of stems shearing, strain and stems with leaves nodes were measured the stretching forces to study Algan Kim clover different harvesting area of main mechanics performance impacting with its mechanized harvest of regularity.

1.1.2 Samples Acquisition: *Alfalfa* were picked from Chan Kou town in Ding xi city of Gansu province, which the main areas of *Alfalfa'*s cultivation city in the 2nd harvesting periods on 3-year growth samples, selecting grow well and no Pest of fresh plants and try to avoid mechanical damage of the stems, under a natural status to align with the platform, than fresh water of samples were measured immediately; the remaining speranskia sample immediately option intact, stem length-weight, moderate, the leaves with good speranskia of 500 fresh samples were sent to test as the 1st part of mechanics performance test samples; and others were saved in 4°C to be tested on the day of upper stems, in middle and lower parts of the large group samples for example **Fig.1.3**, samples are divided into several groups according their diameters, and each group is consists of fifteen samples with similar diameters. As soon as possible, Selecting 300 samples were pulling tests for measuring nodes strength of different parts with stems and leaves such as **Fig.1.5 and Fig.2.1**; and following day, Selecting 100 samples of *Alfalfas* stems were done tensile tests with different angles such as **Fig.1.1, Fig.1.2 and Fig.1.4**.

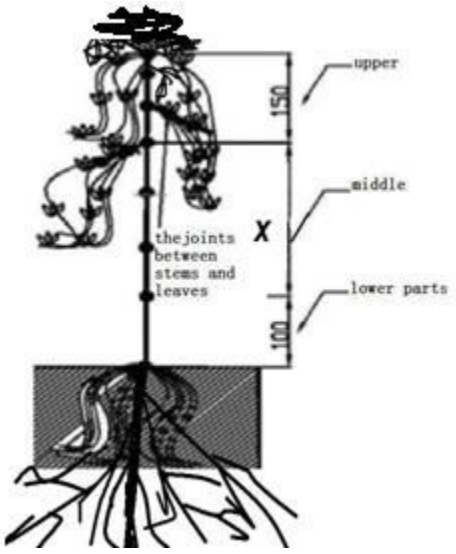


Fig. 1.3: The diagram of strength in different segments samples with Alfalfa's stems and the joints between stems and leaves

Fig. 1.4: *Alfalfa*'s stems samples of testing strength in harvesting period's with different angles

Fig.1.5: Tensile strength testing samples of the nodes junction forces with *Alfalfa*'s stems and leaves in harvesting periods

1.1.3 The methods of testing stems' shearing and the nodes tensile stretch of stems and leaves: Mechanical characteristics of stems can effect on cutting edge and power consumption in the process of forage harvesting. stems cutting characteristics are related with the blades, harvester cutters, harvester forward speed, cutting speed and as well as many other factors [17-20];The nodes junction forces of stems and leaves would have influence on the quality of forage products and the research and development of forage processing machinery. In Stretching tests to measure nodes connection forces between stems and leaves, firstly, two ends of clamps were knotted a width of 10 mm soft rubber with CA8 Instant adhesive for clamping firmness; then, the nodes junction forces were tested by setting *Alfalfa*'s stems and leaves on two ends of clamps.

1.2 Test and study complete stools main chemical characteristics on Alfalfa.

1.2.1 Test materials: Selecting *Alfalfa* 500 samples of same batch in 2nd harvesting periods on 3-year growth were divided into 9 groups according their different diameters, the groups are consisted of following: the upper of short samples、the upper of medium samples、the upper of long samples, the middle of short samples、the middle of medium samples、the middle of long samples, the lower parts of short samples、the lower parts of medium samples、the lower parts of long samples, Selecting 300 samples were made 9 large groups of dry basis samples for testing their complete stools main chemical properties, respectively such as the crude protein(CP), crude fiber(CF), acid detergent lignin(ADL) and the pectin contents; other 250 samples were made 9 large groups dry basis samples for testing their leaves and stems of main chemical properties.

