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Article

Exploring natural ways to maintain keratin production in hair follicles

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SUMMARY

We are looking into natural ways to help hair grow better and stronger by studying keratin synthesis in human hair follicles. The reason for conducting this research was to have the ability to control hair growth through future innovations. We wanted to answer the question: How can we find natural ways to enhance hair growth by understanding the connection with natural resources, particularly keratin dynamics? The main focus of this experiment is understanding the promotion of keratin synthesis within human hair follicles, which is important for hair development and health. While keratin is essential for the growth and strength of body tissues, including skin and hair, our research hints at its specific synthesis within hair follicles. In our research utilizing castor oil, coconut oil, a turmeric and baking soda mixture, and a sugar, honey, and lemon mixture, we hypothesize that oils, specifically coconut oil and castor oil, will enhance keratin synthesis, whereas mixtures, such as the turmeric and baking soda mixture and the sugar, honey, and lemon mixture, will result in a decrease keratin synthesis. The methods used show how different natural substances influence keratin formation within the hair follicles. The experiment involved applying natural resources to hair strands and follicles, measuring their length under the microscope daily, and assessing their health and characteristics over seven days. In summary, our research helps us understand how hair grows better. We found that using natural items like essential oils effectively alters keratin growth within the hair follicles and hair strands.

INTRODUCTION

Keratin is a fundamental protein found in the human body (1). It serves as a building block for many bodily functions, notably in the context of the hair and skin (1). This protein is essential in maintaining tissue strength and serving as a protective barrier against external factors such as temperature changes, chemicals, and physical damage (1).

The human body contains 54 keratin genes, all contributing to the body's health (1). Each keratin gene is used to build nails, heal wounds, and perform many other tasks that aid the body's health (1). There are about 26 keratin genes in hair follicles that maintain hair growth and give hair its vibrant color and texture (1). Beyond hair, keratin is also found in the epidermis, where its job is to heal the skin (1). A hair follicle is a regenerative structure that grows from the skin and creates new hair (2). It forms through interactions between different types of skin cells and can cycle to produce new hair strands (2). The keratin plays a crucial role in maintaining the strength and integrity of the hair within the follicle (2). Almost all of a hair strand is made up of something called hair keratins, making up about 95% of it (3). Hair keratins are made by special cells in hair follicles and are controlled by signals from skin cells (3). As hair grows and forms, these processes keep the shape of the hair follicle intact (3). This is closely linked to the fact that the faster the hair grows, the higher the concentration of keratin reaches (3).

The effect of the body being unable to break down keratin will not make it hard for the body to control the growth. Rather, the effect of being unable to break down keratin will be a high concentration of this substance in the hair and skin (4). Several skin conditions are linked to keratin overproduction, such as keratosis, which affects many adults and teenagers (4). Too much keratin can additionally lead to cysts, better known as keratin plugs (5). Many of these cysts arise when batches of keratin form together in the hair follicles, causing irritation and bumps on the skin (5). With more than 40% of adults and 50-80% of adolescents suffering from this condition, individuals are affected by the overproduction of keratin (6). A shortage of keratin in the body can lead to problems for the systems of the body (7). For example, body parts such as the nails need proper amounts of keratin; if the body does not respond with sufficient levels, events like a slower nail growth rate and discoloration could occur (8). With approximately 30-50% of patients having a family history, it is evident that keratin-related disorders pose a concern (9).

In addition, keratin is used in numerous beauty products for parts of the body that rely on keratin growth (10). Many treatments and medications have keratin mixed with other chemicals that may cause unwanted side effects, such as harming hair fibers (10). Having too much of this protein could lead to damaging effects on your hair (10). Too much keratin on the hair strands can lead to damaging effects as it may result in protein overload, causing an excess buildup of keratin in the hair's cortex and outer layer (11). This buildup makes the hair dry, brittle, and prone to breakage, opposite to the strengthening effect keratin is supposed to have (11). New strategies are needed to regulate keratin growth, aiming to reduce the amount of keratin-related diseases among people.

Coconut oil helps hair grow by forming a protective coating on the hair, sealing the cuticle, preventing tangles, and keeping protein in (12). The rich composition of saturated and medium-chain fatty acids in coconut oil, provides nourishment, moisture, and protection to the hair, contributing to the healthy growth of the hair (12). On the other hand, castor oil, comprising glycerides of various acids, provides a

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moisturizing and nourishing effect for hair growth (12). Castor oil has been shown to stimulate prostaglandin D2 synthase, indicating a role in promoting hair growth (12).

