# The Impact of Over-the-Counter Medications on Yeast Growth in Different Temperatures; Modelling its Effects on Gut Microbes

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# Abstract

## Introduction

Over-the-counter medications(OTC) are drugs sold without a prescription to treat common illnesses such as colds and cases of flu (Sobczak and Goryński (2020)). These medications have significantly increased over the years as they are easily accessible, and patients have more control over how they can consume them. Various OTCs are used; however, the most common ones include Acetaminophen, aspirin, and laxatives. Acetaminophen is a non-opioid drug used for treating joint pain and fever. It is consumed orally and absorbed by the gastrointestinal tract within 30 - 60 minutes. However, exactly how it works has yet to be determined (Gerriets et al., 2024). Aspirin is a non-steroidal anti-inflammatory drug used to treat mild to moderate pain and prevent heart attacks in people who are at risk (Medline Plus, 2021). These two drugs block out cyclooxygenase enzymes 1 and 2, which help synthesize prostaglandins. In addition, prostaglandins mitigate gut conditions by protecting it from inflammation, but they also negatively impact the gut by altering microbiota composition. Laxatives are medications that assist in gastroneal issues such as constipation to help enhance digestion and bowel movements (Bashir & Sizar, 2019). The main goal is to speed up bowel movement; however, doing so can bring changes to the gut microbiome. Furthermore, laxatives alter pH levels and may wash out bacteria, killing microbial diversity (Weersma et al., 2020). All of these medications have proven extremely useful as long as the directions regarding dosage and consumption are followed correctly.

Saccharomyces cerevisiae(budding yeast), more commonly known as baker's yeast, is a single-celled organism that can be used as a model organism for eukaryotes. It is a haploid, oval-shaped cell that grows in the form of a bud on top of its parent's cell until the bud is the

same size as the parent, and then it separates. Just like humans, specific gene groups are in place to perform essential biological processes like cell cycle regulation. The similarities between the two are strong, making yeast an excellent model to help determine the chances of survival in human diseases. Microbiota are tiny particles found throughout the human body in the forms of bacteria, archaea, eukarya and parasites. Some may be helpful and potentially harmful; however, most follow a symbiotic relationship, which benefits the human body and microbiota. Diving into gut microbiota depths and understanding its crucial role in the human body is significant. This is because gut microbiota significantly impacts all other characteristics and substances related to the body. Vise Versa, many substances can cause dysbiosis, which may lead to more significant issues. Using yeast as a model organism to test out different medications and their impact on gut microbiome ensures a safe and insightful way to learn more about gut microbiome, yeast, and over-the-counter medications. (Liu et al., 2017)

# Literature Review

## Yeast Cellular processes

Saccharomyces cerevisiae has 23% homologous genes to humans as they diverged from a common ancestor 1 billion years ago. Many research and experimental studies have been conducted to test the genetic similarity between the two. Gene co-expression networks have been constructed for yeast using weighted gene co-expression network analysis(WGCNA). Researchers identified 17 gene-co-expression sections related to many biological processes, including heat response, cell cycle, and amino metabolism. These functions are also vital for cell processes in the human body, proving yeast to be an excellent model (Liu et al., 2017). Diving deeper, human and yeast cells activate a heat shock response(HSR) when exposed to increasing temperatures. This involves stopping their cell cycle in an early stage to prevent DNA damage or protein misfolding. The cells also increase the production of heat shock proteins (HSPs); yeast and humans release the same proteins, HSP70 and HSP90. In addition, both use sugars to protect cellular structures. In yeast, the sugar is called trehalose, while humans use small molecules called osmolytes, including sugars like glycerol (Verghese et al., 2012).

## Acetaminophen, Non-Sterodial Anti-Inflamatory Drugs(NSAIDs), and Laxatives

### *Tylenol(Acetaminophen)*

A common medication used is Tylenol, which is Acetaminophen and includes supplementary ingredients such as magnesium stearate, modified starch, powdered cellulose, pregelatinized starch, and sodium starch glycolate. Although much is yet to be known about its process, trials have been done on mice to understand how Acetaminophen works and discovered that an overdose of the drug causes acute liver injury. Researchers have assumed it acts similarly

amongst humans (Mossanen & Tacke, 2015). The sub-ingredients in Tylenol, like magnesium stearate, may irritate mucus lining if taken in large amounts, underscoring the importance of taking the correct dosage. Research has concluded that drugs like Tylenol partially influence prostaglandin synthesis as it inhibits major enzymes COX-1 and COX-2. COX-2 enzyme more strongly than COX-1. COX-2 is involved in inflammation and pain, while COX-1 protects the stomach lining. Specifically, the COX-2 enzyme is inhibited by about 83% and COX-1 by 56%. Although these numbers are significant, the inhibition rate is less than that of non-steroidal anti-inflammatory drugs (NSAID) (Hinz et al., 2007).

