SEVENTH EDITION

YGS JOURNAL

YOUNG GLOBAL SCIENTISTS

YGS • A STUDENT-LED JOURNAL FOR THE SCIENCES AND THE SOCIAL SCIENCES • NOVEMBER 2023

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Contents

Sciences

Social Sciences

In Search of Pi

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Sindhia Rao is currently a year 10 student in St Helen's School in London, with a passion for mathematics, and all things infinite.

Abstract

Sometimes when I'm doing my maths homework, I get distracted. While I suspect this is not uncommon, one of my distractions sparked a journey which resulted in me discovering and proving an expression for π as an infinite series of fractions.

I originally thought the result was new. However, after some research, I traced it back over 500 years, to Nilakantha Somayaji, a polymath from the Kerala School of Astronomy and Mathematics, who included the result (without proof) in the 1501 Sanskrit Treatise "Tantrasamgraha". In this paper, I describe my unique journey to discovering the Nilakantha – Rao formula. I then provide a proof of the Nilakantha – Rao formula, by linking it to the more well-known Leibnitz formula for π, and describing the surprising history of Liebnitz and Nilakantha's results.

The Nilakantha-Rao formula for π

$$\pi = 3 - \sum_{n=1}^{\infty} \frac{(-1)^n}{n(2n+1)(n+1)} \quad (\#)$$

Introduction

Pi, an enigmatic and endlessly fascinating number, has captivated the minds of mathematicians for centuries. Known as the unchangeable ratio of the circumference to the diameter of any circle, pi is an irrational number that cannot be expressed as a sum of finite fractions. Yet its digits are fixed, leading some to wonder if there is a pattern hidden within them.

As a young mathematician, I too was intrigued by pi's infinite yet structured nature. This led me to explore the correlation between the digits, and I began to search for a sequence that could represent them.

Initially, I tried using fractions, beginning with the well-known fraction 22/7, which is close to pi. However, it is not infinite, which led me to realise that all fractions used to represent pi must be infinite. I began experimenting with adding recurring fractions, but it didn't work as well as I had hoped.

Undeterred, I tried again, this time starting with the number 4 and subtracting fractions. However, this was not fruitful either. Finally, I hit upon the idea of adding and subtracting fractions. But it still remained a challenge to find a connection between the numbers. The first fraction was always too large to fit with the rest of the sequence.

After several attempts, I decided to separate the digits after the decimal place and the number 3. This made the process much more manageable. I could now search for patterns and connections in the system.

After hours of experimenting with fractions, I settled on 1/6, -1/30, and 1/84 as my starting fractions, which proved to be the most promising. I noticed a common numerator of "1" among the fractions, leading me to explore the possibility of keeping all the fractions under a numerator of 1. Hoping to find a connection, I searched for the tiniest clue. As 6 + 24 = 30 and since 24 + 30 = 54 which happened to be the difference between 30 and 84, I thought maybe 84 + 54 would give us our next difference - leading me to believe that my next denominator would be 222, but my approach was incorrect. Hoping it was quadratic, I went back and replaced 222 with 168. I felt this time I was getting closer, but soon I realised I had decreased my total a little too much, proving that once again something had gone wrong. I felt discouraged.

Remembering Edison's quote, I told myself "I have not failed 10,000 times—I've successfully found 10,000 ways that will not work." Failure lies in not trying. I did not give up. I kept going, hoping that there was some sort of cubic sequence or polynomial I could find. Based on my previous attempts, I could guess that the next denominator had to be between 168 and 222. I increased my previous denominator by 96, making the new denominator 180, with a third difference of 12. After observing the sequence of denominators 6, 30, 84, 180, I discovered a connection between them, which motivated me to carry on. I found that by multiplying 2, 3 and 4 to get 24 and dividing it by 4, it gives us 6. Similarly, by multiplying the next integers 4, 5 and 6 and dividing the result by 4 we obtain 30. Following the same principle, I determined the next denominator 330 (10x11x12)/4) and continued the sequence. Although the digits changed slowly, they still changed.

Excited by my discovery, I shared my findings with my maths teacher the next day. I didn't know how to present my theory formally. I told him that it would be three + the denominator, the cubic sequence $2n^3 + 3n^2 + n$, and the numerator would be 1 and -1 alternating, forever. He decided to put it in excel and after looking at the first 10000 terms, we found that it indeed seemed to converge with π. I was thrilled that it worked.

I had already guessed that the sequence I found would have been discovered by someone, somewhere, but I was still thrilled. I wanted to do this purely for the fun of it. The following day I was shocked to discover from my maths teacher that he had been unable to find any record of the result appearing in print before.

However surreal the situation turned out to be, proving my theory was a daunting task beyond what I had learned in year 9. Under the guidance of my maths teacher, I explored new mathematical concepts on my own. It was a fascinating hunt, the game of pi where digits hold a treasure trove of secrets waiting to be unlocked by my curious mind. I dived into "partial fractions" and the "method of differences", which allowed me to compare my theory to the Leibnitz formula for pi. Over the summer holidays, I completed the proof for Nilakantha-Rao's Law.

A Little Bit of History - Liebnitz, Nilakantha, and the Kerala School

I later discovered that Nilakantha Somayaji, an astronomer-mathematician from India, had already made this discovery in the 1500s. In the world of mathematics and astronomy, the name Nilakantha Somayaji holds significant weight. This Indian astronomer-mathematician made ground-breaking discoveries in the 16th century that continue to shape the field today.

His most influential work, Tantrasamgraha, consisted of 432 verses on astronomy, and he also wrote an elaborate commentary on Aryabhatiya, in which he discussed infinite series expansions of trigonometric functions, problems of algebra, and spherical geometry. Nilakantha's work was instrumental in the establishment of Indian astronomy and mathematics, and his achievements have left a lasting impact.

One of his many accomplishments includes developing the series expansion for arctan(x), which allowed him to determine the value of pi with a high degree of accuracy. This series is now known as the Madhava-Leibniz series or the Nilakantha series.

Nilakantha's contributions to the study of pi laid the foundation for the development of calculus and the discovery of new methods for calculating pi. His work continues to be studied and celebrated to this day.

While the cubic expression on the denominator of the Nilakantha-Rao formula may not seem interesting, if we multiply both the numerator and denominator of the Nilakantha-Rao formula by 4 we get

$$\pi = 3 - \sum_{n=1}^{\infty} \frac{4\,(-1)^n}{2n(2n+1)(2n+2)} \quad (\#)$$

Then we can see that the denominator is the product of three consecutive integers. Without Σ notation this can be written as

$$\pi = 3 + \frac{4}{2\times 3\times 4} - \frac{4}{4\times 5\times 6} + \frac{4}{6\times 7\times 8} - \frac{4}{8\times 9\times 10} + \cdots$$

The Surprising Eastern Origins of Pi

Mathematics is a universal language that transcends cultural barriers and connects scholars from around the world. Pi is a perfect example of this global phenomenon. While many attribute the discovery of the formula for pi to Gottfried Leibniz, the truth is that its origins can be traced back to the Kerala School of Astronomy and Mathematics in India, where brilliant minds like Madhava of Sangamagrama and Nilakantha Somayaji made significant contributions to the study of pi.

Madhava's works in the 16th century were the steppingstones for the formula for pi that we know today. However, it was Nilakantha Somayaji's improvement upon Madhava's series expansion that is truly remarkable.

In the 1500s, Nilakantha developed a faster-converging formula for pi that predates Leibniz's formula by over 150 years. This raises an intriguing question: how did an Indian mathematician from the 16th century discover a formula that was not fully understood in the West until centuries later?

The answer lies in the fact that many mathematical concepts that we attribute to the West actually have roots in Eastern traditions that date back centuries. Nilakantha used a different notation method to write the formula, which was closer to the geometric series he studied in the Kerala School. This highlights the power of the mathematical techniques developed by the school, which were far ahead of their time.

Nilakantha's formula for pi not only has historical significance but also mathematical importance. It converges much faster than Leibniz's formula and accurately calculates the value of pi after just a few terms. It is humbling to discover that my own work has built upon the Indian Mathematical traditions of more than 500 years ago. Nilakantha did not include formal mathematical proof in his Treatise. And while it is very likely that his result has been proved many times since then, I'd like to think that he would be very happy with the proof included here, which relates his work to that of his own forefathers.

The surprising Eastern origins of the Nilakantha series for pi illustrates the rich history of mathematics and the importance of recognising the contributions of scholars from various cultures and regions. Nilakantha's formula serves as a reminder that mathematical concepts are not bound by geography or time, and that the power of mathematics lies in its ability to connect us across cultures

and time periods. The whole journey taught me that I too, through my humble contribution, have built upon them to further enrich the study of mathematics.

Proof

We will prove Rao's law by using partial fractions and the method of differences to demonstrate that Rao's Law is equivalent to the already proven "Leibnitz formula for Pi":

$$\frac{\pi}{4} = \sum_{n=0}^{\infty} \frac{(-1)^k}{2k+1} = 1 - \frac{1}{3} + \frac{1}{5} - \frac{1}{7} + \frac{1}{9} \ldots$$

The proof proceeds in three steps:

Step 1: Partial Fractions

First, use partial fractions to write

$$\frac{1}{n(2n+1)(n+1)} = \frac{a}{n} + \frac{b}{2n+1} + \frac{c}{n+1}$$

⇨ $1 = a(2n+1)(n+1) + b(n)(n+1) + c(n)(2n+1)$

Setting n=-1 gives

$1 = a(2(-1)+1)(-1+1) + b(-1)(-1+1) + c(-1)(2(-1)+1)$

$1 = 0 + 0 + c(-1)(-1)$

$1 = c$

Setting n=-½ gives

$1 = a(2(-½)+1)(-½+1) + b(-½)(-½+1) + c(-½)(2(-½)+1)$

$1 = 0 + b(-¼) + 0$

$-4 = b$

Finally, setting n=0 gives

$1 = a(2(0)+1)(0+1) + b(0)(0+1) + c(0)(2(0)+1)$

$1 = a(1)(1) + 0 + 0$

$1 = a$

So the right-hand side of (#) can be written as

$$3 - \sum_{n=1}^{\infty} \frac{1(-1)^n}{n} + \frac{-4(-1)^n}{2n+1} + \frac{1(-1)^n}{n+1}$$

Step 2: Method Of Differences

$$\sum_{n=1}^{\infty} -\frac{1(-1)^n}{n} + \frac{4(-1)^n}{2n+1} - \frac{1(-1)^n}{n+1}$$

Can be written out term by term as follows:

$$1st\ term = \frac{1}{1} - \frac{4}{3} + \frac{1}{2}$$

$$2nd\ term = -\frac{1}{2} + \frac{4}{5} - \frac{1}{3} \rightarrow$$

$$3rd\ term = \frac{1}{3} - \frac{4}{7} + \frac{1}{4}$$

$$4th\ term = -\frac{1}{4} + \frac{4}{9} - \frac{1}{5}$$

$$Last\ Term = \frac{1}{\infty} - \frac{4}{2\infty + 1} + \frac{1}{\infty + 1} = 0$$

We see that the last term in each row cancels with the first term from the following row, while the middle term in each row does not cancel, nor does the very first term in the first row.

Hence

$$\sum_{n=1}^{\infty} -\frac{1(-1)^n}{n} + \frac{4(-1)^n}{2n+1} - \frac{1(-1)^n}{n+1} = 1 + \sum_{n=1}^{\infty} \frac{4(-1)^n}{2n+1}$$

So

$$3 + \sum_{n=1}^{\infty} -\frac{1(-1)^n}{n} + \frac{4(-1)^n}{2n+1} - \frac{1(-1)^n}{n+1}$$

$$= 3 + 1 + \sum_{n=1}^{\infty} \frac{4(-1)^n}{2n+1} \qquad (*)$$

Step 4: Compare To Leibniz Formula For Pi (Change Of Variables)

The well-known Leibniz Formula for Pi states:

$$\frac{\pi}{4} = \sum_{n=0}^{\infty} \frac{(-1)^n}{2n+1} = \frac{1}{1} - \frac{1}{3} + \frac{1}{5} - \frac{1}{7} + \frac{1}{9} - \cdots.$$

Multiplying through by 4 gives

$$\pi = 4 \sum_{n=0}^{\infty} \frac{(-1)^n}{2n+1} = \frac{4}{1} - \frac{4}{3} + \frac{4}{5} - \frac{4}{7} + \frac{4}{9} - \cdots.$$

$$= 4 + \sum_{n=1}^{\infty} \frac{4(-1)^n}{2n+1}$$

Which is the same as the expression obtained in (*), hence proving that Rao's Law is equivalent to the already proven Leibnitz formula for π, as claimed.

References:

[1] Although I had never heard of partial fractions at the time, I later discovered that it is part of the year 13 A level Maths Curriculum. See for instance section 1 of Atwood, G. et. al, *Edexcel A level Mathematics – Pure Mathematics Year 2*, Pearson 2017.
[2] The method of differences is part of the year 13 A level Further Maths Curriculum. See for instance section 2 of Atwood, G. et. al, *Edexcel A level Further Mathematics – Core Pure Mathematics Book 2*, Pearson 2018.
[3] See for instance Leibniz formula for π - Wikipedia

[4] Summation - Wikipedia

[5] Summing the first 5 terms of Leibnitz formula gives a result which differs from π by about 0.2, while the first 5 terms of Nilakantha's result differs from π by only 0.002. Pi - Wikipedia
[6] Madhava of Sangamagrama - Wikipedia

Customizable Orthotic Socks for Runners

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Abstract

When running, a large force is exerted on the legs and feet. This force is responsible for injuries such as plantar fasciitis and Achilles tendonitis. To prevent these injuries, and to aid in their healing, runners might turn to orthotics. Despite the overwhelming benefits provided by orthotics, the price point of a high-quality, custom orthotic is a deterrent. This study designed a customizable and affordable orthotic sock. The orthotic sock was composed of a sock with pockets in the heel and arch. Within the pockets were removable foam pieces. The orthotic was tested for efficacy by comparing the bounce height of a tennis ball when dropped on the orthotic sock and a control. The results were analyzed using a one-tailed t-test. The orthotic sock provided a lower mean bounce height than the control. The one-tailed t-test with an alpha value of 0.05 resulted in a p-value of 0.001. The p-value of 0.001 proved the results of the experiment significant. Based on the results, the orthotic sock provided a lower bounce height to the tennis ball, signifying shock absorption.

Key Words: orthotic, runner, shock-absorption, sock, customizable

Introduction

Running is one of the most popular recreational sports in the United States with upwards of 47 million participants (Sports and Fitness Industry Association, 2019). Surprisingly, running also happens to be one of the most physically demanding. Runners place extreme pressure and force upon their feet and legs almost daily. According to Gross et al. (1991), this force is equivalent to 250% of the body weight. Repeated impact at such a high force can result in injuries such as Achilles tendinitis, stress fractures, and plantar fasciitis (Yick et al., 2013). Though fairly minor, these injuries can result in long recovery times and decreased running performance.

Due to the likelihood of injury, runners put great importance on the shoes and socks on their feet. Despite the multitude of running shoes on the market, finding shoes that fit perfectly and provide support where needed is difficult. Thus, orthotics are sometimes necessary. An orthotic is a piece of foam or plastic that is worn in the shoe. Orthotics are designed to correct potential causes of running injury, primarily biomechanical abnormalities such as cavus, a high foot arch, and pes planus, flatfoot. These issues result in the foot hitting the ground at an undesirable angle, increasing the likelihood of injury. (Yick et al., 2013) Additional causes of injuries include overtraining and uneven terrain. Orthotics help the foot land correctly and provide cushioning for increased comfort.

Bonanno et al. (2015) tested the injury-prevention properties of orthotics in naval recruits. Incidence of lower limb injuries in naval recruits is incredibly common, up to 79%. Though naval training consists of a large variety of exercises, the subjects likely participated in a large amount of running. When incidents of injury between the control and orthotic groups were compared, it was found that the use of an orthotic resulted in a 34% reduction in the likelihood

of injury. The preventive use of orthotics was further tested by Fauno et al.(1993). This study compared the use of heel inserts versus the lack of inserts in the prevention of soreness in the legs and backs of soccer referees. Throughout a five-day soccer tournament, the average percentage of reported pain in the control group was 85.4% compared to only 55.8% in the orthotic group. Both of these studies demonstrate the effectiveness of shoe inserts in preventing injuries.

In addition to preventing injuries, orthotics can also aid in healing previously attained afflictions. In a study conducted by Donatelli et al. (1988), subjects were treated for their foot problems with a variety of treatments, including stretching and electrical and ultrasound therapies. Each treatment group utilized orthotics in addition to the other variable. The groups all reported decreased pain; however, no significant difference was found between treatments. Therefore, the decrease in pain can only be attributed to the use of orthotics. Furthermore, a survey of long-distance runners who used orthotics conducted by Gross et al. (1991) found that of the 347 participants, 75.5% reported that the use of orthotics resulted in the total dissolution of discomfort and injury. These studies not only demonstrate the effectiveness of orthotics but also their superiority to other methods of injury treatment.

The use of orthotics has been proven beneficial. Thus, it is surprising that few runners utilize them. This might be attributed to the alarmingly high cost of prescription orthotics. A prescription orthotic or custom orthotic is a device created by taking a cast of the patient's foot and designing a foam piece in the same shape. A custom orthotic can range in price from $200 to $800 (Paigen, 2017). Over-the-counter orthotics are made of the same materials as custom orthotics, but they are not shaped to the individual's foot. These orthotics tend to be far less expensive, typically under $100. This brings to question whether prescription orthotics are worth the cost. Abbasi et al. (2019) examined the use of custom versus prefabricated orthotic insoles to treat chronic ankle instability, a common problem in athletes that can result in ankle sprains. A Star Excursion Balance Test was performed to measure the stability and reach of the subjects. Upon testing, the researchers determined that the custom orthotics improved the performance of the athletes more than the prefabricated ones. In contrast, research conducted by Redmond et al. (2009) found that the use of an orthotic, in general, improved plantar pressure of subjects who were considered flatfooted. However, when comparing the plantar pressure provided by custom and over-the-counter orthotics, no significant difference was present. The divide in scientific literature demonstrates the need for further research in comparing the efficacy of prescription and over-the-counter orthotics. Despite this, the individual benefits of prefabricated orthotics, cost efficiency, and prescription orthotics, customizability, are clear.

