HIGH SCHOOL EDITION
Journal of Student Research

Volume 11 Issue 4 (2022)

We've Got the Beet: Using Beetroot, Red Cabbage, and Litmus Strips to Indicate Drink Spiking

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ABSTRACT

Objective: To test the extent to which beetroot and cabbage-based strips can indicate pH changes in comparison to litmus strips. *Hypothesis:* Beetroot and Cabbage will be able to indicate whether a drink has been drugged because the label will change colors as the pH level changes to the same extent that the litmus strips can. *Method:* An experimental design involving making beetroot and cabbage-based strips using coffee-filter paper and then testing the vegetable-based strips and litmus strips in a variety of liquids. *Result:* Beetroot and cabbage-based strips are able to accurately indicate a change in pH level in regard to drink spiking, however, litmus strips are more reliable and evident in their change in color.

Introduction

Throughout the modern world, drink spiking has become increasingly common as perpetrators spike victims' drinks for a variety of reasons. The Alcohol and Drug Foundation defines drink spiking as putting alcohol or drugs into an individual's drink without their knowledge or consent.[1] While some spike drinks for non-criminal motives such as to play a "prank" on someone, drinks are often spiked to aid the perpetrators in committing sexual assault. It was found in a 2017 study of three U.S. colleges that one in thirteen students reported being drugged.[2] Another study, published in 2004, estimated that of the 3,000 to 4,000 drink-spiking incidents in a year in Australia, less than 15% of incidents were reported to the police.[3] Victims of sexual assault that was precursored/facilitated by drink spiking may find it difficult to contact police because they feel shame or are afraid they will not be believed as many drugs used in drink spiking can cause memory loss and sedation.[4] The high prevalence of drink spiking makes researching and developing solutions critical.

The majority of proposed methods regarding testing to indicate if drinks have been spiked involve using pH indicators. pH is a 1-14 scale used to specify the acidity or basicity of a solution and a pH indicator is a chemical compound that can sense the amount of hydrogen or hydroxide ions in the solution.[5] There are various types of pH indicators, natural pH indicators that are sourced from vegetables, and litmus paper that is made by chemically treating the paper with a dye, lichens, that indicates a change in pH level.

Developing pH indicators that can accurately display if a drink has been spiked could not only lead to a decrease in drink spiking incidents but also assist in the conviction of the perpetrators as it could provide solid evidence that the drink had been spiked.

This research intends to investigate the usage of natural pH indicators in comparison to litmus paper to indicate drink spiking. The proposed study would investigate if a vegetable-based pH strip can indicate if a drink has been spiked by changing colors as the pH level of the drink changes to the same extent as litmus paper.

Literature Review

Anthocyanin pH indicators

In this literature review, a few major works examine the properties that allow certain fruits and vegetables to indicate a change in pH. A paper by Simin Pourjavaher, Hadi Almasi, Saeed Meshkini, Sajad Pirsa, and Ehsan Parandi, members of the Department of Food Science and Technology at the University of Tehran, titled "Development of a colorimetric pH indicator based on bacterial cellulose nanofibers and red cabbage extract" explained how anthocyanins, a group of phenolic compounds belonging to the flavonoid family, are responsible for red, purple and blue hues of plant fruits and vegetables. They further explained how anthocyanins are natural, non-toxic, water-soluble pigments that indicate a change in pH due to the presence of phenolic or conjugated substances, such as cyanidin, delphinidin, pelargonidin, peonidin, and petunidin, which are subjected to structural changes when there is a variation in pH.[6]

Swarup Roy and Jong-Whan Rhim, faculty at the BioNanocomposite Research Center at Kyung Hee University, added to the field of knowledge surrounding anthocyanins in their report "Anthocyanin food colorant and its application in pH-responsive color change indicator films." They described how anthocyanin has several functional properties due to its various colors such as antioxidant activity and anti-carcinogenic and anti-inflammatory effects, prevention of cardiovascular disease, obesity, and diabetes.[7] These positive properties of anthocyanin demonstrate why using fruits and vegetables, such as beetroot and red cabbage, that possess anthocyanins have gained popularity over chemical dyes.

