Aqueous and ethanolic leaf extracts of *Ocimum basilicum* (sweet basil) protect against sodium arsenite-induced hepatotoxicity in Wistar rats

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Summary: We evaluated the effects of aqueous and ethanolic leaf extracts of *Ocimum basilicum* (sweet basil) on sodium arsenite-induced hepatotoxicity in Wistar rats. We observed that treatment of the animals with the extracts before or just after sodium arsenite administration significantly ($p < 0.05$) reduced mean liver and serum γ-Glutamyl transferase (γGT), and serum alkaline phosphatase (ALP) activities when compared with the group administered the toxin alone. In addition, treatments of the animals with aqueous or ethanolic extract of *O. basilicum* before the administration of sodium arsenite resulted in the attenuation of the sodium arsenite-induced aspartate and alanine aminotransferase activities: ALT (from 282.6 % to 167.7 % and 157.8 %), AST (from 325.1 % to 173.5 % and 164.2 %) for the group administered sodium arsenite alone, the aqueous extracts plus sodium arsenite, and ethanolic extracts plus sodium arsenite respectively, expressed as percentage of the negative control. These findings support the presence of hepatoprotective activity in the *O.basilicum* extracts.
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INTRODUCTION

The role of environmental factors in the aetiology of most genetic diseases cannot be over emphasized. Exposure to environmental contaminants is inadvertent and difficult to control. On the other hand, dietary components/additives have been implicated as protective agents in the control of cancer (Wattenberg 1985, Popkin 2007). Several vegetables and spices are now known to exhibit medicinal, antioxidant and anticarcinogenic properties and effects (Aruna and Sivaramakrishnan 1992, Myagmar and Aniya 2000, Bajpai *et al.* 2005).

Ocimum group of species have been shown to possess a wide range of chemopreventive and medicinal activities (Godhwani *et al.* 1987, Banerjee *et al.* 1996, Karthikeyan *et al.* 1999, Rastogi *et al.* 2007). In addition, extracts of the leaves displayed powerful antioxidant activity in various assay models

(Jayasinghe *et al.* 2003, Gulcin *et al.* 2007). *O. basilicum* had been found to contain linalool, eugenol, methyl chavicol, methyl cinnamate, ferulate, methyl eugenol, triterpenoids and steroidal glycoside known to exhibit antioxidant activities (Zheljazkov et al., 2008, Siddiqui et al., 2007a, Siddiqui et al., 2007b). It is therefore possible that the extracts may serve as a remedy by blocking or intercepting the activity of environmentally acquired toxins such as mycotoxins, insecticides and pesticides.

Sodium arsenite is widely used as a component of herbicides, fungicides, insecticides, and algaecides, and in the manufacture of arsenical soap (Griffon *et al*. 1961, Da Costa, 1972, Shariatpanahi *et al*. 1981, Chen *et al*. 2006). Drinking water with a high inorganic arsenic concentration is the main source of arsenic exposure for the world population (Chiou *et al.* 1995). Studies have proved sodium arsenite to be highly toxic (Biswas *et al.* 2007, Yousef *et al.* 2008,

El-Demerdash *et al.* 2009). Previous studies in our laboratory have shown that it is hepatotoxic and clastogenic in experimental animals (Odunola *et al.* 2008, Gbadegesin, *et al.* 2009). The principal mechanism of arsenic intoxication is disruption of thiol proteins (Chouchane and Snow 2001). Sodium arsenite has also been shown to decrease glutathione levels and increase lipid peroxidation in liver, kidney and heart (Lee and Ho, 1994, Ramos *et al.* 1995).

The objective of this study is to evaluate the effects of aqueous and ethanolic leaf extracts of *O. basilicum* on sodium arsenite-induced hepatotoxicity in the Wistar rats. The activities of the enzymes aspartate and alanine aminotransferases, alkaline phosphatase, γ-glutamyl transferase and glutathione-S-transferase were monitored in the treated and control animals.

MATERIALS AND METHODS

Chemicals, Reagents and Test Substances: All reagents and solvents were of analytical grade. Sodium arsenite (Na_2AsO_2) was from Sigma Chemical Co., St Louis, MO. It was dissolved in distilled water and administered at 2.5 mg/kg body weight as detailed below.

Plant materials and extraction procedures: Fresh *O.bacilicum* leaves were collected from the University of Ibadan, Ibadan botanical garden and authenticated at the Department of Botany herbarium. The leaves were dried at room temperatures on bench surface at the Department of Biochemistry. The dried leaves were ground into a fine powder in a mill. Aqueous and ethanol extraction methods used were as reported by Gulcin (2005). The solvent were removed using rotary evaporator. The extracts were then suspended in convenient volume of distilled water and administered as shown below.

