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Heavy Metal Content in Mainstream Cigarette Smoke of Common Cigarettes Sold in Kenya, and their Toxicological Consequences

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Abstract

Over the years tobacco research has focused heavily on the toxic organic components of cigarette smoke while giving little attention to the toxicological implications caused by heavy metals in mainstream cigarette smoking. Whereas, it is not in doubt that organic toxins and their corresponding free radicals are directly responsible for a myriad of problems affecting smokers, the clinical effects caused by heavy metals in tobacco burning cannot be ignored. Accordingly, this study investigates the heavy metal content in the gas-phase mainstream cigarette smoke of common cigarettes sold in Kenya and their toxicological implications. Two cigarette brands (SM1 and ES1), and one traditional cigarette (Trd) were selected for this study. To mimic actual cigarette smoking conditions, smoking apparatus were designed according to ISO 3402:1999 standards. Five conditioned cigarettes were smoked per sample. All experiments were conducted in replicates to enhance reproducibility of data. The heavy metal content was determined using atomic absorption spectrometer, AAS, (Shimadzu 6200). The mean results showed that lead had the highest concentration in all cigarette brands; 6.776±0.02, 6.984±0.03 and 7.119±0.0.05 $\mu g g^{-1}$ for traditional (Trd), SM1, and ES1 cigarettes respectively. On the other hand, the lowest heavy metal concentration was cadmium with respectively 0.084±0.004, 0.090±0.002, and 0.030±0.002 $\mu g g^{-1}$ for SM1, ES1, and traditional cigarettes. Moreover, chromium, copper, and zinc were also investigated. The concentration of lead, cadmium, chromium, copper, and zinc partitioned in the cigarette ash of each cigarette blend is also reported in this work.

Keywords: Carcinogenicity, heavy metals, gas-phase, oxidative stress, tobacco, toxicology.

Introduction

This research article explores the concentration of heavy metals in cigarette smoke which are known to cause severe health implications to tobacco consumers. Studies on heavy metals partitioned in the gas-phase cigarette smoke have received little attention as compared to tobacco toxins which are widely reported in literature. This study also investigates the heavy metal content in cigarette ash which may also cause significant biological and environmental problems when inhaled in form of air particles.

Tobacco biomass is of great interest because of its use in the form of cigarettes which generate various smoke compounds during pyrolysis reactions[1]. In the recent past, increased efforts have been devoted to exploration of tobacco by-products and the potency of cigarette smoking[2]. Accordingly, a good number of scientific research and epidemiological evidences have explicitly established cigarette smoking as a serious factor for degenerative diseases including cancers of the lungs and that of other body organs and cardiovascular diseases[1,3]. Previous researches indicate that human beings get exposed to heavy metals through cigarette smoke inhalation with the quantities dependent on the metal concentrations in air, and its retention in the lungs in the case of smokers[4]. Figure -1 gives an illustration of how tobacco is packaged to produce a cigarette. Tobacco cigarette is usually packaged using cellulose paper. A filter tip is incorporated into the cigarette with the general purpose of removing cigarette tar but this plays a negligible role in removing of toxic substances present in cigarette smoke.

Figure-1
The anatomy of tobacco cigarette

Cigarette smoking is an established avenue of toxic elements including cadmium and lead which contribute significantly to induced mental disorder[5,6]. The heavy metals present in cigarette smoke may precipitate serious cell aberrations in biological systems of tobacco consumers[7]. Cadmium(Cd) and Lead (Pb) metals have been reported to cause oxidative stress because of their catalytic action with may result in the formation of reactive oxygen species (ROS)[8] hence these metals are extremely poisonous with Pb being an established carcinogen[9,10]. Copper (Cu) and Zinc (Zn) are heavy metals which participate in the functioning of certain enzymes of biological importance but reports show that too much intracellular accumulation of these metals may be toxic and ultimately injurious to human health[11]. Excessive intracellular deposition of Cu leads to the generation of ROS which are known to cause oxidative stress in addition to cell damage[12,13]. Zn though an essential element in the body, when excessively consumed becomes toxic by inducing pathological conditions associated with oxidative stress[11]. Chromium VI affects negatively the gastrointestinal, respiratory, hepatic, endocrine, immunological and neurological systems[14]. High accumulation levels of Chromium VI exposes individuals to cancer[15,16]. Heavy metals monitoring in cigarette smoke is therefore important in the protection of the environment and the health of higher order animals including man.