Prashant Masali, head of the Department of Biochemistry at Ramnariam Ruia Autonomous College of Arts and Science, developed the main conceptual framework for the literature on this beetroot and its pH indicator properties with his article "Development of natural indicator and Ph indicator strips using beetroot (beta Vulgaris) extract." This article attempted to ascertain whether it is possible to use beetroot as an indicator of changing pH levels as a natural alternative to synthetic indicators. Masali used beetroot powder to create beetroot indicator strips that displayed a change in pH level.[8] Masali's scientific research regarding the use of beetroot as a natural indicator and why it is a safer alternative to synthetic indicators further emphasizes the idea that beetroot could be used to indicate drink spiking.

Other studies examine red cabbages' pH indicator properties and the use of these properties. According to a paper by Pathan Mohd Arif Khan and Mazahar Farooqui, members of the Maulana Azad College Post-graduate and research center, titled "Analytical Applications of Plant Extract as Natural pH Indicator: A Review," the aqueous extract of red cabbage shows a color variation of red (pH=2) to green (pH=12).[9] The change in color is due to the presence of the color compounds (anthocyanin) in cabbage. The color components vary from plant to plant as red cabbage has only one anthocyanin, while others have differing amounts. Together, these studies form the basis of existing literature of proposed methods for anthocyanin pH indicators.

Litmus paper

While the studies mentioned above closely examine the properties of anthocyanins and the previous applications of beetroot and red cabbage pH indicators, others explore different methods for pH indication, such as litmus paper.

A paper titled "Simple and Low-Cost On-Package Sticker Sensor based on Litmus Paper for Real-Time Monitoring of Beef Freshness" by Bambang Kuswandi, Fitria Damayanti, Aminah Abdullah, and Lee Yook Heng, members of the Chemo and Biosensors Group at the University of Jember explained how litmus papers' ability to change color when exposed to an acid or base is the result of the infusion of lichens, a fungus, into paper. The article additionally described how litmus paper is highly sensitive toward acid-base reactions as color changes (from red to blue) take place as a result of the lichen's interactions with pH. The experiment they conducted examined the use of stickers with a litmus paper base as an indicator of pH change of packaged fresh meat. The results showed that lit-

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mus paper was able to effectively indicate the spoilage of the meat, furthering the validity of litmus as a pH indicator.[10]

Gap

While all these mentioned works analyze the inner workings of natural pH indicators and litmus strips, no study focuses solely on examining the use of natural pH indicators and litmus strips in regard to drink spiking. This current gap in literature encourages further research into the use of natural pH indicators and litmus strips as a method for testing drugged drinks. This leads to the question, to what extent can beetroot and cabbage-based strips indicate pH changes in comparison to litmus strips? Through conducting an experiment where beetroot-based and cabbage-based strips are developed and tested in a variety of drinks, and then compared to the results of litmus strips this study may further shed light on a potential method to decrease the ramifications of drink spiking by determining if vegetable-based strips are a viable way of testing drugged drinks in comparison to litmus strips. It is important to determine if vegetable-based strips can be used as a natural alternative to litmus paper because according to OSHA 29-1910.1200, litmus strips are considered to be a hazardous substance and the potential ramifications of using litmus strips in beverages are unknown thus creating the need for a natural alternative.[11] Assumptions made when conducting this research are that the drink spiking phenomenon is common knowledge amongst adults and adolescents who are not in the targeted age group for the drugging of drinks. The hypothesis for this experiment is that if beetroot and cabbage can be procured and made into a label then it will be able to indicate whether a drink has been drugged because the label will change colors as the pH level changes to the same extent that the litmus strips can.

Methodology review

Overview

Studying the usage of different types of pH indicators in beverages is highly relevant to developing a solution to the increasing issue of drink spiking. Research suggests that the pH functions of beetroot, red cabbage, and litmus strips could allow for the strips to indicate the pH change of a drugged drink. The function of the strips allowed for the comparison between the vegetable-based strips, beetroot and cabbage, and the litmus strips. The purpose of this inquiry was to determine if beetroot-based and red cabbage-based strips can be used to indicate if a beverage contains drugs to the same extent as litmus strips. The most practical way to research the effectiveness of the different strips was through an experiment. An experimental design ensured that data would support the research question by allowing for a wide variety of data to be collected from numerous trials. This was chosen over other methods since an experimental method is best equipped to answer the research inquiry as it would yield objective results that serve as evidence, rather than subjective opinions such as those gathered from a survey. The experiment involved making beetroot and cabbage-based strips using coffee-filter paper because of its porous properties that allow for the release of the anthocyanins within the paper. Then, the vegetable-based strips and litmus strips were tested in a variety of liquids: water, Coca-Cola, and Isopropyl alcohol. These beverages were chosen in an attempt to replicate the drinks often served when drinks are spiked.

