



# **Effect of Chronic Oral Exposure to Overdose of Cough Syrups on Rate of DNA Fragmentation in Liver and Brain of Wistar Rats**

**Abolanle A. A. Kayode <sup>a\*</sup>, Omowumi T. Kayode <sup>b</sup>, Auwal A. Mohammad <sup>c</sup>  
and Great O. Alabi <sup>d</sup>**

<sup>a</sup> *Department of Biochemistry, School of Basic Medical Sciences, Babcock University, Ilishan - Remo, Nigeria.*

<sup>b</sup> *Department of Biological Sciences, Mountain Top University, Ogun State, Nigeria.*

<sup>c</sup> *Department of Chemical and Food Sciences, Bells University of Technology, Ota, Ogun State, Nigeria.*

<sup>d</sup> *Department of Physiology, School of Basic Medical Sciences, Babcock University, Ilishan-Remo, Nigeria.*

## **Authors' contributions**

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## **ABSTRACT**

This study was designed to determine the effect of chronic oral exposure of overdose of cough syrups containing codeine (CSC) and dextromethorphan (DXM) on the rate of deoxyribonucleic acid (DNA) fragmentation in the liver and brain of Wistar rats. Forty-five rats divided into 9 groups of 5 rats were used. Groups 1, 2, 3, and 4 were treated with 0.1, 0.2, 0.4, and 0.6 mg/kg b/w of CSC, and Groups 5, 6, 7, and 8 were treated with the same doses of DXM, respectively for 21 days. Group 9 (control) received distilled water once daily and all the rats were sacrificed 24 hours after the last treatment. DNA analysis was done on the harvested liver and brain. Significant reductions ( $p < 0.05$ ) in the rate of DNA fragmentation of the liver tissues were observed in all the groups treated with the overdose of cough syrups when compared to the control. However, there was no significant difference in the rate of DNA fragmentation of the brain in all the groups treated

\*Corresponding author: E-mail: [kayodeab@babcock.edu.ng](mailto:kayodeab@babcock.edu.ng), [bolakayot@gmail.com](mailto:bolakayot@gmail.com);

with cough syrup as compared to the control. The result indicated that overdose of cough syrup may cause suppressed DNA fragmentation of the liver thereby predisposing the organ to dysfunctions and untimely aging.

**Keywords:** Cough syrup; overdose; DNA fragmentation; codeine; dextromethorphan.

## 1. INTRODUCTION

Cough syrup is a medication used for suppressing cold symptoms or cough and it is usually purchased over the counter [1]. Cough syrups consist of various constituents such as codeine and dextromethorphan (DXM). Codeine is one of the globally available and used opiates as an analgesic, antitussive, antidiarrheal agent and a mild to moderate pain reliever [2,3,4]. It can be solely used to suppress cough or combined with another drug [5]. It acts by depressing the central pathways of the cough reflex in the brain [6]. Codeine is mostly metabolized in the liver and minimally in the central nervous system (CNS) and intestine [7]. In the brain, codeine is metabolized into morphine. Concomitant administration of codeine affects the normal functioning of the liver and despite being unable to cross the blood-brain barrier, codeine still elicits some morphine-related effect which further confirms the metabolism of codeine into morphine [8]. Although it is a weak opiate, there is the potential for abuse and misuse; physical and psychological dependence can also occur as a result of long-term use of codeine-containing cough syrups [9, 10]. The minimal lethal oral dose for codeine is approximately 0.5-1.0 g (17- 34 pills containing 30 mg of codeine) [11].