Literature surveys suggest that the levels of some toxic heavy metals in blood of smokers are higher than that those of non-smokers[17]. Human beings get exposed to cigarette smoke by either being active smokers who directly inhale mainstream smoke or passive smokers subjected to side stream smoke or fall victims of Environmental Tobacco Smoke (ETS). Tobacco smoke contains toxic[18], genotoxic[19], mutagenic[20], and carcinogenic properties[21]. About 7000 chemicals have been identified to be present in tobacco smoke including nitrosamines, poly aromatic hydrocarbons and heavy metals which cause disease in human beings with over 5000 of these chemicals generated upon burning tobacco ingredients[22,23]. Therefore diseases associated with the use of tobacco are known to occur as a result of cell impairment due to frequent inhalation of toxic components in cigarette smoke[24]. Such toxins (organics and inorganics) are formed by pyrolysis and pyrosynthesis reactions taking place when tobacco biomass in burned[25].

Tobacco related illness contributes an estimated preventable death tally of about 4 million deaths annually all over the world[26]. The primary focus of this work was to estimate the levels of lead, cadmium, chromium, copper and zinc in mainstream smoke for cigarettes commonly sold in Kenya by using atomic absorption spectroscopy (AAS). The metal content partitioned in the gas-phase and that partitioned in the solid phase are reported in this work. This study has been informed by the fact that most cigarettes sold in Kenya are largely unregulated and may pose fatal consequences to tobacco consumers. Moreover, few studies around the world have explored the heavy metal content in cigarettes. This study therefore is key attempting to demystify tobacco. All results reported in this study were conducted in replicates.

Material and Methods

Materials: Two commercial cigarettes (SM1 and ES1), and one traditional cigarette (Trd) were purchased from vendors and used without further treatment. For confidential purposes, the commercial cigarettes were coded SM1 and ES1 while the traditional cigarette has been abbreviated as Trd.

Sample Preparation: 5 cigarette sticks were randomly selected from a pack of SM1 or ES1 cigarettes, weight and smoked using the apparatus set up presented in figure-2. To analyze for traditional cigarettes the, tobacco in SM1 cigarette stick was emptied and replaced with traditional tobacco. Care was taken to pack the same weight of traditional tobacco to obtain the equivalent weight as the tobacco in SM1 or ES1 cigarettes. All experiments were conducted in a fume chamber to minimize the health hazards associated with cigarette smoking.

A cigarette stick was placed at the tip of tubing connected to a vacuum as shown in figure -2 and lit with a match box. To sustain the burning of the cigarette, a syringe was used to draw in air to the burning cigarette. To prepare one sample, 5 cigarettes were smoked, implying that the heavy metals content reported in this study is an average of 5 cigarettes. That is, the result 5 of cigarettes (according to ISO 3402:1999 standards) is averaged to enhance the reproducibility of data.

The cigarettes were smoked by creating a low pressure using a syringe at a rate of 35 mL/s according to ISO 3402:1999 standards, and cigarette smoke collected in 50 mL analytical grade methanol containing 2 drops of 1M nitric acid in a conical flask as shown in figure-1. The samples were labeled and stored in dark crimp top vials for AAS analysis. The ash collected was mixed with 50 mL methanol and 2 drops of 1M nitric acid, stirred vigorously, and filtered using a filter paper (Whatman no. 4). The filtrate was then prepared for AAS analysis.

AAS Analysis: Cigarette samples for AAS analysis were prepared using the method described elsewhere[27]. The AAS used in this work was Shimadzu 6200 (Japan) with a graphite furnace. The machine was operated thus: wavelength and the slit width were 357.9 and 0.2 nm respectively, Flame type: Air-acetylene, Oxidant flow rate was 1.5 L/min. The sensitivity was 0.055 ppm, Detection limit was 0.001 ppm, lamp current was 5 mA and optimum working range of the instrument was 0.001-20.0 ppm.

Results and Discussion

The heavy metal content partitioned in the gas-phase and the solid-phase in mainstream smoke of selected cigarettes commonly sold in Kenya is presented in this work. These included the concentration of Pb, Cr, Zn, Cd, and Cu. The concentration of each heavy metal was reported as averaged value in $\mu g g^{-1}$ of cigarette.