This research was conducted with the primary goal of assessing how natural resources could be used to regulate keratin synthesis. We aimed to explore how natural substances could impact the production of keratin in the human body, shedding light on their potential roles in regulating this essential protein's levels. We chose the natural resources because of their accessibility, affordability, and ease of preparation, making them easily available to use at home. We hypothesized that natural oils like coconut oil and castor oil will boost keratin synthesis, while mixtures like turmeric and baking soda, as well as sugar, honey, and lemon, will lead to a reduction in keratin synthesis. We conducted the experiments in vitro on a microscope slide, where each of the natural resources was able to affect the hair. We concluded that, indeed, natural resources demonstrated effectiveness in fulfilling their intended purpose, either increasing or decreasing hair growth. In summary, natural resources possess the capability to contribute to and restrict keratin synthesis.

RESULTS

To test our hypothesis, we designed an experiment that involved three groups of hair follicles and strands subjected to different treatments—growth promotion, growth reduction, and a control group. We are using hair growth as a stand-in for keratin synthesis because when hair grows, it's a sign that keratin, a vital protein in hair, is being made. By watching how hair grows in response to different natural products, we can understand more about how these resources affect keratin production.

The experiment included two distinct groups: the "Keratin Growth-Promoting Natural Resources Group" and the "Products Reducing Keratin Growth Group" (**Figures 1 and 2**). Additionally, we established a control group to assess the baseline growth of hair follicles and hair strands in the absence of external factors. Each set of hair follicles had a similar initial length, ranging from 4.4 mm to 4.8 mm (**Figures 1 and 2**). We found the hair follicle from Participant A in the "Keratin Growth-Promoting Natural Resources Group" had a length increase of 1.2 mm when treated with castor oil (**Figure 1A**). The same result occurred for Participant C, with a growth of 1.0 mm (**Figure 1A**). As for Participant B, his hair follicle had an increase in length of 0.9 mm (**Figure 1A**). Coconut oil had less of an impact on the hair follicle compared to castor oil: Participant A produced a slightly lower increase of 1.1 mm (**Figure 1B**). A similar growth pattern occurred for Participant B, who had a growth of 1.0 mm (**Figure 1B**). While Participant C had a growth of 0.5 mm (**Figure 1B**). The "Products Reducing Keratin Growth Group" also had very clear results among the participants. The hair follicles of Participants A and B who received treatment with the turmeric and baking soda mixture decreased in length by -0.2 mm, while Participant C had a decrease in length by -1.1 mm (**Figure 1C**). The hair follicles of Participant A and Participant B who received treatment with the sugar, honey, and lemon mixture displayed a slightly larger reduction of -0.4 mm, while Participant C's hair follicle had the greatest decrease in length of -1.5 mm (**Figure 1D**).

After measuring both the increase and decrease in hair follicle size, we then measured the hair strand length. When both experiments ended, it became evident that the hair strands reacted similarly to how the hair follicles reacted to