Experimental animals and treatments: Thirty-five male Albino Wistar rats weighing between (130-160) g and of ages between (12 – 15) weeks were obtained from the Animal House of the Department of Veterinary Physiology and Pharmacology, University of Ibadan, Nigeria. They were housed in steel metal cages in the Animal House, Department of Biochemistry. The rats were fed pellets (from Ladokun Livestock Feeds Limited, Ibadan, Nigeria) and given water *ad libitum*. The animals were randomly assigned into seven groups (A-G) of five rats each and treated as below:

Group Treatments

A: Distilled water only by oral intubations. This is the negative control group

B: Sodium arsenite via i.p route at 2.5 mg/kg body weight ($^1/_{10th}$ of its LD_{50}). This is the positive control group

C: Aqueous extract of *O. basilicum* leaves only p.o. at 400mg /kg body weight for 14 days: The extracts dose of 400mg/kg body weight was found to be the most effective in the dose range of (100 – 400) mg/kg body weight by Manikandan *et al.* (2007)

D: Ethanolic extract of *O. basilicum* leaves only p.o at 400mg/kg body weight for 14 days

E: Pre-treatment with aqueous extract of *O. basilicum* leaves p.o. at 400mg/kg body weight for 14 days + sodium arsenite for the next 14th day at 2.5 mg/kg body weight (i.p)

F: Pre-treatment with ethanolic extract of *O. basilicum* leaves p.o for 14 days + sodium arsenite for the next 14th day at 2.5 mg/kg body weight (i.p)

G: Sodium arsenite at 2.5 mg/kg body weight (i.p) + ethanolic extract of *O. basilicum* leaves (p.o) at 400mg/kg body weight for 14 days (both arsenite and extract given daily for 14 days)

The animals were allowed to acclimatise for seven days before the commencement of the experiment with 12 hours light/ dark cycle and temperature of 29 ± 2 °C. These conditions were maintained throughout the duration of the experiment.

Enzyme Assay
Gamma-glutamyl transferase (γGT) activity was assayed in the serum and liver homogenates by using the reconstituted γGT diagnostic reagent following the method of Szasz (1969). Serum alanine aminotransferase (ALT) and aspartate aminotransferase (AST) activities were assayed according to Reitman and Frankel (1957). This method involves the reaction of pyruvate, the product of transamination reaction catalysed by ALT or AST, with 2, 4-dinitrophenyl hydrazine to produce intensely coloured hydrazone read at 546 nm using spectronic-20 spectrophotometer. Alkaline phosphatase (ALP) assay was based on the method of Williamson (1972). This is based on spectrophotometric (405 nm) determination of concentration of p-nitrophenol formed by the dephosphorylation of p-nitrophenyl phosphate (PNPP) catalysed by ALP. Hepatic GST activities were determined according to Habig *et al.* (1974). The cytosolic GST activities were determined using 1-chloro-2,4-dinitrobenzene (CDNB) as substrate.

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The reaction was followed by measuring the absorbance at 340 nm at 1 minute intervals for 5 minutes. The specific activities were expressed as nmole of CDNB-GSH conjugate formed per mg of protein. Protein determination of each sample was according to Lowry *et al.* (1951) using BSA as standard.

Statistical Analysis

The data were analysed by One-way Analysis of Variance (ANOVA) followed by Least Significant Difference (LSD). p values less than 0.05 were considered statistically significant. All the results are expressed as mean $\pm$ standard deviation.

RESULTS

Leaf extracts of *Ocimum basilicum* suppressed sodium arsenite-induced γ-glutamyl transferase (γGT) and alkaline phosphatase (ALP) activities