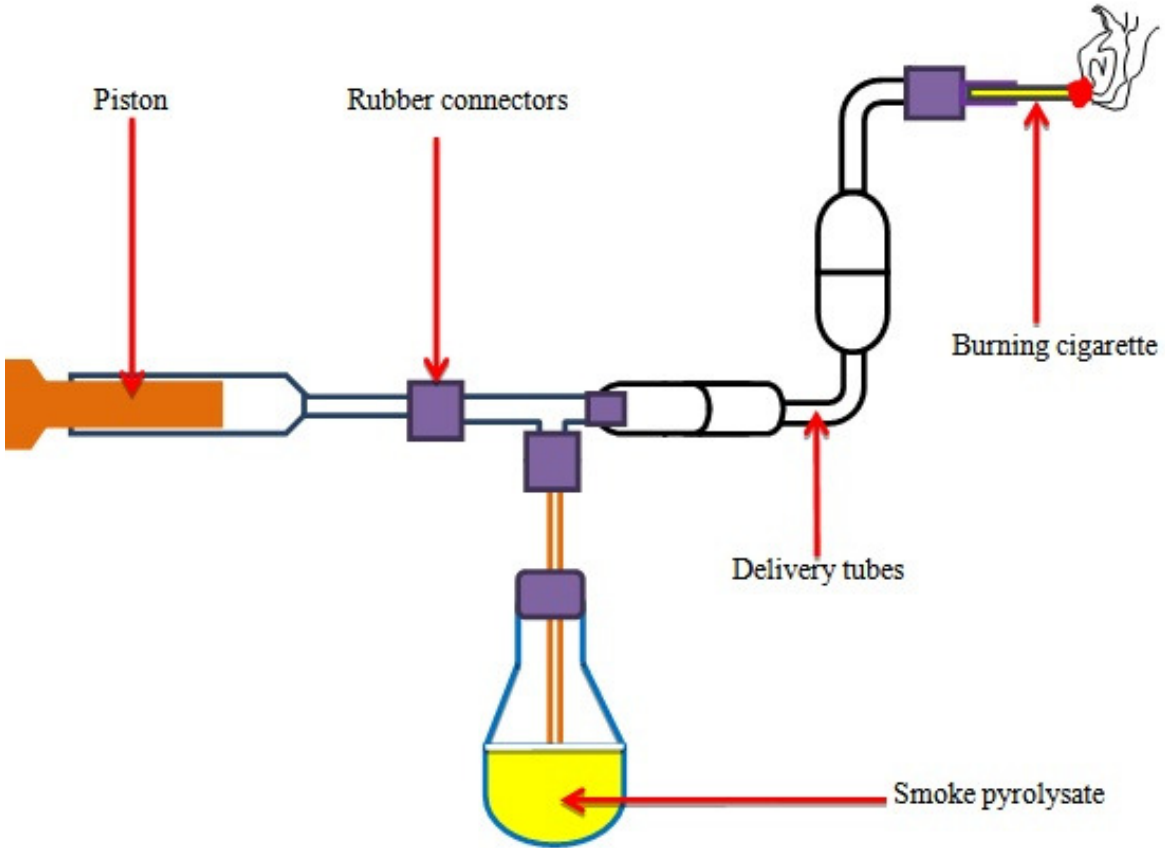

Figure-2
Apparatus set up for smoking cigarettes

Heavy Metal Content in the Gas-Phase of Cigarette Smoke: The gas-phase matter of cigarette smoke is very critical because it is directly inhaled by cigarette smokers. Consequently, it has a direct impact on the health of tobacco users. This study has revealed very startling results on the concentration of heavy metals in the gas-phase of various cigarette brands sold in Kenya. Figure-3 indicates that Pb constitutes the highest concentration of heavy metal content in all cigarettes investigated in this work. SM1 cigarette contained $6.984\pm0.03\mu gg^{-1}$, ES1 contained $7.119\pm0.0.05\mu gg^{-1}$ while the traditional (Trd) cigarette had $6.776\pm0.02\ \mu gg^{-1}$. Notably, chromium is less pronounced in ES1 cigarette brand and may be one of the safest cigarettes when considering the health effects caused by chromium. Nevertheless, this benefit may be offset by the high lead concentrations it contains.

