

Biochemical Basis of Alcohol Metabolism on Human Liver and Alimentary Canal- A Descriptive Study

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Abstract: Alcohol metabolism is a complex biochemical process that occurs primarily in the liver and has significant effects on various organs, particularly the central nervous system. This study aims to develop a comprehensive understanding of the biochemical and physiological mechanisms involved in ethanol metabolism and its effects on human health. Following absorption into the bloodstream, ethanol is metabolized mainly in the liver through the action of alcohol dehydrogenase (ADH), which converts ethanol into acetaldehyde, and aldehyde dehydrogenase (ALDH), which further converts acetaldehyde into acetate. Acetaldehyde is a toxic intermediate that can contribute to cellular damage, while alcohol metabolism may also promote oxidative stress, inflammation, and disruption of normal cellular functions. Repeated and excessive alcohol consumption can lead to liver disorders, including fatty liver disease, alcoholic hepatitis, and cirrhosis. In addition, alcohol affects the central nervous system by altering neurotransmitter activity, particularly gamma-aminobutyric acid (GABA) and glutamate, thereby influencing memory, learning, judgment, coordination, and decision-making. Continued alcohol consumption may also contribute to the development of tolerance and dependence. This research focuses on ethanol absorption and metabolism, the functions of ADH and ALDH enzymes, the effects of acetaldehyde and oxidative stress, and the consequences of alcohol consumption on liver cells and brain function. Overall, the study highlights the importance of understanding the biochemical pathways of alcohol metabolism to explain alcohol-related tissue damage and its broader physiological effects on the human body.

Keywords: Ethanol Metabolism, Alcohol Dehydrogenase (ADH), Aldehyde Dehydrogenase (ALDH), Acetaldehyde, Oxidative Stress, Liver Damage, Neurotransmitters, Central Nervous System.

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I. INTRODUCTION

The alcohol found in alcoholic drinks is called ethanol and it gets into the bloodstream once it has been consumed and is then rapidly broken down by the body. As alcohol cannot be stored in the same way as nutrients, a large part of its metabolism takes place in the liver and therefore the liver is one of the main organs affected by alcohol.

The biochemical process by which ethanol is turned into other substances is known as alcohol metabolism. The primary enzymes taking part in this are alcohol dehydrogenase (ADH) and aldehyde dehydrogenase (ALDH). ADH transforms ethanol into acetaldehyde, a toxic and reactive compound, and ALDH changes acetaldehyde into acetate. Furthermore, another enzyme named CYP2E1

can also play a role in alcohol metabolism and in the formation of reactive molecules.

The liver is the organ most affected since it is responsible for the majority of alcohol metabolism. When alcohol is consumed heavily and repeatedly, it can disrupt fat metabolism and result in fatty liver. If the liver damage caused by alcohol continues, it may lead to oxidative stress, inflammation, fibrosis and cirrhosis, thereby slowly impairing the liver's normal structure and function. Moreover, alcohol has an impact on the digestive system, especially on the tissues that are in contact with alcohol during digestion.

Alcohol has an effect on the central nervous system and the brain by acting upon neurotransmitters including

dopamine, GABA and glutamate. This can in turn influence memory, learning, coordination and judgement. If alcohol is taken repeatedly this can lead to changes in brain signalling and as a result to tolerance and dependence.

The breakdown of alcohol is a complicated biochemical process which involves ethanol, acetaldehyde, enzymes and reactive molecules. If we understand these processes then we can explain how alcohol can have an effect on the liver, the digestive system and the brain, and also how frequent heavy drinking can lead to serious health problems.

➤ *Research Problem:*

The metabolism of alcohol is a biochemical process through which the body breaks down and eliminates alcohol after consumption. Most of the alcohol is absorbed into the bloodstream and transported to the liver, which is the main organ involved in the metabolism of alcohol.

In the liver, ethanol is transformed into an intermediary product called acetaldehyde by the action of the enzyme alcohol dehydrogenase (ADH). This chemical compound has toxic properties and is further transformed into acetate thanks to another enzymatic reaction catalysed by the enzyme aldehyde dehydrogenase (ALDH).