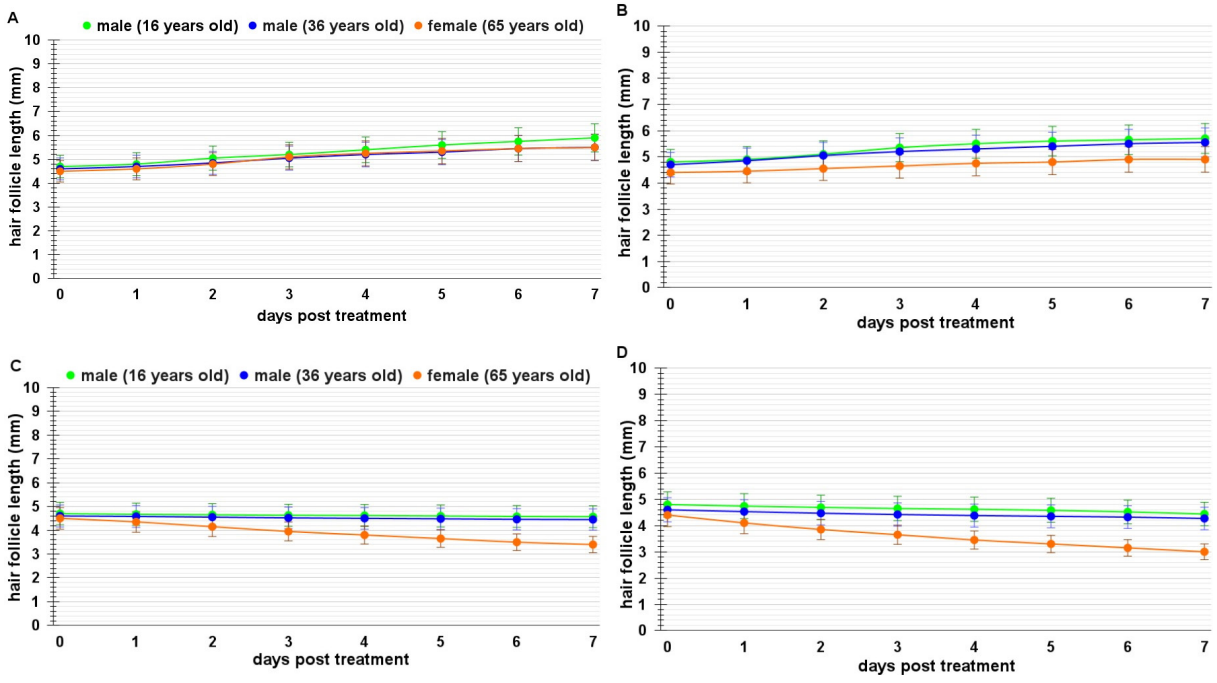

Figure 1: Effects of castor oil, coconut oil, turmeric, and baking soda mixture and the sugar, honey, and lemon mixture on hair follicles. Daily hair follicle growth throughout the week after treatment with (A) castor oil and (B) coconut oil. Daily hair follicles decrease throughout the week after treatment with (C) turmeric and baking soda mixture and (D) sugar, honey, and lemon mixture. Hair follicles from all three individuals—a 16-year-old male (green), a 36-year-old male (blue), and a 65-year-old female (orange)—were coated with the respective natural resources under the same set of conditions.

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the natural resources. In the castor oil treatment, Participant A had a growth of 1.4 mm (**Figure 2A**). Participant B had a similar growth of 1.7 mm, as well as, Participant C who had a growth of 1.7 mm (**Figure 2A**). Likewise, the hair strands of all three participants in the coconut oil experiment of the "Keratin Growth-Promoting Natural Resources Group" all featured the same growth of 1.5 mm (**Figure 2B**). In comparison, both Participant A's and Participant B's hair strands in the turmeric and baking soda mixture of the "Products Reducing Keratin Growth Group" had the same decline in hair length of -0.7 mm (**Figure 2C**). Participant C had a greater decrease of -1.1 mm (**Figure 2C**). The sugar, honey, and lemon mixture also resulted in patterns of growth, with a decline of -0.2 mm for both Participant A's and B's hair strands, and a -0.6 mm decline for Participant C's hair (**Figure 2D**).

The control group displayed hair follicle growth at a rate consistent with the average growth of a hair follicle in a week **(Figure 1)**. Participant A had an initial hair follicle length of 4 mm, while Participant B's initial length was slightly longer at 4.1 mm **(Figure 1)**. The initial hair follicle length for Participant C was measured at 4.3 mm **(Figure 1)**. Both Participants A and B had their follicles grow 1.2 mm, while Participant C's hair follicles grew 1.4 mm **(Figure 1)**. Likewise, Participant A had an initial hair strand length of 6.8 mm, while Participant B's initial hair strand length was 7.5 mm **(Figure 2)**. The initial hair strand length for Participant C was measured at 7.8 mm **(Figure 2)**. Both the male's hair strands grew 1.8 mm, while the female's hair strands grew 2.1 mm **(Figure 2)**.

DISCUSSION

Our study aimed to investigate the impact of different natural resources on keratin growth in human hair follicles and strands, exploring potential implications for overall hair health and development. The results of this experiment showed insights into the effects of various natural resources on keratin growth within human hair follicles and strands. Castor oil and coconut oil, both known for their potential to stimulate keratin growth, demonstrated positive effects on the hair follicle and strand growth (13). Castor oil produced the largest growth effect on hair follicles and hair strands, while the turmeric and baking soda mixture caused a decrease in both hair follicles and hair strand lengths. Coconut oil facilitated hair strand and hair follicle growth, and the sugar, honey, and lemon mixture effectively decreased hair follicle and hair strand growth. When both experiments ended, it became evident that the hair strands reacted similarly to how the hair follicles reacted to the natural resources.

