www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; SP-10(7): 410-414
© 2021 TPI
www.thepharmajournal.com
Received: 16-05-2021
Accepted: 18-06-2021

HY Shrirame
Department of Electrical and Other Energy Sources, College of Agricultural Engineering and Technology, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra, India

AG Mohod
Department of Agricultural Engineering, College of Agricultural, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra, India

YP Khandetod
College of Agricultural Engineering and Technology, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra, India

KG Dhande
Department of Electrical and Other Energy Sources, College of Agricultural Engineering and Technology, DBSKKV, Dapoli, Maharashtra, India

JS Dhekale
Department of Agricultural Economics, College of Agricultural, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli Maharashtra, India

Corresponding Author:
HY Shrirame
Department of Electrical and Other Energy Sources, College of Agricultural Engineering and Technology, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra, India

Fuel properties of cashew nut shells as a feedstock for thermochemical process

HY Shriname, AG Mohod, YP Khandetod, KG Dhande and JS Dhekale

Abstract
The cashew nut shells is the abundant forms of tropical biomass obtained during de-shelling of cashew kernels, which can be used for energy generation. The present study investigate fuel properties of cashew nut shell (CNS), deoiled cashew nut shell (DCNS) and its gasification feasibility for downdraft gasifier. The physiochemical characteristics of CNS and DCNS at moisture content of 9.15% (wb) and 4.91% (wb), respectively were determined. The characterization revealed that CNS contain higher volatile matter (66.54 wt.%), ash and moisture content, whereas DCNS contain lower volatile matter (35.64 wt.%), ash and moisture content also DCNS contain higher fixed carbon (53.85%) than CNS (16.90%). Hydrogen, Nitrogen, Carbon and Oxygen content in CNS were observed as 4.12%, 0.23%, 45.90% and 38.14% respectively. Carbon, hydrogen and nitrogen content of the DCNS were observed as 70.8%, 2.40% and 1.4% respectively. Oxygen content in the DCNS gets reduced to 13.7%, which was comparatively very less than CNS. The thermo gravimetric analysis of CNS and DCNS revealed that, the DCNS were more suitable for gasification than CNS as the average gross calorific value were observed 6549 kcal/kg and 5126 kcal/kg, respectively. The availability and characterization of the DCNS as a fuel revealed its feasibility for thermal application through gasification.

Keywords: cashew nut shell, deoiled cashew nut shell, gasification, thermo-gravimetric analysis

Introduction
Biomass includes various natural and derived materials, such as woody and herbaceous species, wood wastes, energy crops, agricultural and industrial residues, municipal solid waste, grass, waste from food processing, animal wastes, aquatic plants and algae etc. (Mythili *et al.* 2013) [12]. Cashew (*Anacardium occidentale*) was introduced to India from Brazil about 500 years ago as a crop of afforestation and soil conservation (Gawankar *et al.* 2018) [4]. India is the largest producer, processor and exporter of cashews (*Anacardium occidentale* L.) in the world (Das and Ganesh 2003, Mohod *et al.* 2010, Mohod *et al.* 2011) [3, 7, 8]. The total area under cashew in India is about 11.05 lakh hectares with production of 7.42 lakh MT. The productivity of cashew in India is with highest reported in state of Maharashtra with 1169 kg/hectare (DCCD, 2018-19). Cashew nut shells are a residue obtained from cashew shelling, an abundant and cheap biomass residue, and could generate high energy. Currently, cashew nuts shells are rejected by artisanal traders without being valued. They were often burned in open air and cause several socio-environmental problems (Tippayawong *et al.* 2011) [19].
The shell comprises around 50% of the weight of the raw nut, the production of cashew nut shells may be estimated to 3,10,000 tones from available statistics (Mohod *et al.*, 2010) [7]. The waste biomass generated in cashew processing is utilized as a substitute to wood fuel during cashew processing or thrown as a waste. The average higher heating value of the cashew nut shell was reported to be 4890 kcal/kg which makes it suitable fuel for cashew processing industry (Mohod *et al.* 2012) [9]. The cashew consist of approximately 20-25% kernel 60-70% cashew nut shell and 2-5% testa (Rajapakse *et al.* 1977) [17]. Cashew Nut Shell comprises around 50% weight of the raw nut, 25% kernel and remaining 25% Cashew Nut Shell Liquid (CNSL) that obtained during the cooking of the raw nuts and the separation of kernel by roasting (Couto *et al.* 2004) [2].
When the cashew nut shell was used for gasification, the shell oozed natural phenol oil upon gasification, which clogging the gasifier throat, downstream equipment and associated utilities with oil and resulted in ineffective gasification and premature failure of utilities due to its corrosive characteristics. (Ramanan *et al.* 2008) [18]. The fuel properties of CNS need to be evaluated to study its feasibility for the thrmochemical processes. The study of physiochemical properties of CNS and DCNS by indirect method of phenol extraction is important to

determine the system of utilization of energy extraction as well as efficient conversion.