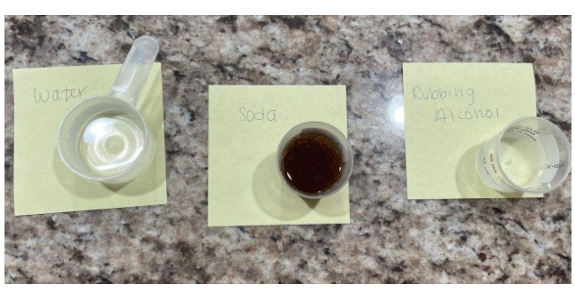


Figure 1. *The beverages strips were tested in throughout each trial.*

The strips were tested in the beverages before and after the addition of the 'drug,' Tylenol. As it is not feasible to conduct this research using the illegal drugs that are used in situations of drink spiking, Tylenol was used in place of "date-rape drugs" to mimic the drugs' properties since it is a highly acidic medication that would lead to a pH change. Because beetroot, cabbage, and litmus strips are basic pH indicators, they do not differentiate between different drugs. Therefore, the strip's ability to indicate lower-level drugs can be applied to the drugs used to spike drinks. By using the beetroot strips, cabbage strips, and litmus strips, the independent variable, the experiment tested the change in pH noted by the visible color change of the strips, the dependent variable.

Procedure

This experiment consisted of three parts. The first portion involved creating the beetroot strips. This included peeling two beetroots (one cup) and shredding them. After the beetroots were shredded, they were then boiled at 350 degrees Fahrenheit in a pot containing three cups of water. Once boiled, the solution simmered for ten minutes to cool down. Whilst the solution is cooling down, the coffee filter paper was cut into 18 three-inch by one-inch rectangular strips. After the solution cooled, it was put through a strainer and collected in a tray. The rectangular strips of filter paper were soaked for one hour in the beetroot solution until uniformly stained and then dried.

The second portion of the experiment consisted of preparing the red cabbage strips. The first part involved chopping the cabbage into small pieces until there were two cups of chopped cabbage. The cabbage was placed in a glass measuring cup and two and a half cups of boiling water were added to cover the cabbage. Next, ten minutes were taken to allow the color to leach out of the cabbage. While waiting these ten minutes, the coffee filter paper was cut into 18 three-inch by one-inch rectangular strips. Then, the plant material was filtered out to obtain the cabbage solution. After the solution cooled down, the solution was put through a strainer and collected in a tray. The rectangular strips of filter paper were soaked in the cabbage solution until uniformly stained and then dried. These steps were followed to ensure that the strips were able to accurately accomplish their intended purpose of pH detection.

This leads to the final part of the experiment which involved testing the beetroot strips, cabbage strips, and litmus strips in water, soda, and isopropyl alcohol. The labels were tested by dipping a paintbrush in each liquid, before and after adding Tylenol and painting the liquid on each pH indicator strip. The color of the strips changed depending on the acidic or basic nature of the liquid.

Results

In order to determine if vegetable-based strips or litmus strips are able to better indicate a change in pH level after a substitute for drugs was added, four experiments were conducted. The qualitative data was compiled after each procedure was completed with three trials per beverage both prior to and after the addition of the substitute for drugs. Through comparison of the reaction of the vegetable-based strips and the reaction of the litmus strips, it was established that the litmus strips were able to better display differences in pH through a change in color.

Vegetable-based Strips

This portion of the experiment consisted of two procedures, both of which garnered similar results. The first procedure involved boiling beets and soaking filter paper in the liquid to create beetroot-based strips that were tested in different beverages prior to and after the addition of the drug, Tylenol. The second procedure involved chopping up and boiling red cabbage to then soak filter paper in the cabbage water to make the cabbage-based strips which were then tested in the same manner as the beetroot-based strips.