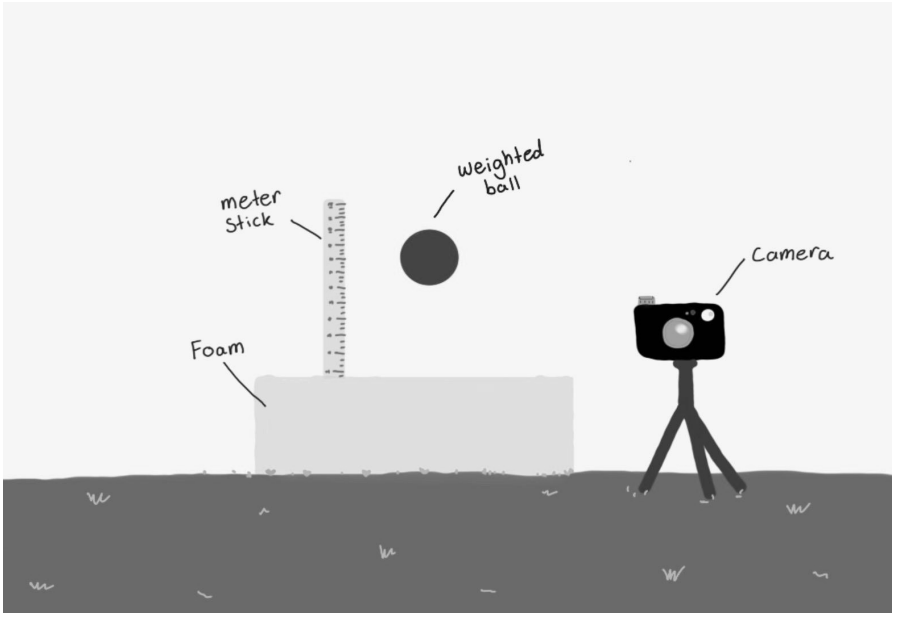
An orthotic needs to be created that melds the customizability of prescription orthotics with the price of over-the-counter ones. This research attempts to fill the gap in orthotic technology. The resulting orthotic was a sock filled with foam pieces. The sock was made of sweat-wicking fabric with pockets in the arch and heel of the foot. The orthotic pieces were constructed from ethylene-vinyl acetate (EVA) foam. The orthotic sock could then be customized by inserting or removing the various foam pieces. The orthotic sock was tested against a control by measuring the bounce the orthotics provided. It was hypothesized that the orthotic sock would produce an increased bounce compared to the control. The resulting bounce heights were compared graphically and analyzed through the use of a t-test.

Methods & Materials

The following experiment attempted to formulate a customizable orthotic sock that paired the cost of a prefabricated orthotic and the personalization of a prescription orthotic. The sock was tested by comparing the efficacy to that of a control. The control was simply the mannequin foot with a lack of orthotic and sock. The hypothesis was that the orthotic sock would provide greater bounce when tested. Additional materials for the socks included one meter of 95% cotton 5% spandex fabric, fifty meters of cotton thread, a sewing machine and a half meter worth of ethylene-vinyl acetate foam sheets. Ethylene-vinyl acetate was selected as it is commonly used in sporting shoes due to its flexibility and durability. To test the orthotics, a mannequin foot, meter stick and camera were used.

The purpose of this experiment was to create an orthotic sock. This was completed using a pattern, Sew It Forward Sock Pattern, from Ellie & Mac Sewing Patterns. The fabric was cut out according to the pattern with an additional one cm seam allowance along the edges. The pieces were then sewn together on the sewing machine using a straight stitch. A second heel and arch piece were cut out using the aforementioned pattern, again with a one cm seam allowance. These pieces were sewn onto the sock using a straight stitch leaving a four cm space that was not secured, forming pockets. Then, pieces of ethylene-vinyl acetate foam were cut using the heel, toe, and arch patterns. To complete the sock, the foam pieces were inserted into the pockets and the sock was flipped inside out.

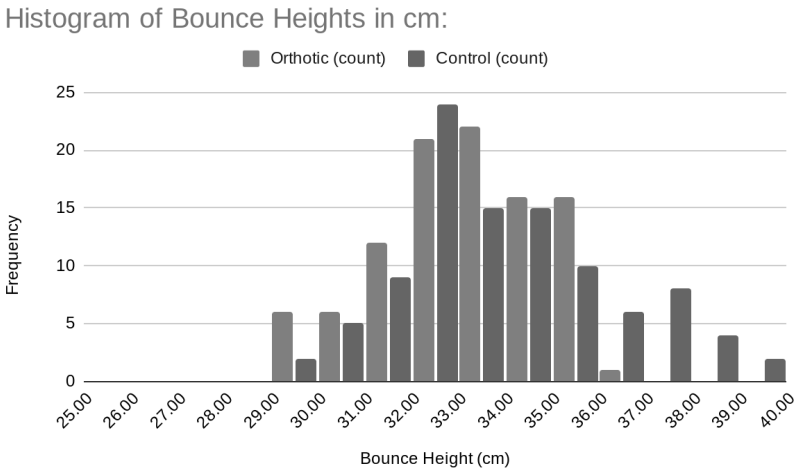
The experimental setup was assembled by standing a meter stick up vertically and positioning a camera in front of it (Figure 1). A tennis ball was dropped upon the mannequin foot, void of any orthotic, from a height of one meter, measured from the top of the ball, whilst the camera was recording. The maximum bounce height was found by reviewing the footage and recording the peak height the tennis ball reached on the first bounce. This served as the control. This process was repeated with the orthotic sock. To ensure the accuracy of the results, three trials of each variation were completed before rotating to the next treatment. A total of 100 trials were completed for each variation. The results were analyzed using a t-test, with an alpha value of 0.05, to determine the significance.



(Figure 1)

Results

This study examined the differences in bounce provided by a custom orthotic sock made with ethylene-vinyl acetate foam inserts and a control. The bounce height was measured by dropping a tennis ball upon both the orthotic sock and the control and measuring the maximum height reached by the ball on the first bounce. A lower bounce height was expected to indicate increased support. One hundred trials of each treatment were completed and the results were analyzed. The control, void of sock and orthotic, provided bounce heights ranging from 29 cm to 39 cm, a range of 10 cm. The orthotic sock trials resulted in bounce heights between 29 cm and 36 cm, a range of 7 cm (Figure 2).



(Figure 2)

The control bounces tended to be slightly higher than that of the orthotic. The mean of the control was 33.5 cm and the mean for the orthotic sock was 32.6. The control bounce heights were more inconsistent than the orthotic ones with standard deviations of 2.29 cm and 1.73 cm respectively. The bounce heights of the tennis ball were most commonly in the 32 cm to 33 cm range for both treatments (Figure 3).

Descriptive Statistics for Bounce Height of Custom Orthotic Socks vs. No Orthotic

Treatment:	Mean (cm)	Median (cm)	Mode (cm)	Standard Deviation (cm)
Custom Orthotic Sock:	32.64	33	33	1.726326163
No Orthotic Sock:	33.52	33	32	2.289545851

(Figure 3)

The results of the bounce test were analyzed for statistical significance using a one-tailed t-test. The significance level was 0.05. The t-test produced a p-value of 0.001. This value demonstrated that the results were significant and allowed for the rejection of the null hypothesis, that there was no difference in bounce height between the control and the orthotic sock. The alternate hypothesis, that there is a

quantifiable difference in the bounce provided by the orthotic sock when compared to the control, was confirmed. The bounce height of the ball on the orthotic sock was lower than that of the control.

Discussion

This experiment aimed to create an orthotic sock that would have the ability to be customized while still being inexpensive. The hypothesis, that the orthotic would provide less bounce to the tennis ball than the control, was supported by the results. Though the descriptive statistics of the custom orthotic and the control were fairly similar, with means of 32.6 cm and 33.5 cm, a median of 33 cm for both, and modes of 33 cm and 32 cm, the large number of trials allowed for the small difference to become significant. Thus it can be confirmed that the orthotic sock reduces the impact force upon the foot resulting in less tennis ball bounce height. This aligns with a study conducted by Fauno et al. (2010), which examined the damping properties of orthotics. This study similarly found that the use of ethylene-vinyl acetate foam increased shock absorption. The shock absorption properties of the orthotic sock will decrease the chances of common stress-related injuries such as Achilles Tendinitis, stress fractures, and plantar fasciitis (Yick et al., 2013).

Through the use of descriptive statistics, it was found that, overall, the orthotic sock provided a decreased bounce height to a tennis ball when compared to the control. These results were proved significant by a one-tailed t-test with an alpha value of 0.05 and p-value of 0.001. This allowed for rejecting the null hypothesis that there was no significant difference in bounce height between the orthotic sock and the control.

While testing, a control environment was attempted. However, certain factors, such as inconsistencies in the dropping of the tennis ball and the potential degradation of the ethylene-vinyl acetate foam within the orthotic, were not controlled for. In order to improve this experiment, an automated dropping system could be created to ensure accurate results. A machine that has a heel-shaped stamp would be ideal due to its consistent results (Bruckner et al., 2010).

Further experimentation could be done concerning this concept of a customizable orthotic sock by testing the product on real runners rather than the mannequin foot utilized in this experiment. In addition, the comparison of the customizable orthotic sock to prescription and prefabricated orthotics could provide information on the effectiveness of the orthotic sock. Orthotics, as a whole, are greatly important in the prevention and healing of injuries in runners. The concept of an orthotic that is both inexpensive and customizable has the potential to fill the gap in the current orthotic market.

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Probability and Calculus: Analyzing the Leaching of Nutrients in Garden Soil and Agriculture

Arnav Ghai

Abstract

Gardeners strive to maintain optimal nutrient levels in the soil to support healthy plant growth. However, nutrient leaching, the loss of essential nutrients from the soil due to excessive watering or rainfall, can be a challenge. This research paper aims to investigate the process of nutrient leaching in garden soil using probability and calculus. The study involves theoretical calculations to analyze the likelihood of nutrient-leaching events based on factors such as soil type, rainfall intensity, and irrigation practices. Practical experimentation is conducted to simulate various leaching scenarios in a controlled garden setting. Soil samples are collected and nutrient levels are measured to compare with the theoretical calculations. This research provides insights into the probability of nutrient leaching in garden soil under different conditions and sheds light on the impact of irrigation and rainfall on nutrient management in gardens. The findings can be useful for gardeners and farmers in making informed decisions about irrigation practices and nutrient management strategies to maintain optimal soil fertility and promote healthy plant growth. This study also highlights the application of probability and calculus in understanding real-life events, exemplified by the phenomenon of nutrient leaching in garden soil. In addition, it also encourages students to explore the intersection of mathematics and everyday life. Further research and experimentation can be conducted to refine the findings and expand the understanding of nutrient-leaching dynamics in different soil types, climates, and cropping systems.

Nutrient leaching is a natural process that occurs when water moves through the soil, carrying dissolved nutrients along with it. This can happen when there is excess water in the soil due to irrigation, rainfall, or other factors, and the water percolates through the soil profile, taking nutrients with it as it moves downwards.The leaching process can be influenced by several factors, including soil type, rainfall intensity, irrigation frequency, nutrient concentration in the soil, and the presence of drainage systems. Sandy soils, for example, are more prone to nutrient leaching due to their coarse texture and low nutrient-holding capacity. Heavy rainfall and excessive irrigation can also increase the probability of nutrient leaching. This is due to the additional water volume in the soil which potentially leads to more nutrients being carried away.The loss of nutrients through leaching can have significant impacts on plant growth and crop production. Nutrients such as nitrogen, phosphorus, and potassium, which are essential for plant growth and development, can be leached from the soil, reducing their availability to plants. This can result in nutrient deficiencies, decreased plant vigor, and lower crop yield.

(Part 1) Probability and Nutrient Leaching: Understanding the Relationship

Probability is a mathematical concept that allows us to estimate the likelihood of an event occurring. In the context of nutrient leaching, probability can be used to estimate the chances of nutrient loss due to irrigation or rainfall events, and help us make informed decisions about nutrient management practices.Probability is typically expressed as a value between 0 and 1, with 0 representing an impossible event and 1 representing a certain event. A probability of 0.5, for example, represents a 50% chance of an event occurring, while a probability of 0.25 represents a 25% chance, and so on.

When it comes to nutrient leaching, the probability of nutrient loss can be influenced by various factors, such as the frequency and intensity of irrigation or rainfall events, the nutrient concentration in the soil, and the soil type. By understanding these factors and their relationship to nutrient leaching, we can estimate the probability of nutrient loss and make informed decisions about nutrient management practices in gardening and agriculture.

Calculating the Probability of Nutrient Leaching:

The probability of nutrient leaching can be estimated using probability theory and mathematical formulas. In the case of our hypothetical garden plot with sandy soil, receiving irrigation every other day and experiencing rainfall events with an average intensity of 10 mm per day, we can use the Poisson distribution formula to calculate the probability of rainfall events, and assume a probability of nutrient leaching due to irrigation based on the frequency of irrigation events.

Step 1: Calculating the Probability of Rainfall Events:

Let's assume that rainfall follows a Poisson distribution with an average intensity of 10 mm per day, as mentioned in our hypothetical scenario. The Poisson distribution is a probability distribution that is commonly used to model events that occur at a constant rate and independently of each other, such as rainfall events.

The formula for the Poisson distribution is given by:
P(X=k) = (λ^k * e^(-λ)) / k!

Where:
P(X=k) is the probability of k rainfall events occurring

λ is the average intensity of rainfall events (in this case, 10 mm per day)

e is Euler's number, a mathematical constant approximately equal to 2.71828

k is the number of rainfall events we want to calculate the probability for

k! is the factorial of k, which is the product of all positive integers from 1 to k

Let's say we want to calculate the probability of 1 rainfall event occurring in a day, using the average intensity of 10 mm per day. We can plug these values into the formula to get:

P(X=1) = (10^1 * e^(-10)) / 1!

P(X=1) = (10 * 0.000045) / 1

P(X=1) = 0.00045

So, the probability of 1 rainfall event occurring in a day in our hypothetical garden plot is 0.00045 or 0.045%.

Step 2: **Assuming Probability of Nutrient Leaching due to Irrigation**

In our hypothetical scenario, we assumed that irrigation is done every other day. Therefore, we can assume a probability of nutrient leaching due to irrigation based on the frequency of irrigation events.

Let's say we assume a probability of 0.2 (or 20%) of nutrient leaching due to irrigation. This means that for every irrigation event, there is a 20% chance that nutrient loss may occur due to leaching.

Step 3: **Calculating Total Probability of Nutrient Leaching**

To calculate the total probability of nutrient leaching, we can combine the probabilities of rainfall events and irrigation events occurring together. Let's denote the probability of nutrient leaching due to rainfall as **P(Rain)** and the probability of nutrient leaching due to irrigation as **P(Irrigation)**.

From **Step 1**, we calculated that **P(Rain)** , the probability of 1 rainfall event occurring in a day, is 0.00045 or 0.045%.

From **Step 2**, we assumed that **P(Irrigation)**, the probability of nutrient leaching due to irrigation, is 0.2 or 20%.

Now, we can calculate the total probability of nutrient leaching, **P(Total)**, as the sum of **P(Rain)** and **P(Irrigation)**:

P(Total) = P(Rain) + P(Irrigation) P(Total) = 0.00045 + 0.2

P(Total) = 0.20045 or 20.045%

So, the total probability of nutrient leaching in our hypothetical garden plot with sandy soil, receiving irrigation every other day and experiencing rainfall events with an average intensity of 10 mm per day, is approximately 20.045%.

This calculation will give you the probability of nutrient leaching occurring in the garden soil within a week due to both rainfall and irrigation, based on the assumptions and parameters used in this example.

Note: The actual probabilities and parameters may vary depending on the specific conditions of the garden soil and the location, and may require data collection and analysis to obtain accurate results.

Conclusion Of Part 1:

The experiment conducted to estimate the probability of nutrient leaching in a hypothetical garden plot with sandy soil, receiving irrigation every other day and experiencing rainfall events with an average intensity of 10 mm per day, has provided valuable insights into the complex dynamics of nutrient management in gardening and agriculture.

One unique insight gained from this experiment is the significance of considering multiple factors that influence nutrient leaching, and using probability theory and mathematical formulas to estimate the likelihood of nutrient loss. In this experiment, factors such as soil type, rainfall intensity, irrigation frequency, and nutrient concentration in the soil were taken into account to calculate the probability of

nutrient leaching. This highlights the importance of a comprehensive approach that accounts for various variables when managing nutrients in agricultural systems.

Furthermore, the use of probability theory, specifically the Poisson distribution formula, provided a quantitative approach to estimate the probability of rainfall events occurring and the subsequent nutrient leaching. This approach allowed for a more precise estimation of the probability of nutrient leaching, taking into account the random nature of rainfall events. This demonstrates the potential of using mathematical modeling and probability theory as powerful tools in agricultural decision-making processes.

Another important insight from this experiment is the recognition of the inherent uncertainty and variability associated with nutrient management in real-world agricultural systems. Agriculture is influenced by numerous uncontrollable factors such as weather patterns, soil conditions, and plant growth dynamics, which can vary significantly over time and space. The use of probability theory acknowledges this inherent uncertainty and provides a framework for quantifying and managing risk associated with nutrient management practices.

Additionally, the experiment underscores the significance of understanding the potential impacts of irrigation on nutrient leaching. Irrigation is a common practice in agriculture and gardening to provide water to crops, but it can also contribute to nutrient leaching if not managed properly. By assuming a probability of nutrient leaching due to irrigation based on the frequency of irrigation events, the experiment highlights the need for careful irrigation management to minimize nutrient loss and optimize nutrient use efficiency.

The findings from this experiment have practical implications for nutrient management in gardening and agriculture. They emphasize the importance of considering site-specific factors, such as soil type, climate, and management practices, when estimating the probability of nutrient leaching and making informed decisions about nutrient management strategies. The use of probability theory and mathematical modeling can provide valuable insights into the dynamics of nutrient cycling and help optimize nutrient management practices to reduce nutrient losses and improve overall nutrient use efficiency.

In conclusion, the experiment conducted to estimate the probability of nutrient leaching in a hypothetical garden plot has provided unique insights into the complexity of nutrient management in agricultural systems. By considering multiple factors, using probability theory and mathematical modeling, and acknowledging the inherent uncertainty in agricultural systems, this experiment highlights the importance of a comprehensive and quantitative approach to nutrient management. These findings can contribute to more informed decision-making and improved nutrient management practices in gardening and agriculture, ultimately enhancing sustainability and productivity in agricultural systems.

(Part 2) Optimizing Nutrient Uptake in Garden Plants using Calculus

Research Methodology:

1. Experimental Setup:
   A controlled garden plot will be set up with a specific plant species, such as tomatoes, in a suitable growing medium. The garden plot will be divided into several treatment groups, each with a different nutrient application rate and timing. The nutrient application rates will be carefully measured and controlled, and the timing of nutrient application will be varied according to the experimental design.

2. Nutrient Uptake Modeling:
   To model the uptake of nutrients by the plants, we will use calculus-based approaches. The rate of nutrient uptake by the plant can be modeled using differential equations, which describe how the nutrient concentration changes over time in the plant roots and shoots. Let's assume that the rate of nutrient uptake is proportional to the difference between the nutrient concentration in the soil and the nutrient concentration in the plant roots. This can be expressed mathematically as:

   dN/dt = k * (Ns - Nr)

Where,

dN/dt is the rate of nutrient uptake

k is the proportionality constant

Ns is the nutrient concentration in the soil

Nr is the nutrient concentration in the plant roots

3. Optimization Strategies:
   We will use calculus to develop optimization strategies for nutrient application rates and timing. The objective will be to find the optimal nutrient application rate and timing that maximizes the plant's nutrient uptake and growth. We can formulate this as an optimization problem with constraints on nutrient availability in the soil and the plant's ability to uptake nutrients. The optimization problem can be expressed mathematically as:

   Maximize: $\int$**(k * (Ns - Nr)) dt**

   Subject to: **Ns(t)** ≥ 0, **Nr(t)** ≥ 0, $t \geq 0$

Where, the integral represents the accumulated nutrient uptake over time, subject to the constraints that the nutrient concentrations in the soil and plant roots must always be non- negative, and time must be greater than or equal to zero.