These metabolic transformations ensure the processing of alcohol. However, the production of acetaldehyde can lead to some level of cellular damage. Alcohol can undergo other metabolic transformations, such as those triggered by an enzyme system involving CYP2E1. An increase in their activities produces several substances that contribute to oxidative stress and cellular damage. Metabolism of alcohol can happen elsewhere in the gastrointestinal tract and acetaldehyde can impact organs from the digestive system.

How does the biochemical metabolism of alcohol cause progressive damage to the liver and digestive system? What are the specific biochemical processes causing such damage?

What role do enzymes such as ADH, ALDH, the presence of acetaldehyde and the different pathways used for the metabolism of alcohol play in causing cellular damage related to alcohol intake.

➤ *Research Objectives:*

The purpose of this research is to formulate an adequate and extended understanding of alcohol metabolism and its biochemistry. Alcohol metabolism is a complex biochemical process that occurs primarily in the liver, however, it also has a range of effects on the body outside of the liver, for instance, in the central nervous system. Thus, this study will focus on alcohol metabolism from biochemical and physiological perspectives.

● *To Study the Biochemistry of the Alcohol Metabolism:*

- ✓ The main objective of this research is to study the process of human body absorption and metabolism of ethanol, particularly, the key stages of ethanol absorption and their significance.

- ✓ The primary focus will be on the liver because it is the primary site of alcohol metabolism. The study will highlight the biochemical processes that occur inside the liver as a result of alcohol consumption.

- ✓ Furthermore, the research will elaborate on why the proper functioning of the liver is essential for the human body, particularly when heavy alcohol abusers are concerned.

● *To Study the Role of Alcohol Dehydrogenase and Aldehyde Dehydrogenase:*

- ✓ Another objective of this research is to study the role of alcohol dehydrogenase and aldehyde dehydrogenase in the metabolism of alcohol. Specifically, the study will seek to determine why the proper functioning of these enzymes is essential for the human body.

● *To Examine the Effects of Alcohol Metabolism on the Liver Cells:*

- ✓ One of the objectives of this research is to examine the impact of alcohol metabolism on the liver cells. Since the liver is the primary site of alcohol metabolism, there is a wide range of adverse effects that heavy drinkers may face as a result of heavy alcohol consumption.

- ✓ In particular, the research will highlight how heavy drinkers may suffer from fatty liver disease as a result of heavy drinking and alcohol abuse.

● *To Understand the Role of Acetaldehyde and Oxidative Stress in Alcohol-Related Damage:*

- ✓ Another objective of this research is to understand the role of acetaldehyde and oxidative stress in alcohol-related damage. Acetaldehyde is a harmful byproduct of ethanol metabolism that is highly toxic to living tissues.

- ✓ Moreover, the process of ethanol metabolism can lead to increased levels of oxidative stress within the body. Thus, this study will highlight the biochemical mechanism of acetaldehyde and oxidative stress, as well as their impact on the human body.

● *To Examine the Effects of Alcohol on the Brain:*

- ✓ One of the main goals of this research is to examine the effects of alcohol on the brain. Ethanol can have a range of adverse effects on the central nervous system and impair numerous cognitive functions controlled by the brain.

➤ *Hypothesis:*

Alcohol damages digestion and liver function as ethanol is partially processed to acetaldehyde, which is highly toxic and contributes to oxidative stress, causing tissue damage and cell death. Ethanol consumption affects all functions of the digestive system and the liver. Consequently, the continuous intake of alcohol interferes with the regular structure and performance of the digestive system and liver cells.

- *Study of Alcohol Metabolism:*

- ✓ The first stage of the research involved studying the alcohol metabolism after its ingestion. The information related to ethanol absorption and metabolism was reviewed, with the emphasis on the liver as the central organ of alcohol metabolism.
- ✓ The key enzymes catalyzing ethanol oxidation were reviewed and described, including alcohol dehydrogenase (ADH), which catalyzes ethanol oxidation into acetaldehyde and aldehyde dehydrogenase (ALDH), which catalyzes acetaldehyde oxidation into acetate.
- ✓ Understanding the steps of alcohol metabolism was essential to study the mechanisms of alcohol toxicity and the development of adverse effects of ethanol consumption.
- ✓ Other enzyme systems playing a role in alcohol metabolism, including those of the cytochrome P450 family, were also reviewed as they may play a significant role under certain conditions of alcohol exposure.