DXM is also highly effective in the suppression of cough and the daily allowable dosage is about 120 mg/day [12]. Due to its availability, effectiveness, and safety at appropriate doses, it is the most widely used cough suppressant. DXM can induce psychosis characterized by paranoia, hallucination, and delusions when consumed at doses higher than 150 mg/day [13]. It acts on the cough reflex of the medulla oblongata and increases the cough reflex threshold by 50 years [14]. Therapeutic overdose of DXM has been shown to affect the central nervous system causing tachycardia, hypertension, ataxia, disorientation, confusion, impaired coordination, and hallucinations [15,16,17]. Dextrorphan, an active metabolite of DXM is a non-competitive N-methyl-D-aspartate (NMDA) receptor antagonist and is metabolized by cytochrome P450

(isoenzyme CYP2D6) [18]. CYP2D6 expression is controlled genetically and the polymorphism of the enzyme can influence the toxicity of a cough syrup containing DXM, especially when illicitly combined with other drugs or used at an inappropriate dosage [19]. The abuse of cough syrups has been discovered to cause damages to the white matter of the brain [20], folate deficiency [21], aberrant functional organization, and volume loss in the ventral medial prefrontal cortex [22].

Studies have investigated the effect of overdose of cough syrup containing codeine and DXM on biochemical indices but there is no documented study on the effect on the rate of DNA fragmentation in the liver and brain. Therefore this study was designed to evaluate the effect of overdose of cough syrup containing codeine and DXM on the rate of DNA fragmentation in the liver and brain tissues.

## 2. MATERIALS AND METHODS

Tutolin containing codeine produced by Tuyil Pharm Industry Limited and Greenlin containing dextromethorphan produced by Greenlife Pharmaceuticals Limited were purchased from a registered pharmacy store. The normal approved dosage of the cough syrup is 10 mL, which is taken four times a day. From this data, any dosage above this quantity can be considered an abuse. A total of 45 wistar rats were randomly distributed into nine groups of 5 rats in each group and the dosages were according to a study by Kayode et al. [23].

Group 1: Cough syrup containing codeine (CSC-1) (0.1 mg/kg b.w)

Group 2: Cough syrup containing codeine (CSC-2) (0.2 mg/kg b.w)

Group 3: Cough syrup containing codeine (CSC-3) (0.4 mg/kg b.w)

Group 4: Cough syrup containing codeine (CSC-4) (0.6 mg/kg b.w)

Group 5: Cough syrup containing dextromethorphan (DXM-1) (0.1 mg/kg b.w)

Group 6: Cough syrup containing dextromethorphan (DXM-2) (0.2 mg/kg b.w)

Group 7: Cough syrup containing dextromethorphan (DXM-3) (0.4 mg/kg b.w)

Group 8: Cough syrup containing dextromethorphan (DXM-4) (0.6 mg/kg b.w)

Group 9: Control (distilled water)

The administration of cough syrup lasted for 21 days.

### 2.1 Extraction of DNA from Organs

Extraction of DNA from animal tissues was carried out using the Qiagen DNA extraction kit which uses the spin column method. 25 mg of tissue (10 mg for brain and liver) was cut into small pieces, placed in a microcentrifuge tube and 180  $\mu$ L of Buffer ATL and 20  $\mu$ L of proteinase K were added. The content was mixed thoroughly on a vortex mixer and incubated at 56°C overnight until the tissues were completely lysed. After complete lysis of the tissue, 200  $\mu$ L of buffer AL was added, mixed thoroughly followed by the addition of 200  $\mu$ L of ethanol (96 - 100%). The whole mixture (including any precipitate) was pipetted into the DNeasy mini spin column placed in a 2mL collection tube and centrifuged at 6000 X g for 1 minute. The flow-through was discarded while the spin column was placed in a new 2 mL collection tube. After this, 500  $\mu$ L of buffer AW1 was added and centrifuged at 6000 X g for 1 minute. The flow-through was discarded while the spin column was placed in a new 2mL collection tube and 500  $\mu$ L of buffer AW2 was added, centrifuged at 20000 X g for 3minutes to dry the DNeasy membrane and flow-through was discarded. The DNeasy mini spin column was then placed in a clean 2 mL microcentrifuge tube and 200  $\mu$ L of buffer AE was pipetted directly into the DNeasy membrane and incubation was carried out at room temperature for 1 minute and

then centrifuged at 6000 X g for 1 minute to elute the DNA. The eluted DNA was quantified using Fisher Scientific Nano drop spectrophotometer and kept at -20°C until used (Ausubel, 2002).