Figure-3 shows that the concentration of chromium and zinc were also significant in all the cigarette brands. Copper and cadmium however exhibited the least concentrations. Except for the high concentrations of lead realized in processed tobacco (ES1 and SM1), traditional cigarette (unprocessed tobacco) showed high levels of chromium and copper than the 'modern' cigarettes. Interestingly, low levels of cadmium were observed in Trd cigarette ($0.003\ \mu gg^{-1}$) as compared to SM1 ($0.090\ \mu gg^{-1}$) and $0.084\ \mu gg^{-1}$for ES1 cigarette. The concentrations of Pb and Cr are generally above the recommended levels of heavy metal content in cigarette smoke[4]. Nonetheless, the concentrations of Cd, Zn and Cu fell within the range given by International Energy Atomic Agency[4] (IAEA-359). The trend observed in figure-2 may be attributed to processing, packaging and technological processes such as use of additives which may increase the heavy metal content in tobacco cigarette[28]. Growing conditions and fertilizer applications may also be responsible for the high levels of heavy metals observed in all the cigarette brands examined in this work[29].

Heavy Metal Levels Partitioned in Cigarette Ash: Whereas heavy metal content in cigarette residue (ash), may appear unnecessary to report because it is not consumed by smokers, its environmental impact as 'fly ash' cannot be underestimated. Cigarette ash contains fine particles in the micron region. Coupled with the critical levels of heavy metals it contains, it is remarkable to say that cigarette ash is indeed poisonous and needs further investigation to classify them as either $PM_{2.5}$ or PM_{10}. Fine particles, in this case cigarette ash, can cause respiratory problems, act as irritants in the respiratory tract and may eventually cause asthma and emphysema. Heavy metals in the ash are precursors for mental retardation, nervous breakdown, and cancer related illnesses.