There was significant increase ($p < 0.05$) in the serum and liver γGT activities of the rats treated with sodium arsenite, as compared with the negative control rats treated with distilled water alone (group A vs B, Figure 1). We observed that treatment of the animals with the extracts 14 days before or just after sodium arsenite administration (groups E, F and G) significantly ($p < 0.05$) reduced mean liver and serum γGT activities when compared with group administered the toxin alone (group B). Treatment with the extract of *O. basilicum* alone resulted in higher liver and serum γGT as compared with the negative control group. However, there are no significant differences ($p > 0.05$) in the observed γGT values within the groups of rats treated with *O. basilicum* aqueous or ethanolic extract alone (group C or D) and the negative control group (group A). Serum ALP activities of the treated rats also showed trends similar to what was observed for the γGT activities (Figure 2).
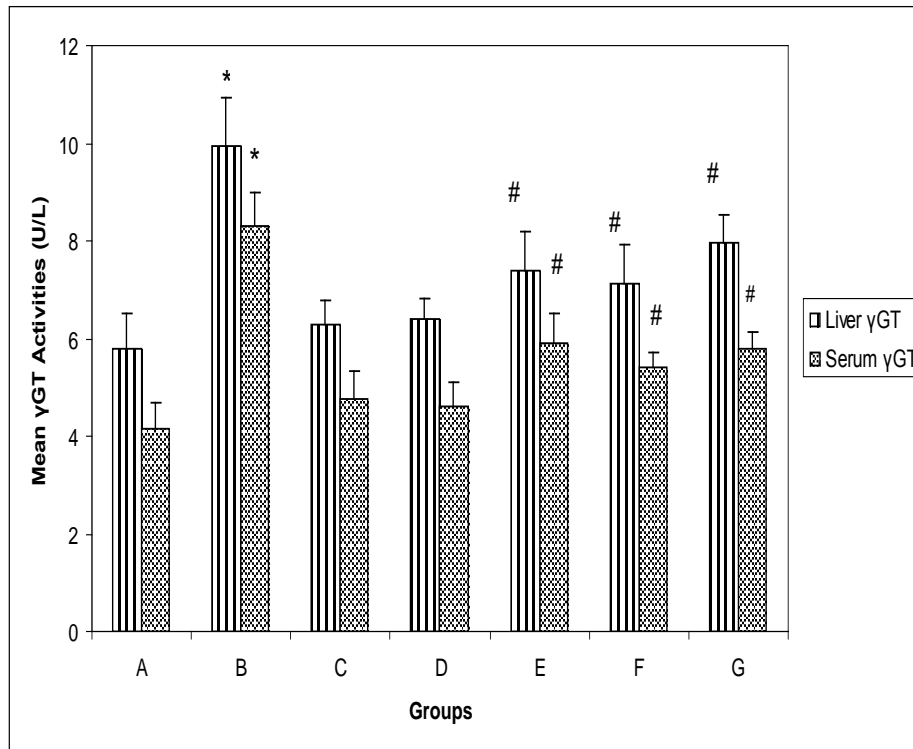

Fig. 1:

Leaf extracts of *Ocimum basilicum* suppressed sodium arsenite-induced liver and serum γ-glutamyl transferase (γGT) activities in the Wistar rats. A, group of rats given distilled water only (this is the negative control group); B, group of rats given sodium arsenite (this is the positive control group); **C**, animals in this group were given aqueous extract of *O. basilicum* leaves alone; **D**, animals in this group were given ethanolic extract of *O. basilicum* leaves only; **E**, group pre-treated with aqueous extract of *O. basilicum* leaves before sodium arsenite; **F**, group pre-treated with ethanolic extract of *O. basilicum* leaves before sodium arsenite; **G**, animals were given sodium arsenite same time as aqueous extract of *O. basilicum* leaves. Values are Mean $\pm$ SD; n=5. *Significantly different from the negative control; # significantly different from positive control group ($p < 0.05$).
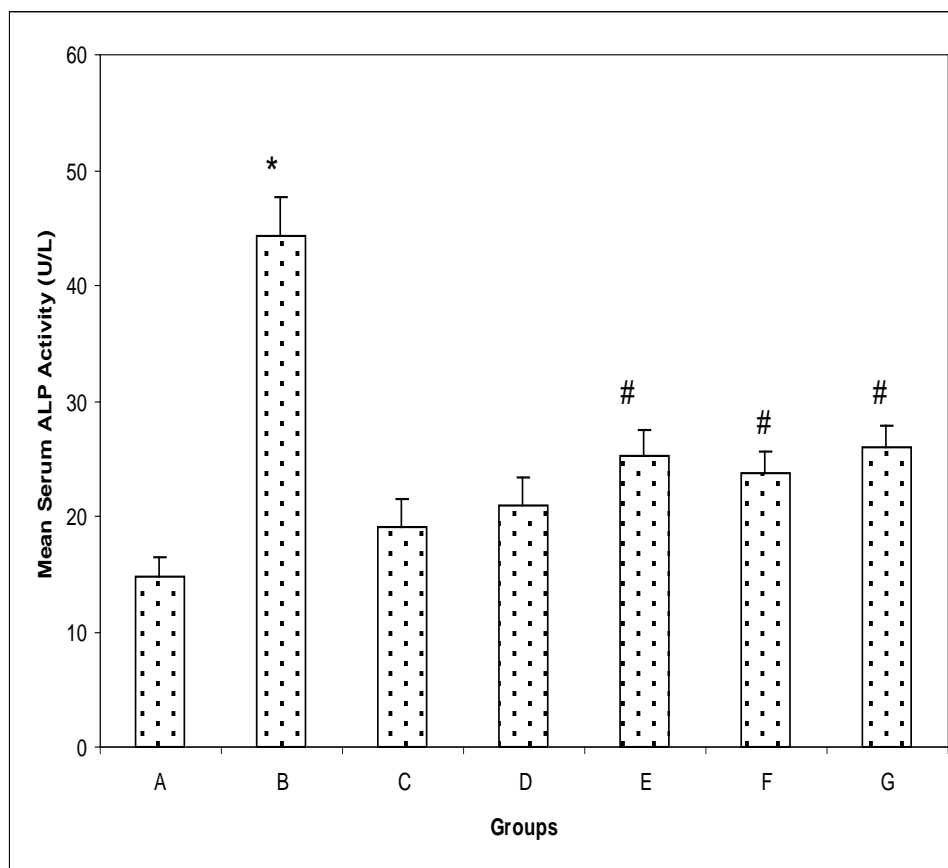
Fig. 2:
Leaf extracts of *Ocimum basilicum* suppressed sodium arsenite-induced serum alkaline phosphatase (ALP) activities in the treated rats. **A**, group of rats given distilled water only (this is the negative control group); **B**, group of rats given sodium arsenite (this is the positive control group); **C**, animals in this group were given aqueous extract of *O. basilicum* leaves alone; **D**, animals in this group were given ethanolic extract of *O. basilicum* leaves only; **E**, group pre-treated with aqueous extract of *O. basilicum* leaves before sodium arsenite; **F**, group pre-treated with ethanolic extract of *O. basilicum* leaves before sodium arsenite; **G**, animals were given sodium arsenite same time as aqueous extract of *O. basilicum* leaves. Values are Mean $\pm$ SD; n=5. *Significantly different from the negative control; # significantly different from positive control group (p < 0.05).

Attenuation of sodium arsenite-induced serum alanine (ALT) and aspartate aminotransferase (AST) activities by leaf extracts of *O. basilicum*

Experimental rats administered sodium arsenite (i.p) have elevated serum alanine (282.6 %) and aspartate aminotransferase (325.1 %) activities as compared with the negative control group (Figure 4). Treatments of the animals with aqueous or ethanolic extract of *O. basilicum* before the administration of sodium arsenite resulted in the attenuation of the sodium arsenite induction of these serum enzymes: ALT (167.7 % and 157.8 %), AST (173.5 % and 164.2 %) for the aqueous and ethanolic extracts treatment respectively before sodium arsenite administration expressed as percentage of the negative control. There were no significant (p > 0.05) differences in the mean enzyme activities between the group pre-treated with the ethanolic extract before sodium arsenite (group F) and the group administered the extract just after the toxin (group G) or between the groups given the aqueous or ethanolic extract pre-treatments (groups E and F).

Effect of sodium arsenite and leaf extracts of *O. basilicum* on glutathione-S-transferase (GST) in rats