Material and Method

The Cashew nut shell (CNS) of variety 'Vengurla-4' available from cashew processing industries after removal of cashew kernel from steamed cashew nut shells were selected for experimentation. The steamed Cashew nut shell (CNS) were deoiled by radiant heat (indirect heat) of downdraft gasifier system, simultaneously extract the cashew nut shell liquid (CNSL). The physical properties like size, shape, surface area, bulk density, angle of repose of cashew nut shell (CNS) and deoiled cashew nut shell (DCNS) were studied using both the standard procedure and derived formulae (Mohsenin, 1986: Karaosmanoglu *et al*., 1999, Kachru *et al.*, 1994) [10, 6, 5]. The proximate, ultimate and thermogravimetric analysis of steamed cashew nut shell (CNS) and deoiled cashew nut shell (DCNS) was carried out to determine the fuel properties.

Proxiamate Analysis of Cashew nut Shell and Deoiled Cashew Nut Shells

The proximate analysis were carried out using the analytical method ASTMD-3173, 3174 and 3175 for determination of moisture content, volatile matter, fixed carbon content and ash content in the cashew nut shell and deoiled cashew nut shell. The proximate analysis and calorific value were determined using both the standard procedure and derived formulae (Sengar *et al.* 2011) [15]

Moisture content

The moisture was determined based on oven drying method ASTM-D-3173. After removing moisture from the biomass, the following procedures were carried out.

Ash and Volatile Matter

The standard ash and volatile matter were determined according to ASTM-D-3174 and ASTM-D-3175, respectively. The fixed carbon percentage was determined by difference.

Gross Calorific Value (GCV)

The bomb calorimeter was used to determine the gross calorific values of selected biomass using standard method of analysis based on ASTM E-711.

Ultimate Analysis of Cashew nut Shell and Deoiled Cashew Nut Shells

The 2400 CHNS Organic Elemental Analyzer 100V, PerkinElmer was used to determine the contents of Carbon (C), hydrogen (H), nitrogen (N) and sulphur (S) available in selected biomass.

Thermogravimetric Analysis of Cashew nut Shell and Deoiled Cashew Nut Shells

Thermo-gravimetric analysis (TGA) for the feasibility study of CNS and DCNS was conducted in a high purity nitrogen (99.95%) environment with flow rate of 20 ml/min to investigate the mass loss characteristics as a function of temperature and time. The thermo-gravimetric analysis (TGA) was performed with a thermo-gravimetric analyzer (TGA) STA 7300 Hitachi, Germany to measure the finely powdered samples of CNS and DCNS weights 5.0 mg and 14 mg respectively, by keeping the heating rate 20°C/min form 30°C to 900°C. The experiment for CNS and DCNS samples were repeated three times using same operating conditions to establish the validation of the data (Pawar and Panwar, 2020).

Result and Discussion

The Cashew nut shell (CNS) available at cashew processing industries after removal of cashew kernel was selected for experimentation. The moisture content of the CNS and DCNS used for the present investigation were found to be 9.15% (wb) and 4.91% (wb) respectively. The physical properties of CNS and DCNS were determined and revealed that, the average values of surface area (cm^2), bulk density (kg/m^3) and angle of repose (°) of CNS were found to be 5.86, 350 and 20.96 for, respectively. The values for DCNS were found to be 5.28, 207 and 21.60 (Chaudhari *et al.* 2013) [1].

Proximate analysis of CNS and DCNS

Proximate analysis of CNS and DCNS for determination of moisture content, volatile matter, ash content and fixed carbon was carried out. High heating values of the CNS and DCNS were determined using standard procedure (ASTM E-711). The result obtained are summarised in Table-1.