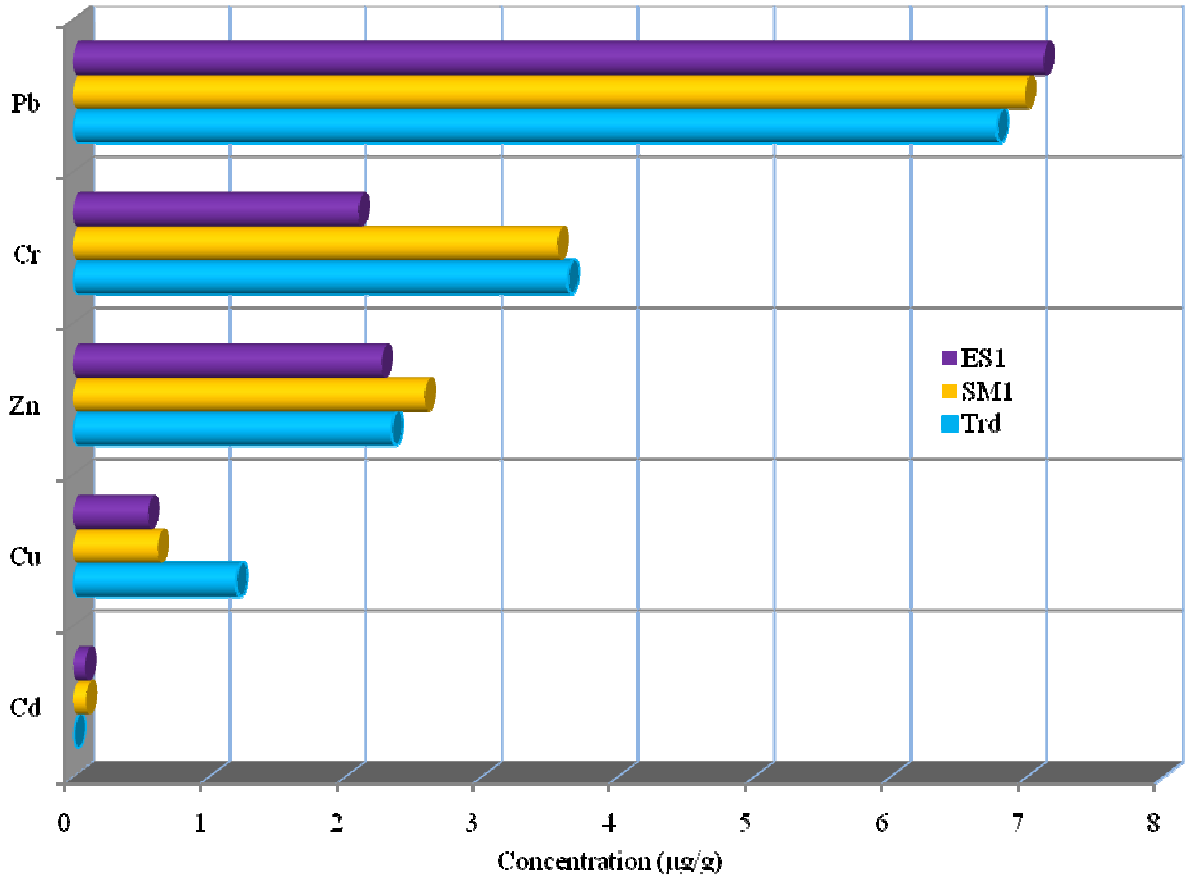

Figure-3
The gas-phase heavy metal concentration in various cigarette brands (ES1, SM1 and Trd)

Table-1
The level of heavy metals partitioned in cigarette ash of cigarette brands investigated in this work

Cigarette Brand	Concentration of ($\mu g g^{-1}$)				
	Cd	Cu	Zn	Cr	Pb
Trd	0.093±0.02	2.818±0.02	1.143±0.04	3.605±0.02	6.712±0.1
SM1	0.063±0.01	2.668±0.03	0.219±0.03	3.293±0.05	6.637±0.07
ES1	0.073±0.01	1.914±0.01	0.329±0.03	1.590±0.03	7.066±0.04

It is evident from table-1 above that lead and chromium constitute more than 70% of the heavy metal content in the traditional and SM1cigarettes while it contributes more than 80% in ES1 cigarette. Nonetheless, contrary to the observations made in the gas-phase of cigarette smoke, Zn was detected in low amounts in cigarette ash. On the other hand, the amount copper partitioned in the cigarette ash was higher than that partitioned in cigarette smoke.

Conclusion

Tobacco is a killer plant in any form; whether smoked, chewed, or sniffed. Evidently, the health burden contributed by heavy metal content in tobacco must be a subject of eminent concern because the clinical effects they cause are equally devastating as those caused by organic toxins present in tobacco. The primary heavy metal component in all the cigarette brands investigated was lead while Cd was detected in low amounts. It is very important to note that generally, all cigarette brands gave high concentrations of heavy metals both in the gas-phase (cigarette smoke) and the solid phase (cigarette ash). Remarkably, there was no substantial difference in concentration of all heavy metals tested in the three cigarette brands investigated in this work. Interesting results however, have been reported on the heavy metal levels in cigarette ash. These levels are equally injurious to human health as those partitioned in the cigarette smoke. This is because inhalation of such particulate matter may cause severe respiratory problems such as whizzing and throat cancer.

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References

1 Kibet J.K., Mathenge A.B., Limo S.C. and Omare M.O., Theoretical Modeling and Experimental Investigation of Propanol and Phenol in Mainstream Cigarette Smoking, *The African Review of Physics,* **9**, 251-258 **(2014)**

2 Zhou S., Wang C., Xu Y. and Hu Y., The pyrolysis of cigarette paper under the conditions that simulate cigarette smouldering and puffing, *J. Thermal Analysis and Calorimetry,* **104**, 1097-1106 **(2011)**

3 Ghosh A. *et al.*, Toxicology, *J.tox,* **292**, 78 **(2012)**

4 Iwuoha G.N., Oghu E.I. and Onwuacu U.I., Levels of selected heavy metals in some brands of Cigarettes marketed in University of Port Harcourt, Rivers State, *Ajol.,* **17**, 561-564 **(2013)**

5 Kazi T.G. *et al.*, Evaluation of toxic metals in blood and urine samples of chronic renal failure patients, before and after dialysis, *Renal failure,* **30**, 737-745 **(2008)**

6 Espinoza E., Escudero R. and Tavera F., Waste Water Treatment by Precipitating Copper, Lead and Nickel Species, *Research Journal of Recent Sciences,* **(2012).**