Beetroot-based Strips

The beetroot-based strips underwent six trials, three prior to the addition of the medication and three after. The strips were tested in three beverages, water, Coca-Cola, and Isopropyl alcohol. For the initial testing of the beetroot strips (without the drug) the strips had no reaction in water as water has a neutral pH level (7). However, no reaction occurred despite the addition of acidic Tylenol (refer to Tables 1 & 2). This stayed consistent through both natural label procedures.

For all three trials, the beetroot strips turned red when submerged in Coca-Cola, which indicates that the beverage is initially acidic. After the Tylenol was added a new strip was tested in the drugged beverage and turned a deeper shade of red for all three trials, indicating that an acidic substance was added to increase the pH of the beverage. The strips turning a deeper shade of red is an essential piece when calculating the success rates for each trial as the difference between the strips before and after the addition of the Tylenol is the factor that determines if the strips can properly indicate if the drink has been drugged. The beetroot strips had a 100% success rate in soda, meaning that it was able to display a difference in reaction both prior to and after the addition of Tylenol (refer to Tables 1 & 2).

When the strips were tested in Isopropyl alcohol prior to the addition of the drug they turned red for two of the three trials. After the Tylenol was added to the Isopropyl alcohol, the strips clearly displayed red undertones for all three trials. The deeper red undertones for all trials after the addition of the Tylenol suggest that the strips were able to display the increase in acidity as the acidic Tylenol was added to the liquids. The beetroot strips initially had a 66% success rate in Isopropyl alcohol which increased to a 100% success rate after the addition of Tylenol (refer to Tables 1&2). Combining the data gathered throughout each trial, the overall success rate for beetroot strips was 92%.

Table 1: *The table indicates the reaction of the beetroot-based strips prior to the addition of Tylenol.*

Beetroot-based strips	Water	Soda	Isopropyl alcohol
Trial 1	N/A	Red	Red
Trial 2	N/A	Red	No change
Trial 3	N/A	Red	Red

Table 2: *The table indicates the reaction of the beetroot-based strips after the addition of Tylenol.*

Beetroot-based strips	Water	Soda	Isopropyl alcohol
Trial 1	N/A	Red	Red
Trial 2	N/A	Red	Red
Trial 3	N/A	Red	Red

Cabbage-based Strips

The cabbage-based strips went through six trials, three preliminary trials prior to the addition of Tylenol, and three after. The strips were tested in three beverages, water, Coca-Cola, and Isopropyl alcohol. The strips had no reaction in water before and after the addition of the drug so therefore they did not display a pH change within the water despite the addition of acidic Tylenol (refer to Tables 3 & 4).

For the first trial of the strips in Coca-Cola, the strips turned red, properly indicating the acidic properties of soda. When the strips were tested in the soda with the added Tylenol, the strips turned red for each of the three trials to indicate that an acidic substance was added to increase the pH of the beverage. The cabbage strips initially had a 33% success rate in Coca-Cola which increased to a 100% success rate after the addition of Tylenol (refer to Tables 3 & 4).

The strips were then tested in Isopropyl alcohol (prior to the addition of Tylenol) and they turned red to indicate the acidity of the alcohol for two of the three trials. After the Tylenol was added to the Isopropyl alcohol, the strips clearly showed red undertones for all three trials displaying the pH change as an acidic substance was added. The cabbage strips initially had a 66% success rate in Isopropyl alcohol which increased to a 100% success rate after the Tylenol was added (refer to Tables 3&4). The combined data from each trial demonstrates that the overall success rate for cabbage strips was 75%.

Figure 2. *Cabbage-based strips displaying red undertones after being tested in Isopropyl alcohol.*

Table 3: *The table indicates the reaction of the cabbage-based strips prior to the addition of Tylenol.*

Cabbage-based strips	Water	Soda	Isopropyl alcohol
Trial 1	N/A	Red	Red
Trial 2	N/A	N/A	N/A
Trial 3	N/A	N/A	Red

Table 4: *The table indicates the reaction of the cabbage-based strips after the addition of Tylenol.*

Cabbage-based strips	Water	Soda	Isopropyl alcohol
Trial 1	N/A	Red	Red
Trial 2	N/A	Red	Red
Trial 3	N/A	Red	Red

Litmus Strips

Litmus strips have a wider, more specific range of color for pH changes that range from a dark red, orange, yellow, green, blue, and purple in comparison to vegetable strips' more limited and basic range of green and shades of red. To ensure the results were comparable to the results of the vegetable-based strips trials, the litmus strips underwent six trials, three prior to the addition of the Tylenol and three after. The strips were tested in the same three beverages as the vegetable-based strips: water, Coca-Cola, and Isopropyl alcohol.