Table 1: Physicochemical properties of CNS and DCNS

Parameter	Specifications/Method	CNS	DCNS
Bulk density (kg/m^3)	IS:4333-III (1967)	350	207
Angle of repose (º)	IS: 6663 (1972)	20.96	21.60
Moisture content (% wet basis)	ASTM-D-3173	9.15	4.91
Volatile matter (% dry basis)	ASTM-D-3175	66.54	35.64
Ash content (% dry basis)	ASTM-D-3174	7.10	5.59
Fixed carbon (% dry basis)	(By difference)	16.90	53.85
Gross calorific values (Kcal/kg)	ASTM E-711	5126	6549

From proximate analysis it was observed that the moisture content was 9.15 wt% and the CNS contained 66.54 dry% of volatile matter and 16.90 dry% of fixed carbon whereas 4.91 wt%, 35.64 dry% and 53.85 dry% in DCNS. These values of proximate analysis are similar to those already described for CNS from different topographical origins. Only the ash content of CNS and DCNS (7.10 dry% and 5.59 dry% respectively) was greater than in previous studies, which were in the range of 0.9–2.0 dry% (Das *et al.* 2003: Tsamba *et al.* 2006, Uamusse *et al.* 2014) [3, 20, 22]. The gross calorific value is considered an important property of solid biofuels and CNS showed a value of 5126 kcal/kg whereas DCNS has 6549 kcal/kg that is among the highest found for different types of biomass (Sengar *et al.* 2011, Yin 2011) [15].

Ultimate analysis of Cashew Nut Shell and Deoiled Cashew Nut Shell

The ultimate analysis of CNS and DCNS were carried out in order to determine its C, H, N, O and S percentage. The results obtained are shown in Figure 1. It was observed that, carbon, hydrogen, nitrogen and oxygen content of CNS were observed as 45.90%, 4.12%, 0.23% and 38.14%, respectively. Similarly, the values of ultimate analysis of DCNS were observed as 70.8%, 2.40%, and 1.4%, respectively. Oxygen content in the DCNS gets reduced to 13.7%, which was comparatively very less than CNS. The resultant values of C, H, N, O and S contents of CNS and DCNS were similar to the ones described in the literature (Das *et al.* 2003 and Tsamba *et al.* 2007, Sengar *et al.* 2011) [3, 21, 15].