Experimental rats treated with sodium arsenite have mean liver GST activities that were significantly lower (p < 0.05) than the observed mean value in the negative control rats treated with distilled water alone (groups B vs A; Figure 4). On the other hand, the group of rats treated with *O. basilicum* leaf extracts alone (groups C and D) recorded mean liver GST values that were significantly higher (p < 0.05) than the negative control group (A). Treatment of the animals with aqueous or ethanolic leaf extracts of *O. basilicum* before or just after the administration of sodium arsenite resulted in mean GST values that are similar to those obtained when the animals received the distilled water alone.
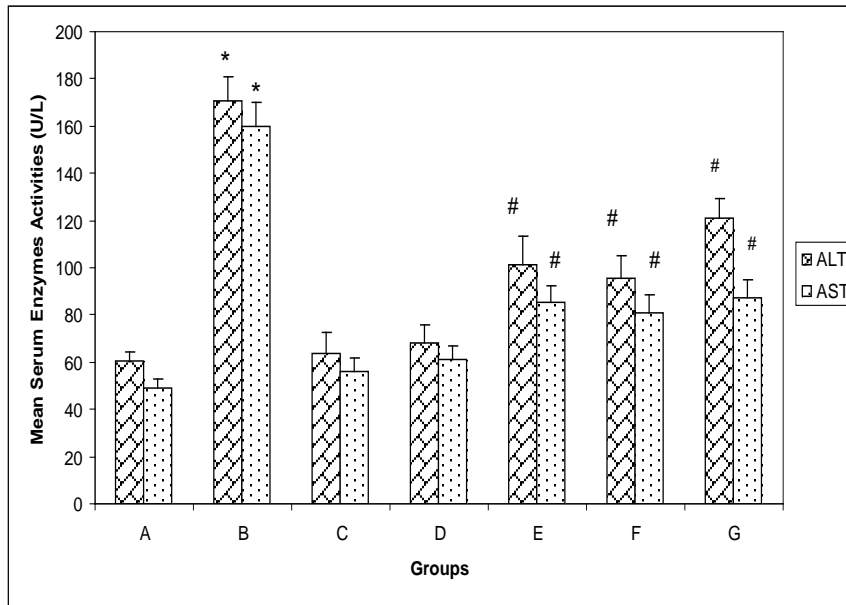
Fig. 3: Attenuation of sodium arsenite-induced serum alanine and aspartate aminotransferase activities by leaf extracts of *O. basilicum*. **A**, group of rats given distilled water only (this is the negative control group); **B**, group of rats given sodium arsenite (this is the positive control group); **C**, animals in this group were given aqueous extract of *O. basilicum* leaves alone; **D**, animals in this group were given ethanolic extract of *O. basilicum* leaves only; **E**, group pre-treated with aqueous extract of *O. basilicum* leaves before sodium arsenite; **F**, group pre-treated with ethanolic extract of *O. basilicum* leaves before sodium arsenite; **G**, animals were given sodium arsenite same time as aqueous extract of *O. basilicum* leaves. Values are Mean $\pm$ SD; n=5. *Significantly different from the negative control; # significantly different from positive control group ($p < 0.05$).

Fig. 4: **Effect of sodium arsenite and leaf extracts of *O. basilicum* on glutathione-S-transferase activities in the Wistar rats**. **A**, group of rats given distilled water only (this is the negative control group); **B**, group of rats given sodium arsenite (this is the positive control group); **C**, animals in this group were given aqueous extract of *O. basilicum* leaves alone; **D**, animals in this group were given ethanolic extract of *O. basilicum* leaves only; **E**, group pre-treated with aqueous extract of *O. basilicum* leaves before sodium arsenite; **F**, group pre-treated with ethanolic extract of *O. basilicum* leaves before sodium arsenite; **G**, animals were given sodium arsenite same time as aqueous extract of *O. basilicum* leaves. Values are Mean $\pm$ SD; n=5. *Significantly different from the negative control; # significantly different from positive control group ($p < 0.05$)
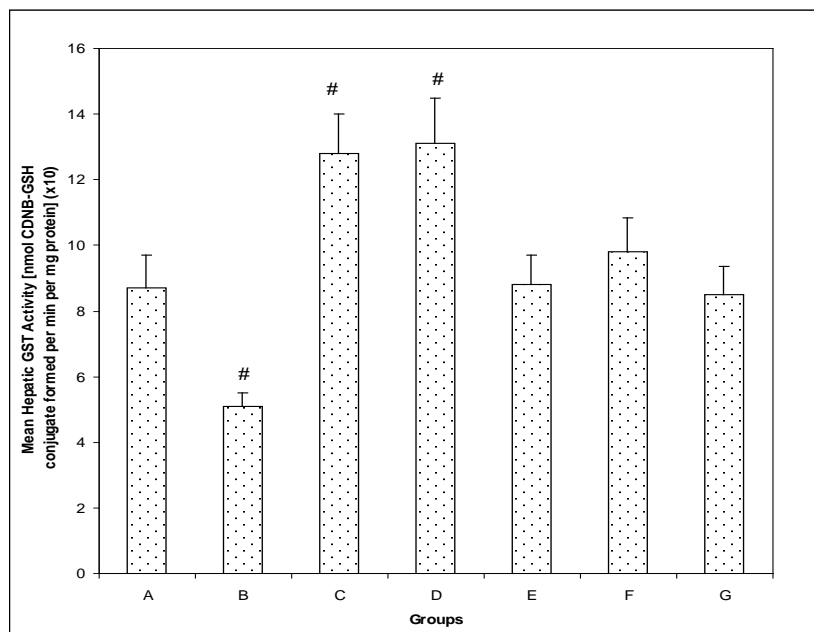
O. basilicum attenuate arsenite toxicity