- *Study of Liver Effects:*

- ✓ The next step of the research involved studying the effects of alcohol metabolism on the liver. The scientific literature related to alcohol-induced liver damage was reviewed to highlight the effects of ethanol consumption on the liver, beginning with fatty liver disease and leading to cirrhosis.
- ✓ Particular attention was paid to the biochemical processes involved in alcoholic liver disease progression, including the impact of acetaldehyde oxidation and other metabolic changes on liver cells' functioning.
- ✓ This review was crucial to understand the mechanisms linking alcohol metabolism and liver damage.

- *Study of Oxidative Stress and Cellular Damage*

- ✓ The study of the effects of alcohol metabolism involved reviewing the literature on oxidative stress resulting from ethanol consumption. Particular attention was paid to the mechanisms of reactive oxygen species production and the role of CYP2E1 enzyme in alcohol-induced oxidative stress.
- ✓ The impact of altered ethanol metabolism on the homeostasis of reactive oxygen species and the effect of oxidative stress on cellular functioning were analyzed. The review of the literature also included the discussion of oxidative stress contribution to cellular damage, particularly in the liver, and the progression of liver disease.

- *Study of Alcohol and Brain Function*

- ✓ The research also involved studying the effects of alcohol on the brain. The resources and publications of NIAAA related to neuroscience were reviewed to assess the impact of alcohol on the brain, with the focus on cellular communication mechanisms.
- ✓ Particular attention was paid to the effects of ethanol on the GABA and glutamate systems.

- ✓ Moreover, the review also included the discussion of the role of brain reward circuits and the development of alcohol tolerance and dependence after repeated ethanol exposure.

- *Organization and Analysis of Information*

- ✓ After completing the collection of secondary data, the gathered information was organized into several key topics related to the research question and objective.
- ✓ The information reviewed and analyzed included that related to alcohol metabolism, ADH and ALDH roles, acetaldehyde impact, oxidative stress development, liver damage, the effects of alcohol on cellular communication, tolerance, and dependence.
- ✓ The analysis of the data involved comparing the findings retrieved from different sources to identify key themes and patterns, such as the connection between altered alcohol metabolism and liver damage, oxidative stress development, and changes in cellular signaling.
- ✓ The research did not use one primary source of information for all the sections of the paper, as it would present a biased perspective. Instead, multiple credible sources were used for each section to provide a comprehensive view of each topic studied in the research.

- *Interpretation of Findings*

- ✓ The findings collected from the study were interpreted to explore the connection between alcohol metabolism and the impact of ethanol consumption on human body functioning and health.
- ✓ Particular attention was paid to the relationships between the processes of ethanol oxidation, acetaldehyde oxidation, and oxidative stress development and the impact of these biochemical changes on the liver and the brain.
- ✓ The findings were also used to discuss the development of alcohol tolerance and dependence to highlight the long-term effects of alcohol consumption. The key points discovered in the research were structured to present a comprehensive view of the effects of ethanol metabolism on human body functioning and health.

II. METHODOLOGY

The primary sources of information used in the research are the publications and educational materials of the National Institute on Alcohol Abuse and Alcoholism and scientific literature available at the National Center of Biotechnology Information.

➤ *Biochemical Mechanism of Alcohol Metabolism:*

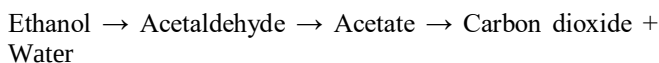
Alcohol metabolism refers to the series of biochemical reactions through which the body breaks down ethanol after it is consumed. Ethanol is the type of alcohol that is present in alcoholic beverages.

Following consumption of alcohol, it is absorbed into the bloodstream and transported around the body. The majority of alcohol is then processed by the liver; hence, it is

the main organ that is involved in alcohol metabolism.

Throughout this process, the enzymes mainly catalyse the transformation of ethanol into less harmful compounds that can be eventually eliminated.

Alcohol metabolism mainly involves the action of alcohol dehydrogenase (ADH) and aldehyde dehydrogenase (ALDH). The overall reaction can be summarised as:

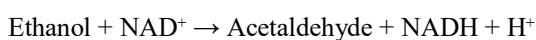


Each of the successive stages of the reaction involves a different biochemical process and can have various consequences.

