Detection and Estimation of Arsenic and Lead in Coconut Water - A Kerala Study

Pillay VV¹, Anu Sasidharan², Arathy SL³, Sundaram K R⁴, Greeshma C R⁵

¹Chief, Poison Control Centre, Department of Forensic Medicine & Toxicology, ²Associate Professor, Department of Forensic Medicine & Toxicology, ³Senior Research Officer, Analytical Toxicology Laboratory, Department of Forensic Medicine & Toxicology, ⁴Professor & Head, Department of Biostatistics, ⁵Tutor, Department of Biostatistics, Amrita School of Medicine, AIMS, Amrita Vishwa Vidyapeetham, Kochi

ABSTRACT

Coconut is a popular food ingredient in many parts of the world and the water it contains is believed to be the purest form of natural drink available. The water is rich in potassium, sodium, chloride and many vitamins, and hence is considered the beverage of choice. In medical practice, coconut water is recommended as the preferred oral rehydration fluid in cases of severe dehydration due to diarrhoea.

Chronic heavy metal poisoning has been shown to occur from plant products. However there is scanty research work relating to coconuts and heavy metal contamination. Among the various metals, lead is said to be the commonest metal involved. Arsenic is only second to lead in the incidence of chronic toxicity. When plants are exposed to heavy metals, mostly through contaminated water (irrigation), or contaminated soil, they accumulate in edible parts such as the fruits.

This study was undertaken to detect the presence of two of the commonest heavy metals - arsenic and lead – in coconut water present in coconuts sold in different parts of Ernakulam district of Kerala state, and to quantitatively assess their levels. It was also decided to detect the differences in the levels of the metals between tender and mature coconut water, and also to detect inter-zonal variations within Ernakulam district in the levels of the two heavy metals, in tender and mature coconut water.

Keywords: Coconut; Coconut water; Heavy metal; Lead; Arsenic.

INTRODUCTION

Coconut is a ubiquitous food ingredient in many South Indian dishes. Coconut water is assumed to be safe as it is believed to be the purest form of natural drink. The water is rich in potassium, sodium, chloride and the full range of B vitamins (except B6 and B12), and hence is considered the beverage of choice in some countries of the world.¹,²

In medical practice, coconut water is recommended as the preferred oral rehydration fluid to replenish fluid losses in cases of severe dehydration due to diarrhoea.³,⁴ It has even been tried with some success as an IV infusion (close to the nature of human blood).⁵

In severe physical exercise, production of reactive oxygen species can occur. The antioxidant properties of coconut water can help in neutralising the effects of these by-products of exercise.⁶,⁷ Tender coconut water (as compared to mature coconut water) has minerals such as calcium (for bones), magnesium (for heart) and potassium (for muscles) in high levels. In addition to these benefits, sports nutrition medicine experts claim that coconut water provides hydrating effects similar to those of carbohydrate-electrolyte sports drinks.⁸,⁹

Chronic heavy metal poisoning is unfortunately not uncommon in India and it has been proven that even vegetables can be contaminated with heavy metals.¹⁰,¹¹
However it was noted that there has been scanty research work done on coconuts for estimation of heavy metal contamination. The problem of environmental pollution due to toxic metals has long been a major cause for concern in many parts of the world including India. Lead is said to be the commonest metal involved in chronic poisoning and is abundant in soil. Arsenic is only second to lead in the incidence of chronic toxicity. Lead is widely used for domestic, industrial, and other purposes. Similarly, arsenic poisoning occurs as a result of industrial exposure or consumption of contaminated water/food. Children are more susceptible to heavy metal poisoning because of the increased absorption from gastrointestinal tract as compared to the adult. Chronic arsenic poisoning in India is said to occur from consumption of contaminated well water because of the high levels of arsenic in the soil in many parts of the country.

When plants are exposed to heavy metals, mostly through contaminated water used for irrigation, or contaminated soil in which they are grown, they accumulate in edible parts such as the fruits. Soil contamination with heavy metals due to rapid growth in industrialization is becoming a major problem on a global scale.

Metals have a tendency to accumulate in the soil to hazardous levels due to their non-degradable nature, and this happens when soils gets contaminated due to long term application of industrial waste water. Such waste water is composed of effluents containing heavy metals and other toxicants. The solubility of heavy metal salts in water is the reason why they can be very toxic.