DISCUSSION

Reduced glutathione (GSH), γ-glutamyl transferase, (γGT) and glutathione-S- transferase (GST) play important role in the protection of cells against carcinogenic chemicals (Locigno and Castronovo, 2001). In addition, elevation in the level of the enzymes, γGT and alkaline phosphatase (ALP) has emerged as an index of a liver lesion (Lum and Gambino 1972, Friedman *et al.* 1996). Arsenicals are becoming environmental contaminant of significance. In fact, long term exposures to arsenic through drinking wells' water with high concentration of arsenic have been associated with the aetiology of some cancers (Chen *et al.* 1992, Chow *et al.* 1997). Rats treated with sodium arsenite (positive control group B) have mean liver and serum γGT and serum ALP at levels that are significantly higher than the value observed for the negative control group (group A). Previous studies in our laboratories showed that sodium arsenite induced γGT activity in laboratory animals (Odunola *et al.* 2008, Gbadegesin *et al.* 2009). The elevation in the level of the two enzymes, γGT and ALP, is an indication of a liver lesion (Lum and Gambino 1972, Ideo *et al.* 1972). On the other hand, we found that the aqueous and ethanolic leaf extracts of *O. basilicum* attenuates the sodium arsenite-induced enzymes. Treatment with leaf extracts of *O. basilicum* before or just after administration of sodium arsenite significantly ($p <$ 0.05) reduced mean liver and serum γGT and ALP activities when compared with groups administered only sodium arsenite, supporting the presence of hepatoprotective components in the extracts against the hepatotoxicity of the sodium arsenite.

In addition, we found that sodium arsenite-induced higher level of serum ALT (282.6 %) and AST (325.1 %) in the treated rats as compared with the negative control group that received distilled water alone. This is consistent with findings with other hepatotoxins (Hsiao *et al.* 2001, Ritter *et al.* 2004). Treatment with leaf extracts of *O. basilicum* before or after sodium arsenite led to reduction in the level of sodium arsenite-induced ALT and AST activities.

Furthermore, treatment of the experimental rats with the *O. basilicum* extracts led to enhanced level of hepatic GST compared with the treatment with distilled water alone. *Ocimum basilicum* extracts treatment also reduced the decreased GST activity observed with sodium arsenite treatment to the level similar to the negative control group. The findings here are similar to the report about extract from *Ocimum sanctum* by Prashar *et al.* (1994). This suggests that the extracts contain reduced glutathione replenishing ability. The hepatoprotective effects of *Ocimum basilicum* (sweet basil) extracts may be linked to their antioxidant activities. Further studies are on to elucidate the mechanism by which *O. basilicum* extracts is able to protect against sodium arsenite induced hepatotoxicity in the experimental animals. The findings here support the growing evidence that vegetables, spices and fruits exhibit protective effects against chemicals and toxins (Prashar *et al.* 1994, Biswas *et al.* 1999, Karthikeyan *et al.* 1999, Rastogi *et al.* 2007).

REFERENCES

Aruna, K. and Sivaramakrishnan, V. M. (1992). Anticarcinogenic effects of some indian plant products. *Food Chem Toxicol,* 30, 953-6.

Bajpai, M., Mishra, A. and Prakash, D. (2005). Antioxidant and free radical scavenging activities of some leafy vegetables. *Int J Food Sci Nutr,* 56, 473-81.

Banerjee, S., Prashar, R., Kumar, A. and Rao, A. R. (1996). Modulatory influence of alcoholic extract of ocimum leaves on carcinogen-metabolizing enzyme activities and reduced glutathione levels in mouse. *Nutr Cancer,* 25, 205-17.

Biswas, R., Poddar, S. and Mukherjee, A. (2007). Investigation on the genotoxic effects of long-term administration of sodium arsenite in bone marrow and testicular cells in vivo using the comet assay. *J Environ Pathol Toxicol Oncol,* 26, 29-37.

Biswas, S., Talukder, G. and Sharma, A. (1999). Protection against cytotoxic effects of arsenic by dietary supplementation with crude extract of emblica officinalis fruit. *Phytother Res,* 13, 513-6.

Chen, C. J., Chen, C. W., Wu, M. M. and Kuo, T. L. (1992). Cancer potential in liver, lung, bladder and kidney due to ingested inorganic arsenic in drinking water. *Br J Cancer,* 66, 888-92.

Chen, Z., Cai, Y., Solo-Gabriele, H., Snyder, G. H. and Cisar, J. L. (2006). Interactions of arsenic and the dissolved substances derived from turf soils. *Environ Sci Technol,* 40, 4659-65.