➤ *Conversion of Ethanol into Acetaldehyde:*

The first major stage in alcohol metabolism involves the conversion of ethanol into acetaldehyde. This biochemical process mainly occurs in the liver and is catalysed by alcohol dehydrogenase (ADH).

ADH facilitates the oxidation of ethanol into acetaldehyde (CH_3CHO). In this reaction, ethanol loses hydrogen atoms and transfers them to NAD^+ , which is reduced to NADH. The overall reaction can be represented as:

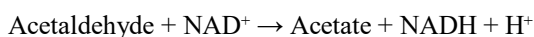


The product of this reaction, acetaldehyde, is a highly reactive and toxic compound. According to the National Institute on Alcohol Abuse and Alcoholism (NIAAA), it is also a known carcinogen. Although the body efficiently converts acetaldehyde into another substance, its presence can have damaging effects.

For instance, acetaldehyde can combine with cellular components and impair their normal functioning. Thus, the first stage of alcohol metabolism is not merely a harmless biochemical process but can have harmful consequences.

➤ *Conversion of Acetaldehyde into Acetate:*

The second major stage of alcohol metabolism involves the conversion of acetaldehyde into acetate. This reaction is primarily facilitated by aldehyde dehydrogenase (ALDH). The overall reaction can be represented as:



Compared with acetaldehyde, acetate is considerably less toxic. Hence, the second stage of alcohol metabolism is critical because it eliminates one of the most damaging by-products of ethanol consumption. However, the rate at which this conversion occurs can vary considerably among individuals.

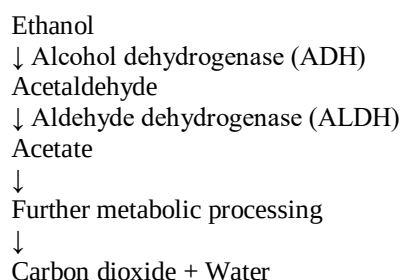
This variation can be attributed to differences in the activity of the ALDH enzyme. If the rate of acetaldehyde conversion is low, its accumulation in the body can have

adverse effects. Consequently, the second stage of alcohol metabolism is also of critical importance.

➤ *Further Metabolism of Acetate:*

The product of the second stage, acetate, can then enter further metabolic reactions. According to the NIAAA, acetate is eventually broken down into carbon dioxide and water.

Acetate can also be further processed into acetyl-CoA, which is a component of the normal intermediary metabolism. The overall metabolic sequence that converts ethanol into potentially harmful by-products and eventually into carbon dioxide and water can be summarised as:



Each of the subsequent stages of alcohol metabolism is summarised in this pathway.

➤ *Other Pathways of Alcohol Metabolism:*

Although alcohol dehydrogenase (ADH) is the predominant enzyme that is involved in alcohol metabolism, the NIAAA states that other enzymes also facilitate this process. Cytochrome P450 2E1 (CYP2E1) is an enzyme that is primarily involved in the metabolism of drugs and chemicals. However, it can also convert ethanol into acetaldehyde.

This alternative pathway becomes more prominent when individuals consume large amounts of alcohol. In addition, repetitive alcohol consumption also promotes the activity of CYP2E1. One of the major consequences of this enzymatic reaction is the production of reactive oxygen species (ROS).

➤ *Toxic Effects of Acetaldehyde:*

As mentioned above, acetaldehyde is a highly reactive and toxic substance. It can combine with cellular components and interfere with their normal functioning. Therefore, it is one of the major contributors to the damaging effects of alcohol. When alcohol is consumed, the majority of its metabolism occurs in the liver.

Consequently, acetaldehyde also accumulates in this organ, which can have detrimental effects. However, alcohol metabolism is not restricted to the liver; substantial amounts of ethanol can also be metabolised in other tissues such as the gastrointestinal tract, pancreas and brain.

In addition, the NIAAA highlights that the metabolism of alcohol via CYP2E1 can also cause oxidative stress. This can impair various cellular processes, which contributes to the development of liver disease.

➤ Overall Biochemical Significance:

The overall significance of the described biochemical processes can be summarised as follows. The body converts ethanol into acetaldehyde and then into acetate. Acetaldehyde is extremely toxic; therefore, rapid conversion into acetate is essential.