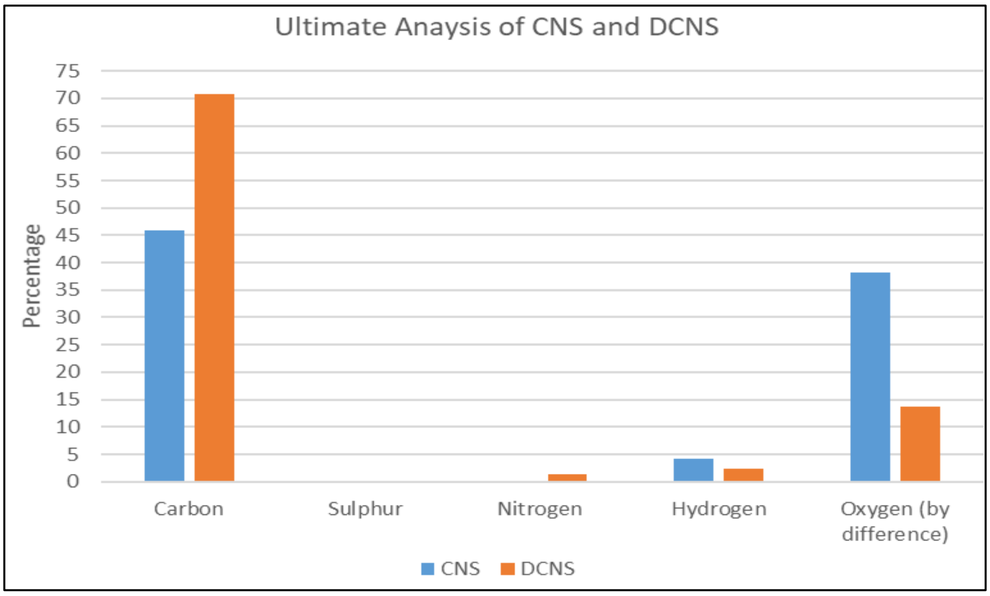

Fig 1: Ultimate analysis of CNS and DCNS

Thermal-gravimetric Analysis of Cashew Nut Shell

The TGA and derivatives thermal-gravimetric curves of CNS done with thermo-gravimetric analyser (TGA) STA 7300 Hitachi, Germany, operated under highly purity nitrogen (99.95%) environment (20 ml/min) at a heating rate of 20°C/min is shown in Figure 2. It was observed that the mass loss of CNS was distributed in three different stages: stage-I, stage-II and stage-3 which is drying, devolatilisation, and finally residues (char and ash), respectively. In stage-I, mass loss with respect to pyrolysis temperature around 150°C, which was attribute to removal of initial unbound moisture content and simultaneously degradation of volatile matter of CNS. The stage-II, was the active pyrolysis stage, at temperature ranged from 150 to 450°C, on which degradation of organic hemicellulose and cellulose material was occurred. In this stage-II, there are two distinct peaks from temperature of 150 to 450 °C. Among the two peaks, the first peak was attributed to thermal decomposition of hemicellulose at temperature 150 to 250 °C and the second peak, thermal decomposition of cellulose at temperature 250 to 450 °C (Tsamba *et al.* 2006) [20]. The stage-III start from 450 °C onwards indicate the degradation of lignin, due to exothermic and endothermic reactions at temperature range 450 to 600 °C (Tsamba *et al.* 2006 and Moreira *et al.* 2017) [20, 11]. In char formation zone, all the volatiles were evolved at temperature range 600 to 900°C and only the char remained (Uamusse *et al.* 2014) [22].

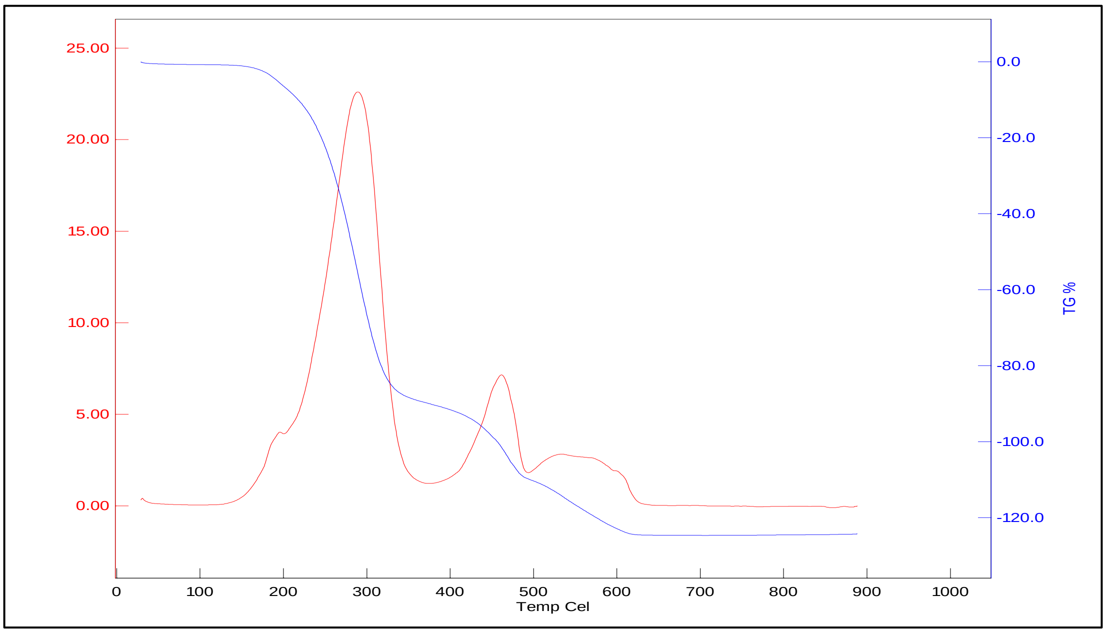

Fig 2: TG and DTG thermo-gravimetric analysis of CNS at 20 °C/min heating rate

Thermal-gravimetric Analysis of Deoiled Cashew Nut Shell

The TG-DTG curves of DCNS using similar instrument is shown in Figure 3. The TGA analysis of DCNS basically carried out to analyze the thermal resistance and its pyrolytic performance (Rafiq *et al.* 2016) [15]. It was observed that the moisture content and some extractives from DCNS has been removed upto temperature 300°C, this is the stage-I of thermal degradation. In stage-II, some parts of hemicellulose and cellulose were degraded in the temperature range of 300 to 550 °C. This stage mainly known as active pyrolysis stage. Stage-III, is started from temperature range 550 to 800 °C in which degradation of lignin was occurred, which may be happened due to the exothermic and endothermic reactions takes place between the organic compounds (Prasad *et al.* 2014) [13]. And from temperature range 800 °C to onwards, char formation stage where percentage of mass loss in DCNS was observed almost stable, which indicate the complete conversion of DCNS into char i.e. char formation stage.