### 2.2 Electrophoresis of Extracted DNA

1% agarose gel (100 mL) was prepared in 1X TAE (Tris Acetate EDTA) buffer, boiled in a microwave oven to dissolve the agarose, allowed to cool for about 60°C and 5  $\mu$ L of ethidium bromide was added and mixed thoroughly. The agarose gel was then poured into the gel tray after the comb had been fixed in the tray. The agarose was allowed to solidify and the comb was removed to create the wells where the DNA was loaded. Loading buffer (2  $\mu$ L) was added to 8 $\mu$ L of the DNA extracted and this mixture was loaded along with DNA marker into the wells of the gel. After loading, electrophoresis was carried out at 70 volts for 45 minutes in 1X TAE buffer and DNA was viewed using UVP gel documentation system (Alonso, 2012).

## 3. RESULTS

Lane 1a and 1b treated with 0.1mg/kg bd wt of codeine, Lane 2a and 2b treated with 0.2 mg/kg bd wt of codeine, Lane 3a and 3b treated with 0.4 mg/kg bd wt of codeine, Lane 4a and 4b treated with 0.6 mg/kg bd wt of codeine, Lane 5a and 5b treated with 0.1 mg/kg bd wt. DXM, Lane 6a and 6b treated with 0.2 mg/kg bd weight DXM, Lane 7a and 7b treated with 0.4 mg/kg bd wt DXM, Lane 8a and 8b treated with 0.6 mg/kg bd wt DXM, Lane 9a and 9b treated with distilled water.

Codeine and dextromethorphan suppressed genomic DNA fragmentation in the hepatic cell. The influence of the cough syrups on DNA fragmentation was evaluated by measuring the level of fragmented DNA by detecting DNA ladders on agarose gel electrophoresis. It was observed that Group 1 showed marked suppressed DNA fragmentation as compared with the control. Analysis of DNA from the apoptotic cell by agarose gel electrophoresis produced a characteristic DNA pattern, which is regarded as a biochemical hallmark of apoptosis. The cough syrups showed a typical DNA ladder pattern in the liver of the rat.

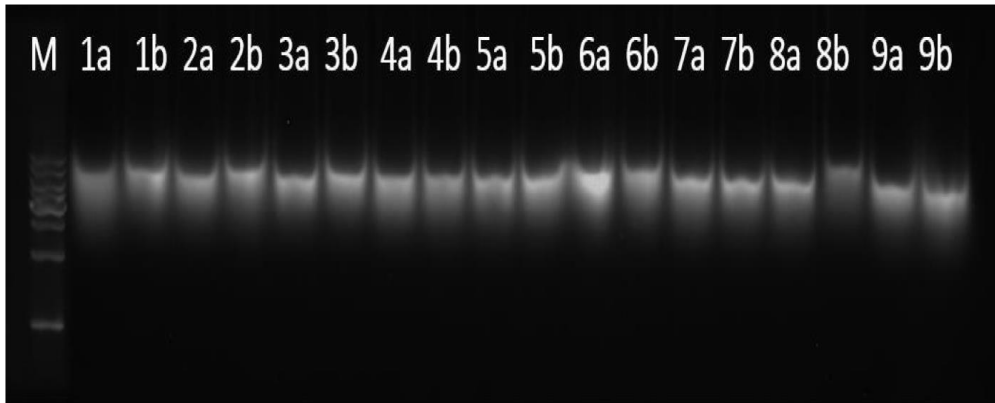


Fig. 1. Analysis of cough syrups containing codeine and DXM on DNA fragmentation in the liver revealed by agarose gel electrophoresis