4. Calculations:
   To solve the optimization problem, we will use calculus techniques, such as differentiation and integration, to find the optimal nutrient application rate and timing. Let's assume that the initial nutrient concentration in the soil is **Ns(0)** known and constant, and the initial nutrient concentration in the plant roots **Nr(0)** is also known. We can differentiate the equation for the rate of nutrient uptake with respect to time **t** to obtain:

   d^2Nr/dt^2 = k * (dNs/dt - dNr/dt)

This is a second-order ordinary differential equation (ODE) that describes the dynamics of nutrient uptake by the plant roots. We can rearrange the equation to isolate **dNr/dt** on one side:

dNr/dt = (k/Nr) * dNs/dt - (k/Nr) * (d^2Nr/dt^2)

Next, we can integrate both sides of the equation with respect to time **t**, using appropriate initial conditions, to obtain an expression for **Nr(t)**:

∫(dNr/dt) dt = ∫((k/Nr) * dNs/dt - (k/Nr) * (d^2Nr/dt^2)) dt

Integrating the left-hand side will give us **Nr(t)**, and we can use numerical methods, such as Euler's method or Runge-Kutta method, to approximate the right-hand side of the equation, which involves the rate of change of nutrient concentration in the soil and the second derivative of nutrient concentration in the plant roots.

Once we have an expression for **Nr(t)**, we can plug it back into the equation for the rate of nutrient uptake: **dN/dt = k *(Ns - Nr)**, and integrate it with respect to time **t** to obtain the accumulated nutrient uptake over time. We can then optimize the nutrient application rate and timing by varying the values of **k**, **Ns**, and **Nr**, and observing the effect on the accumulated nutrient uptake.

5. Results and Discussion:
   Based on the mathematical calculations and optimization strategies, we can analyze the results of the experiment and draw conclusions. We can compare the performance of different nutrient application rates and timings in terms of the accumulated nutrient uptake by the plant. We can also evaluate the sensitivity of the results to changes in parameters such as the proportionality constant **k**, initial nutrient concentration in the soil **Ns**, and initial nutrient concentration in the plant roots **Nr**. Furthermore, we can discuss the implications of the findings in the context of optimizing nutrient management practices in real-world gardening or agricultural settings. We can highlight the potential benefits of using calculus-based optimization strategies for improving nutrient uptake and plant growth, and the practical implications of these findings for sustainable gardening practices.

Conclusion Of Part 2:

This part of the research paper presents a methodology for optimizing nutrient uptake in a garden using calculus-based approaches. By modeling the nutrient uptake dynamics using differential equations and formulating an optimization problem, we can determine the optimal nutrient application rate and timing that maximizes plant nutrient uptake and growth. The results of the experiment and the mathematical calculations can provide valuable insights into nutrient management practices in gardening and agriculture, and contribute to the advancement of sustainable gardening techniques.

An Unique Insight:
One unique insight that can be gained from this research is the importance of optimizing nutrient

application rates and timing for maximizing plant nutrient uptake. The use of calculus-based approaches allows for a quantitative and systematic approach to nutrient management, taking into account the dynamics of nutrient uptake and the interplay between soil and plant root nutrient concentrations. This can help gardeners and farmers to make informed decisions about nutrient application rates and timing, leading to more efficient and sustainable gardening practices.

In conclusion, the integration of calculus-based optimization strategies in gardening and agricultural research can provide valuable insights and practical solutions for optimizing nutrient management practices. By understanding the dynamics of nutrient uptake and using mathematical calculations to determine optimal nutrient application rates and timing, we can enhance plant growth and maximize nutrient uptake in gardens, leading to more sustainable and efficient gardening practices. Further research in this area can continue to advance our understanding of nutrient management in gardening and agriculture, contributing to the development of sustainable and environmentally- friendly gardening practices.

A message from Arnav:

My name is Arnav Ghai, and I am a Grade X student from Chandigarh, India, with a passion for STEM (Science,Technology, Engineering and Mathematics) and ecology. I am enthusiastic about understanding the natural world and its intricate processes. Also,I'm particularly fascinated by the field of gardening and nutrient management. Recently, I had the opportunity to conduct my own research project in my garden, using calculus-based approaches to optimize nutrient uptake in plants and also an analytic-based soil leaching probability report. Through this research, I delved into the dynamics of nutrient absorption, application rates, and timing to maximize plant growth and productivity. It was an exciting and challenging experience, and I learned a great deal about the crucial role of nutrient balance in plant health and yield.

Interleukin-6 Levels in Nasal Secretions as a Potential Diagnostic Tool for Alzheimer's Disease

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Abstract

Alzheimer's disease (AD) is a debilitating condition affecting millions worldwide, and early detection is crucial for effective treatment and management. Due to the cluster of amyloid beta plaques and neurofibrillary tangles, the neurons in the brain begin to undergo gradual and irreversible neuronal loss. This is why early detection of AD is crucial for effectively treating and managing the disease. However, the current diagnostic methods, such as imaging scans, are not always accessible and cannot be diagnosed early on. This study investigated the potential of nasal secretion as a non-invasive diagnostic tool for AD. The study employed two assays including a Bicinchoninic acid (BCA) assay and an Enzyme-Linked Immunosorbent Assay (ELISA), to measure protein and Interleukin-6 (IL-6) levels in nasal secretion samples. Blood samples were also collected to serve as a comparison tool. The findings suggest that nasal secretion may be a promising diagnostic tool for AD, with elevated levels of IL-6 found in the nasal secretion of mice with AD-like pathology. The average IL-6 concentration in mice diagnosed with Alzheimers was approximately 0.139515 pg/mL, compared to the nasal secretion in the healthy mice cohort between 0.102 pg/mL. The study contributes to the research on the IL-6 biomarker in AD. It shows that utilizing nasal secretion as a diagnostic tool could allow for early detection and improved quality of life for patients. Future research should investigate the accuracy of nasal secretion as a diagnostic tool and compare it to other current methods.

Keywords

Neuroscience; Cognitive Psychology; Alzheimer's Disease; Nasal Secretion; Interleukin-6

Introduction

Alzheimer's Disease is a neurodegenerative disorder typified by the accumulation of beta-amyloid plaques and neurofibrillary tangles in the brain. The amyloid beta peptide, a key component of beta-amyloid plaques, is prone to forming insoluble aggregates outside neurons. In contrast, hyperphosphorylated tau protein accumulates inside neurons, a key component of neurofibrillary tangles. These neuropathological changes have been observed to cause synapse and neuron loss, resulting in cognitive decline and, eventually, dementia. Additionally, AD is characterized by inflammation, oxidative stress, and further neurodegeneration, all contributing to the disease's complex and multifaceted Etiology.[1]

Expanding upon our knowledge of Alzheimer's disease pathology, it is noteworthy to acknowledge that the discovery of this condition is rooted in the groundbreaking work of Alois Alzheimer, a distinguished psychiatrist and neuropathologist of the 20th century.[2] In 1906, Dr. Alzheimer recorded observations of a patient with a myriad of symptoms, including progressive sleep disorder, memory disturbance, aggression, paranoia, and confusion.[3] Upon the patient's demise, Dr. Alzheimer conducted an autopsy and identified the presence of abnormal clumps, now recognized as amyloid plaques and tau-related tangles.[4] Presently, clinicians can diagnose Alzheimer's disease before autopsies are conducted, which was previously unattainable a few decades ago. There have been remarkable advancements in testing methods for Alzheimer's disease, including Computed Tomography (CT), Magnetic resonance imaging (MRI), and Positron emission tomography (PET) imaging scans. Furthermore, variations of PET scans, such as amyloid/tau PET scans, enable improved detection and accuracy in diagnosis.[5] Despite the usefulness of these imaging techniques, they can be costly and not easily accessible, especially in resource-limited settings. Moreover, these imaging techniques may not be suitable for detecting the early stages of Alzheimer's disease. For example, while MRI and CT scans can identify structural changes in the brain associated with Alzheimer's, they may not detect the illness until significant neuronal loss has occurred.[6]

Recent advancements in medical technology have emerged biomarkers as valuable tools for the early diagnosis of various neurological conditions, including Alzheimer's disease (AD). These biomarkers can serve as vital indicators of AD, even before the manifestation of noticeable symptoms. They include amyloid beta (Aβ), cortical amyloid PET ligands, low cerebrospinal fluid Aβ42, and elevated CSF phosphorylated tau.[7] These biomarkers have proven to help predict the onset and progression of AD, enabling healthcare providers to take timely measures to manage the condition and improve the quality of life of affected individuals. Despite significant advancements in the field of AD biomarkers, there remain challenges to their practical use. The analysis of cerebrospinal fluid biomarkers, crucial for detecting some biomarkers, requires a lumbar puncture, an invasive procedure with potentially adverse effects.[8] Additionally, cerebrospinal fluid biomarker analysis variability across different laboratories is high, limiting their consistency and reliability.[9] Studies on blood-based biomarkers for AD pathology, such as plasma Aβ and tau, have been conducted in recent years. However, the reliability and consistency of these blood-based biomarkers have yet to be established consistently across studies, and further validation is required.[10] Hence, there is an urgent need for cost-effective and feasible methods for the early diagnosis of AD. These methods should have minimal side effects and be accurate, reliable, and consistent across different studies and laboratories.

Nasal secretion holds immense potential as an effective diagnostic tool for detecting AD related biomarkers due to its non-invasive and easily accessible nature. Recent studies have shown the presence of amyloid beta, tau, and other markers of neurodegeneration in nasal secretion, indicating its potential as a diagnostic tool.[11] Compared to traditional methods such as cerebrospinal fluid analysis and imaging techniques like PET and MRI scans, utilizing nasal secretion as a biomarker offers a more straightforward, more cost-effective, and minimally invasive method.[12] The olfactory system is intricately connected to the brain, with individuals suffering from neurodegenerative disorders reporting a loss of sense of smell. This loss suggests a possible link between the olfactory system and Alzheimer's disease.[13] Studies demonstrate a correlation between protein levels of amyloid beta/tau in nasal secretion and the development of Alzheimer's disease.[14] In conclusion, the potential of nasal secretion as a diagnostic tool for Alzheimer's disease presents a promising avenue for improving the accuracy and early detection of this debilitating condition. Further research into nasal secretion biomarkers could revolutionize Alzheimer's diagnosis and pave the way for effective treatments. This study hypothesizes that nasal secretion can be a non-invasive diagnostic tool for Alzheimer's disease (AD) by measuring the biomarker Interleukin-6 (IL-6). IL-6 is an inflammatory

cytokine that is increased in the blood during chronic inflammation, and its increase has also been associated with AD. While increased IL-6 levels are not necessarily indicative of AD, here it is used as a proxy for an AD biomarker candidate that can be detected in nasal secretions. This study aims to investigate the accuracy of measuring IL-6 levels in nasal secretion compared to blood samples and to determine if nasal secretion can offer a more accessible and cost-effective method for the early detection of AD.

Methods

Study Population

The primary study population for the initial experiment comprised four male-aged mice, >18 months old. Nasal lavage was performed on two mice to procure nasal secretion samples, cardiac blood specimens were obtained from two mice, and tail blood was collected from all four animals. The subsequent investigation included two healthy female mice that were 2 months old, one aged healthy male mouse, and two aged mice afflicted with AD pathology (APP/PS1 transgenic mice). The purpose of obtaining blood samples from the mice was to compare the protein concentrations in the blood and the nasal secretion samples. Therefore, including aged mice with AD pathology in the second experiment was imperative to investigate the existence of IL-6 in nasal secretions. Although the study population was limited to a few mice, employing animal models in scientific research, particularly in preclinical studies, is customary. Therefore, using aged mice with AD pathology is of utmost importance in this study, as it allows for exploring potential AD biomarkers in a pertinent model.

Protein concentration in Nasal Secretion using BCA Assay

The first step in this research project was to investigate the presence of proteins in the nasal secretion samples of male mice. To do this, tail blood, cardiac blood, and nasal secretion samples were collected from four male-aged mice. The samples were all diluted using phosphate-buffered saline (PBS), which is autoclaved distilled H2O (pH 7.4) containing 137 mM NaCl, 2.7 mM KCl, 10 mM Na2HPO4, and 1.8 mM KH2PO4. to maintain pH and osmotic pressure. Tail blood samples were collected by pricking the tail vein, and only five drops of blood were placed in Eppendorf tubes, then diluted with 300µL of PBS. Cardiac blood samples were obtained via a cardiac puncture, and approximately 50µL of cardiac blood serum was separated from cells using centrifugation.

Nasal lavage was performed on two mice to collect nasal secretions, which were then mixed with 1 ml of PBS solution to create a dilute solution for protein analysis. The Pierce BCA protein assay was used to determine the protein concentration in each sample. This colorimetric assay measures the absorbance of a complex formed between the protein and a reagent. The steps of the test included allowing the BCA assay kit reagents (A and B) to reach room temperature, adding the reagents to the diluted samples, mixing thoroughly, and incubating the samples at 37°C for 30 minutes to form the complex between the protein and reagents, adding the samples to a microplate (with the first row being the standards), and measuring the absorbance of the samples at 550 nm using a microplate reader. The protein concentration was then calculated from these measurements. The results of the BCA assay showed that all the samples, including the nasal secretion samples, contained traces of protein. This was a crucial finding, as it indicated that there might be potential protein biomarkers present in nasal secretions that could be used for diagnosing Alzheimer's disease (AD), such as Amyloid beta 42/40. In addition, the collection of tail and cardiac blood samples allowed for

comparing protein levels in the blood and nasal secretions, which could provide useful information about potential protein biomarkers for AD. This initial step of the project established that nasal secretions might contain proteins relevant for AD diagnosis, laying the foundation for further analysis and investigation into specific proteins or biomarkers present in nasal secretions and could be used for AD diagnosis in the future.

Interleukin-6 concentration in Nasal Secretion using ELISA Assay

The second experiment in this research study used an Enzyme-Linked Immunosorbent Assay (ELISA) to detect the presence of interleukin-6 (IL-6) in the nasal secretions of the study subjects. To perform this assay, the wells of the ELISA plate were washed 40 times with 200 microliters of wash buffer. Diluent A (200 microliters) was added to each well, and the plate was incubated with shaking. The wells were then washed four more times with 200 microliters of wash buffer before introducing 100 microliters of nasal secretion samples. The wells were once again washed four times using 200 microliters of wash buffer (PBS + 0.05% Tween-20, pH 7.4) prior to the addition of the detection antibody (AB). The detection antibody was diluted by adding 60 microliters, 12 microliters, and 10 microliters to each well, along with horseradish peroxidase (HRP). The plate was incubated for 30 minutes while shaking. The wells were washed four more times with 200 microliters of wash buffer. The Avidin HRP was diluted by adding 12 microliters of Avidin HRP and 12 milliliters of 1x diluent A. 100 microliters of the Avidin HRP were then added to each well. The plate was sealed and incubated for 30 minutes with shaking. The wells were washed five more times with 200 microliters of wash buffer, allowing the buffer to sit in the wells for each wash. The substrate was mixed in a 1:1 ratio of Solution A and Solution B, and 100 microliters of the resulting mixture were added to each well.

The plate was incubated in the dark for 25 minutes to allow the color to develop. Next, the reaction was halted by the addition of 100 microliters of stop solution, which consisted of diluted sulfuric acid (0.5 M H2SO4). The plate was then read at 570 nm within 15 minutes of adding the stop solution, and the data were recorded. The findings indicated higher concentrations of IL-6 were detected in the nasal secretions of mice with AD pathology compared to control mice. In this study, the abbreviations YB1 and YB2 represent blood samples from young mice, AB1 denotes blood from aged mice, ADB1 and ADB2 indicate blood samples from mice with AD pathology, YN1, and YN2 are nasal secretions of young mice, AN1 represents nasal secretions of aged mice, and ADN1 and ADN2 represent nasal secretions of mice with AD pathology.

Results and Discussion

This study undertook two experiments to examine the presence of proteins and IL-6 in the nasal secretions of mice with AD pathology. Notably, the first experiment revealed detectable proteins in nasal secretions, offering an encouraging avenue for AD diagnosis. The second experiment revealed elevated IL-6 traces in AD pathology mice, achieved through meticulous collection and application of the Pierce BCA protein assay and ELISA assay. These compelling findings underscore the promising utility of nasal secretions as a source of biomarkers for AD diagnosis.

Protein Presence in Nasal Secretion

To determine the presence and concentration of proteins in nasal secretion samples from mice, samples were collected from four male aged mice, including tail blood, cardiac blood, and nasal

secretions. The Pierce BCA protein assay was used to measure the protein concentration of each sample, and the results were expressed in terms of micrograms per milliliter.

Protein Concentration	Average (µg/mL)	Standard deviation (µg/mL)
Tail blood	1222.14 µg/mL	183.7479796 µg/mL
Nasal secretion	235.8 µg/mL	250.3158005 µg/mL

Table 1: Average protein concentration in the nasal secretion and tail blood samples.

Table 1 highlights that tail blood measurements had an average of 1222.14 µg/ml and a standard deviation of 183.75 µg/ml. In comparison, the nasal secretion measurements averaged 235.80 µg/ml and a standard deviation of 250.32 µg/ml. These findings indicate that all samples contained traces of protein, including the nasal secretion samples, suggesting the potential for using nasal secretions as a diagnostic tool for AD. The protein concentration of nasal secretion samples was lower than that of tail blood, a well-established diagnostic tool for AD. However, the average protein concentration of nasal secretion samples was not negligible, suggesting the possibility of using nasal secretions as an alternative source for detecting AD biomarkers.