The overall sequence of reactions can be represented as:

Ethanol

→ ADH → Acetaldehyde

→ ALDH → Acetate

→ Further metabolism → Carbon dioxide + Water

➤ Progressive Effects of Alcohol on the Liver:

• Fatty Liver

Fatty liver, also called steatosis, is one of the first changes that can happen in the liver when too much alcohol is consumed. Fatty liver is marked by a build-up of fat, especially triglycerides inside liver cells. The liver usually processes food and fat. Helps keep the body's energy in balance. When too much alcohol is taken these normal processes can be disrupted.

When alcohol is broken down in the liver it alters the balance of substances that normally manage metabolism. This can raise the amount of fat that builds up inside liver cells. Because of this the liver may grow larger. Hold too much fat. At this point the problem might not show signs and the liver can still do most of its usual work.

Alcohol-related fatty liver matters because fatty liver signals an early phase of liver disease linked to alcohol. If heavy drinking goes on the risk of serious liver damage, such as alcoholic hepatitis, fibrosis or cirrhosis can grow.. Fatty liver does not always lead to these severe stages especially if drinking stops.

There fore the build-up of fat in liver cells can be seen as a sign that alcohol is disturbing the normal biochemical work of the liver.

• Oxidative Stress

Oxidative stress is another factor through which alcohol can cause harm to the liver. It happens when the body makes more reactive molecules than it can handle. These reactive molecules include oxygen species, which can cause damage to important parts of cells.

One of the pathways involved in breaking down alcohol is an enzyme system that includes cytochrome P451. This enzyme can break down ethanol. Becomes more active with regular or heavy drinking. As this happens reactive oxygen species can be created.

Reactive oxygen species are active molecules that can connect with parts of cells like fats, proteins and DNA. Damage to fats in cell walls is called lipid peroxidation. Can change how liver cells look and work. Damage to proteins and DNA can also stop cell processes from working right.

Oxidative stress can also cause inflammation inside the liver. When liver cells are often harmed by stress their normal work can get worse. This can make alcohol-related liver injury get worse.

So CYP2E1 and the making of oxygen species show an important link, between how the body breaks down alcohol and the damage it causes to liver cells.

• Alcoholic Hepatitis

Alcoholic hepatitis is a swelling condition of the liver that happens when alcohol is drunk. Alcoholic hepatitis is a serious phase of alcohol-related liver damage where liver cells are hurt and the body reacts with inflammation.

Continued drinking and the by-products of alcohol can strain liver cells. Acetaldehyde, a waste product of alcohol breakdown can harm cells. Oxidative stress and other chemical changes can add damage to liver tissue.

When liver cells are hurt the body's immune and inflammatory systems react to the injury. This triggers swelling inside the liver. The swelling can block liver cell work and cause more tissue damage.

Alcoholic hepatitis can be mild or severe. In cases big swelling in the liver can stop the liver from doing its normal jobs. Continued drinking can also raise the chance of permanent changes in the liver such as scar tissue and cirrhosis.

Therefore alcoholic hepatitis is a step in the worsening of alcohol-related liver disease. Alcoholic hepatitis links the harmful effects of alcohol to later more lasting liver damage.

• Fibrosis

Fibrosis is a process that happens when much scar tissue builds up in the liver. This usually occurs after the liver has been hurt for a long time. When liver cells get damaged again and again—like from alcohol or its effects—the liver tries to heal itself.. If the damage keeps happening the healing process can go too far. This overreaction leads to a buildup of tissue which is the start of fibrosis.

Hepatic stellate cells play a role in this process. Normally these cells help keep the liver's structure in place.. When the liver is injured repeatedly these cells change. They become active. Start making more of the building blocks for the extracellular matrix, like collagen. Over time this makes a lot of tissue.

As fibrosis gets worse the normal layout of the liver starts to change. The liver's normal structure breaks down. Blood flow through the liver gets slower. The way liver cells talk to each other gets worse. This affects how the liver works.

Fibrosis matters because it can keep getting worse if the cause of the liver damage is not fixed. In cases of alcohol-related liver disease drinking alcohol continues to hurt the liver. That means damage, more scarring and more fibrosis.

When fibrosis becomes severe it can lead to cirrhosis—a condition where the liver is permanently damaged and can't function properly.

So fibrosis is a step in the path from repeated liver injury, to permanent damage. It's not a side effect. It's a warning sign that the liver is struggling to heal itself and if things don't change the damage could become irreversible.