When the litmus strips were initially tested in the water, they displayed no clear reaction. However, after the Tylenol was added, the strips turned green for all three trials to indicate the change in pH as the water became more acidic due to the acidic properties of the Tylenol. The litmus strips had a 100% success rate in water, meaning that it was able to display a difference in reaction both prior to and after the addition of the Tylenol (refer to Tables 5 & 6).

The strips were then tested in Coca-Cola where they displayed a light red color before the addition of the drug, and a noticeably deeper red after the drug was added for all three trials to illustrate how an acidic substance was added to increase the pH of the beverage. Consequently, litmus strips had a 100% success rate in Coca-Cola, signifying that it was able to display a difference in reaction both before and after the addition of Tylenol (refer to Tables 5 & 6).

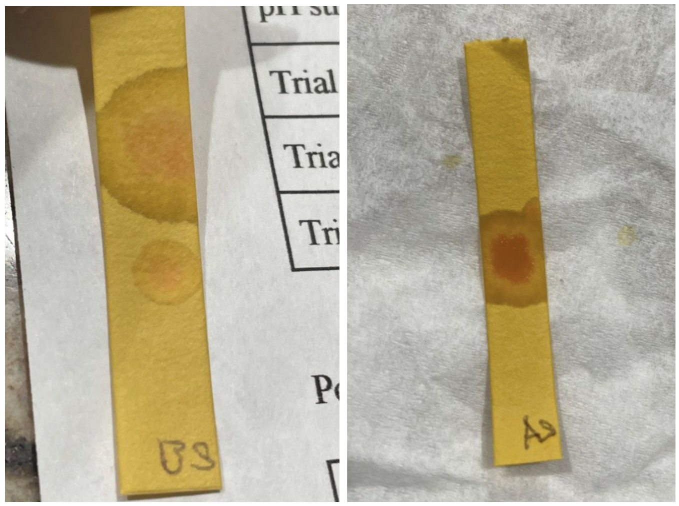
When the strips were tested in the Isopropyl alcohol, they initially turned green, and when the Tylenol was added to the Isopropyl alcohol the strips turned a yellow hue to indicate that an acidic substance was added to increase the pH of the beverage. The litmus strips had a 100% success rate in Isopropyl alcohol, meaning that it was able to display a difference in reaction both prior to and after the Tylenol was added (refer to Tables 5 & 6). Using the data gathered throughout each trial, the overall success rate for litmus strips was found to be 100%.

Table 5: *The table indicates the reaction of the litmus strips prior to the addition of Tylenol.*

Litmus strips	Water	Soda	Isopropyl alcohol
Trial 1	N/A	Red	Green
Trial 2	N/A	Red	Green
Trial 3	N/A	Red	Green

Table 6: *The table indicates the reaction of the litmus strips after the addition of Tylenol.*

Litmus strips	Water	Soda	Isopropyl alcohol
Trial 1	Green	Red	Yellow
Trial 2	Green	Red	Yellow
Trial 3	Green	Red	Yellow



Figures 3 & 4. *Litmus strips before and after the addition of medication to the Coca-Cola that the strips were tested in, red reaction shown.*

Discussion

The results of this experiment answered the research question of if vegetable-based strips can indicate if a drink has been spiked in comparison to chemically produced, pre-made litmus strips. The data shows that the initial hypothesis has been supported as seen through how the natural-based strips turned red to illustrate a change in pH level as a drink was spiked, the change in color was more evident within the litmus strips. Regarding the gap of findings within the examined prior literature, there are findings that have remained consistent and some that diverge. In Prashant Masali and Kanad Ghaisas's study where they attempted to ascertain whether it is possible to use beetroot as an indicator of changing pH levels, they concluded that the beetroot indicator strips displayed a clear change in pH level. This corroborates with the data collected in this experiment as they concluded that beetroot can accurately illustrate the change in pH via a change in color. This research has displayed beetroot-based strips' ability to indicate the pH of beverages and properly display the difference between the pH levels before and after the addition of a drug to different liquids.