***Aspirin Extra Strength(NSAID)***

*Aspirin* is a common NSAID that inhibits prostaglandins in the body to stop inflammation, pain and fever. The active ingredient is acetylsalicylic acid, which inhibits platelet aggression, prevents blood clots, and inhibits COX enzymes, specifically COX-1 and COX-2 (*Aspirin - Uses, Side Effects, Interactions - MedBroadcast.com*, n.d.). Unlike other NSAIDs, inhibiting these enzymes caused by aspirin is irreversible, slowing the production of prostaglandins. Furthermore, it is proven to inhibit COX-1 more, which protects the stomach lining and regulates blood platelets. However, aspirin does inhibit COX-2, which helps reduce inflammation and provide relief. Managing doses effectively minimizes gastrointestinal irritation (Qureshi & Dua, 2024).

***RestoraLAX(Laxative)***

RestoraLAX is a common medication containing the active ingredient polyethylene glycol, which makes it a laxative. It works within the gastrointestinal tract and is classified as an osmotic laxative. It stores water in the stool to help produce more effortless bowel movements (Bolen, 2024). Due to the minimal absorption of polyethylene into the body, the chances of

systemic side effects are reduced.  A study on mice examines the impact of osmotic diarrhea, which may result from over-dose of osmotic laxatives on gut microbiota. It highlights how the immune system was affected, which led to increased antibodies against certain gut bacteria even after the diarrhea stopped. This concludes that high osmolality could stop the growth of certain gut bacteria and potentially lead to extinction (Tropini et al., 2018).

**Prostaglandin Synthesis and Inhibition**

Prostaglandin synthesis is a crucial biochemical process in the human body, and it occurs when a 20-carbon unsaturated fatty acid called arachidonic is converted into prostaglandins. Two main enzymes, COX-1 and COX-2, are responsible for this conversion. Prostaglandin-1(PGE1) and Prostaglandin-2(PGE2) are compounds that moderate physiological responses. PGE1 is responsible for blood vessels and the inhibition of platelets that adhere to each other. PGE2 promotes inflammation and fever and moderates immune responses. COX-1 helps maintain cellular functions, whereas COX-2 is released during inflammatory processes and is targeted by NSAIDs. Understanding prostaglandins and cyclooxygenase enzymes is vital because they play a significant role in the human body. Any alterations regarding either can impact different microbial communities, which may lead to other effects on the human body (Ricciotti & FitzGerald, 2011).

**Gut Microbiome**

Gut microbes are incredibly versatile as they are a complex community of microorganisms. A host's immune system shapes the microbial community without leading to a specific immune response. The microbial adaptability allows them to withstand physical and chemical stresses in the gut. In addition, their functions are categorized into four sections.

***Metabolic Functions***

Metabolic functions include the microbiota's interactions with macromolecules. They help digest carbohydrates, more specifically, dietary fibres that are resistant to human digestive enzymes. Undigested proteins are metabolized into peptides and amino acids in the large intestine with the help of gut bacteria such as Clostridium and Bacteroides. This process can produce beneficial compounds and harmful side effects linked to different diseases. In large amounts, lipids harm gut microbiota composition as they can increase inflammation by causing microbial dysbiosis.

***Protective and Structural Functions***

Gut microbiota often interacts with the gastrointestinal tract and immune system structures. Together, they work to form protective barriers and modulate immune responses. For instance, a mucus layer in the gastrointestinal tract protects cells from contact with microbes. It also acts as a nutrient source for certain bacteria. Epithelial cells secrete antimicrobial peptides that prevent pathogenic bacteria from surfacing to maintain gut homeostasis.

***Neurological Functions***

The brain and gut work together to control hormonal and immunological processes. The brain and body's reactions could be influenced by gut microbiota, leading to changes in behaviour and cognitive functions. Furthermore, some bacteria in the gut produce serotonin and dopamine, which play a significant role in regulating mood. Metabolizing dietary compounds influences neurological processes through the blood-brain pathway (Adak & Khan, 2018).

## Methodology

This research adopted an experimental approach to observe yeast growth when mixed with common OTCs at different temperatures.