1.2.2 Testing Methods : Moisture were measured as soon as possibly in the 9 large groups of fresh samples which selecting from harvesting period fields in nature circumstance, then, 9 large groups of powdered dry basis samples were prepared at 100 ~105℃ on oven; Cellulose、lignin contents and ash contents were tested by *Х1Н.Починок method*; Coarse proteins were tested in k9860 Kjelmet Auto Analyzer with full automatic Kai certain nitrogen scanner; Pectins were tested by *colorimetric* methods in the Sp-752pc type of colors spectrophotometer instruments.

2. EXPERIMENTAL RESULTS AND ANALYSIS

Selecting 1000 samples of Gan nong NO 3 *Alfalfa in* the second harvesting periods on growing 3-years at ChanKou town in Dingxi city, the average moisture content is up to 67.08±0.6408%, and the maximum height was measured up to 1000 mm, the lowest samples was measured up to 270 mm, and the average height was up to 606.57 mm.

2.1. Research on the anti-stretching forces of different harvesting areas: Selecting the above-mentioned *Alfalfa* 100 samples of the first groups were tested the pulling strength with stems and leaves nodes junction force of the anti-stretching test, the experimental results were statistically analyzed such as **Fig.2.1.** Test results demonstrated that: the nodes junction forces with *Alfalfa*'s stems and leaves in lower parts of Stems with 1.47 ~3.68 mm diameters were greater than the middle parts of junction forces and the upper samples with 1.16 ~2.41 mm diameters; the junction forces with *Alfalfa*'s stems and leaves in lower segment stems were up to 0.786N and 26.316% higher than the upper segment of nutritious stems and leaves node which average junction force up to 0.62225N, as the results of that mechanical harvesting upper segment of *Alfalfa* were easy to lose more nutrimental leaves than harvesting the complete stools which cutting from the lowest parts of *Alfalfa.* The results were the theoretical foundation which provides the theoretical parameters to design the separator equipment of stems and leaves、deeply processing facility and harvesting upper segment machine,etc, and it is the key technologies to implement on harvesting forages technology.

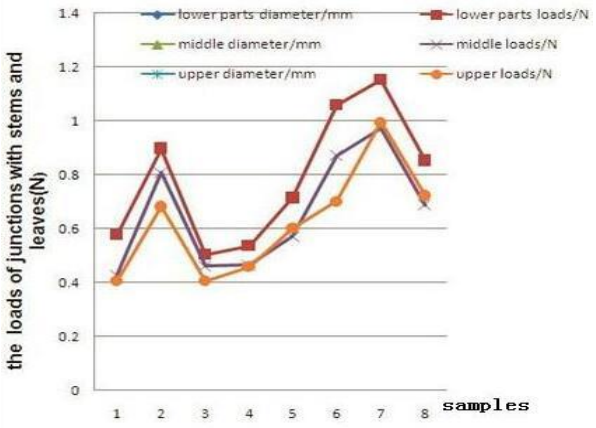


Fig.2.1: Stretching tests results of different parts nodes junction forces with *Alfalfa*'s stems and leaves

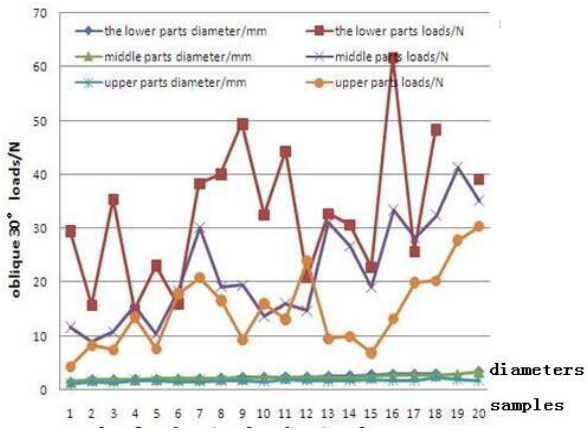


Fig.2.2: Oblique Shearing tests results of the different parts with Alfalfa's stems