Our findings hold implications that the natural resources used in this study have a direct relationship with the hair's growth. This implies that castor and coconut oil demonstrate keratogenic and trichogenic properties, signifying their ability to boost hair growth by promoting keratin synthesis and stimulating hair follicles. The sugar, honey, and lemon mixture, as well as the turmeric and baking soda mixture, have exhibited keratolytic properties, indicating the potential to repress hair growth by decreasing keratin production. The control group displayed a tendency for keratogenesis, leading to gradual and consistent hair growth. The negative hair strand length observed in the "Products Reducing Keratin Group" at the end of the study suggests that exfoliation did take place. Exfoliation refers to the shedding or removal of dead skin cells or other substances from the surface of the skin or hair.

Additionally, when comparing our results with existing scientific knowledge and literature, our findings align with the literature, indicating a clear relationship between the selected

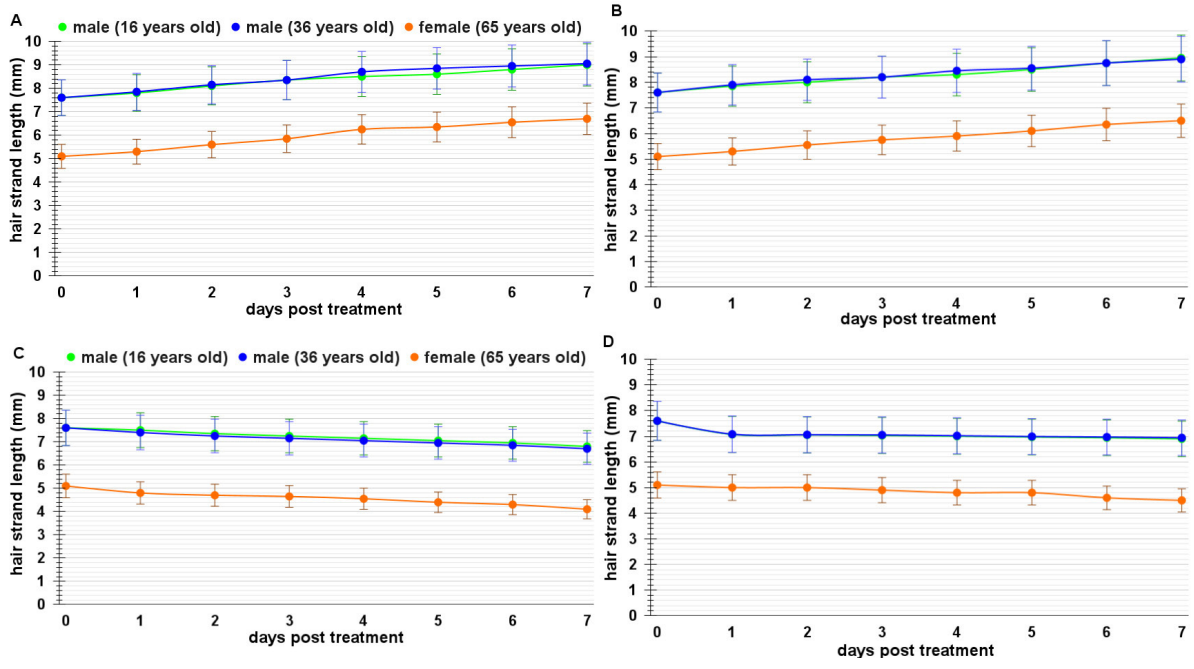

Figure 2: Effects of castor oil, coconut oil, turmeric, and baking soda mixture and the sugar, honey, and lemon mixture on hair strands. Daily hair strands growth throughout the week after treatment with (A) castor oil and (B) coconut oil. Daily hair strands decrease throughout the week after treatment with (C) turmeric and baking soda mixture and (D) sugar, honey, and lemon mixture. Hair strands from all three individuals—a 16-year-old male (green), a 36-year-old male (blue), and a 65-year-old female (orange)—were coated with the respective natural resources under the same set of conditions.

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natural resources and hair growth. Our research and existing research indicated that coconut oil's benefits on the hair include building healthy hair and boosting hair development (14). The coconut oil's moisturizing and protective properties, attributed to its richness in medium-chain fatty acids like lauric acid, can contribute to overall hair health by hydrating the hair shaft and shielding it from environmental stressors, supporting keratin production (15). As well, we discovered that castor oil, supported by existing studies, has the potential to boost hair growth just like how our experiment showed (16). The ricinoleic acid in castor oil can stimulate prostaglandin E2 production in the scalp, promoting hair growth by increasing blood circulation to the hair follicles and enhancing keratin synthesis (17). Our experiment aligned with this study that reports the turmeric and baking soda mixture can shrink the hair follicle (18). Curcumin, an active compound in turmeric, is seen to reduce hair growth (19). As well, baking soda, with its high pH of nine, can potentially reduce hair growth and cause breakage in the hair follicles (20). The sugar, lemon, and honey mixture is shown to exploit the hair follicle, which is confirmed by our experiment showing that this mixture reduced hair growth (21). The combination of lemon and sugar exfoliates the skin, removing dead skin cells, while honey soothes any redness or irritation, making it a natural exfoliant for hair loss (21). Our study stands out as one of the very few to conclusively demonstrate the direct impact of natural resources on both hair growth and hair loss.