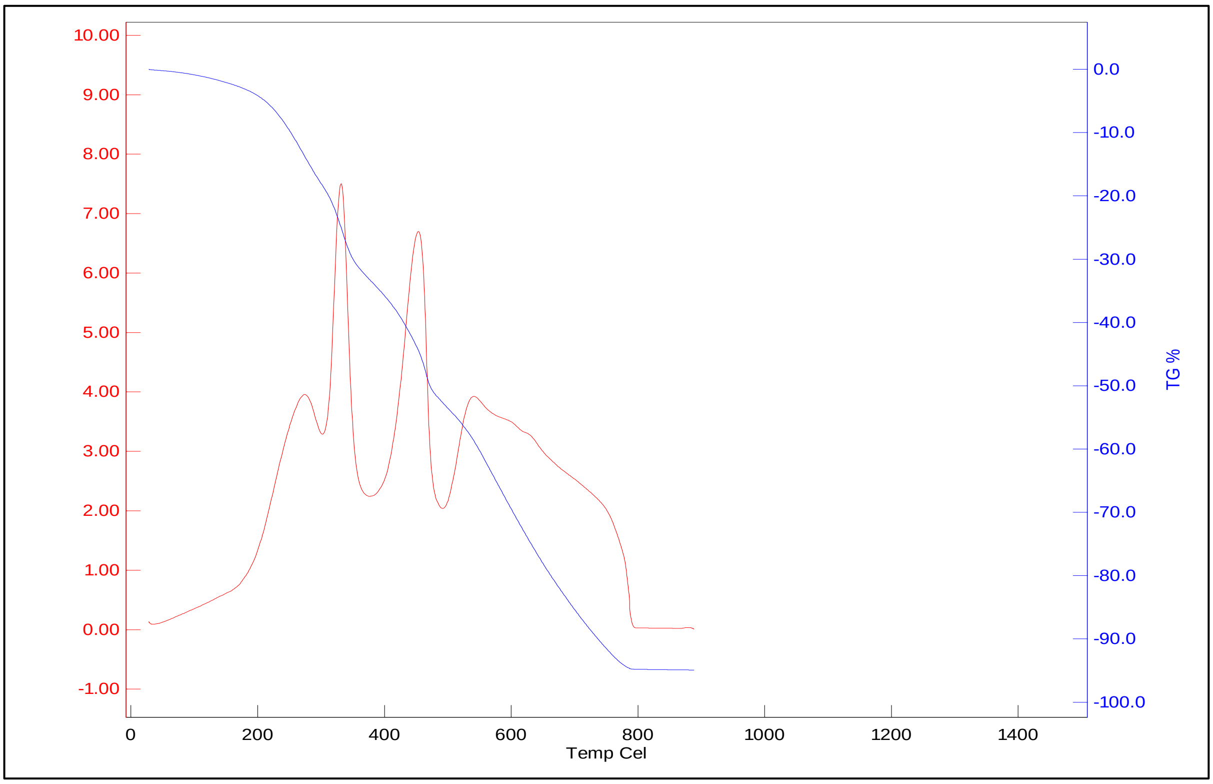

Fig 3: TG and DTG thermo-gravimetric analysis of DCNS at 20 °C/min heating rate

Conclusion

The study on cashew nut shell (CNS) was carried out as an alternative source of energy through pyrolysis and thermochemical processes. The pyrolysis process of CNS and DCNS were achieved in three different mass loss regions. A low heating rate (20 °C/min) was suitable for thermal degradation of the CNS and DCNS, resulting in less amount of residue (char). The above study observed that DCNS were an excellent feedstock for gasification, due to their fuel characteristics, which was comparable to CNS. It was observed that maximum fixed carbon percentage found in DCNS as 70.80 per cent. The higher heating value is the factor determining the suitability of fuel for gasification. The observed result showed that the DCNS has higher gross calorific value 6549 kcal/kg than CNS 5126 kcal/kg presenting suitable properties for use as energy source.

Acknowledgments

The authors would like to express thanks to Dr. N. L. Panwar, Department of Renewable Energy Sources, College of Technology and Engineering, MPUAT, Udaipur-313038 (Raj.) for providing facility of Thermal-gravimetric Analysis for experimental work.