2.2 Test research of different harvesting segment stems: Shearing strength were tested by selecting the stems of above-mentioned 100 samples, and experimental results showed that such as **Fig.1.3, Fig.1.4 Fig.1.5 and Fig.2.3:** The Figures of different outside diameters from 1.16 mm to 3.68mm, the different harvesting segments from on upper、in middle and lower parts, the average tensile strength of the upper segment stems were up to 26.55N, it is lower than middle segment's average tensile strength with 56.2827N, and also lower than lower segment's average tensile strength with 56.22N, More failure results of the lower parts stems tensile test than the middle and upper segments show that the lower segment of stems contained more cellulose and lignin with high strength and lower flexibly.The results provides the theoretical foundation for researching the different harvesting segments to select suitable cutting force

which also related by the structures of cutter edge[16]、the ratio of walking and cutting speeds and other parameters.

Selecting the stems of 300 samples with different harvesting parts of the first groups were tested the shearing strength with different shearing methods; the results of using statistical software analysis showed that: the average shearing strength by vertical cutting the lower parts stems with damater from 1.57mm to 3.68 mm is up to 41.27N, the average shearing strength by vertical cutting the middle segments stems from 1.39 mm to 3.27 mm is up to 32.5785N; the average shearing strength by vertical cutting the upper segments stems with average diameter 1.8335 mm is up to 21.5963N as shown in **Fig.1.1, Fig.1.2 and Fig.2.3**; the average shearing strength by vertical cutting the upper segments stems is higher 16.31% than Slipping cutting with the slippery angle of 30°such as in **Fig.2.3 and Fig.2.2;** the knives cutting resistance and life were high impacted by Sliding angle, and when cutters with smooth edge Sliding angle varieties from 14°to 20°, the cutting resistance would be increased 15%; the smaller Sliding angle, the easier to cut, but too smaller sliding angles would be make the blade easier to break. So testing results showed that the shear strength was 15.5852N~24.762N using the dynamic-knives with teeth-edge and sliding angle with 20°、cutting edge with 2 mm thickness and edge hardness was up to HRC 53~62 with T9 tool steel materials which reliability and quality are better than the parameters of NY standard,The results provide the key technical parameters and the theoretical foundation for designing prefix forage crusher with Toothed-chain[21] and designing the parts of cutter's geometry structure, separator equipment of stems and leaves、 deeply processing facility with lower power consumption, etc.

2.3 Test and analysis on main chemical properties in different segments with *Alfalfa*'s complete stools、 leaves and stems in harvesting period: First, samples were gathered and individually classified with the upper, the middle and lower parts of *Alfalfa*'s complete stool following with **Fig.1.5**; Then,