### Materials

- Saccharomyces cerevisiae (baker's yeast)
- RestoraLAX (polyethylene glycol)
- Tylenol (acetaminophen)
- Aspirin(acetylsalicylic acid)
- Water
- Measuring spoon
- Plastic containers
- Glass cups
- Refrigerator, room temperature environment
- Stirring stick
- Mortar and pestle

### Preparing Yeast and Medication

1. Yeast Solution
    a. One teaspoon of yeast was dissolved in ¼ cup warm water
    b. Two teaspoons of sugar was added to the solution
    c. The solution was stirred until the yeast was dissolved
2. Medication
    a. Directed doses of medications were used:
        i. RestoraLAX - 17g

ii. Tylenol - 2 tablets

iii. Asprin - 2 tablets

b. Medications were crushed into powder for mixing

**Experimental Setup**

1. Control groups:
    a. Two control samples were created of yeast solution without any medication
        i. One was placed at room temperature, while the other was in the fridge
2. Medication groups:
    a. Medication was mixed and dissolved into a yeast solution
    b. Two samples were created of each- one placed at room temperature while the other in a refrigerator
3. Temperatures
    a. Room temperature was approximately 23 degrees Celsius
    b. The refrigerator temperature was 4 degrees Celsius

**Observation and Data Collection**

Samples were observed over 6 hours with observation points every 2 hours to note fundamental changes in yeast growth. A sheet was used to observe any visual changes. The data was then analyzed by comparing yeast growth and activity between different temperatures through qualitative observations.

The methodology outlines the procedure of the experiment performed to analyze yeast growth at different temperatures with different medications. This is used to interpret results and develop conclusions of gut microbiota reactions.

## Results

| TYPE | TEMPERATURE | OBSERVATION |
|---|---|---|
| Control | Room Temp | Highest rise, thick |
| Control | Fridge | Less rise than room temp, thick |
| RestoraLAX + Yeast | Room Temp | Rose, bubbly |
| RestoraLAX + Yeast | Fridge | Rose up, then soaked down from the middle, yeast settled at the bottom |
| Asprin + Yeast | Room Temp | Bubbling, yeast settled at the bottom |
| Asprin + Yeast | Fridge | More bubbling than room temp, yeast settled at the bottom |
| Tylenol | Room Temp | Some bubbles formed, diluted |
| Tylenol | Fridge | Similar to room temp, well diluted. |

## Discussions

### Control Group and RestoraLAX Results

The control samples showed significant yeast growth, with more at room temperature than in the refrigerator. This indicates that temperature may influence yeast metabolism. RestoraLAX samples showed some growth and bubbling while the yeast and water separated. The suggested polyethylene glycol may alter the yeast's metabolic activity as well. This is particularly interesting since RestoraLAX is an osmotic laxative, and the separation could mimic the hydrating effect of the medication on yeast. Similarly, we can assume its behaviour in the gut, where it may alter microbial water, thus impacting its activity.

### Aspirin and Yeast

The aspirin samples demonstrated a bubbling result due to the reaction between acetylsalicylic acid and yeast cells. The bubbling could be because of metabolic disruption or an immune response in yeast. This models how aspirin may also cause unusual responses amongst gut microbiota and disturb metabolic processes. In addition, the bubbling could hint at increased carbon dioxide production, which may affect gut microbial dynamics and gas production.

### Tylenol and Yeast

Tylenol samples showed minimal changes in both temperatures, including some bubbling. This suggests that acetaminophen does not affect yeast growth much under these conditions. However, considering that Tylenol inhibits COX enzymes, it may tell us that there is a minimal impact on cellular processes. Minor ingredients such as magnesium stearate may have a minor effect on yeast, which may have led to bubbling.

### Limitations

The study provides brief, valuable information and encourages further research regarding over-the-counter medications, yeast, and gut microbiota. However, many limitations need to be considered. Firstly, saccharomyces cerevisiae as a model organism has proven useful, but it can only partially model the gut microbiota as it is a much more complex environment. Secondly, the conditions in which the experiment was performed do not reflect the dynamic environment of the human gut. Some factors to consider include pH and other microbial interactions. Furthermore, the dosage of medications used was standardized. However, it varies from person to person and depends on human consumption patterns. Finally, the study mainly focuses on the short-term effects. However, medications may leave a lasting impact on gut microbiota.

Future research should include ways to model the human gut environment better and consider specific microbial species. In addition, the studies should involve more dosages and observe the long-term effects of these drugs.

## Conclusion

In conclusion, this study explored the effects of common over-the-counter medications- Tylenol, Aspirin, and RestoraLAX- on the growth of Saccharomyces cerevisiae under different temperature conditions to model the impact on gut microbiota. The results indicated that each medication affected yeast growth differently. RestoraLAX demonstrated osmotic effects, which may alter water balance, while Asprin, a non-steroidal anti-inflammatory drug (NSAID), produced bubbling, suggesting metabolic or stress responses. Tylenol had a minimal impact, reflecting its mild inhibition of COX enzymes compared to NSAIDs.

These results underscore the importance of understanding interactions between common medications and gut microbiota due to their crucial role in digestion and immune function. It also highlights the value of yeast as a model organism.

While over-the-counter medications are used for pain relief benefits, they may present adverse effects on gut microbiota and lead to dysbiosis, which may lead to other health complications. Future studies regarding these topics should help create a better understanding of the gut microbiome.

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