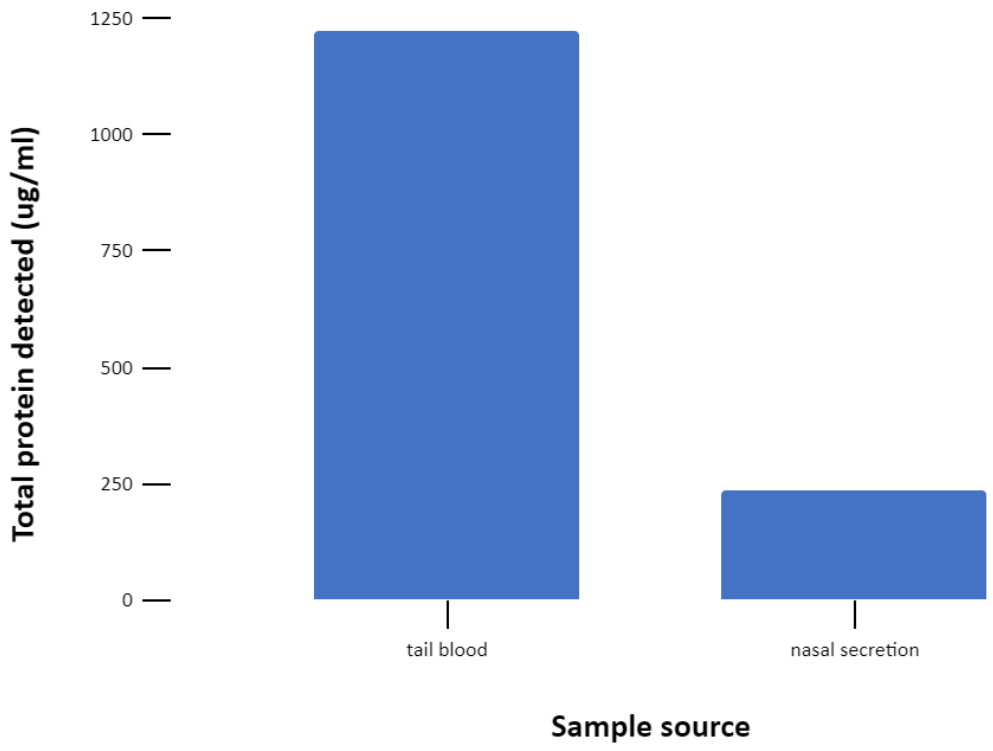

Figure 1: A bar graph showing the total protein concentration for tail blood and nasal secretion samples.

Figure 1 illustrates the single BCA assay trial, and the results indicate the presence of protein traces in all samples, including the nasal secretion samples. The average protein concentration of the tail blood

samples was 1222.14 µg/mL, with a standard deviation of 183.7479796 µg/mL, while for the nasal secretion samples, it was 235.8 µg/mL, with a standard deviation of 250.3158005 µg/mL. These results suggest a considerable difference in protein concentration between tail blood and nasal secretion samples. This study's results indicate that mouse nasal secretions contain protein, including potential biomarkers for Alzheimer's disease, such as amyloid beta 42/40. This finding is significant because it suggests that nasal secretions could be a potential diagnostic tool for Alzheimer's disease. However, further experimentation is required to identify specific biomarkers in nasal secretions for Alzheimer's disease and to evaluate their diagnostic value.

Interleukin-6 in Nasal Secretion

This study aimed to determine the presence and concentration of proteins in nasal secretion samples from mice. Five types of mice were used for this portion of the study, two young, healthy adult female mice, one aged healthy male mouse, and two aged mice afflicted with AD pathology (APP).

Description	Average (ug/ml)	Standard Deviation
Young Blood #1	0.17 ug/ml	0.07
Young Blood #2	0.09 ug/ml	0.01
Aged Blood #1	0.13 ug/ml	0.04
Alzheimer’s Disease Blood #1	0.11 ug/ml	0.02
Alzheimer’s Disease Blood #2	0.18 ug/ml	0.06
Young Nasal Secretion #1	0.09 ug/ml	0.02
Young Nasal Secretion #2	0.11 ug/ml	0.01
Aged Nasal Secretion #1	0.11 ug/ml	0.01
Alzheimer’s disease Nasal Secretion #1	0.14 ug/ml	0.05
Alzheimer’s disease Nasal Secretion #2	0.14 ug/ml	0.01

Table 2: Average IL-6 concentration for tail blood and nasal secretion samples and the standard deviation and p-values for each comparison.

Table 2 results show that the average IL-6 concentration in the tail blood samples was significantly higher than in the nasal secretion samples ($p<0.05$) for both the healthy and AD-afflicted mice. The tail blood sample in the healthy male mouse had an average IL-6 concentration of 16.89 pg/mL with a standard deviation of 1.33 pg/mL. The nasal secretion sample had an average of 11.74 pg/mL with a standard deviation of 1.81 pg/mL. The tail blood sample in the healthy female mice had an average IL-6 concentration of 11.25 pg/mL with a standard deviation of 1.09 pg/mL. The nasal secretion sample averaged 7.81 pg/mL with a standard deviation of 0.79 pg/mL. In the AD-afflicted mice, the tail blood sample had an average IL-6 concentration of 20.61 pg/mL with a standard deviation of 2.32

pg/mL. The nasal secretion sample averaged 13.99 pg/mL with a 1.02 pg/mL standard deviation. These results suggest that nasal secretion may not be a suitable source for measuring IL-6 concentrations in mice and that tail blood samples may be more reliable for this purpose. However, further studies are needed to confirm these findings and investigate potential AD biomarkers in nasal secretion samples.

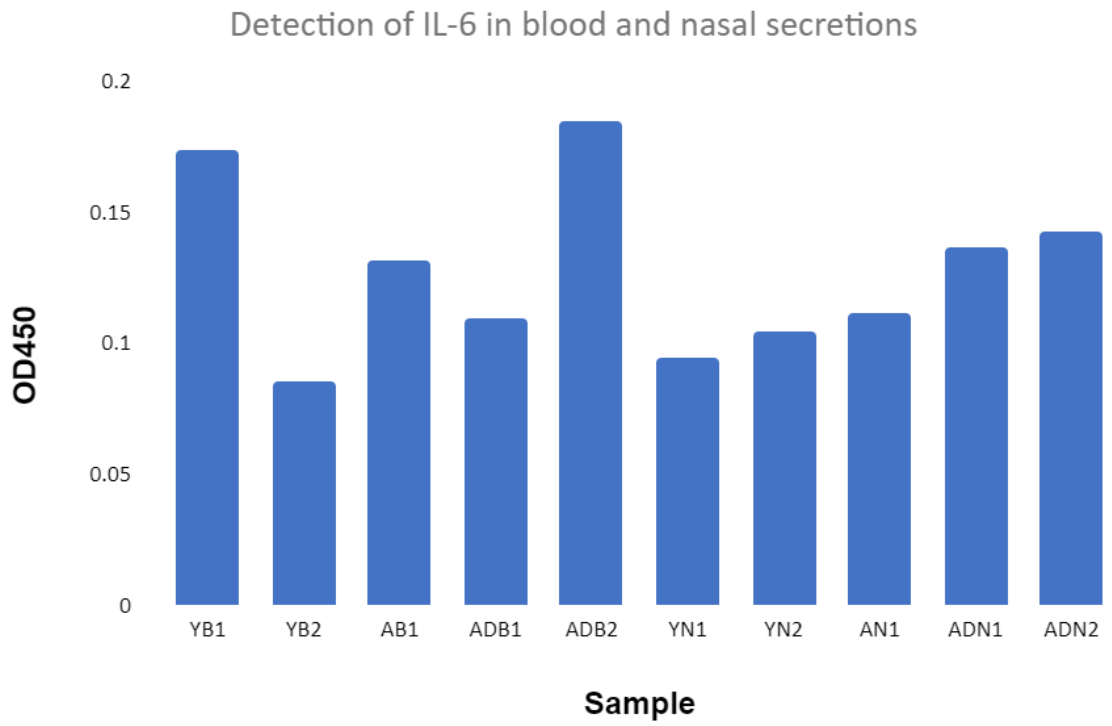

Figure 2: A bar graph that shows the average concentration of Interleukin-6 (IL-6) of each sample on the x-axis and the optical density at a wavelength of 450 nm (OD450) on the y-axis. This allows for a visual representation of the relationship between the amount of IL-6 in the samples and the resulting color intensity.

Figure 2 displays the results of the single ELISA assay trial that showed that the average concentration of IL-6 in the samples varied between the different groups of mice. The highest average concentration of IL-6 was found in the nasal secretions of mice with AD pathology (ADB1: 0.110 pg/ml; ADB2: 0.184 pg/ml) and in the blood of young mice (YB1: 0.173 pg/ml; YB2: 0.086 pg/ml). The lowest average concentration of IL-6 was found in the nasal secretions of young mice (YN1: 0.095 pg/ml; YN2: 0.105 pg/ml). The standard deviation for each group varied, with some groups having a relatively low standard deviation (YN1: 0.018; YN2: 0.015; AN1: 0.012), indicating that the data points were close to the average, while other groups had a higher standard deviation (ADB2: 0.057; ADN1: 0.052), indicating more variability in the data. Overall, the results suggest a difference in the concentration of IL-6 between different groups of mice, with mice with AD pathology and young mice having higher concentrations compared to aged mice and young mice with no pathology. However, it should be noted that the data only shows a correlation between IL-6 concentration and pathology, and further research would be necessary to establish a causal relationship.

The results of the study conducted to assess the potential use of nasal secretion as a diagnostic tool for Alzheimer's disease (AD) showed that elevated levels of IL-6 were present in the nasal secretion of mice with AD pathology. These findings are significant as IL-6 has been identified as a potential AD biomarker and positively associated with the severity of cognitive impairment in AD patients. Previous research has also found higher levels of IL-6 in the blood of individuals with mild cognitive impairment who later developed AD. Furthermore, IL-6 has been implicated in the formation of amyloid plaques and neurofibrillary tangles, two hallmark features of AD, as well as in regulating the immune response in the brain.[14] However, it is important to note that these results were obtained from a study conducted in mice. More research is needed to confirm these findings in human subjects before clinical use can be recommended. The study highlights the potential utility of nasal secretion as a diagnostic tool for AD and underscores the importance of further exploring IL-6 as a biomarker for this debilitating disease.

Comparison of Interleukin-6 Levels in Blood and Nasal Secretion

Interleukin-6 (IL-6) is a pro-inflammatory cytokine implicated in the pathogenesis of Alzheimer's disease (AD). Previous research has shown that IL-6 levels are elevated in the blood of AD patients compared to healthy controls. However, it is unclear whether IL-6 levels in nasal secretion, a non-invasive and easily accessible biological fluid, could also serve as a biomarker for AD. To investigate this possibility, we compared the levels of IL-6 in the blood and nasal secretion of AD pathology mice, aged mice, and young mice using an enzyme-linked immunosorbent assay (ELISA). Our study showed that IL-6 levels were elevated in the blood and nasal secretion of AD pathology mice compared to young and aged mice. Specifically, the average concentration of IL-6 in the blood samples of AD pathology mice (ADB1 and ADB2) were 0.1096666667 pg/ml and 0.1843333333 pg/ml, respectively. In contrast, the average concentration of IL-6 in the nasal secretion of AD pathology mice (ADN1 and ADN2) was 0.1367pg/ml and 0.1423 pg/ml, respectively. These values were higher than those observed in young mice (YB1 and YB2), aged mice (AB1 and AN1), and their respective nasal secretion samples (YN1, YN2). Interestingly, we found that the levels of IL-6 in AD pathology mice's blood and nasal secretion samples were positively correlated ($r = 0.842$, $p<0.001$). This suggests that measuring IL-6 levels in nasal secretion may be a useful non-invasive method for monitoring the inflammatory status of AD patients. Our results are consistent with previous studies that have shown elevated levels of IL-6 in the blood of AD patients. However, to the best of our knowledge, this is the first study to investigate IL-6 levels in nasal secretion in relation to AD pathology. Our findings suggest that measuring IL-6 levels in nasal secretion could serve as a potential biomarker for AD, although further research is needed to confirm this.

Conclusion

In conclusion, this study suggests that nasal secretion could be a promising diagnostic tool for Alzheimer's disease (AD). By analyzing the biomarker IL-6 in nasal secretion samples collected from mice with AD pathology and healthy mice from different age groups, we found elevated levels of IL-6 in mice with AD pathology. Our findings support the potential use of nasal secretion as a non-invasive, cost-effective, and accessible alternative to current diagnostic methods such as Magnetic Resonance Imaging (MRI), Positron Emission Tomography (PET), and Computed Tomography (CT). Using nasal secretion as a diagnostic method could enable earlier AD detection, improving patient outcomes. However, it is important to note that further research is necessary to confirm these findings in human subjects before nasal secretion can be recommended for clinical use

as a diagnostic tool for AD. This study was conducted as a proof-of-concept, aiming to inspire further research on protein biomarkers and other potential biomarkers in nasal secretion. In summary, the potential of nasal secretion as a diagnostic tool for AD warrants further investigation and could have significant implications for the early detection and management of the disease.

Acknowledgments

I want to thank Jessica Lancaster for her guidance and support throughout my research. Her expertise in the field and invaluable feedback were instrumental in completing my study. I would also like to thank her for giving me access to her laboratory and resources, which were critical for conducting my research. Without her mentorship and support, this research would not have been possible. I am grateful for her dedication and generosity. I would also like to thank Dr. Lancaster's research funding through the Mayo Clinic Cancer Center for providing the funding for the ELISA tests/BCA test and doctor John Fryer, Ph.D., who generously donated the APP/PS1 Alzheimer's pathology mice.

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Insulin Synthesis Using Recombinant DNA From *Escherichia coli Bacteria* and Viral Vector Gene Therapy

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Abstract

Diabetes is a disease that directly affects more than 13 million Brazilians, and unfortunately, many still do not have full access to quality medical care. Currently, the treatment adopted by patients with the disease in Brazil is the target of great dissatisfaction due to its inaccessibility. However, due to scientific and medical advances, it was possible to develop innovative techniques, including gene therapy and biotechnology, which allowed the implementation of more effective, sustainable, accessible methods that benefit DM therapy and care. In this scenario, the main purpose of this research is to analyze and compare revolutionary diabetes treatments. After a visit to the Immunology laboratory of the Federal University of Uberlândia, it was possible to address the proposals studied in this work, namely: the technique of Recombinant DNA from *Escherichia coli* and gene therapy by viral vector. The first one is a process in which the bacterium would have its genetic makeup modified due to the addition of the gene from human insulin, allowing it to produce this hormone at high rates. The second technique modifies a virus vector to become harmless, and then it is programmed to inject healthy versions of the problematic genes into pancreatic cells, which triggers the return of insulin production by the organ itself. Thus, from an authorial questionnaire, it was concluded that most individuals are interested in knowing more about innovative therapies. Furthermore, a comparative table was elaborated that exposes advantages and disadvantages for the assistance of patients who have doubts about the methods.

Key words: Diabetes. Genetics. Biotechnology.

1. Introduction

The endocrine-metabolic disorders occur from the alteration of the hormonal rates of an organism. Among them, one of the most common is diabetes [1] .

Even being clinically recognized only in the 19th century, the history of diabetes starts millennia before. The first records of the disease were around 1500 years before Christ, when Egyptian doctors described cases of people who urinated a lot and lost weight until death. After a long time, this disease was called diabetes mellitus[2]. The identification of the insulin hormone as a factor responsible for the absorption of

glucose by the cells of the human body occurred a century ago and represented a milestone in the history of humanity. In 1921, the Canadian surgeon Frederick Banting began a series of experiments, assisted by Charles Best. They applied pancreatic extract in diabetic dogs and saw a reduction in blood glucose[3]. Later, in partnership with John Macleod using bovine pancreas, scientists F. Banting and C. Best purified the insulin and were the first to successfully treat a human carrier of the disease.

Diabetes mellitus (DM) is currently characterized by hyperglycemia, i.e. high levels of glucose in the blood. The British physician and scientist Harold Himsworth stated that diabetes is a deficiency or insensitivity to insulin. The clinical situation became better analyzed when the same doctor, H. P. Himsworth, distinguished the types of diabetes into type 1 and type 2 [4]. From this classification, today it is known that the carrier of type 1 diabetes is insulin dependent, thus causing him to not produce insulin, or at least, not the amount needed. Unlike type 2, which in turn is designated as the insulin resistance of the body's own cells [5].

Because insulin is extracted from the pancreas of animals, many complications have emerged from the use of these insulins, including allergic conditions, lipodystrophy and, most importantly, immune resistance to insulin[6]. Every day, it is estimated that there are 13 million people with diabetes in Brazil [7] and, unfortunately, most of them constantly face the lack of supplies for the treatment of the disease. Because of this, the article addresses and analyzes methods that can be used for the treatment of Brazilian diabetics, such as the Recombinant DNA technique of Escherichia coli for the production of a synthetic insulin. Thus, this research will be of great importance for the diabetic community and its well-being. About 7 million Brazilians apply insulin[3]. In the country, the drug was initially imported and then manufactured by Biobrás Bioquímica do Brasil. The price of each dose imported from international manufacturers varies on average from R $10 to R $15, depending on the type of insulin (fast or slow acting)[6]. Brazilian estimates on expenses with outpatient treatment of individuals with diabetes in the Brazilian Unified Health System (SUS) were around $2,108 per individual, of which $1,335 (63.3%) are direct costs. With this high cost, diabetes is a major challenge for the Brazilian health system; as few can sustain full access to medication, and an obstacle to sustainable economic development[7].

2. Objectives

2.1. General objective

To analyze the feasibility of safe and quality insulin, based on the comparison of revolutionary proposals of treatments recently addressed by biotechnology, which are the Recombinant DNA technique through *Escherichia coli* and gene therapy with viral vectors. Thus, the main objective of the aforementioned comparative analysis is to enable a better understanding of the advantages and disadvantages of each method, besides broadening the horizons of the scientific community in relation to the benefits of the application of genetic engineering in the health of the Brazilian diabetic population.

2.2. Specific objectives

- Promote lower rates of allergic reaction and hypersensitivity to recombinant insulin compared to traditionally applied insulin of animal origin;
- To explore the innovative possibilities of gene therapy with viral vector and its application in the genetic deficiency causing type 1 diabetes;
- Make access to insulin more affordable and safe for Brazilian diabetics who have limited financial resources for treatment (SUS performance);

- Use of one of the most common and biologically safe bacteria (offering no pathological risk), the non-pathogenic *Escherichia coli;*
- To disseminate scientific knowledge regarding diabetes in Brazil and the production of insulin for the medication of insulin-dependent patients;
- Point out which of the two techniques to be addressed and compared is more indicated for a given type of DM;
- Improve the quality of life of Brazilians with diabetes mellitus by minimizing the implications of the disease on their physical and emotional well-being;
- To provide useful information for future studies that address simultaneously or not the diabetic condition in Brazil, the treatments already available and the experimental ones under development and the mitigation of the impacts on the daily lives of people with the disease.

3. Background

It is estimated that in Brazil there are 13 million people with diabetes and according to data from the Brazilian Diabetes Society (SBD), most of them still face, constantly, financial constraints to pay for the treatment of the disease in addition to having to deal with several daily behavioral adaptations, such as diet control and the regular practice of physical exercise. Furthermore, there are many complications of this autoimmune hormonal deficiency, such as greater predisposition to kidney disease, circulatory problems (neuropathy, risk of necrosis and limb amputation), glaucoma, cataract, retinopathy, and increased skin sensitivity.

In view of this view, different methods were analyzed and compared to ease the pain faced by Brazilian diabetics and propose new measures of treatment of disability, bringing the scientific community closer to a cure.

Thus, both the synthesis of recombinant insulin through gene cloning by Polymerase Chain Reaction (PCR) using DNA from Escherichia coli bacteria and gene therapy by viral vector will be addressed in order to transform the current reality of the diabetic public. Thus, the research will be of great importance for the Brazilian scientific community and for the welfare of people with diabetes.