Chiou, H. Y., Hsueh, Y. M., Liaw, K. F., Horng, S. F., Chiang, M. H., Pu, Y. S., Lin, J. S., Huang, C. H. and Chen, C. J. (1995). Incidence of internal cancers and ingested inorganic arsenic: A seven-year follow-up study in taiwan. *Cancer Res,* 55, 1296-300.

Chouchane, S. and Snow, E. T. (2001). In vitro effect of arsenical compounds on glutathione-related enzymes. *Chem Res Toxicol,* 14, 517-22.

Chow, N. H., Guo, Y. L., Lin, J. S., Su, J. H., Tzai, T. S., Guo, H. R. and Su, I. J. (1997). Clinicopathological features of bladder cancer

associated with chronic exposure to arsenic. *Br J Cancer,* 75, 1708-10.

Da Costa, E. W. (1972). Variation in the toxicity of arsenic compounds to microorganisms and the suppression of the inhibitory effects by phosphate. *Appl Microbiol,* 23, 46-53.

El-Demerdash, F. M., Yousef, M. I. and Radwan, F. M. (2009). Ameliorating effect of curcumin on sodium arsenite-induced oxidative damage and lipid peroxidation in different rat organs. *Food Chem Toxicol,* 47, 249-54.

Friedman, L. S., Martin, P. and Munoz, S. J. (1996) In *In: Hepatology: A textbook of liver disease*(Eds, Zakim, D. and Boyer(eds), T. D.) WB Sauders, Philadelphia, pp. 1293-309.

Gbadegesin, M. A., Odunola, O. A., Akinwumi, K. A. and Osifeso, O. O. (2009). Comparative hepatotoxicity and clastogenicity of sodium arsenite and three petroleum products in experimental swiss albino mice: The modulatory effects of aloe vera gel. *Food Chem Toxicol,* 47, 2454-7.

Godhwani, S., Godhwani, J. L. and Vyas, D. S. (1987). Ocimum sanctum: An experimental study evaluating its anti-inflammatory, analgesic and antipyretic activity in animals. *J Ethnopharmacol,* 21, 153-63.

Griffon, H., Kiger, J. and Delabesse, P. (1961). [comparative analytical study of various commercial shampoos and possible consequences of their use concerning the content of arsenic of the hair.]. *Ann Pharm Fr,* 19, 407-18.

Gulcin, I. (2005). The antioxidant and radical scavenging activities of black pepper (piper nigrum) seeds. *Int J Food Sci Nutr,* 56, 491-9.

Gulcin, I., Elmastas, M. and Aboul-Enein, H. Y. (2007). Determination of antioxidant and radical scavenging activity of basil (ocimum basilicum l. Family lamiaceae) assayed by different methodologies. *Phytother Res,* 21, 354-61.

Habig, W. H., Pabst, M. J. and Jakoby, W. B. (1974). Glutathione s-transferases. The first enzymatic step in mercapturic acid formation. *J Biol Chem,* 249, 7130-9.

Hsiao, G., Lin, Y. H., Lin, C. H., Chou, D. S., Lin, W. C. and Sheu, J. R. (2001). The protective effects of pmc against chronic carbon tetrachloride-induced hepatotoxicity in vivo. *Biol Pharm Bull,* 24, 1271-6.

Ideo, G., Morganti, A. and Dioguardi, N. (1972). Gamma-glutamyl transpeptidase: A clinical and experimentalstudy. *Digestion,* 5, 326-36.

Jayasinghe, C., Gotoh, N., Aoki, T. and Wada, S. (2003). Phenolics composition and antioxidant activity of sweet basil (ocimum basilicum l.). *J Agric Food Chem,* 51, 4442-9.

Karthikeyan, K., Ravichandran, P. and Govindasamy, S. (1999). Chemopreventive effect of ocimum sanctum on dmba-induced hamster buccal pouch carcinogenesis. *Oral Oncol,* 35, 112-9.

Lee, T. C. and Ho, I. C. (1994). Differential cytotoxic effects of arsenic on human and animal cells. *Environ Health Perspect,* 102 Suppl 3, 101-5.

Locigno, R. and Castronovo, V. (2001). Reduced glutathione system: Role in cancer development, prevention and treatment. *Int J Oncol,* 19, 221-36.

Lowry, O. H., Rosebrough, N. J., Farr, A. L. and Randall, R. J. (1951). Protein measurement with the folin phenol reagent. *J Biol Chem,* 193, 265-75.