- **Cirrhosis**

Cirrhosis is a stage of chronic liver disease. In this condition a lot of tissue replaces healthy liver tissue. The normal shape of the liver changes a lot because of this damage. It can happen when the liver is hurt over time. One common cause is drinking too much alcohol.

As fibrosis gets worse more and more scar tissue grows inside the liver. This scar tissue blocks the liver cells from working the way they should. The healthy parts of the liver can't do their jobs properly. The liver might also form lumps. Blood flow through the liver can become slow. Blocked. That makes it harder for the liver to function.

The liver has important jobs. It changes food into energy. It makes proteins that the body needs. It cleans substances out of the blood. It also helps the body use energy effectively. When cirrhosis becomes worse the liver might not be able to do these jobs. This can lead to health problems.

Alcohol-related cirrhosis is often the stage of a process that can begin with fat building up in the liver. The process usually goes like this:

Fatty Liver → Alcoholic Hepatitis → Fibrosis → Cirrhosis

But not everyone who drinks alcohol will go through all these steps. The way the disease develops can be different, for each person. Some people might have damage. Others might have scarring. Cirrhosis is the result of long-term liver damage. When healthy liver tissue is replaced by tissue the liver changes permanently.

This change affects how the liver looks and how it works. Once cirrhosis starts the damage often gets worse over time. The liver cannot repair itself fully. So the condition becomes more serious. Prevention and early treatment are crucial to stop or slow the process.

III. THE CHEMISTRY INVOLVED IN ALCOHOL ADDICTION

Alcohol affects the neurotransmitters, receptors and neural circuits in the brain. A neurotransmitter is a chemical which is used for transmitting nerve impulses across a synapse from one neuron to another. Alcohol has an effect on the networks which are involved in reward, regulation, stress, learning, memory, decision-making and emotions.

Alcohol addiction or alcohol-use disorder (AUD) is not merely due to the pleasurable sensations caused by drinking alcohol. As the National Institute on Alcohol Abuse and

Alcoholism (NIAAA) states, alcohol does not only activate in the brain those areas which are linked to the reward system but also inhibits the parts of the brain that deal with stress and anxiety. After repeated exposure to alcohol, changes can occur in the brain's response to alcohol and to cues associated with alcohol.

➤ *Alcohol and the Reward Pathway*

Alcohol has an effect on the brain's reward system, a system that is responsible for detecting rewarding events and strengthening them. This reward pathway involves the tegmental area (VTA) and the nucleus accumbens.

Because of alcohol the release of dopamine is increased, leading to a greater activation of the nucleus accumbens and thus contributing to some of the reinforcing effects of alcohol.

Dopamine is also involved in incentive salience, as it enables the brain to establish associations between alcohol and the various cues connected with it. For instance, people, places, things, or events that are connected with drinking can act as triggers and thus cause someone to seek out and consume alcohol. This process is called incentive salience and is closely linked to addiction.

Dopamine is not only linked with pleasure but also allows learning to occur about the associations between alcohol and the environmental stimuli related to it.

➤ *The Function of GABA*

GABA is the main inhibitory neurotransmitter in the central nervous system and inhibitory signals have the effect of reducing neuronal activity.

Alcohol increases the activity of the GABAergic system, which causes changes in brain function related to balance and concentration when a person is under the influence of alcohol.

Apart from GABA, alcohol also affects the dopamine, glutamatergic and opioid systems, changing the brain's response to the drug. The way the brain responds to alcohol is influenced by its neuroplasticity – that is, its capacity to modify and adapt as a result of an experience. Tolerance and dependence to alcohol can therefore arise as a result of continuous use.

➤ *The Role of Glutamate and NMDA Receptors*

Glutamate is the main excitatory neurotransmitter in the brain and takes part in most cognitive processes, such as learning and the formation of memory. One type of glutamate receptor is the NMDA receptor.

Alcohol affects the way the brain processes information by blocking the action of NMDA receptors.

The GABA and glutamate systems usually play a role in keeping the balance between excitation and inhibition in the brain, and chronic alcohol use can disturb this balance, thus leading to the development of tolerance, dependence,

and withdrawal symptoms; these changes may also affect the brain's capacity to handle stress.

Moreover, glutamate is also important in regard to the persistence of the craving and in the person's ability to focus on alcohol-related stimuli.