This study was undertaken with three objectives in mind. The first objective was to detect the presence of two of the commonest heavy metals - arsenic and lead – in coconut water present in coconuts sold in different parts of Ernakulam district of Kerala state, and to quantitatively assess their levels. The second objective was to detect the differences in the levels of the metals between tender and mature coconut water. The third objective was to detect inter-zonal variations within Ernakulam district in the levels of the two heavy metals, in tender and mature coconut water.

MATERIALS AND METHOD

Tender and mature coconuts (eight each) were purchased from vendors (from four different zones of Ernakulam District) twice every month. The four zones from where coconuts were purchased were – Chittoor (Zone 1), Cheranalloor (Zone 2), Edappally (Zone 3) and Kothad (Zone 4). This is a pilot work as no previous literature is available with regard to contamination of coconuts/coconut water with heavy metals. The sample size was therefore kept relatively low - 176 coconuts (88 tender and 88 mature coconuts). Spoiled coconuts were excluded from this study. Five tender coconuts and 28 mature coconuts were purchased from Zone 1. From Zone 2, twenty tender coconuts and 19 mature coconuts were obtained. Thirty six tender coconuts and 19 mature coconuts were bought from Zone 3, and from Zone 4, twenty seven tender coconuts and 22 mature coconuts were purchased. The coconuts were cut open using a chemically treated stainless steel knife to avoid any artificial contamination with metals. The coconut water was then collected and digested using nitric acid.

This is a prospective cross-sectional study. The statistical analysis was done using IBM SPSS v. 20. The mean and standard deviation of the quantitatively assessed levels of heavy metals (arsenic and lead) were computed for each of the four zones separately. There was high variation and non-normal distribution of the values of the variables. To test the statistical significance of the difference in the mean values amongst the four zones, Kruskall Wallis One Way Anova was applied. Since it was non-significant, the data from all the four zones were pooled. The statistical significance of the levels of arsenic and lead between the tender and mature coconut water was tested using Wilcoxon’s Rank sum test. A p value of <0.05 was considered to be statistically significant.

RESULTS

Arsenic was not detected in any of the samples (mature or tender coconut water). Out of the total 176 samples, lead was detected in 19.31% of the samples (34 samples). Among tender coconut water samples, lead was detected in 6 of the water samples, the majority being from Zone 2. In case of mature coconut water, lead was detected in 28 samples; the majority belonging to Zone 4 (Table 1).
Table 1: Distribution of Heavy Metal Lead in Coconut Water Samples

<table>
<thead>
<tr>
<th>Zone</th>
<th>Tender Coconut</th>
<th>Mature Coconut</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>Percentage</td>
<td>Frequency</td>
<td>Percentage</td>
</tr>
<tr>
<td>Zone 1 - Chittoor</td>
<td>1</td>
<td>16.7</td>
<td>5</td>
<td>17.9</td>
</tr>
<tr>
<td>Zone 2 - Cheranalloor</td>
<td>3</td>
<td>50.0</td>
<td>5</td>
<td>17.9</td>
</tr>
<tr>
<td>Zone 3 - Edappally</td>
<td>1</td>
<td>16.7</td>
<td>7</td>
<td>25.0</td>
</tr>
<tr>
<td>Zone 4 - Kothad</td>
<td>1</td>
<td>16.7</td>
<td>11</td>
<td>39.3</td>
</tr>
<tr>
<td>Total</td>
<td>6</td>
<td>100.0</td>
<td>28</td>
<td>100.0</td>
</tr>
</tbody>
</table>

The highest value detected was 1.22ppm (parts per million) which was that of a sample of mature coconut water from Zone 2. The lowest value detected was 0.01ppm from a sample of tender coconut water belonging to Zone 1.

The variation of the lead levels between tender and mature coconut water samples was analysed next after taking the mean and the S.D. of the lead levels (Fig 1).

![Fig 1: Comparison of Mean Lead Values between Tender and Mature Coconut Water Samples](image)

The mean value of the levels of lead in mature coconut water was higher (0.0762ppm) when compared to that of 0.0045ppm in tender coconut water. On analysis this variation between the tender and mature coconut water samples was found to be highly statistically significant (p value < 0.001)

The inter-zonal variations in the levels of lead were statistically analysed next (Table 2).