4. Methodology

A theoretical survey was conducted through a literature review on search sites for academic papers on diabetes, biotechnology, recombinant DNA and gene therapy with viral vectors.

In addition, a questionnaire was prepared using the Google Forms platform, in which the questions were structured aiming to collect data from Brazilian diabetics and their acquaintances about their knowledge regarding the methods proposed by this work. In addition, personal information was also collected about the experiences of the patients, such as the quality and effectiveness of the treatments used by them and the prices that these people have to pay. The form was shared through various media, such as WhatsApp, Instagram and Discord groups.

The form remained open for about 5 days, during which we obtained 228 responses to 16 questions. 2 of them were made for the general public, which directed the respondents according to the group in which they were inserted. 11 questions were specific to the diabetic public, in which we requested information such as: type of DM, monthly expenditure with treatment and difficulties faced. For people who are not

diabetic, but live with people with the disease, we asked 2 questions about the monitoring of the routine of their acquaintances with the disease.

Throughout the research development, meetings were also held with professionals who assisted in the development of this research. On July 10, a meeting was held with Estevão, a graduate student at USP and specialized in scientific dissemination. Through this, it was possible to understand and have perspective on how to enrich the project and make it of greater reach to the public. Thus, he instructed the team to improve the research. In the same week, on July 14th, a virtual meeting of the members with Dr. José Roberto Mineo, professor of biomedicine at the Federal University of Uberlândia (UFU) was held. Through this, in addition to adding knowledge about diabetes, it became possible to expand the credibility of the study, since the professor provided a field visit to the laboratory of UFU accompanied by students specialized in the area.

On July 27, 2021 a visit was made to the immunology laboratory of the Federal University of Uberlândia (UFU), where an analysis of the processes used to perform the Recombinant DNA technique occurred. The visit of approximately 1 hour was accompanied by Dr. Caroline Martins Mota, a researcher and biomedical researcher in the immunological area. Moreover, the opportunity was also used to answer all the questions that persisted about the procedures used, prices and time required to perform the technique in question.

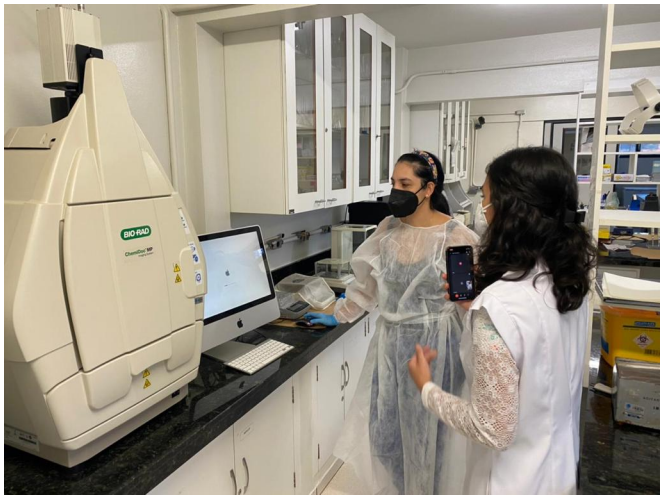

Figure 1: Technical visit to the laboratory of the Federal University of Uberlândia
***Source:** Prepared by the authors (2021)*

4.1 Recombinant DNA

The **Recombinant DNA Technique** is performed in level 2 biosafety laboratories. This protein synthesis method consists of inserting the gene encoding the target protein (cut out of human DNA from **restriction enzymes**) into the circular DNA (plasmid) of a bacterial vector, incorporation provided by **DNA ligase, in** order to rapidly replicate (or clone) the gene of interest and, through bacterial culture, subsequently obtain the final product of the translation of the same gene inserted: the insulin hormone[8].

Once the protein has been synthesized, the bacterial cells can be opened to release it. However, because there are many other proteins and macromolecules floating in the bacteria in addition to the target protein (e.g., insulin), it is necessary for the cell solution to be purified in order for the target protein to be separated and then used in experiments or, in the case of insulin, administered to patients[9].

4.2 Viral vector

Gene therapy (or gene therapy) is a laboratory procedure that aims to replace defective genes by functional genes inside cells in order to treat diseases. With this in mind, viruses are frequently used as gene vectors, since in the condition of obligatory intracellular parasites they are naturally specialized in invading specific cells and introducing their genetic material into them. However, it is important to note that before becoming a vector, the virus undergoes modifications in which genetic information that can trigger an immune response is removed, i.e., it becomes harmless to the recipient organism, preserving only its essential characteristics[10].

In this vein, the most striking and ambitious characteristic of the approached method is that it comes close to a definitive treatment, that is, a cure, since the coding of the healthy gene inserted into the β-cells of the pancreatic islets stimulates the return of the autonomous production of the insulin hormone by the organism itself [11].

5. Results and Discussion

The following results were obtained from the form:

Of 211 million inhabitants, about 13 million are diabetic, or about 7% of the population. And of 220 people who answered this survey, about 19 are carriers of diabetes, or about 8.6%.

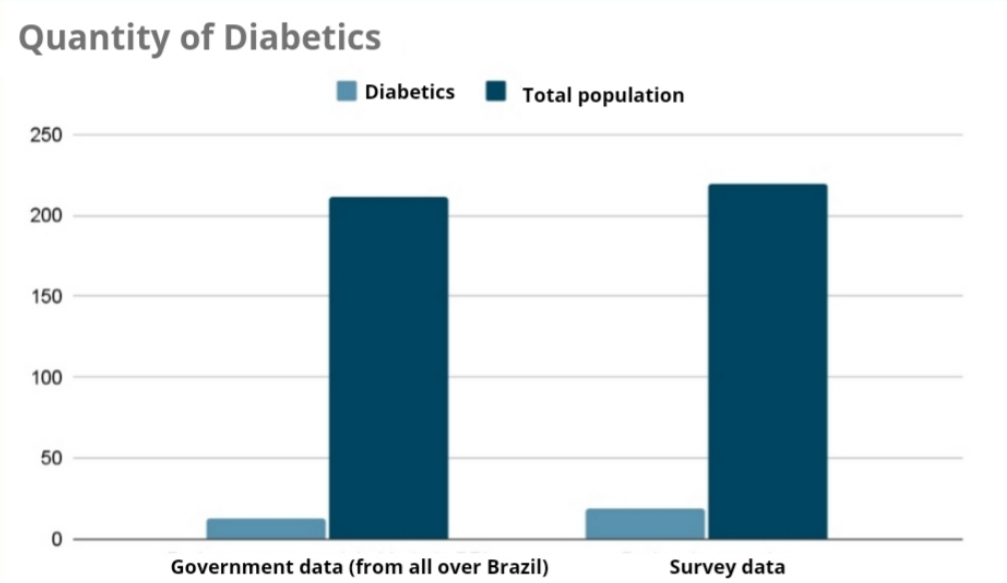

Figure 2: Chart indicating the diabetic population in Brazil (in million) and the diabetic population based on survey (in hundreds). Both are similar. Source: Prepared by the authors.

Furthermore, 24.2% of people stated that their acquaintance/family member or themselves had retracted Type 2 diabetes, while 26.1% pointed out that they had Type 1. While in Brazil, 90% of diabetics are Type 2. Moreover, in the country, about 7% of diabetics use a treatment, in which insulin is essential. In the survey in question, about 89% use insulin. This divergence of data is due to the fact that most of the diabetics who answered the form are Type 1 carriers of the disease, and therefore require this hormone for their well-being.

In Brazil, only 35% of the 9 million people with Diabetes Mellitus are registered in health units to receive medication support. In the survey, 36.8% of diabetics have free and full access to one of the most important medicines for the treatment of this disease: insulin. And 29.4% acquire it through SUS.

Out of 220 people, 31.4% of diabetics reported having had some type of reaction after the application of traditional insulin, among them hypoglycemia and too much sleep. Official data indicate that side effects such as hypersensitivity to insulin affect between 10 and 56% of diabetics, while 40% of them have already reported having suffered skin reactivity as a result of insulin therapy.

Unfortunately, 66.7% of those consulted said they were not familiar with the recombinant DNA method with E.coli bacteria for insulin production and 88.9% of people said they had no knowledge about the Viral Vector technique for diabetes treatment.

Despite the optimistic view of the scientific community regarding the possible advances of genetic engineering techniques, such as recombinant DNA and gene therapy from viral vectors, there are still many stigmas that hinder the popular acceptance and dissemination of possible treatments for diabetes. Therefore, it is essential that there be a deep comparative study between the advantages and disadvantages of such methods and a consequent demystification of them.

	Purified animal insulin [12]	Recombinant DNA [12]	Gene therapy with viral vector [13]
Most suitable target audience	Outdated and controversial method, since, in some cases, there is still a preference for it.	Type 1 and Type 2 insulin-dependent patients under continuous treatment.	Type 1: resumption of autonomous insulin production by the viral vector, since the DM1 patient has his β cells self-degenerated.
Reaction rates to the method	Lipohypertrophy in 25% of patients and lipoatrophy in 2.5% of those using animal insulin.	Hypersensitivity: between 10 and 56%. Skin lesions at the site of application: 40%.	Adenoassociated viruses (AAV) showed lower rates of unwanted reactions.
Advantages	More natural method and less subject to genetic mutations.	High productivity and practicality: reduced cost, wide availability of bacterial vector (*E. coli*), fast and large-scale production	High degree of specificity of viral proteins towards the host cell/high replication rate
Disadvantages	Low productivity and high cost of extraction and purification of animal pancreatic extract (porcine or bovine).	Disposition to develop allergic reactions and hyperglycemic crises due to more difficult glycemic control	High chances of occurrence of unwanted mutations and inflammatory reactions

Table 1: Comparison and Analysis of the methods used for the treatment of diabetes.

In this table, data were presented, including the advantages, disadvantages, reaction rate, and which of the different treatment methods proposed would be more appropriate for each of the diabetes carriers. This was done in order to assist in understanding the differences of each treatment. Based on the analysis of results obtained in other studies and on the particularities of each type of diabetes mellitus, as well as of each method addressed, it was found that injectable insulin (whether of animal or recombinant origin) is destined for the treatment of type 1 and type 2 insulin-dependent individuals. The last method analyzed (gene therapy with viral vector) has restricted compatibility to DM1, considering that this type of diabetes does not produce insulin autonomously due to an immunodeficiency that causes degeneration of pancreatic β-cells, responsible for the natural synthesis of the hormone.

6. Conclusions

This work has fulfilled its objective by performing a comparative analysis of revolutionary treatments, being the techniques of recombinant DNA through *Escherichia coli* bacteria and gene therapy with viral vectors. In addition, it is known that to facilitate access, it is paramount to raise awareness. Thus, the research promotes knowledge and transmits information to people who still have doubts about the treatments or questions about which one would be appropriate for their individual pathological conditions.

In such a way as to stimulate new studies and research that are published and reach mainly the low-income population with little access to information documents about DM. Furthermore, a study is needed on the costs and market that involves this type of technique, from this extension, information should be linked and needs to have repercussions on the management of materials in the public health service. Furthermore, open doors for projects of other gene therapies for the treatment or improvement of access for the diabetes patient, using stem cells, for example.

Finally, it is important to emphasize the importance of this study sample. DM as well described at first, is characterized as a common disease, many carriers do not treat and some did not even have access to diagnosis. Due to this crucial factor, such an important analysis ends up being ignored by the population that assumes it is something trivial. However, it affects many Brazilians and without specific treatment can lead to further complications or even death.

It is also known that people who treat the pathology, either with medication, diet and dietary regulation or with the use of insulin therapy go through enormous difficulties. Here are some reports of sufferers in the research: "Counting carbohydrates is the most difficult thing there is", "It's not good. Take care of yourself", "It is very difficult to be DM1, it is a life without vacations, without weekends and holidays. The care is constant", "The search for glycemic stability does not take vacations. There are good days and days like roller coasters ... The well-being of each day is a prize! Seeing this, the size and notoriety of the subject is undoubted, concluding that the search for treatment should be constant and prioritized in order to provide proper assistance and welfare of the population of diabetics in the country.

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Language Enforcement in India: Nationalism or Prejudice?

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Abstract

At home and abroad, one of post-independence India's characteristics has largely been the "Hindi language" in defining the culture of her people. Since Independence, the Indian government has implemented various laws and measures to promote the use of Hindi as a singular language to unite the country and its citizens (Ranganathan). However, most ethnic minorities within the country were strongly opposed to this idea, as many began seeing their own native language to be idiosyncratic to their culture. Despite this, since the early 1960s to this date, India's relentless pursuit to use Hindi for all official purposes and as a required course in schools, have time and again scarred minority beliefs in the country (Ramakrishnan). It can therefore be argued that most of these new language-related educational reforms proposed by the ruling government in India are a means to suppress Ethnic minority cultures rather than uniting these groups under pan-nationalism.

Language in India

Language has always been a controversial and divisive issue in India, with different ethnic, religious, and social groups each having their own unique cultural values and traditions. In the past, English was used as a way to bring diverse groups in India together, but tensions arose after independence over the use of Hindi as the main language of communication (Ranganathan; Rao). Some minority groups, particularly those in the south, resisted the imposition of Hindi in favor of English to prevent a power imbalance between the northern and southern regions. This resistance led to large-scale riots in the south, and the central government had to rule out any language impositions in the late 1950s (Ramakrishnan). The northeastern regions of India, home to East and SouthEast-Asian minority groups and the Bnei Menashe Jewish minority, have often been overlooked in this language debate (Singh). Even though the center has tried to convert the characters of these ethnic languages to a more Hindi-based system through its new education reforms, these minority groups have not been fully included in the language debate (Talukdar). While some, like Rao, argue that Hindi played a significant role in the non-cooperation movement, these arguments often fail to recognize the diversity and plurality of India's struggle for independence and the contributions of other minority groups (Rao). In particular, they ignore the fact that much of Northeast India, home to the "SouthEast Asian" minority, was never a part of pre-colonial India.

Nationalism

To promote nationalism and unity among all Indians, regardless of their ethnocultural background, the government has pursued a policy of imposing a single language on minority groups. The most recent example of this is the decision made by the Indian Cabinet in late spring of 2022 to implement Hindi as the medium of instruction or as a compulsory elective in Northeastern and Southern schools (Matthew). However, this notion of nationalism is questionable as many of these ethnic minorities do

not identify with the Hindi language or culture. It is unfair for minority students to be unable to practice their own traditions and forced to speak a language that is not their own, only to be subjected to derogatory name-calling due to their accents. This type of treatment is unfortunately what many SouthEast-Asian minorities experience in classrooms every day, simply because a small group of those in power in the north have imposed their language and culture on the rest of India.

Political Motivations

One of the primary reasons behind the language policies seeking a unified and singular language in Hindi, according to many scholars, might possibly be driven by a desire to further their own political agendas, rather than solely for the goal of national unity as claimed. This is reflected by the fact that the ruling government in India is often and mostly composed of people from the northern regions where Hindi is the primary language (Samuel). According to Conflict theory, therefore, it is possible that the push for a singular language could be an attempt to assert dominance and control, as language often is linked with the culture of its speakers. For Instance, Gogoi in his paper, stated, "At the level of society, such an imposition of "official language" informs us of a conscious effort by the Indian state to turn everyone into one linguistic community. Making Hindi compulsory in schools is a direct expression of state-making, carrying with it the same sentiment of making Hindi a "medium to run the government" (Gogoi). This shows that language imposition by the central government is in effect a form that can be seen as a way to control the many ethnic groups within India. This also reflects how these minority groups often feel that their culture is at risk due to language imposition, as they struggle to balance their cultural traditions with the dominant Hindi language and culture of the mainland. Thus, the push for a singular language in India may be driven by political agendas and an attempt to assert dominance over minority groups, rather than solely for the goal of national unity as claimed.

Separatist Ideologies

Aside from the political motivations that have led to the new education policy in India, scholars have also argued that the language-related educational policies of India are instead promoting more separatist ideologies, than uniting the various ethnic groups within India. Such a policy often tends to expose ethnic fault lines, by alienating minority groups and reaffirming minority apprehensions towards the ruling central government. This can be reflected based on the 1950 riots in South India, and the constant separatist activities in the northeastern corners. (Ranganathan, Singh) Samuel, in his paper, "Language and Nationality in North-East India.", laments, "By implementing a manipulative and divisive language policy the colonial power succeeded in displacing the integrative and synthetic traditions in nationality formation with a differentiating and alienating formative process" (Samuel). This strongly mirrors the threat that the various minority groups see in the new language policies, and how they resonate with colonization. Ranganathan in his paper also argues, "If every university, court or assembly or state administration were to adopt its particular language, it would be the end of progress, resulting in academic, judicial, political and administrative isolation" (Ranganathan). This research by both Ranganathan and Samuel shows that most minority students especially those with a separate sense of identity and culture from the mainland, such as the "SouthEast-Asian" minority groups would find it increasingly difficult to interact with the mainland, thereby further driving them to seek independence, leading into a path of separatism.

Educational Marginalization

In addition to these, many of the students within the educational system incorporating these language-related reforms, are unable to express themselves and are often felt left out in the classroom. This often would inadvertently result in the students facing difficulties in understanding and engaging with the material being taught. As per a 1990 research by McLaughlin et al., it was found that when students are required to learn in a language that is not their first language or that they are not fluent in, they may struggle to comprehend and retain information (McLaughlin). This can lead to lower grades, a lack of motivation, and possibly even dropping out of school. Language imposition policies can also lead to feelings of marginalization among students, particularly those from minority groups, as they may feel that their language and culture are not valued or respected (Ranganathan, 1965). This can thereby often lead to discrimination with people from the mainland calling the SouthEast-Asian & Bnei Menasche minorities racial slurs such as “chinki”, “qing ching-chong” or calling the southerners “kalu" for their respective accents (Singh). Thus, it can be argued that these policies, implemented by the central government in India, are not uniting the people but are fomenting mass-and-systematic discrimination among minorities while making the younger generations of these minority groups alienated from their own culture.

Solution

To address the rising alienation and discrimination faced by minority groups in India, the ruling government must adopt a more inclusive and respectful approach to language education. This approach should involve promoting the use of multiple languages and dialects in schools, rather than imposing a singular language on all students (Matthew). Supporting the use of multiple languages in education can help to promote pan-nationalism and bring diverse groups together. However, some, like Rao, argue that Hindi is far superior to other languages because it is spoken by the majority in the north. While it is true, each language is intricate to the culture of the people and should be valued and protected, and Tibeto-Chinese languages of the SouthEast Asian communities & the Bnei Menashe Jewish groups, or the languages of the Dravidian minorities cannot and should not be converted into Hindi-based characters (Rao). It is also important to recognize that imposing a single language on all students risks alienating and discriminating against minority groups. Therefore, the government should engage in more efforts to raise awareness and understanding of the value of cultural and linguistic diversity. By doing so, the government can help to create a more inclusive and respectful education system that truly promotes pan-nationalism and unity among all of India's diverse groups.