➤ *Effects on Learning and Memory*

Alcohol has the ability to interfere with learning and memory since glutamate and NMDA receptors play a role in this process. Drinking alcohol over a long period of time can affect the way the brain establishes associations.

Alcohol also helps to link alcohol with all sorts of environmental stimuli. Objects, individuals, places, and situations associated with drinking can act as triggers for cravings and drinking behaviour.

The stronger the associations become, the greater will be the cravings for alcohol and the desire to drink in response to cues related to alcohol.

➤ *Effects on Coordination and Cognitive Function*

Alcohol has the effect of interfering with the parts of the brain that are responsible for balance, attention, decision-making and the control of impulses. While consuming alcohol the way that neurons communicate can be changed so as to disturb the functioning of different brain circuits. In the case of heavy drinking there occur disturbances in the brain circuits involved with motivation, memory, decision-making, concentration and sleep patterns.

The prefrontal cortex plays a vital role in decision-making, in controlling impulses and in the regulation of emotions. Consumption of alcohol in large amounts can interfere with its function and thus impair a person's ability to control his impulses and to stop drinking.

➤ *Alcohol, the Basal Ganglia and Habit Formation*

An action or behaviour can become habitual if it is repeated. The basal ganglia are important for the formation of habits and the prefrontal cortex is involved in making decisions and in controlling impulses.

Because repeated associations are formed between alcohol, the cues related to alcohol and the behaviours connected with it, there is an increase in activity in the basal ganglia which in turn reinforces these associations and makes them habitual. Alcohol drinking and the desire for alcohol can take over so that a person is no longer able to control them since they occur automatically. Meanwhile, changes in the prefrontal cortex can impair impulse control. Hence, the seeking of alcohol and drinking itself can be both habitual and compulsive.

➤ *Alcohol and the Stress System*

Alcohol has an effect on the brain circuits which are in charge of managing stress and negative emotions, and the extended amygdala is a major brain area taking part in stress reactions.

The continuous and excessive consumption of alcohol can cause changes in the way the body's stress mechanisms function, and the more alcohol is abused, the greater the increase in negative emotions that individuals may suffer.

The NIAAA says that this maladaptive response to stress during withdrawal may manifest as anhedonia or hyperkathesia.

Alcohol use and abuse may cause a greater number of negative emotions when one is withdrawing, and for this reason people may choose to drink in order to avoid those negative states.

➤ *The Three-Stage Cycle of Addiction*

The NIAAA identifies the addiction cycle as a three-step process:

Intoxication → Negative Affect → Anticipation

In the intoxication stage of addiction, alcohol causes the brain to release more dopamine, GABA, glutamate and opioids, thus activating the brain's reward systems.

In the negative affect phase the dopaminergic pathways are inhibited while the stress systems are activated. This in turn leads to negative emotional states which can act to encourage further alcohol consumption.

In the anticipation phase the cravings and urges to drink alcohol get stronger and the reasons for drinking are based on the expectation of the rewarding effects of alcohol.

It proves that the chemical basis of addiction lies in complex associations in the brain, which include various neurotransmitters, receptors, neural circuits, and brain areas and not merely one chemical.

➤ *Neuroplasticity and the Formation of Dependence*

The brain has the capacity to change and to adapt. Exposure to alcohol over a long period of time can lead to changes in the brain, affecting the neural circuits that are involved in the experience of reward, stress, the formation of habits, and self-control.

Because of chronic alcohol consumption a person can become tolerant so that the same amount of alcohol produces a smaller effect. Neuroplasticity too can play a role in the development of dependence as a result of changes in the brain's reward system. Furthermore, the NIAAA says that neuroplasticity can also help towards recovery and stopping the use of alcohol since the brain is capable of adapting to not having alcohol.

➤ *The General Chemical Basis of Alcohol Addiction*

The chemical basis of alcohol addiction is complicated and depends on the interaction of different neurotransmitter systems. The main neurotransmitters concerned are dopamine, since it is linked to reward and learning, GABA, which reduces brain activity, glutamate, which is excitatory and takes part in learning and memory, and opioids, which

are responsible for the pleasurable effects of alcohol. Stress mechanisms can lead to the emergence of negative emotional states when a person is going through withdrawal. The prefrontal cortex plays a central role in making decisions and in controlling impulses, while the basal ganglia are important for the formation of habits and the amygdala is involved in the regulation of emotion.