<table>
<thead>
<tr>
<th>Zone</th>
<th>n</th>
<th>Mean</th>
<th>S D</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1 - Chittoor</td>
<td>33</td>
<td>0.087</td>
<td>0.259</td>
<td></td>
</tr>
<tr>
<td>Zone 2 - Cheranalloor</td>
<td>39</td>
<td>0.044</td>
<td>0.196</td>
<td>0.452</td>
</tr>
<tr>
<td>Zone 3 - Edappally</td>
<td>55</td>
<td>0.009</td>
<td>0.025</td>
<td></td>
</tr>
<tr>
<td>Zone 4 - Kothad</td>
<td>49</td>
<td>0.041</td>
<td>0.079</td>
<td></td>
</tr>
</tbody>
</table>
The mean value of the levels of lead was highest in Zone 1 (Chittoor – 0.087) and was lowest in Zone 3 (Edappally – 0.009). Statistically these variations between the zones were not significant.

Finally all the zones and the groups (tender and mature coconut water samples) were pooled and the mean values were statistically analysed (Fig 2). It was not significant.

![Fig 2: Comparison of Mean Lead Values between the Four Zones in Both Groups](image)

**DISCUSSION & CONCLUSION**

It is evident that most of the studies in the existing literature focus on estimation of the levels of lead in vegetables or fruits. The literature on estimation of arsenic is limited and in one such study the level of arsenic was found to be highest in green leafy vegetables (spinach). However in the current study arsenic was not even detected in any of the samples. This may be because the soil in this part of the country is not contaminated with significant levels of arsenic, though this cannot be stated with certainty unless soil analysis or analysis of the water used for irrigation is tested for the presence or absence of arsenic.

The presence of lead however has been recorded in a wide range of research publications. One of the studies is related to lead contamination of deciduous fruits. It was seen that 97.5% of the fruit samples were contaminated within the maximum permissible limits with different heavy metals. Only 0.4% of these were contaminated with lead. On the other hand, in a study concerning heavy metal contamination of vegetables, cauliflower and onion showed high amounts of lead. However, even this was within the permissible limits of human consumption. An interesting research work showed that school going children (from school vegetable gardens) were exposed to heavy metal contamination in vegetables. Elevated concentrations of lead were seen in the school vegetable samples; but they were found to be again within permissible limits.

The only work remotely similar to the current work is the research done on various parts of coconut palms. In this study, heavy metal estimation of soil, water, coconut leaf, coconut root and coconut water samples was undertaken. The heavy metals analysed included Fe, Zn, Cr, Cu, Pb, Ni and Cd. It was concluded that the heavy metal contamination in coconut water was under permissible limits of drinking water. It was further opined that the coconut plants probably possess the ability to control the presence of heavy metals in coconut water, whatever be the amounts of these heavy metals in the contaminated irrigation water. In the current study, arsenic was not detected at all in any of the coconut water samples.

Lead was detected in 34 samples (19.31%). It was detected in 28 of the mature coconut water samples, and 6 of the tender coconut water samples. The highest
value of 1.22ppm was seen in one of the mature coconut water samples. When the variations of the levels of lead were analysed between tender and mature coconut water samples, the mature water samples showed higher lead value of 0.0762ppm (mean). The mean value in the case of tender coconut water was only 0.0045ppm. According to the revised Indian Standards for drinking water (IS 10500:2012) the acceptable limit of lead in drinking water is 0.01ppm or mg/L. This means that the amount of lead in mature coconut water is marginally higher than acceptable limits, while in tender coconut water it is far below (safer) the acceptable limits. Statistically this variation of lead levels between mature and tender coconut water samples was found to be highly statistically significant (p value <0.001).

Further, the inter-zonal variations were analysed and the water samples of mature coconut from Zones 1, 2 and 3 were found to be having marginally higher amounts of lead levels (Zone 1 being maximum – 0.087ppm).

Lastly, a comparison was made pooling data from all the zones, and both the groups for over-all statistical significance. This was found to be statistically not significant.

However, this study has a small limitation as far as the low sample size is concerned. Further studies are recommended considering multiple zones all over the state of Kerala, so that the results for a larger population can be made available. Heavy metal contamination of the coconut meat portion can also be included in future studies. This work was done only as a pilot study in order to assess whether there is a need for a larger study, perhaps utilising greater resources/more samples.

In closing, it can be concluded that coconut water from mature coconuts is not as safe as tender coconut water with regard to heavy metal contamination, especially lead, in the location of the study.

Conflict of Interest: There are no conflicts of interest in this research work

Source of Funding: We are thankful to Dr. Prem Nair, Dr. DM Vasudevan and Dr. (Col) Vishal Marwaha of AIMS for providing the funds towards this research work.

Ethical Clearance: Ethical Clearance was not required in this research work.

REFERENCES

13. Venkatesh T. Lead poisoning: The hidden Indian