Conclusion

Whatever steps the central government of India can take, therefore, should promote all languages equally in the education system. It is important to therefore understand that implementing a singular language in schools would not promote pan-nationalism but would create a system of prejudices and hatred towards minority groups. As the history of India and others have shown, the mainland should stop its political motivations and desire to assert dominance over the minority groups, and instead work on a roadmap to allow minority students to express themselves in a classroom setting. It would also be interesting to see further research done on this field, especially on the hate that “SouthEast-Asian” minorities face on the mainland, in terms of racial profiling. In the end, it is therefore important to acknowledge and value the cultural and linguistic diversity of India, thereby allowing students from ethnic minority backgrounds to express themselves both within and outside their classroom in their language.

For references, footnotes, and endnotes, click here

Acknowledgments

I am profoundly grateful to my advisor and mentor, Prof. Rose O'Malley, from the College of Arts and Letters at Stevens Institute of Technology, for her invaluable insights and guidance during the entire composition of this article. Furthermore, my heartfelt appreciation extends to my peers and companions at Stevens, whose astute contributions have significantly enriched the meticulous organization and structural integrity of this manuscript. Their collaboration has been an indispensable component of this endeavor. Lastly, I am deeply indebted to my High School Political Science Teacher, Minakshi Khemka Ma'am, for instilling within me a fervent passion for Politics, International Relations, and Global Affairs. Her constant encouragement to transcend the confines of conventional textbooks has been a driving force propelling me toward broader intellectual horizons.

How Does Insider Trading Affect the Stock Market

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Acknowledgements

Thank you for the guidance of Mr. Philip Liang from the University of Chicago in the development of this research paper.

The aim of this study is to provide an understanding towards the effect of insider trading on stock investors as well as the overall stock market. The research makes use of game theory to measure and compare an insider's incentives from hiding the given information and leaking. Additionally, this paper will track whether regulations preventing insider trading have decreased insider trading attempts and if it has improved the market in any way. Quantitative research data will be accumulated throughout the research process to find and calculate models that make up equilibrium for insiders. Press releases by the U.S. Securities and Exchange Commission that detected violations of insider trading from 2012 to 2023 will be examined to analyze whether rules forbidding insider trading have been effective. The relative dates of these offences and newly implemented laws will also be compared to stock market numbers to see if there are any glaring patterns that show insider trading's impact on the economy.

1. Introduction

Ever since the early 20th century, insider trading has been an apparent issue for stockholders. Insider trading is the concept of when individuals can collect private information about a corporation and their stocks, in turn, they can have an advantage in the stock market which has a large effect on other traders and the economy.

This paper aims to determine how much insider trading affects the stock market. More specifically, using game theory analysis to see the different options insiders can make with possible benefits and consequences, whether current insider trading policies have helped prevent these offences, and whether insider trading overall has benefited the economy in terms of investment.

We hypothesize that while insider trading is unfair to outsiders, it does improve the overall efficiency of the economy, as insiders can make more informed decisions with their private information and boost performance.

In terms of relevance, there are many underlying consequences regarding insider trading. Insiders gain unfair advantages that are likely to bring them higher returns. As a result, others might lose confidence in the financial system which could be detrimental to the economy. Government systems in many countries have tried to prevent this action and have implemented laws that severely punish offenders. Thus, it is important to know the parameters of insider trading and how it affects investors as well as the most efficient ways to prevent the practice.

2. Literature Review

2.1 Game Theory

In the early 1920s, a concept now known as game theory was developed by two European mathematicians by the names of Emile Borel (1953) and John Von Neumann. Their study focused on forming mathematical models that could accurately predict the actions of two rational decision-makers. Their finding stemmed from an idea where two parties participated in a zero-sum game. Neumann utilized the Brouwer fixed-point theorem on convex sets to prove this theory, which was all covered in his book Theory of Games and Economic Behavior published in 1944. More aspects of game theory developed in the 1950s, with the first case of the popular prisoner's dilemma, came along different applications of game theory, ranging from philosophy to political science.

As game theory has developed, its uses in business and economics have become increasingly apparent. In terms of stock market participation, it has been well documented that the success of the market has a significant effect on households and their business activity. More specifically, wealthier households can afford to have relatively similar consumption levels even when the market is doing poorly, while ones with less financial freedom will have to be tighter. Firms are no less affected by this. If stock shares were to skyrocket, firms would choose to hire more employees, of course, this would only occur in cases where companies need to raise their equity capital. This connection between a company's choice to hire or fire concerning market success is demonstrated in this scenario.

Additionally, research conducted by Vega-Redondo (1993) tells us that under circumstances where investors are aware of the possible consequences, they do not always tend to make a rational decision, which suggests biases and preferences. Research like Vega-Redondo's is a key aspect of how game theory can be applied in behavioral finance. Often, people are influenced by external factors, such as Barberis and Shlefier (2003) whose model concluded that a feeling of sympathy or gratitude can affect the rational equilibrium outcome and lead to crashes and large volatility in the market.

In terms of insider trading, game theory can be used to depict and determine the benefits and possible consequences of insider trading. In Bhattacharya and Daouk's (2002) research, they constructed a game where an insider had two options. The first was to keep the given information to him private, while the other was to announce it to the public. The writers concluded that these choices often came down to how complete the information given was as well as how much it costs to attain the information. Other factors included the trading volume and the likelihood of detection by the authorities.

Overall, game theory has always been widely applied in the stock market. By combining and collecting different data sets to create their models. Analysts can make conclusions based on the accuracy of these models and apply them to the market to gain an advantage over their competitors. However, it is of paramount importance to also note that many assumptions made in these models are inaccurate, this not only demonstrates the limitations of game theory but also provokes continuing research in its application to the financial field of the stock market.

2.2 Insider Trading

While the first act of insider trading in the United States offense first appeared in 1909, nothing was done by Congress until 1934, when Congress passed the Securities Exchange Act. Section 16(b) of that act states that it prohibits any insiders from interacting with company stock during a six-month time window. This regulation was reinforced by the Williams Act Amendments in 1968. The Williams Act Amendments regulated insider trading on tender offer information (Ma, Yulong, and Sun, 1998). [PL1] Over a decade later in the mid to late 1980s, Congress decided it was best if the consequences for insider trading grew as both the Insider Trading Sanctions Act of 1984 (ITSA) and the Insider Trading and Securities Fraud Enforcement Act of 1988 (1988 Act) increased fines by up to 900%.

Many countries have made policies that forbid insider trading, Bhattacharya and Daouk (2002) found that 87 out of 103 outlawed insider trading at the end of 1998, In the Korean Journal of Financial Studies, Sehyun Park (1992) found that insider trading has increased despite harsher consequences, as research has supported that the government will only hold those investors accountable when details are extremely clear and detailed. In addition to the information mentioned, as of 1998, only 38 of the 87 countries have prosecuted at least one insider trading case, insinuating that it has not been an emphasis for many governments. This is not to mention that in the US, insider trading takes place in an estimated 20% of merger and accusation events and one in twenty quarterly earnings announcements (Patel and Putniņš, 2021). This leads us to the question: How and should the current policies that are regulating insider trading change?

Whether insider trading should be legalized has been a large debate among many investors over the decades (Bhattacharya and Daouk, 2002). On one hand, people argue that it is a major disadvantage to those who are not aware of the situation and can decrease the liquidity of the stock, discourage company investment, and in turn limit market growth. On the other, investors in support of insider trading like the idea that it improves market efficiency and encourages price discovery (King et al, 1988)

It is important to realize how effective, or lack thereof, is insider trading for investors. Different studies, there seems to have different findings on this matter. Zaman (1988) discovers that this illegal activity is not able to earn a significant amount of profit through insider trading, which poses the question of whether banning it is necessary. However, King and Roell (1988) suggest otherwise, mentioning that insider trading occurring in the US has reflected 'abnormal' gains and long-term rewards. Doffou (2003) supports that insider trading is most effective when having complete data sets. He also asserts that as the penalties for this offence have worsened, investors are trying to use inside information through other financial instruments to get high returns.

The extent of this review is limited. Research has yet to discover the nature of these transactions. More importantly, the lack of reduction in insider trading cases suggests that the current policies are perhaps ineffective and that there needs to be new ways to stop this illegal action.

3. Methodology

This paper tries to examine the effects of insider trading on the stock market in the United States. To do so, we decided to use both quantitative and qualitative data analysis.

To collect information regarding investment, data from the Federal Reserve Bank of St. Louis was used to find changes in gross private domestic investment through quarterly intervals between 2012 to 2022, and to find a relationship between newly implemented insider trading regulations and investment behavior.

The parties involved in this study are trading companies in the United States. We collected data on insider trading cases that occurred between the years 2012 and 2022 from various sources, including the Securities and Exchange Commission (SEC) and different news outlets.

Through the SEC's website that published official insider trading offences in the US, we collected data on the average dollar fine per insider trading case documented by the SEC from 2012 to 2021. We also conducted a qualitative analysis of major insider trading offences that happened from 2012 to 2021. We identified these events by reviewing news articles. By doing this, we identified common patterns in these events, as the types of individuals, effect on the stock market, and regulatory responses can be reflected.

For the quantitative analysis, we used statistics from the SEC's database to examine the frequency and severity of insider trading cases over time. We were able to calculate and find the number of cases and average fine per year from 2012 to 2021.

4. Figures, tables, and equations

Observation Dates (Quarterly)	Gross Private Domestic Investment, Millions of Dollars
2012-01-01	638154
2012-04-01	648053
2012-07-01	693223
2012-10-01	642324
2013-01-01	666275
2013-04-01	689452
2013-07-01	758037
2013-10-01	712251
2014-01-01	708999
2014-04-01	749034
2014-07-01	817434
2014-10-01	768711
2015-01-01	785982
2015-04-01	817879
2015-07-01	852864
2015-10-01	780437
2016-01-01	773182
2016-04-01	803135
2016-07-01	832789
2016-10-01	795931
2017-01-01	773918
2017-04-01	854087
2017-07-01	901633
2017-10-01	855828
2018-01-01	856564
2018-04-01	904003
2018-07-01	964963
2018-10-01	916766
2019-01-01	919681

2019-04-01	965461
2019-07-01	1001950
2019-10-01	920257
2020-01-01	918134
2020-04-01	792342
2020-07-01	981182
2020-10-01	963946
2021-01-01	953057
2021-04-01	977540
2021-07-01	1066319
2021-10-01	1108251
2022-01-01	1128010
2022-04-01	1150019
2022-07-01	1194624
2022-10-01	1146676

Years	Number of Penalties
2022	43
2021	28
2020	33
2019	30
2018	51
2017	43
2016	48
2015	39
2014	52
2013	44
2012	58

Years	Average Fine per Case ($ and in millions)
2022	N/A
2021	3.17
2020	3.31
2019	4.03
2018	2.73
2017	1.67
2016	1.79
2015	1.97
2014	2.22
2013	1.83
2012	1.63

Years	Imprisonment Sentences (Years)
2022	N/A
2021	2.96
2020	3.41
2019	2.87
2018	2.88
2017	2.41
2016	2.41
2015	2.58
2014	2.99
2013	3.03
2012	3.52

4. Results

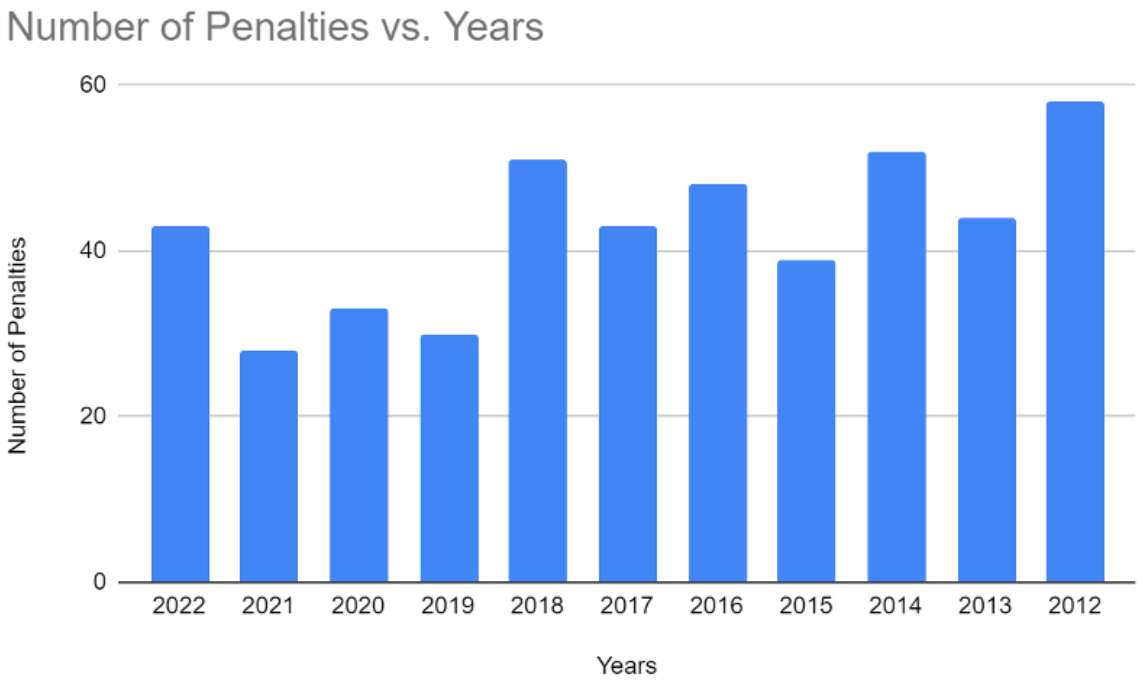

Figure 1

Represents the number of insider trading offences that have taken place from 2012 to 2022 in the United States.

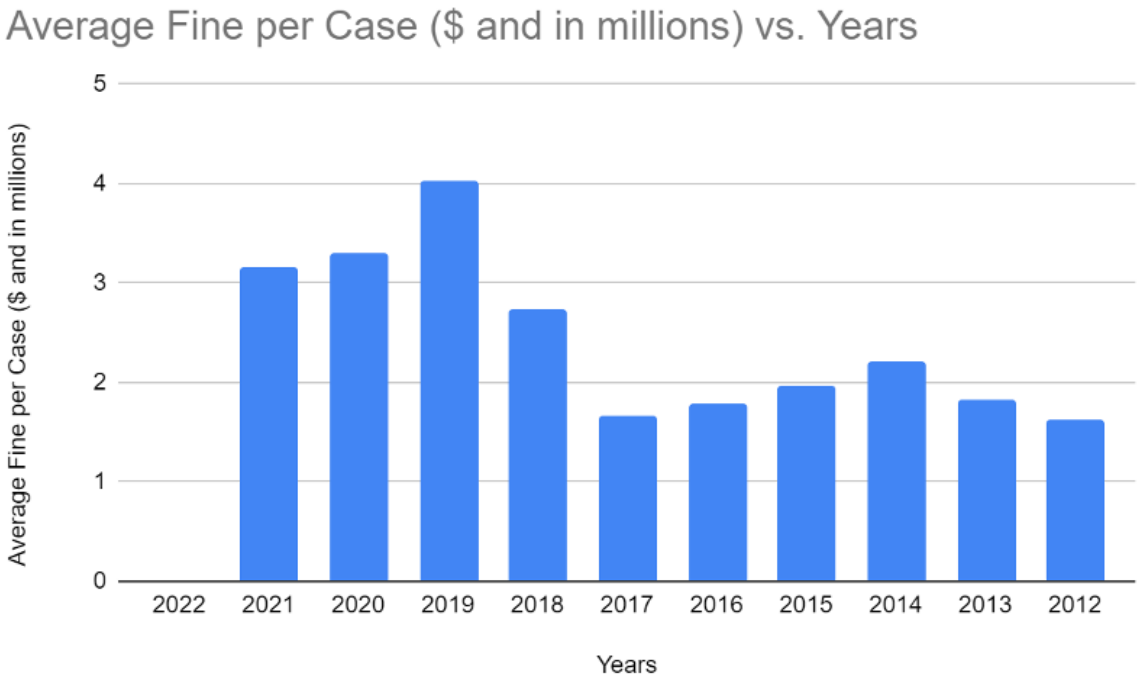

Figure 2.

Represents the average dollar fine per insider trading case documented by the SEC from 2012-2021 in the United States.

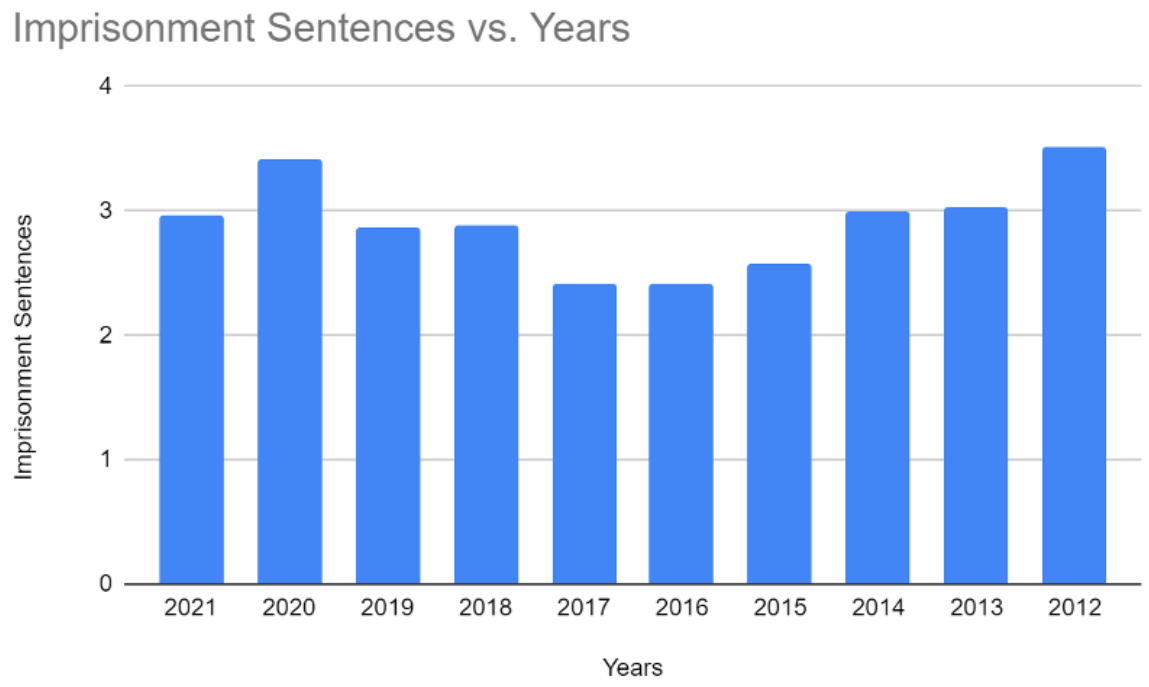

Figure 3.