7 Harun Ç. and Ali Ö., Determination of Iron, Copper, Cadmium and Zinc in Some Cigarette Brands in Turkey, *International Journal of Science and Technology,* **2**, 29-32 **(2007)**

8 Afridi H.I. *et al.*, Evaluation of cadmium, lead, nickel and zinc status in biological samples of smokers and nonsmokers hypertensive patients, *Journal of Human Hypertension,* **24**, 34-43 **(2010)**

9 Rangnekar S., Sahu S., Pandit G. and Gaikwad V., Study of Uptake of Pb and Cd by Three Nutritionally Important Indian Vegetables Grown in Artificially Contaminated Soils of Mumbai, India, *International Research Journal of Environment Science,* **2**, 1-5 **(2013)**

10 Tiwari S., Tiwari H.L. and Tripathi I.P., Lead Effects on Health, *Int. Res. J. Environment Sci.,* **2**, 83-87 **(2013)**

11 Ajab H. *et al.*, Evaluation of trace metals in tobacco of local and imported cigarette brands used in Pakistan by spectrophotometer through microwave digestion, *The Journal of Toxicological Sciences,* **33**, 415-420 **(2008)**

12 Medici V. *et al.*, Metallothionein and antioxidant enzymes in Long-Evans Cinnamon rats treated with zinc, *Archives of toxicology,* **76**, 509-516 **(2002)**

13 Ashish B., Neeti K. and Himanshu K., Copper toxicity: a comprehensive study, *Research Journal of Recent Sciences,* 2502 **(2013)**

14 Solidum J., Lead, Cadmium and Chromium in Selected Local Cigarettes Available in the Philippines, *International Journal of Chemical and Environmental Engineering,* **4**, 205-208 **(2013)**

15 Agency for toxic substances and disease registry, A. chromium toxicity, **(2008)**

16 Nwajei G., Okwagi P., Nwajei R. and Obi-Iyeke G., Analytical assessment of trace elements in soils, tomato leaves and fruits in the vicinity of paint industry, Nigeria, *Research Journal of Recent Sciences,* **1**, 22-26 **(2012)**

17 El-Agha O. and Gökmen İ., Smoking habits and cadmium intake in Turkey, *Biol Trace Elem Res.,* **88**, 31-43 **(2002)**

18 Chiba M. and Masironi R., Toxic and trace elements in tobacco and tobacco smoke, *Bulletin of the World Health Organization,* **70**, 269 **(1992)**

19 Husgavfel-Pusiainen K, Mutation Research, **567**, 447 **(2004)**

20 Demarini D.M, *Mutation Reseach,* **567**, 447 **(2004)**

21 Eyre H. *et al.*, Preventing cancer, cardiovascular disease, and diabetes: a common agenda for the American Cancer Society, the American Diabetes Association, and the American Heart Association, *Circulation,* **109**, 3244-3255 **(2004)**

22 Pappas R.S., Polzin G.M., Watson C.H. and Ashley D.L., Cadmium, lead, and thallium in smoke particulate from counterfeit cigarettes compared to authentic US brands, *Food and Chemical Toxicology,* **45**, 202-209 **(2007)**

23 Chalouhi N. *et al.*, Cigarette Smoke and Inflammation: Role in Cerebral Aneurysm Formation and Rupture, *Mediators of Inflammation,* **12, (2012)**

24 Abdulkadir Levent, Yavuz Yardim and Demir., C. Determination of Trace Metal and Mineral Levels in the Tobacco and Cigarette samples using by FASS, *J.Chem.Soc.Pak,* **35**, 257-261 **(2013)**

25 Baker R.R. and Bishop L.J., The pyrolysis of tobacco ingredients, *Journal of Analytical and Applied Pyrolysis,* **71**, 223-311 **(2004)**

26 WHO, Tobacco: deadly in any form or disguise, **(2006)**

27 Christian G.D., *Analytical chemistry*. 6th edn, (John Willy and Sons 2005), **(2015)**

28 Stephen N.M., Goom L.K., Flora M.B., Holow C.D. and Andy X.J., Contamination of Sedimentby leads, cadmium and zinc, *Environmental Pollution,* **2**, 60-79 **(2003)**

29 Feng J.W., Zheng S.K. and Maciel G.E., EPR investigations of charring and char/air interaction of cellulose, pectin, and tobacco, *Energy and Fuels,* **18**, 560-568 **(2004)**