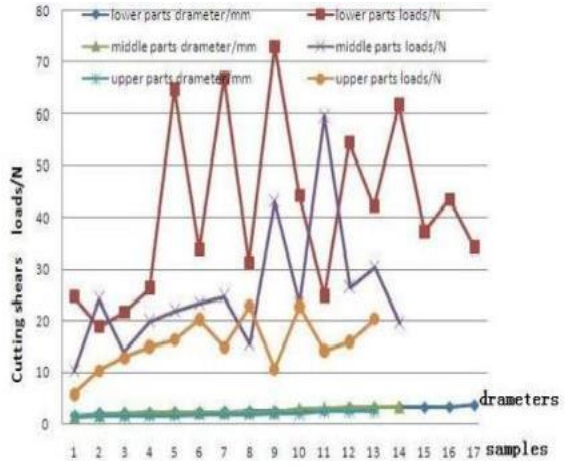


Fig.2.3: Cutting tests results of Alfalfa different parts's stems

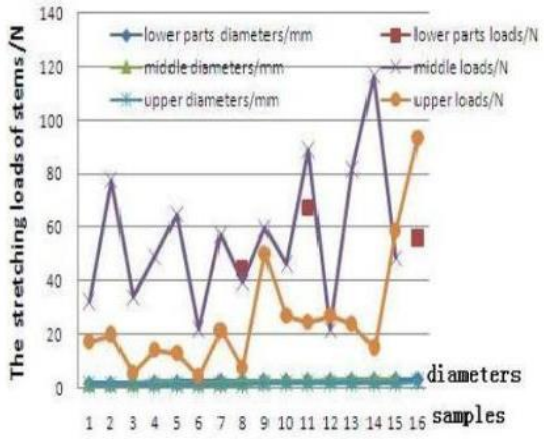
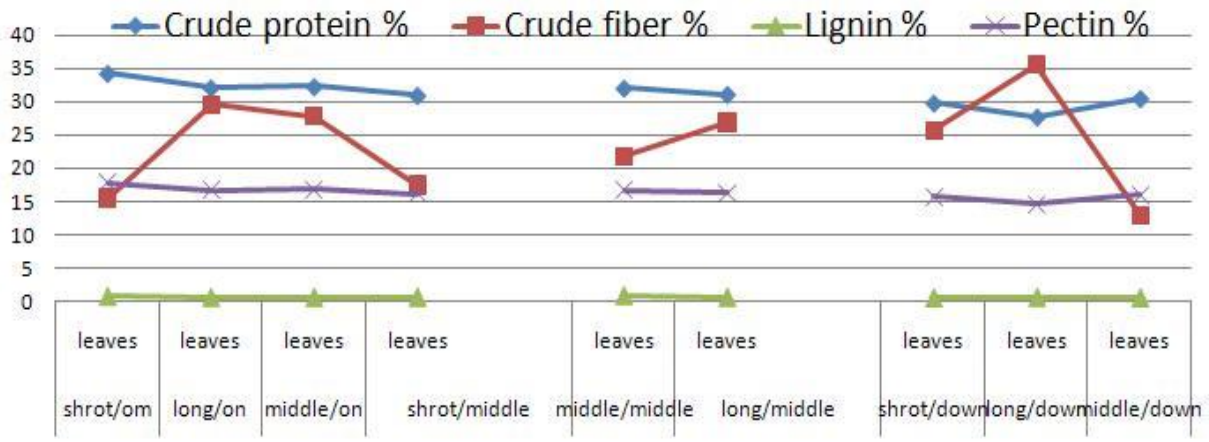


Fig.2.4: Stretching tests results of *Alfalfa* different parts stems

Coarse protein, cellulose and lignin, pectin in different harvesting parts of *Alfalfa* samples which the

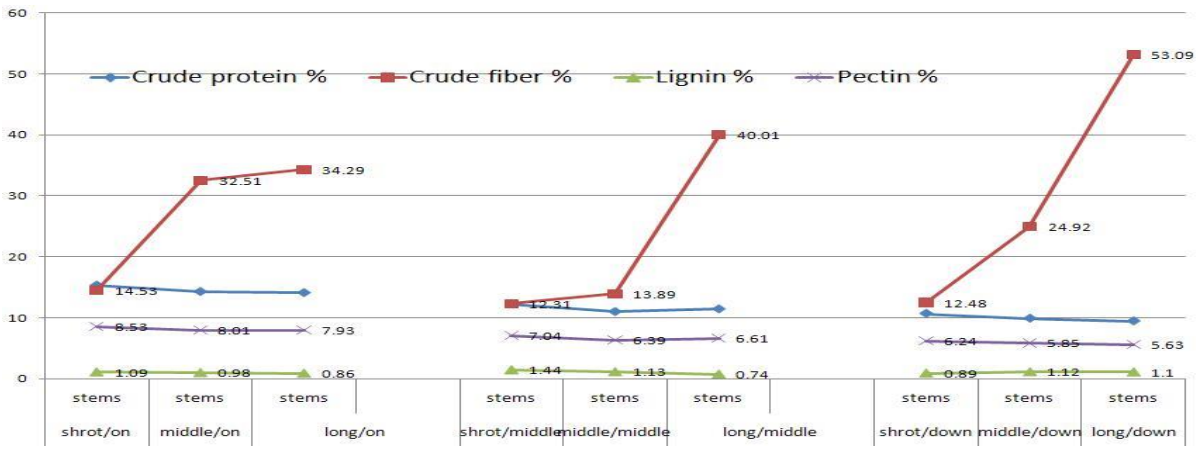
Alfalfa's complete stools、leaves and stems were tested respectively as shown in **Fig.2.5, 2.6 and 2.7**, the results showed that: The average crude protein in upper part *of Alfalfa* complete stools samples is up to