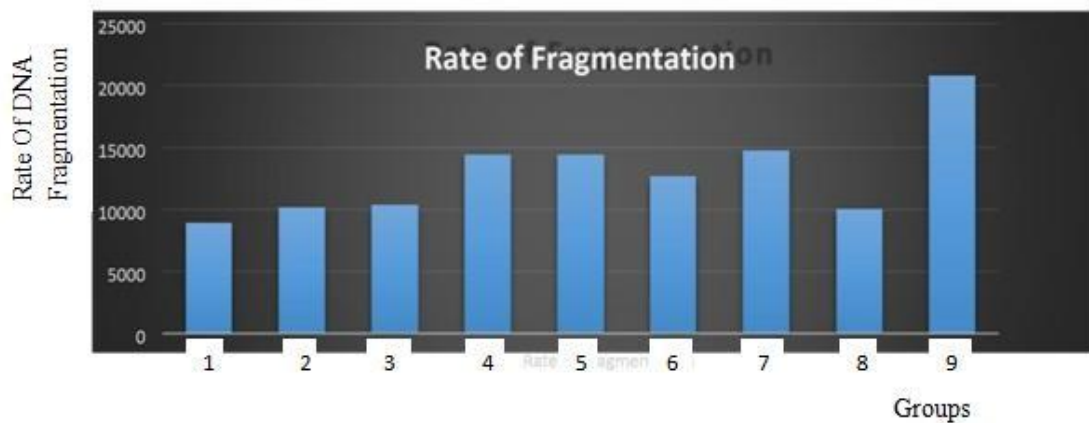


Fig. 2. Histogram showing rate of liver DNA fragmentation suppressed by cough syrups containing codeine and dextromethorphan

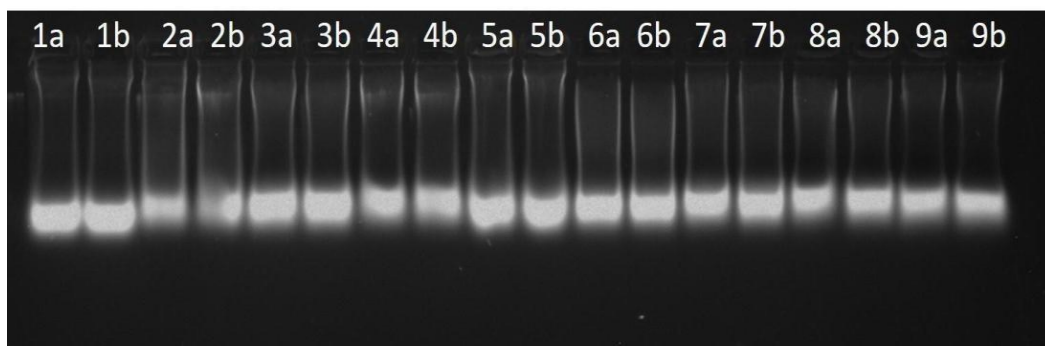


Fig. 3. Analysis of DNA fragmentation of brain influenced by cough syrups containing codeine and DXM revealed by agarose gel electrophoresis Lane 1a and 1b treated with 0.1 mg/kg bd wt of codeine, Lane 2a and 2b treated with 0.2 mg/kg bd wt of codeine, Lane 3a and 3b treated with 0.4 mg/kg bd wt of codeine, Lane 4a and 4b treated with 0.6 mg/kg bd wt of codeine, Lane 5a and 5b treated with 0.1 mg/kg bd wt DXM, Lane 6a and 6b treated with 0.2 mg/kg bd wt DXM, Lane 7a and 7b treated with 0.4 mg/kg bd wt DXM, Lane 8a and 8b treated with 0.6 mg/kg bd wt DXM, Lane 9a and 9b treated with distilled water

#### 4. DISCUSSION

Cough syrups containing either codeine or DXM are being used to suppress cough or cold symptoms. The long-term usage of cough syrup has been discovered to cause hepatotoxicity, nephrotoxicity and also have depressive effects on the CNS among other side effects [9]. The abuse of cough syrups containing codeine or DXM among the youths has become a global public health concern and is becoming a rapidly growing trend in Nigeria.