Lum, G. and Gambino, S. R. (1972). Serum gamma-glutamyl transpeptidase activity as an indicator of disease of liver, pancreas, or bone. *Clin Chem,* 18, 358-62.

Manikandan, P., Murugan, R. S., Abbas, H., Abraham, S. K. and Nagini, S. (2007). Ocimum sanctum linn. (holy basil) ethanolic leaf extract protects against 7,12-dimethylbenz(a)anthracene-induced genotoxicity, oxidative stress, and imbalance in xenobiotic-metabolizing enzymes. *J Med Food,* 10, 495-502.

Myagmar, B. E. and Aniya, Y. (2000). Free radical scavenging action of medicinal herbs from mongolia. *Phytomedicine,* 7, 221-9.

Odunola, O. A., Uka, E., Akinwumi, K. A., Gbadegesin, M. A., Osifeso, O. O. and Ibegbu, M. D. (2008). Exposure of laboratory mice to domestic cooking gas: Implications for toxicity. *Int J Environ Res Public Health,* 5, 172-6.

Popkin, B. M. (2007). Understanding global nutrition dynamics as a step towards controlling cancer incidence. *Nat Rev Cancer,* 7, 61-7.

Prashar, R., Kumar, A., Banerjee, S. and Rao, A. R. (1994). Chemopreventive action by an extract from ocimum sanctum on mouse skin papillomagenesis and its enhancement of skin glutathione s-transferase activity and acid soluble sulfydryl level. *Anticancer Drugs,* 5, 567-72.

Ramos, O., Carrizales, L., Yanez, L., Mejia, J., Batres, L., Ortiz, D. and Diaz-Barriga, F. (1995). Arsenic increased lipid peroxidation in rat tissues by a mechanism independent of glutathione levels. *Environ Health Perspect,* 103 Suppl 1, 85-8.

Rastogi, S., Shukla, Y., Paul, B. N., Chowdhuri, D. K., Khanna, S. K. and Das, M. (2007). Protective effect of ocimum sanctum on 3-methylcholanthrene, 7,12-dimethylbenz(a)anthracene and aflatoxin b1

O. basilicum attenuate arsenite toxicity

induced skin tumorigenesis in mice. *Toxicol Appl Pharmacol,* 224, 228-40.

Reitman, S. and Frankel, S. (1957). A colorimetric method for the determination of serum glutamic oxalacetic and glutamic pyruvic transaminases. *Am J Clin Pathol,* 28, 56-63.

Ritter, C., Reinke, A., Andrades, M., Martins, M. R., Rocha, J., Menna-Barreto, S., Quevedo, J., Moreira, J. C. and Dal-Pizzol, F. (2004). Protective effect of n-acetylcysteine and deferoxamine on carbon tetrachloride-induced acute hepatic failure in rats. *Crit Care Med,* 32, 2079-83.

Shariatpanahi, M., Anderson, A. C., Abdelghani, A. A., Englande, A. J., Hughes, J. and Wilkinson, R. F. (1981). Biotransformation of the pesticide sodium arsenate. *J Environ Sci Health B,* 16, 35-47.

Siddiqui, B. S., Aslam, H., Ali, S. T., Begum, S. and Khatoon, N. (2007a). Two new triterpenoids and a steroidal glycoside from the aerial parts of ocimum basilicum. *Chem Pharm Bull (Tokyo),* 55, 516-9.

Siddiqui, B. S., Aslam, H., Begum, S. and Ali, S. T. (2007b). New cinnamic acid esters from ocimum basilicum. *Nat Prod Res,* 21, 736-41.

Szasz, G. (1969). A kinetic photometric method for serum gamma-glutamyl transpeptidase. *Clin Chem,* 15, 124-36.

Wattenberg, L. W. (1985). Chemoprevention of cancer. *Cancer Res,* 45, 1-8.

Williamson, T. (1972). A comparison between the phosphastrate and phenyl phosphate methods of alkaline phosphatase assay. *Med Lab Technol,* 29, 182-7.

Yousef, M. I., El-Demerdash, F. M. and Radwan, F. M. (2008). Sodium arsenite induced biochemical perturbations in rats: Ameliorating effect of curcumin. *Food Chem Toxicol,* 46, 3506-11.

Zheljazkov, V. D., Callahan, A. and Cantrell, C. L. (2008). Yield and oil composition of 38 basil (*ocimum basilicum* l.) accessions grown in mississippi. *J Agric Food Chem,* 56, 241-5.

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