24.54% and higher 37.63% than the lower part with average crude protein is up to 17.83%; the average pectin of upper segments is up to 13.037% and higher 33.713% than the lower part is up to 9.75%; while the quality ratio of crude fiber / lignin in the lower part of the complete stools samples is up to 27.1053% and higher 1.493 times than upper part samples with the quality ratio up to 18.158%; that is the strength of the lower part is highest, while flexibility is lowest, which means the dynamic-knives' cutting speed need slower than harvesting upper parts for producing high-protein products. The average crude protein *of Alfalfa* leaves in upper parts is up to 32.8333% and higher 12.085% than the lower parts. The average pectin *of Alfalfa'* leaves in upper parts are up to 17.1% and higher 9.6154% than the lower parts with up to 15.6%; regardless of the length of stems, the quality ratio of the average pectin is basically stability in the same parts,



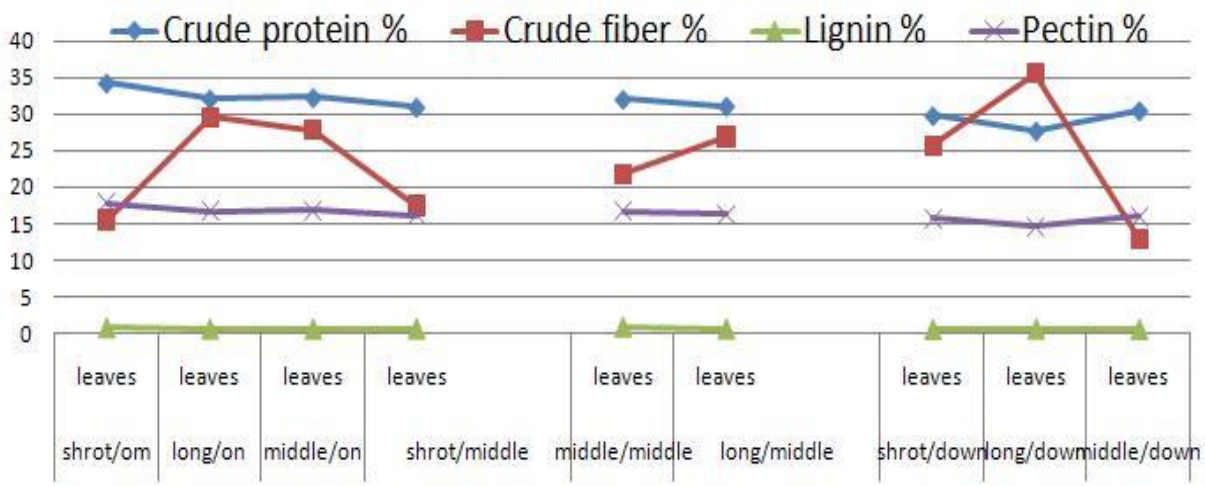
a. on the upper **b. in the middle** **c. lower parts**

Fig.2.5: Main chemical composition in different parts of *Alfalfa*'s complete stools in 2nd harvesting periods



a. on the upper **b. in the middle** **c. lower parts**

Fig.2.6: Main chemical composition in different parts of *Alfalfa*'s leaves in 2nd harvesting period



a. on the upper **b. in the middle** **c. lower parts**

Fig.2.7: Main chemical composition in different parts of *Alfalfa*'s stems in 2nd harvesting periods