Codeine is commonly used to treat mild-to-moderate pain and coughs. It is classified as an opioid which means it has morphine-like properties and this is because codeine is metabolized into morphine [8] which makes it effective in relieving pain. DXM is an antitussive agent which acts on the cough reflex in the medulla oblongata [14]. Exposure to an overdose of cough syrup containing DXM causes hallucination, intoxication, paranoia and delusions [13].

In a previous study by Kayode et al. [23], elevated levels of Aspartate aminotransferase (AST), Alkaline phosphatase (ALP) and Alanine transaminase (ALT) were observed in Wistar rats exposed to an overdose of cough syrups containing codeine and DXM when compared to the control group that received distilled water. An elevation in the levels of these enzymes could be an indicator of liver damage or disease [24], this is because the liver is a site of multiple oxidative reactions and formation of free radicals [23]. An elevation in ALT is a precise indicator of liver inflammation and AST also increases due to infiltration of the liver cells as a result of damage of the mitochondria [25]. It has been observed that the abuse of DXM products containing acetaminophen could also result in damage to the liver [26].

DNA fragmentation is the main biochemical feature of apoptosis which is the body's mechanism of eliminating excessive, mutated, damaged and infected cells [27]. It can also be attributed to permanent cell death, apoptosis or necrosis in the nuclear DNA exposed to oxidative stress [28]. Reactive oxygen species (ROS)-mediated oxidative stress has been discovered to attack DNA and cause DNA lesions such as base modifications, single-strand or double-strand breaks, oxidized purines and pyrimidines which could lead to mutations, genomic instability and cell death [29].

In this study, a significant reduction ( $p < 0.05$ ) in the rate of DNA fragmentation in the liver tissues was observed in all the groups treated with the overdose of cough syrups containing codeine and DMX when compared to the control group. In the codeine-containing cough syrup group, group 1 had the lowest rate of DNA fragmentation while in the DXM containing cough syrup group, group 8 had the lowest rate of DNA fragmentation. The reduced DNA fragmentation rate in the liver tissue observed in this study could pose a problem indicating the suppression of apoptotic process which could lead to the accumulation of excess, mutated and damaged cells. This could prevent the development of new hepatocytes thereby subduing the regenerating ability of the liver.

Normally the liver is a very active organ in terms of cell turnover and cells or tissue regenerations which helps to rejuvenate and restore worn tissues of the liver. Any substance or drug that reduces or suppresses this ability of the liver will result in rapid and untimely aging of the liver. Invariably, such liver may have expired, aged, or 'pack up' earlier than normal and these may result in many related liver diseases, reduced physiological and biochemical functioning of the liver. Failure in the removal of DNA from damaged cells could also lead to autoimmune diseases [27].

In humans and rats, there is the expression of CYP2D6 in the hepatic and brain microsomes [30]. CYP2D6 is an enzyme involved in the metabolism of Dextrophan, an active metabolite of DXM and it can influence the lethality of a cough syrup containing DXM, especially when used at an inappropriate dosage [19]. This could be a reason for the suppression in the rate of DNA fragmentation in the liver.

In a study by Archibong et al. [31], a decrease in Superoxide dismutase (SOD), Catalase (CAT) and an increase in Malondialdehyde (MDA) levels which are indicators of oxidative stress were observed in prolonged administration of codeine-containing cough syrup. This could also result in glucose hypometabolism eventually leading to brain failure. In this study, there was no significant difference in the rate of DNA fragmentation in the brain in all the groups treated with cough syrups compared to the control group. This could be due to the inability of the substances to cross the blood-brain barrier.

The expression of CYP2D6 in the brain is about 1- 4% of the expression in the liver [30]. This could be the reason for the insignificance in the rate of DNA fragmentation observed in the brain tissues in this present study.

## 5. CONCLUSION

Overdose of codeine and DXM containing cough syrups decreased the rate of DNA fragmentation in the liver but the brain showed no decrease in the rate of DNA fragmentation. This suppression of DNA fragmentation could predispose the organ to dysfunctions and untimely aging.

## CONSENT

It is not applicable.

## ETHICAL APPROVAL

As per international standard or university standard written ethical approval has been collected and preserved by the author(s).

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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