Represents the imprisonment sentences for insider trading between 2012 to 2021 in the United States

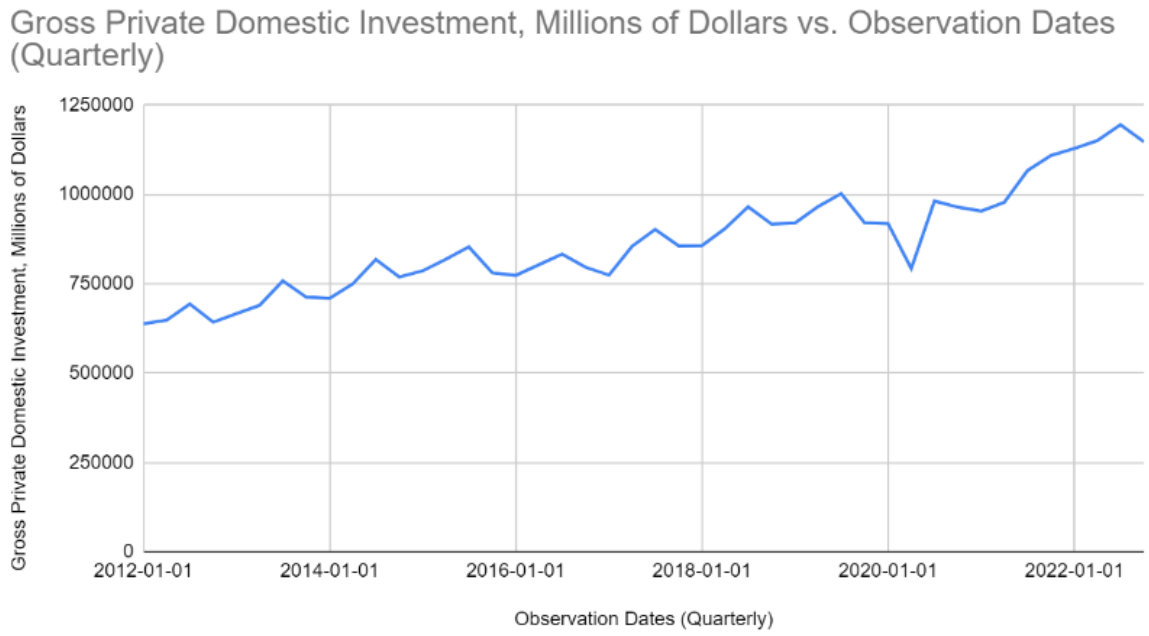

Figure 4.

Shows the gross private domestic investment in quarterly intervals from January 2012 to January 2022

Major insider trading events in the US from 2012 to 2022:

2012:

The STOCK Act (Stop Trading on Congressional Knowledge Act) has been signed. It prohibits members of Congress and their staff from using non-public information for personal advantages in the market.

The SEC (Securities and Exchange Commission) and DOJ (Department of Justice) bring charges against the fund manager and founder of the Galleon Group Raj Rajaratnam for insider trading, leading to an 11-year prison sentence.

2013:

The SEC brings an insider case investigation to billionaire investor Carl Icahn and professional golfer Phil Mickelson, claiming that they got a hold on insider information related to stock. However, both weren't found guilty and were not charged.

2014:

The SEC announces a settlement with SAC Capital Advisors, which includes a $1.8 billion penalty, the largest ever on an insider trading case.

The DOJ wins a case against Mathew Martoma, a former portfolio manager at SAC Capital Advisors, for insider trading. He was sentenced to 9 years of imprisonment, the longest sentence to date.

2016:

The SEC adopts new rules that force companies to reveal more information about their executive compensations, including instances of misconduct like insider trading.

2020:

The SEC brought charges against traders who were accused of using private information to profit from market-moving news releases. The traders are accused of earning over $50 million in profits.

2021:

The SEC charges a former finance executive of Amazon with insider trading, alleging that he traded private information concerning the company's financial success.

The SEC declares a settlement with a group of traders who had claimed to use insider trading to make profits in the market. The case includes over $8 million in penalties

2022:

The SEC adopts policy changes that modernize rule 10b5-1. The new changes included amendments that restricted the use of multiple trading plans and limited the affirmative defence for a single trading plan over one year.

To conclude, there has been a trend towards harsher punishments for insider trading in the US spanning almost a decade, with bigger fines and longer prison sentences. However, there have still been cases where insider trading has been left off the hook and instances where the punishment deserved to be harsher.

Game Theory Model

Participants:

Seller

Insider Buyer

Outsider Buyer

Payoffs:

Seller: revenue earned from his or her selling shares

A buyer with inside information: the value of shares minus the price paid

A buyer without inside information: the value of shares minus the price paid

Time:

The seller offers a price. Both the insider and outsider choose whether or not they should purchase the shares at the offered price.

If only one buys, they get both shares.

If both buy, they split the two shares.

Scenario and Assumptions:

The stock has a 50% chance of being worth $1 and a 50% chance of being worth $2. The insider buyer knows the true value of the stock while the outsider buyer is only able to see its price on the market. The seller owns two shares and wants to sell them for the most profit possible.

Analysis:

If the inside buyer is present, the maximum possible price that sells both shares all the time is $4/3. If the seller sold at a higher price, the shares would not be bought. If it was placed at a lower price, the seller would lose out on potential revenue.

Without any insider information, the outsider's decision to buy cannot depend on the stock's true value. On the other hand, the insider will only purchase when the stock is worth $2. This is because when the non-public information tells him that when the stock is worth $1, it is not worth purchasing at a higher price.

It is important to note that if insider trading is prohibited, the shares will sell for $1.5, as there is no information advantage for the inside buyer. In this model, the presence of insider trading decreases liquidity by making it impossible to consistently sell shares at their expected value of $1.5.

In an extended version of the model where the seller is now an investor who can choose whether or not to fund the company or not, the anticipation of a low sale price due to insider trading can hinder investment if the cost per share is between $4/3 and $1.5. This stems from the idea that the investor may not want to fund the firm as they are aware that it is likely they will be unable to sell shares at high prices due to insider trading.

The game theory model presented demonstrates the potential negative effects of insider trading on the overall health of the stock markets. The thought of low sale prices due to concerns about insider trading could hinder investment, which can be detrimental to future economic growth and job creation.

When the STOCK Act was signed in early April 2012, which emphasized the reporting of financial transactions, we see that the quarterly domestic investment reached a yearly high of $693,223,000,000, suggesting that regulations preventing insider trading encourage more investment. However, this has not been the case in all instances. In 2016, the SEC announced new regulations that focused on market transparency to fix problems such as insider trading. The following quarter after this statement was announced, the gross domestic investment turned out to be unreasonably low, standing at $773,918,000,000, the lowest number in the past 6 years.

When the two biggest insider trading took place in 2014, one involving the largest imprisonment sentence of 9 years and the other being the largest fine at 1.8 million dollars, the private domestic investments were $768,711,000,000 and $785,982,000,000, the two lowest quarters between July 2014 and July 2015. Despite the harsher punishments, this could perhaps demonstrate a decrease in investor confidence and the lack of optimism consumers have toward the market, which could drive down economic growth. The similarities are seen when the SEC charged a former executive of Amazon, Laksha Bohra, with insider trading. The following quarter of this event saw a low of $953,057,000,000 in private domestic investment, the lowest total since April 2020.

There were a total of 469 penalties for insider trading cases from 2012 to 2022. The number of penalties fluctuated over time, ranging from 28 in 2021 to as much as 58 in 2012. However, the first six-year interval in this period saw insider trading casing reach more than 40 at least 5 times, in comparison to only 2 in the following five years,suggesting that insider trading is becoming less frequent in the US. However, this does not seem to have a strong connection with share prices. While it is true that insider trading usually has a positive effect on share prices, insiders buying shares from their respective firms knowing its positive future outlooks could make others also invest in its stock, driving prices up. Another perspective is that if an insider knows negative information about a company, it is likely they pull away which has a butterfly effect on the rest of the investors, lowering its share prices (Chakravarty and McConnell, 1999). It also needs to be considered that other factors could influence share prices and that insider trading does not give an accurate result of a stock's value (Fishman, 1992).

The average fine per case also varied from year to year, ranging from a low of $1.63 million in 2012 to a high of $4.03 million in 2019. While the fines have significantly increased with the average breaking over the $2 million mark for four consecutive years from 2018-2021, the previous 6 only had one breaking the mark, with the average fine per case being $2.22 million in 2014.

This has not directly correlated with the average imprisonment sentence for insider trading cases as they ranged from 2.41 years in 2016 and 2017 to 3.52 years in 2012.

Insider trading can harm the stock market as it hurts investor trust in the financial system in terms of accountability and transparency. When insiders obtain private information, they get an advantage over other investors, which could make others lose trust.

Data points out that newly implemented regulations preventing insider trading have been somewhat effective. The number of penalties for insider trading cases has fluctuated over the years, with a general downward trend since 2012. This could be due to increased efforts by the SEC and DOJ to prevent this illegal practice, as well as increased awareness around the country.

There also seems to be a variation in the average fine, but there has been a general upward trend since 2016. This insinuates a result of increased penalties for insider trading violations or a greater focus on imposing significant fines as a deterrent to others.

Conversely, the average imprisonment sentence for insider trading cases has remained relatively consistent over the years, with generally few fluctuations. This could mean that policymakers tend to punish offenders through larger fines rather than hit them with longer prison sentences.

It is significant to note that the data used could have inaccuracies as there could be cases not caught by the SEC and DOJ, therefore not documented on their main page. Moreover, it is worthy to state that gross private investment does not depend solely on insider trading, therefore the analysis presented above is not an accurate representation of the connection between investment and inside trading. Other limitations include the fact that only the situations in the US were documented, as the insider trading situation in the United States might not reflect its effect on the world stage.

5. Conclusion

From our study, we find that insider trading has been an apparent issue for a long period. However, it continues to pose problems for regulators and traders in the marketplace. Our analysis determined that while both fines and prison sentences have increased over the past decade, the number of cases has not dropped marginally. In terms of investment, we see consumers are likely to not invest when large insider trading scandals occur, suggesting a lack of confidence in the market. No direct correlation, however, is found when new regulations are being made to prevent this practice.

Our game theory model illustrates that insider trading hurts the market by posing an unfair advantage for some, which could deter investment as a result of lower investor confidence and market efficiency. Thus, future studies could continue to find the effects of insider trading on financial markets, preferably around the world. Moreover, regulators should continue to advocate for more transparency from politicians and companies regarding their market transactions.

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Color Psychology and Business Applications

Samarth Jhunjhunwala

Abstract

It has long been known that the way people think has a longstanding relation with the colors they view. Colors dynamically possess implications on human perceptions, beliefs, and behaviors. Therefore, this study tries to find the impact of color on consumer behavior and use these findings to justify the need for color-based research in brand marketing. Through the research, this hypothesis is proved to be correct since an analysis of various secondary sources corroborates the need to employ the right colors for effective display. The study concludes that each color has specific emotions associated with it. Further, different people have different perceptions of the same color. Finally, the study suggests that the understanding of these vectors finds its applications in advertising and branding a product.

Keywords: color, perception, color psychology, marketing, consumer behavior

Introduction

Color has a pervasive impact on human psychology, stimulating the way we think, feel, and perceive our surroundings. Hues form the fundamentals of the lens through which mankind makes cognitive decisions, consciously or otherwise. In a world where color continually influences mindsets governing the masses, it has never been more important for businesses to base their strategies against a backdrop of color psychology.

The ‘color revolution’ amongst brands is a reality of the present and companies must strive to leverage the potential of understanding their consumers by the means of colors. It would not be wrong to say that color governs consumer behavior, likewise, their buying decisions and thus the accurate use of this visual tool forms the basis of forging relations with the customer. Based on these assumptions, a hypothesis is put forth, imputing that color has applications in the marketing processes brands employ. It is predicted in this research that brands must understand the implications of specific colors to make their products attractive to their consumers. The results obtained by compiling journals, studies, and articles will comprehensively prove the need for brands to adopt a user-centered approach, primarily stressing colors, in their marketing discussions.

Psychological Impact of Color

Think of all the colors we encounter and how they possess a subconscious effect on our emotions. Historically, colors have been found to influence one’s moods and subsequently impact their behaviors and thereby arising decisions. Research reveals people make an involuntary judgment about a person, environment, or product within 90 seconds of initial viewing and that between 62% and 90% of this assessment is based on color alone. (Khattak et al., 2021)$_1$ Hues of red have long been believed to be associated with antagonistic couplets of ‘danger’ and ‘love’. Perhaps, commensurate to this tendency, red roses have evolved into a Valentine's Day requisite while simultaneously stop signs on roads are accoutred with a similar shade. Likewise, over the years, each color has come to be

representative of a set of ideas which at least to some extent transcend the barriers of geography. A study from 2020 that surveyed the emotional associations of 4,598 persons from 30 different countries found that people commonly associate certain colors with specific emotions. Results from the survey as portrayed in Figure 1 of the appendix included 52% of respondents associating yellow with joy while 43% of them imputed the feeling of relief to white. (JJonauskaite et al., 2020)[2]

Artistic Use of Color:
Numerous studies based on the works of eminent artists have proven the hypothesis that the colors used by artists draw inspiration from the mental state prevalent in their lives. (Hussain, 2021)[3] It would thus be veracious to conclude that a work of an artist is a reflection of the psychology of the artist. Picasso is said to have reflected his state of depression over a close aide's suicide and, sadness owing to persistent poverty by painting 'icy-blue' paintings revealing 'suffering' as is apparent in 'The Old Guitarist' (figure 2 in appendix). Gradually, however, Picasso's paintings brighten in what has been termed as the 'rose' period with the use of sprightly shades in 'Family of Saltimbanques'. (figure 3 in appendix)

Placebo Effect:
While implicit, the Placebo Effect suggests that the color of a pill has an impact on the efficacy of the pill itself. In principle, this phenomenon deals with how colors affect the perceived action of a drug and thus seem to influence its effectiveness. The color of drug formulations might cause different expectations in patients, and could therefore produce different therapeutic effects. Patients begin to believe that they are getting better simply owing to the positive feeling they associate with the color of the pill. A study conducted on the impact of colored drugs corroborated this hypothesis, finding that red, yellow, and orange are associated with a stimulant effect, blue and green with tranquilizers, and white with painkillers. (de Craen et al.,1996)[4]

Audience Perception and Targeting

Gender:
Through the propagation of stereotypes, society has actively assigned a set of colors to the conventional binary which has been highlighted through various researches conducted in the past. Further evidence comes from a developmental study (Burkitt et al.,2003)[5] which tested the color preference of 330 UK children, aged between 4 and 11 years old. Children were asked to point to their preferred color from a set of 10 colors (black, blue, brown, green, orange, pink, purple, red, white, and yellow), and continued pointing until all colors were chosen. It was found that girls significantly preferred pink, purple, and red more than boys. In contrast, boys showed a greater preference than girls for black, blue, brown, green, and white. These findings verify the Gender Schema Theory propounded by Sandra Bem in 1981, which explains how gender-linked identifiers are transmitted to other members of a culture. However, more recently, with mindset shifts rapidly occurring in society, the gender schema is fading away. Today, blue stands as the favorite, and brown stands as the least favorite color of both men and women as portrayed in Figure 4 of the appendix. (Rider, 2010)[6]

Age:
As a brand, understanding the demography of the population you are catering to becomes extremely important, because different age groups tend to prefer different colors and shades. Scientifically, for the elderly age groups, existent colors appear to become darker resulting in a preference for lighter shades. Young children often possess an affinity with a variety of bright hues while young adults tend to prefer subtle pastels. (Rider)

Ethnicity and Nationality:
People belonging to sundry cultural backgrounds might differ in their perception of a given color. This may be, because of contrasts in their religious and traditional connotations of the same hue. For instance, green is a symbol of sustainability to the Europeans while the same green is considered a

representation of infidelity by the Chinese. These ripples have accurately been captured in the Ecological Valence Theory put forth by Palmer and Schloss in 2010. This theory states that "preference for a given color is determined by the average affective valence of the objects which are associated with that color when averaged across persons." (Casas et al., 2019)[7] To a layman, this would suggest that we attribute certain emotions to a given color because of the objects our culture often associated with that color. For instance, in India, red is representative of a sense of purity, which perhaps stems from the use of red apparel by the woman at a Hindu wedding ceremony.

Business Implications and Applications

Advertising:
We have been able to establish that color has a profuse impact on consumer choices and their buying decisions. Therefore as a company, it becomes essential to understand the psychological impact of color on consumers while endeavoring in advertising and marketing campaigns. The adroit use of colors primarily imputes three advantages to the company:

a) The ability to draw the consumers' attention to specific parts of the advertisement

b) An increase in the likelihood of a viewer retaining the visual in their memory for a longer duration.

c) Sensitizing with the desired audience by taking into consideration their gender, age, and cultural backgrounds as previously accentuated. (Meredith Ballard, 2012)[8]

Case Study:
Most of us resonate with red and yellow upon thinking about the logo of McDonald's. However, more recently, the company has adopted a green backdrop for the European setting as depicted in Figure 5 of the appendix. To adapt to the health and environmental consciousness gaining prominence all over Europe, they believe that the use of green will reposition the company with a 'healthier' and more 'eco-friendly' attitude. This is also in line with efforts to combat rising speculations that the company's products are contributing to child obesity. This example establishes that a brand needs to dynamically evolve the colors it uses in advertisements to keep up with the variety prevalent in the cultural ethos across the globe.

Website Building:
In the modern world of marketing, the usage of the right colors on your website has a lot to do with the way consumers engage with your platform. Studies have proven that 'screen color' has an effect on one's perception of time thus influencing the quickness of perceived downloads. The research titled, 'Waiting for the Web: How Screen Color Affects Time Perception' (Gorn et al., 2004)[9] proves that the usage of blue as a backdrop to a website, has a quicker perceived sense of download as opposed to another adorning yellow. These findings work on the assumption that supports links between color and feelings of relaxation and between feelings of relaxation and time perception. In principle, blue is supposed to initiate a calming effect when compared with yellow. Convention denotes that when one is calm, time appears to pass quicker than in a stressful state. This corroborates the findings as represented in their paper while also suggesting that the color of the website influences the likelihood of a user remembering the website and recommending it to others.

Brand Identity:
In 1995, the SCOTUS ruled that colors or even shades of a single color can be trademarked by companies, thus demonstrating the importance the usage of color has on building a stable brand identity. The incorporation of consistent color palettes is a necessity for stimulating brand loyalty. For a long time now the usage of red has been an important facet of Coca-Cola's business strategies. "The color red in marketing portrays power, excitement, energy, and passion. It also stimulates the appetite, which makes it an excellent choice when branding food or drink." as quoted by a blog on Strategic Factory.10 Once a brand establishes consumer-appropriate color choices, they tend to be synonymous with that color itself. In fact, in Coca-Cola's case, this phenomenon was so much so, that they claim to be responsible for popularizing the modern-day Santa Claus, adorning red as seen in the appendix. The loyalty towards the brand is best portrayed through the 'Pepsi Paradox', wherein consumers preferred Pepsi over Coke in blind tests, but produced contradictory opinions when the test was carried out with an exposure to the packaging of each company.