Testing results of pectin and crude protein contents showed that the average error is up to 0.01222% compared with the linear equation results of Guo Yanli and Hao ZhengLi scholars researching on *Long dong Alfalfa*、*Xinjiang Grand leaves* and *Derby*,ect, it is true that only testing the rough protein and using the linear equations: $Y=2.0398x-2.0528$ can calculate the corresponding percentage of varieties pectin quality; The references of Number ten shows that using the higher pectin contents of *Alfalfa*, nutrient digestion and utilization rates can significantly be increased, the mechanized harvesting *Alfalfa* not only to avoid the loss of *Alfalfa* coarse protein, but also should be more concerned about the pectin contents; Field tests showed that the lifetime of cutting knives were impacted by the pectin contents. The crusher rollers with higher wear resistance (General abradability parameter is about to 200) 、corrosion resistance such as corrosion acid pectin, the appropriate crusher force would be applied the gentle fracturing stems with surface on the cuticle wax layer while maintaining the leaves intact, thereby increasing the fracturing stems contact with air surface area , lower stratum corneum holding water would be reduce the drying time, the coarse protein and pectin contents of *Alfalfa's* prodects would be significantly increased, it is provided the foundation theories and the main technology parameters for designing and developing the equipment with lower power and high quality facilities, and it is main technology for further development of Farming Database systems in-depth exploration of forage biomechanics and its mechanized harvesting.

3. RESULTS AND DISCUSSION

Statistical Analysis results showed that:

(1). The average tensile strength to lower parts of nodes junction forces with *Alfalfa* fresh stems and leaves at the Speed of 20 mm/min of load addition is higher 26.316% times than upper parts, the average Stretching forces of lower parts nodes junction is up to 0.62225N; The average cutting strength of the lower parts stems with *Alfalfa*'s complete stools is 16.31% times higher than lower parts with 30°sliding cutting; the smaller with Sliding angle would make easier to cut, Considering the lifetime of cutting edges, the cutter with self-sharpening and sliding 20°angle structures are more suitably for cutting

forage,and the shearing strength is up to 15.5852N~24.762N.So, Mechanical harvesting the upper part of *Alfalfa* are easy to lose the nutrimental leaves than harvesting the complete stools which cutting from the lowest parts of *Alfalfa*. It provided the technical parameters and theoretical basis for designing forage crusher with lower power、 separator equipment of stems and leaves、deeply processing facilities, etc.

(2). From Fig2.1, Fig2.5, Fig2.6 and Fig2.7, It can be seen that: The average nutritious crude protein in upper segments *of Alfalfa*'s complete stools samples are higher 37.63% times than the lower parts; the average pectin of upper segment are higher 33.713% times than the lower parts; while the cellulose contents on the upper parts are lower 32.369% times than the lower part samples; however, the average pulling forces are smaller on upper parts samples with the nutritious stems and leaves nodes than the lower parts. As the result of that, the method of lowest cutting forces for forage crusher with high quality mechanized harvesting the complete stools basing on the ground is angle of 20° as ridge with the slippery.

(3). Research has shown that it is important factors to remain the pectin contents which can improve the ratio of nutrition digestion, and only testing the rough protein and using the Linear equations: $Y=2.0398\ x^{-2.0528}$ can calculate the corresponding percentage of varieties pectin quality; The result shows that the mechanized harvesting *Alfalfa* not only avoids the loss of *Alfalfa* coarse protein, but also is more concerned about the pectin contents; Gently and evenly crushed stems keeping leaves intact is evaluated as important indicators of the crusher quality. The conclusions were provided the basic data for development of farming database systems coupling biomechanics with forage machinery.

ACKNOWLEDGEMENT

Chunhua wishes to thank the supervisor Simon Blackmore scholar of International Precision Agriculture Engineering, authors also thank for Key Laboratory of Forages land Ecosystem Ministry of Education in Gansu Agricultural University, where made some of experiments available for researching and provided valuable data and information for analysis. The mission were funded by National Natural Science Foundation of China (51565002) , Special Fund for Agro-scientific Research in the Public Interest（201203024）; Research and Development of the main Project in Gansu（17YFINA061）and First session Fu Xi outstanding talent project of Gansu Agricultural University (GAU20131117).

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