References

1. Chaudhari AP, Thakor NJ, Sonawane SP, Sawant AA. Physical properties of cashew nut shells. International Journal of Agricultural Engineering 2013;6(1):254-260.
2. Couto HS, Duarte JBF, Bastos-Netto D. Biomass Combustion Chamber for Cashew Nut Industry. The Seventh Asia-Pacific International Symposium on Combustion and Energy Utilization. Hong Kong SAR. 2004, 15-17.
3. Das P, Ganesh A. Bio-oil from pyrolysis of cashew nut shell-a near fuel. Biomass and Bioenergy 2003;25:113-117.
4. Gawankar MS, Salvi BR, Pawar CD, Khanvilkar MH, Salvi SP, Dalvi NV *et al*. Technology Development For Cashew Apple Processing In Konkan Region-A Review. Advanced Agricultural Research & Technology Journal 2018;2(1):40-47.
5. Kachru RP, Gupta RK, Alam A. Physico-Chemical Constituents and Engineering Properties of Food Crops. Scientific Publishers, Jodhpur 1994.
6. Karaosmanoglu F, Tetik E, Gurboy B, Sanli I. Characterization of the straw stalk of the rapeseed plant as a biomass energy source. Energy Sources 1999;21:801-810.
7. Mohod A, Jain S, Powar AG. Energy option for small-scale cashew nut processing in India. Energy Research Journal 2010;1(1):47-50.
8. Mohod A, Jain S, Powar AG. Cashew Nut Shell Waste:

Availability in Small-Scale Cashew Processing Industries and Its Fuel Properties for Gasification. International Scholarly Research Network ISRN Renewable Energy 2011, 1-4.
9. Mohod A, Jain S. Energy conversion potential of cashew as a gasifier feedstock. JESC 2012;02(01):99-108.
10. Mohsenin NN. Physical Properties of Plant and Animal Materials. 2nd Ed. Gordon and Breach Science Publishers, New York 1986.
11. Moreira R, Orsini RR, Vaz JM, Penteado JC, Spinace EV. Production of Biochar, Bio-Oil and Synthesis Gas from Cashew Nut Shell by Slow Pyrolysis. Waste Biomass Valor 2017;08:217-224.
12. Mythili R, Venkatachalam P, Subramanian P, Uma D. Characterization of bioresidues for biooil production through pyrolysis. Bioresource Technology 2013;138:71-78.
13. Prasad L, Salvi BL, Kumar V. Thermal degradation and gasification characteristics of Tung Shells as an open top downdraft wood gasifier feedstock. Clean Techn Environ Policy 2014. (DOI 10.1007/s10098-014-0891-8).
14. Pawar A, Panwar NL. Experimental investigation on biochar from groundnut shell in a continuous production system. Biomass Conversion and Biorefinery 2020. (https://doi.org/10.1007/s13399-020-00675-4).
15. Sengar SH, Mohod AG, Khandetod YP, Shrirame HY, Deshmukh AS. Study of Carbonization for cashew nut shell. Research Journal of Chemical Sciences 2011;1(2):43-55.
16. Rafiq MK, Bachmann RT, Rafiq MT, Shang Z, Joseph S, Long R. Influence of pyrolysis temperature on physico-chemical properties of corn stover (*Zea mays* L.) biochar and feasibility for carbon capture and energy balance. Plos One 2016;11(6):1-17.
17. Rajapakse RA, Gunatillake PA, Wijekoon KB. A Preliminary study on processing of cashew nuts and production of cashew nut shell liquid (CNSL) on a commercial scale in Sri Lanka. Journal of the National Science Foundation of Sri Lanka 1977;5(2):117-124.
18. Ramanan MV, Lakshmanan E, Sethumadhavan R, Renganarayanan S. Performance prediction and validation of equilibrium modeling for gasification of cashew nut shell char. Brazilian Journal of Chemical Engineering 2008;25(3):585-601.
19. Tippayawong N, Chaichana C, Promwangkwa A, Rerkkriangkrai P. Gasification of cashew nut shells for thermal application in local food processing factory. Energy for Sustainable Development 2011;15:69-72.
20. Tsamba AJ, Yang W, Blasiak W. Pyrolysis characteristics and global kineticvs of coconut and cashew nut shell. Fuel Processing Technology 2006;87:523-530.
21. Tsamba AJ, Yang W, Blasiak W, Wojtowicz MA. Cashew nut shells pyrolysis: individual gas evolution rates and yields. Energy Fuel 2007;21:2357-2362.
22. Uamusse MM, Persson KM, Tsamba AJ. Gasification of Cashew Nut Shell Using Gasifier Stovein Mozambique. Journal of Power and Energy Engineering 2014;2:11-18.
23. Yin CY. Prediction of higher heating values of biomass from proximate and ultimate analyses. Fue 2011;90:1128-1132.