Case Study:
Every year, ahead of Valentine's Day, Saudi Arabia places an embargo on 'all things red' terming the celebration to be a non-muslim activity (Blake Hounshell, 2008)11. What's interesting to note, however, is that the government places a ban not on 'roses' or 'cards' specific to the event but rather on the color associated with it. This example puts forth learnings for businesses to emulate the success of red in representing the entire concept of Valentine's Day while making their decisions on a branding front.

Methodology

This research paper includes a combination of essential quantitative and qualitative data to provide a comprehensive insight to the reader to view color psychology from facets of business. Secondary sources have framed the premise for the presentation of quantitative data, which have duly been acknowledged and cited to justify the accuracy of the statistics depicted. The qualitative data has been portrayed with the help of interactive tools including case studies of modern concepts, diagrams and pertinent theories propounded to strengthen the concepts put forth. The paper justifies its hypothesis from a logical viewpoint, by first establishing the influence of color on human psychology and making use of this foundation to elucidate its use by businesses. Visuals added to the appendix at the end of the paper enable a well-rounded perspective to be developed. While other papers speak on a similar subject, this research displays a holistic approach to the topic while including relevant viewpoints to ensure understanding. The first study (Khattak et al.) presents numeric data on the influence of visual aspects on perception, which enables a link to be framed between color and its effects on mindset development. The second study (JJonauskaite et al.), the results of which have been displayed in the appendix, provides statistics on primary colors and their conventional implications. It helps us understand through quantitative data how people tend to associate certain emotions with specific colors. The third study written by Hussain A.R. presents to us the theory that artists depict their emotions through the colors they make use of in their artworks, which further draws attention to the cognitive aspects of color choices. The fourth study (de Craen et al.) presents the implications of the placebo effect. The fifth study(Burkitt et al.) and the next research by RM Rider put forth the perception of color by different audience segments. An explanation of the Ecological Valence Theory is highlighted by the following source(Casas et al.). The eighth study(Meredith Ballard) explains applications in advertising while the one which succeeds(Gorn et al.) provides interesting implications of color on website-time perception. The last two sources corroborate their examples and case studies respectively.

Conclusion

Through this study, my hypothesis can be deemed correct, as a comprehensive analysis of various journals and surveys accentuates the importance of colors used by brands in governing consumer behavior. The paper first proves the psychological impact of color in governing mindsets and uses this premise to establish the relationship between colors and consumers. The study finds that different colors have conventionally been associated with different emotions by the masses. Appending to this result, the study further finds the difference in the perception of a given color by different audiences based on distinctions in their gender, age, and culture. It partially contradicts its initial findings, suggesting that though certain colors have specific emotions attributed to them, with variety in context, these implications might vary for consumers of diversity. The study goes on to prove that color has three primary uses by brands. First, they may use colors tactically to stimulate attraction towards their advertisements and packaging. Second, the right colors increase consumer engagement and interaction with websites. Third, those colors form the basis for a brand to formulate its identity which eventually builds loyalty amidst the consumer base.

Appendix

Figure 1: General perception of different colors

- Black: 51% of respondents associated black with sadness
- White: 43% of people associated white with relief
- Red: 68% associated red with love
- Blue: 35% linked blue to feelings of relief
- Green: 39% linked green to contentment
- Yellow: 52% felt that yellow means joy
- Purple: 25% reported they associated purple with pleasure
- Brown: 36% linked brown to disgust
- Orange: 44% associated orange with joy
- Pink: 50% linked pink with love

Figure 2, 3: Works of Pablo Picasso and the hidden implications of color psychology

The Old Guitarist

Family of Saltimbanques

The Old Guitarist Family of Saltimbanques

Figure 4: Weakening of the Gender Schema in color perception

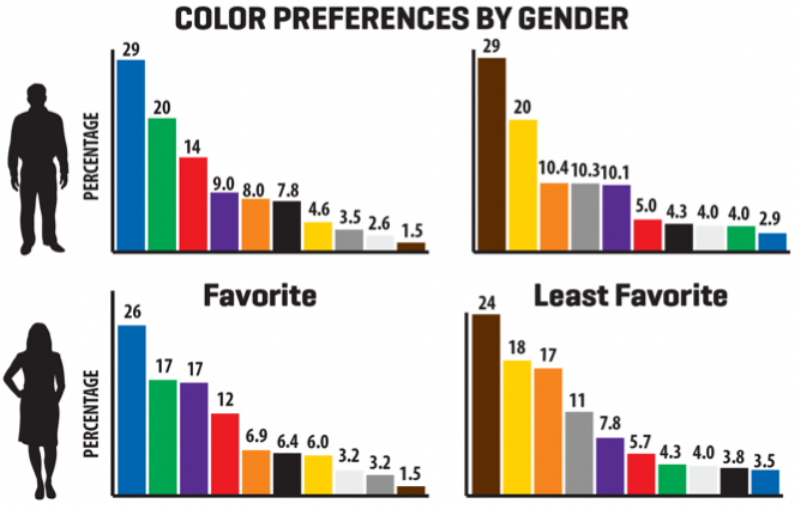


Figure 5: Mc Donald's Logo in USA vs Europe

Europe Logo USA Logo

Figure 6: Development of modern day Santa Claus through Coca Cola

For references, footnotes and endnotes, click here.

The Evolution of Women in Technology: *From the Early Eighteenth Century to the Modern Era*

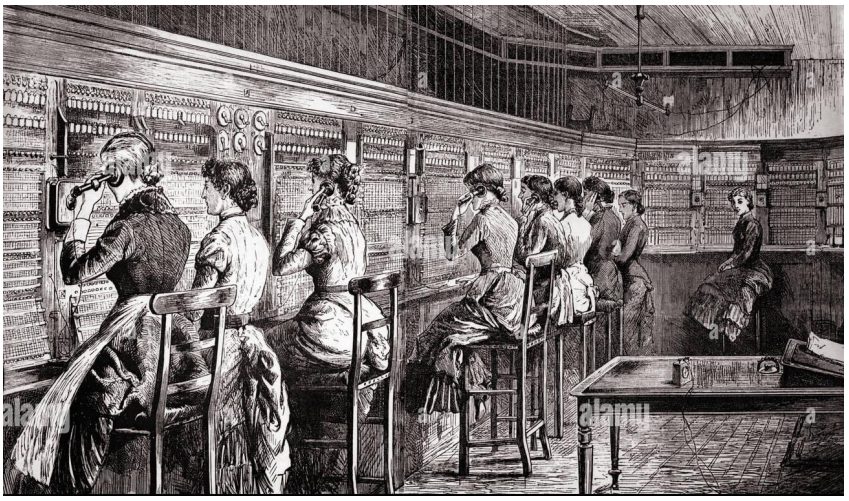
Rhea Yadav, *United States of America*

Technology – a world full of computers, types of machinery, codes, software, and applications – a word that was unknown to many women during the early eighteenth century across the globe, specifically in the United States. During the early 1700s, women were not intended to pursue their interests, rather, they were to remain in their domestic sphere and perform daily household tasks. However, a major shift occurred during World War II, 1939, when women were able to take on wartime occupational jobs. Various mathematicians, computer programmers, and scientists contributed to their societies by showcasing their logical and problem-solving skills. One of the early individuals, most notably, Nicole-Rein Lepautre, a French astronomer and mathematician, during the 1700s contributed to the field of astronomy by accurately predicting a comet's appearance in the night sky. Following this, Ada Lovelace, during the 1800s was a remarkable woman who is known as the first-ever computer programmer and scientist. Lovelace paved the way for women in technology tremendously. Her work ethic strongly portrays her inspiration to other women in the technology field.

As the timeline progresses, the evolution of women's strengths, bravery, and courage are showcased. Factors such as the market and the industrial revolution significantly affected women's role in the technology field. As the need for women grew larger, during the midst of the Second World War many women gained the experience of working in factories with large machinery. According to statistics, data shows that by the year 1900, eighty percent of telephone operators were women and progressed as the main operators by the 1960s. Theories developed which lead to logical thinking and modern computer algebra emerged as a consequence. As a result of the second World War, many women became computer programmers; however, they were not recognized highly. Moreover, in 1945 during the wave of feminism, society saw large numbers of women as computer programmers, later they would be recognized as "human computers."

During the twentieth century, society saw many individuals whose legacies and stories are still known today. Their role in the field of computer science has shaped society and modern technology. To name a few, Grace Hopper was a prominent computer scientist who created the first computer programming language all in English, and Annie Easley advocated for women in Science, Technology, Engineering, and Mathematics (STEM) fields while simultaneously working as a computer programmer at the National Aeronautics and Space Administration (NASA). Their contributions to society have overall affected computer science and programming which created a significant increase for women in technology.

Within the technology industry, statistics further illustrate that the percentage of female computer science bachelor's degree recipients has increased from fourteen percent in 1970 to twenty-one percent in 2019, respectively. During the years, the percentage peaked in 1985; however, it significantly decreased following 2019. Despite the rise women have seen in technology and engineering fields, women have also faced a significant gender gap with employment rates and lower as well as unfair wages. Although women are the minority in the technology field, they have made remarkable contributions to society that have been impactful and their achievements will continue to stay as a legacy. All in all, the evolution of women in the technology industry has undergone significant changes. In the modern era, many advocates are raising awareness about the distinct differences in the gender gap. Ultimately, as women faced difficulty in the industries, their bravery and confidence highlight their determination.



Women during the late 1890s and early 1900s working as switchboard operators

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How Have Sustainable Practices Helped in the Eradication of Food Insecurity?

Florence Moma

RESEARCH TOPIC: Sustainable living

RESEARCH QUESTION: How have sustainable practices helped in the eradication of food insecurity?

Introduction

Food insecurity has always been at the limelight of global issues. Stemming from issues like food waste, poor public transits, and more, it seems to be increasing day by day. A document published by EatrightPRO,2021, suggests that the United Nations (UN) estimates world population to skyrocket to 9.7 billion by 2050 and 11.2 billion in 2100. This implies that in this age of the Anthropocene, our food availability depends on how it is managed by humans. According to research carried out by the UN's Food and Agricultural Organization (FAO),2008, food security is when everyone constantly has access to enough food physically available to them and affordable, such that it meets their requirements for a healthy living. Yet what we fail to realize is that not everyone is given this privilege, for there is a prospect that people may not have access to ample food either presently or in future. About 153 million people in Sub-Saharan Africa (SSA) experienced extreme food insecurity in 2015 (Sicar, A., 2018). This high rate of food insecurity is contrary to the UN's Sustainable Development Goal (UN SDG) Two: *zero hunger*. As such, having a sustainable lifestyle can be a way forward to this global issue. Living sustainably involves minimizing the use of the earth's natural resources by making sustainable choices and counteracting negative environmental concerns (Sustainable Jungle, 2021). Consequently, this report targets at digging into possible options of sustainable practices that can help annihilate this problem, in order to make food accessible to everyone.

Significance of Research Question

There are many concerns that have sprung up from food insecurity. As such, this topic is significant for investigation because despite the earth's abundant resources, not everyone has the privilege of not experiencing a feeling of extreme hunger. Now, with the continuous trend in population growth, there are higher chances that more people will not have food, raising the rate of poverty and hunger worldwide. Thus, such an issue should be addressed with an analysis of how living sustainably can help tackle this problem. This report therefore focuses on those methods of sustainability that can aid in deciphering this hurdle at a global and national scale. At the national level, the West African developing country—my home country—, Cameroon shall be evaluated.

Methodology

This research question shall be evaluated using secondary data from web articles and web pages related to the question.

Primary data will be collected via an online survey using polls.

Sustainable Practices That Contribute to Food Security

Sustainable Agriculture

According to Guzdek G.,2020, we are so close to consummating our natural resources, yet food insecurity still poses an ever-present issue. There might not necessarily be a lack of resources, but a lack of proper maintenance of land to grow food needed to feed the world, is a problem. Experts believe that about 26.4% of the world population face moderate to acute levels of food insecurity, making an amount of about 2 billion people (Meacock J., 2021). The distribution of food in many food insecure settings are affected by factors like inundation, droughts, and pest invasions. The employment of cover crops in these areas can help alleviate the effects of these factors. Some cover crops like radishes, legumes, wheat, corn and even oats extract carbon out of the air and convert it to nitrogen (natural fertilizer) and grow without needing the soil to be tilled. Cover crops protect the soil from erosion and enrich the soil with nitrogen, thereby increasing soil fertility. This in return raises the yield of crops, consequently ensuring the availability of food. In the US for example, Joe Biden has earmarked $30 billion to help pay farmers implement this sustainable practice (Folk E., 2020).

Ifad organization (2020) cited Mabiso & Benfica, 2019, saying that Africa's population is fast growing, with 2.2 billion people expected to be reached by 2050. In addition, SSA reports for more than half of world population growth between 2019 and 2050. This growth, however, diminishes the access of food to each and every inhabitant.

Sustainable agriculture has been universally commended as the primary method to address the obstacle of meeting the food requirements of the rapidly growing population of SSA while ensuring that of the future generations. In SSA, the incorporation of livestock, like cattle, into agriculture contributes to raising food security, as it is used as animal draught power. Also, the usage of animal manure brings about the nutrients needed for crop production in Africa (A.A. Ayantunde et al.,2018).

Livestock ownership is essential for fighting food insecurity in many African countries. In the Northern and Adamawa region of Cameroon, for example, there is inadequate food, especially with the growing population, as farmers and herdsmen have begun to engage in livestock farming (Djamen, P. et al., 2006). With the increase in demand for meat, herdsmen and farmers have raised the supply of it from their livestock. This has not only fought against hunger, but these people now earn an income from this practice, as northerners earn a living through the selling of meat especially in a form called 'Suya'. In order to prove this, I carried out a survey where I asked a considerable number of my family members and friends, including friends on the internet by carrying out a poll (all aged between 11 to 63 years of age). The poll conveyed that a majority of them, 68%, often consume 'suya'. Their purchases thereby provide income to the sellers, permitting them to afford their own food as poverty is another cause of food insecurity.

Furthermore, Aquaculture has become one of the largest food producing sectors in the world. Four million ponds have been located in rural southern Bangladesh, and through a recent initiative carried out by CGIAR (Consultative Group for International Agricultural Research), the ponds are being used by the women as sources of food and income (Kabi A., 2014). This in return educates and trains the women on new aqua farming techniques.

In my home country, Cameroon, aquaculture in the form of fish farming has been practiced since 1948(FAO, 2021). Nevertheless, there has been a decline in domestic food catches, and the government was forced to import frozen fish, which has been more disadvantageous to them. In consequence, they decided to revive the sector and encourage fisheries and Aquaculture in Cameroon. Cameroon's favorable geographical location and climate favors the implementation of this procedure. Regions like Adamawa, Centre, East, Littoral, West and even North West indulge in this practice which has led to the rise in the fish supply of the various rural environments and even the country as a whole. Fish farmers gain income via the sale of surpluses, thus feeding the rest of the population, and combating food insecurity; Additionally, the income gained permits these farmers to be able to afford food.

Training and Educating youths

Research from the University of Nairobi-Kenya suggests that the Non-Governmental Organization (NGO), Ukamba Christian Community Services (UCCS) in Mwingi District, reaches out to Community Based Organizations (CBOs) like Nzauni CBO in which this CBO divides willing households into self–help groups. Each group fights against famine; some groups establish green houses, tree nurseries, sand dams, and other upgrading projects to fight food insecurity (Muoko, S. 2010). Households sell the seedlings and use the money to purchase food and their basic needs. Above all, UCCS put in follow-up strategies to ensure the sustainable utilization of resources by both CBOs and self-help groups.

Likewise, in Cameroon, agricultural faculties did not exist that much, but now new ones are being created to educate the youths. The youths are the future leaders of tomorrow; as such, training and educating them towards agriculture as agricultural engineers and veterinary technicians, for example, is another mechanism of fighting the issue of food insecurity in the country. This is because in the long term, they will practice what they have been taught and research on new agricultural strategies that will aid in combatting the threat of food insecurity. For example, we have the Faculty of Agronomy and Agricultural sciences (FASA) at the University of Dschang and Higher institute of Agriculture and Rural development in Bamenda, which aims at guiding students to use technology, consequently ensuring local, national, and even international food security as well as rational management of resources.

Sustainable Transport

Without proper transportation, many families are denied access to nutritious food. For many low-income individuals, mobility and housing locations affect their ability to have food. Certain neighborhoods especially in the rural areas are being located farther away from stores and markets without any proper transit means for them to get food.

A survey from Portland State University from the Transportation Research and Agricultural Center (TREC) suggests that out of a total of 437,502 food insecure individuals in Tampa Bay, 31% of them do not have adequate access to proper means of transport. It also says that although there is a bus stop in Tampa Bay, transits should be made more straight-forward and efficient for the people. More transits should be used in areas where food insecurity is the highest as it is cost effective. In addition, strategies to increase grocery stores should be implemented in those rural areas for the transportation-disadvantaged.

In Cameroon, however, it is the opposite, as urban areas instead do not have access to nutritious and affordable food. The main source of income in the rural areas is obtained through farming, as such transportation does not really affect them in terms of food supply. On the other hand, the urban areas are especially affected due to the poor farm to market roads. This ergo causes foodstuffs like tomatoes to take a lot of time to reach the cities, causing them to perish. This shortage raises the prices of food, rendering it more expensive for people in the cities to afford it, most especially if they are of low incomes.

Creating good tarred roads limits this wastage and betters the transport of food to the cities. From Ekondo-Titi (a rural area) to Douala (a city) in Cameroon, the bad rural-urban roads cause little food to arrive in the city. Due to this, the people in that urban area suffer from the high prices imposed. In the past, people transported food items on their heads and walked long distances, but with the introduction of motor-bikes locally known as “benskin” and taxis, transportation of food is eased. This thereby aids in the eradication of food insecurity.

Conclusion

To conclude, writing this report has opened my eyes, as I am now able to see the gravity of the situation of food insecurity. My view on this has changed a lot, as I have further realized the harm I caused with my own hands by wasting food. Many women, men, and children in different parts of the world, walk for miles just to get drinking water, which I find to be quite outrageous. As such, we as humans need to bring heads together and solve this problem.

Governments as well as NGOs should fund micro-entrepreneurship skills in the youths to enable the eradication of poverty and consequently, food insecurity. Alternatively, governments should enforce and establish strict laws and regulations, such as food distribution at subsidized prices to the population, to promote food security. Additionally, penalties should be imposed on any citizen who go against these laws.

Conversely, educating the citizens, most especially the youths, on the impact of how our day-to-day activities affect the world's food system, and even educating them on sustainable practices that aids in food security, would tremendously help in fighting against this issue.

This helps in ensuring that people understand the risk we put ourselves and the earth in. Food insecurity is not only a present issue but it is a problem that can extend into the future and affect future generations’ needs, as such, the nonchalance exercised by people should immediately be stopped. We have to re-evaluate this issue as a core issue. Altogether, we need to watch our ways, save the earth and minimize its resources to ensure that food is on the table of all, before things get out of hand and beyond us.

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