As there is no single neurotransmitter which is solely to blame for alcohol addiction, the risk of alcohol use disorder can slowly increase due to a variety of changes in the brain's self-regulation systems. Over time, the disruption of the reward and learning circuits, the formation of habits, and the alterations in decision-making and stress responses can all lead to alcohol consumption and use. The chemical basis of alcohol addiction shows the ways in which alcohol can affect the brain's ability to learn, to remember, to experience pleasure, to maintain balance and to regulate emotions, all of which contribute to the development of alcohol use disorder.

IV. DISCUSSION AND RESULTS

Ethanol is metabolized mainly in the liver, where it undergoes a series of biochemical reactions in which ethanol is transformed into acetaldehyde. This reaction takes place through the help of an enzyme called ADH. Then, another enzyme called ALDH transforms the acetaldehyde into acetate. Acetaldehyde may be damaging to cells. Oxidative stress and inflammation of tissues may also arise during the breakdown of the alcohol. Drinking alcohol regularly may damage the liver over time and cause scarring leading to cirrhosis. Alcohol also alters the chemical composition of the brain through such neurotransmitters as GABA and glutamate. Such alterations affect the ability to learn, to make decisions, to balance and to have memories. Tolerance of alcohol may be acquired by the brain during adaptation to alcohol intake and may result in dependence.

➤ *Limitations of the Methodology*

The research did not involve conducting any experiments, as it was a theoretical study reviewing the data published by other scientists. The findings of the study are based on the research conducted by others, but it did not involve collecting new data through clinical studies or laboratory research.

Another limitation of the research is that the study was conducted using the information available to the public. Therefore, the findings of the study cannot be generalized to all populations, as individual response to alcohol varies depending on a person's genotype, alcohol consumption patterns, and overall health.

Altogether, these limitations highlight the importance of further research to better understand the mechanisms of alcohol's impact on the human body and the development of alcohol-related diseases.

V. CONCLUSION

In conclusion alcohol metabolism is a biochemical process. Ethanol is mainly broken down in the liver by enzymes such as ADH and ALDH. This process produces acetaldehyde and acetate. Although this process helps the body remove alcohol, acetaldehyde is highly reactive. Acetaldehyde can contribute to damage. Excessive alcohol consumption can also increase stress. This happens through pathways involving CYP2E1. This can lead to inflammation and liver damage. This damage may progress from fatty liver to cirrhosis. Alcohol also affects the nervous system. It alters neurotransmitter activity. This can impair coordination, learning, memory and judgement. It may contribute to tolerance and dependence. Overall the findings support the hypothesis that alcohol metabolism can have effects. These harmful effects are on the liver, brain and other body systems. The findings show the importance of understanding alcohol metabolism. The importance is on its effects on human health.

RECOMMENDATIONS

Based on the study of alcohol metabolism and its biochemical and physiological effects on the human body, the following recommendations are proposed:

Promote awareness of alcohol metabolism: Educational programs should be conducted to explain how ethanol is absorbed and metabolized in the body and how excessive alcohol consumption can affect overall health.

Encourage responsible alcohol consumption: Individuals should be informed that alcohol consumption carries health risks and that reducing or avoiding alcohol can help lower the risk of alcohol-related diseases.

Emphasize liver health: Regular medical check-ups and early assessment of alcohol-related liver damage should be encouraged, particularly among individuals with a history of heavy or prolonged alcohol consumption.

Highlight the role of metabolic enzymes: Further research should investigate the functions of alcohol dehydrogenase (ADH) and aldehyde dehydrogenase (ALDH), including how genetic variations in these enzymes influence alcohol metabolism and individual susceptibility to alcohol-related harm.

Investigate acetaldehyde toxicity: More studies should be conducted to understand how acetaldehyde damages cells, contributes to inflammation, and promotes the development of alcohol-related liver diseases.

Study oxidative stress and inflammation: Research should focus on the mechanisms through which alcohol metabolism generates reactive oxygen species, disrupts cellular functions, and contributes to liver injury.

Increase awareness of neurological effects: Public health initiatives should explain how alcohol affects neurotransmitters such as GABA and glutamate, potentially

impairing memory, learning, judgment, coordination, and decision-making.

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