When compared, the findings in this research do differ from other research within the field of literature as the beetroot and cabbage-based strips were considered to be unreliable since there was no clear pattern for which beverage the strips reacted to. When comparing the data between the vegetable-based strips and litmus strips it became evident that the vegetable-based strips were inconsistent in their display of pH change as the strips did not react at all for some trials and others turned slightly red. The litmus strips were the most reliable of the strips tested as for every trial they reacted according to the pH level of the beverage and the drug tested.

New Understanding

The new understanding that has been developed from this study is that while natural strips such as beetroot and cabbage-based strips are able to indicate a change in pH level in regard to drink spiking, litmus strips are more reliable and evident in their change in color. These findings address the gap of how no study focuses solely on examining and comparing the use of vegetable-based strips as a pH indicator in comparison to litmus strips in regard to drink spiking. This study effectively answered the research question as results displayed that while vegetable-based strips are able to indicate a change in pH level, litmus strips are better able to display changes after the addition of a drug.

Limitations

Although there were conclusive results regarding the effectiveness of the labels, there are limitations to this data. For one, the experiment was conducted without access to the materials needed to recreate the circumstances in which a drink would be drugged, and the factors involved such as the drugs typically used like GHB (gamma-hydroxybutyric acid), Ketamine, and Rohypnol, all of which were unobtainable for testing purposes. This limitation also applies to the drinks that were tested on account of how the alcoholic beverages that are commonly used in situations of drink spiking were inaccessible. This could have potentially skewed the results due to how the circumstances in which the strips would be used are different from the environment in which the experiment was conducted. However, the data set is still valid as the materials that were used in the experiment were substitutions for the drugs and alcohol because of their similar properties. It is also important to note that because beetroot and cabbage are natural pH indicators, they would not be able to differentiate between high doses of inhibitors and the over-the-counter medication that was used when indicating pH changes.

Conclusions

As drink-spiking incidents continue to increase across the world among young adults, drug-facilitated sexual assault and the subsequent effects have continued to rise. As this persists, the need for researching and developing potential solutions is critical to combat this issue. Applying previous research on prior use of pH indicators to this topic has shown that investigating the use of pH indicators to indicate drink spiking can provide a solution to this problem.

This research inquiry has presented findings that conclude that beetroot-based indicator strips, red cabbage-based indicator strips, and litmus indicator strips are all effectively able to indicate a spiked beverage with litmus strips being the most successful and consistent. With this outcome, it becomes possible to consider using pH indicator strips as a method to indicate if a drink has been spiked which creates a new understanding of this topic as it was not previously known if pH indicators, specifically vegetable-based and litmus strips, could be used in this manner. This knowledge could result in a possible decrease in successful drink spiking incidents as well as assisting in the conviction of the perpetrators by providing solid evidence that a drink had been spiked. The results could be applied within college campuses, specifically at college gatherings where the majority of drink-spiking incidents take place. Future distribution of these strips could decrease the number of people consuming spiked drinks which therefore would decrease the amount of drug-facilitated sexual abuse and prevent the subsequent trauma experienced.

These findings are corroborated by other researchers in the field such as the data in Prashant Masali and Kanad Ghaisas's study that demonstrated that beetroot strips are able to indicate the pH of different liquids. The data collected furthered this as it showed that beetroot can accurately indicate a change in pH 92% of the time.

For future research, the experimenter should have access to a wider variety of materials and opportunities to ensure that the results are accurate and able to be replicated. For example, a researcher should have access to the variables that are commonly used in drink-spiking scenarios such as drugs that can be used as inhibitors and the alcoholic beverages that often play a part in drink-spiking situations. It would also be beneficial to the existing body of knowledge to study the potential mass production of these labels. Future researchers should consider how their results could be applied to the production of these strips and how the strips would be used in situations where drinks are spiked and aid in the prevention of this.

Ultimately, it is critical to research and develop solutions to the current issue of drink spiking to prevent further impairment to those impacted by the outcomes of drink spiking. Conducting similar research on the application of pH indicators to the subject of spiked drinks in the future is imperative to find a solution to this problem.

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