However, it is crucial to acknowledge the limitations of our study, such as the relatively small sample size and the short observation period. The scale of this experiment is rather small, with only three participants per experimental group of various ages and genders. This small sample size might not accurately reflect the treatment response's range of variability. Furthermore, the experiment only lasted one week, which might not have been long enough to notice long-term effects on keratin growth. Besides, if we had a wider variety of races and ethnicities, we may have found more accurate results for the general public. Also, we did not focus on external factors influencing hair growth, which underscores the need for comprehensive investigations to provide a more holistic understanding of factors affecting hair health and development. Another limitation is the use of human hair follicles and individual hair strands as the experimental units. Recognizing the small and imbalanced sample size in our study is also a caveat in our experiment. With only three participants per experimental group, variations in treatment responses may not fully capture the broader population dynamics. Additionally, variations in the length of each hair strand on a person's head should be acknowledged, as this could contribute to variability in the results. These limitations show the importance of further research with larger and more diverse cohorts to enhance the data and findings of our study.

While using this method makes it possible to test how natural resources affect keratin growth, it might not accurately reflect the complexity of the human hair and how it reacts to outside influences. The experiment, focusing on intact follicles, closely mimics real-life conditions for understanding how natural resources impact hair health. Future studies should explore broader interactions, including factors like blood circulation, to gain a comprehensive understanding of these influences on hair growth. Further research should also consider including participants from various racial and ethnic backgrounds to provide a more detailed understanding of how different groups of people respond to natural resources regarding keratin synthesis and hair health.

Taken together, castor oil and coconut oil emerged as promising resources, encouraging hair growth in both hair follicles and hair strands. On the other hand, the turmeric and baking soda combination, as well as the sugar, honey, and lemon, showed promise in slowing the growth of keratin. These results highlight how natural resources may have an impact on hair growth and shed light on how they might be used in hair care products and treatments. Future studies should confirm and build upon these preliminary findings with larger sample sizes and longer periods. This will enhance our knowledge of the underlying mechanisms and enable the creation of efficient, natural-based strategies for improving hair growth and maintenance.

MATERIALS AND METHODS

The experiment aimed to determine the impact of certain natural resources on hair growth and reduction. The equipment we used in the experiment included an AmScope binocular biological compound microscope, 30 petri dishes, 30 sterile containers, a VEVOR lab incubator, disposable gloves, tweezers, a sterile spatula, and pipettes. The materials used in the study were all-natural castor oil and all-natural coconut oil. We used Sky Organics castor oil and Viva Naturals Organics coconut oil in our study. "All-natural" in this context indicates that the castor oil and coconut oil used were in their purest form, free from synthetic additives or artificial processing. Both of the oils went through the cold-press extraction method rather than chemical extraction, ensuring the preservation of their vitamins and antioxidants. Then, we used a mix of sugar, honey, and lemon, and another mix of turmeric and baking soda.

We then prepared and utilized a mixture consisting of sugar, honey, and lemon, and another mixture comprising turmeric and baking soda. The sugar, honey, and lemon mixture contained precisely 12 teaspoons of sugar, 6 teaspoons of honey, and 45 milliliters of lemon juice. The turmeric and baking soda mixture consisted of 12 grams of turmeric powder and 6 grams of baking soda. For each participant, five hair follicles and associated hair strands were utilized for testing. In total, 15 hair follicles and 15 connected hair strands, corresponding to their respective follicles, were used throughout the whole experiment.

A hair follicle is a microscopic structure located within the skin that is responsible for producing and supporting each hair. These hair follicles serve as the starting point for each hair strand. When we refer to hair follicles in our study, we specifically examined these structures to assess keratin growth. The hair strands that were a part of the experiment were still connected to the hair follicle. The hair samples and follicles were collected from a diverse set of individuals, including a 16-year-old male of white race and Italian ethnicity, a 36-year-old male of black race and African American ethnicity, and a 65-year-old female of Asian descent with Vietnamese ethnicity. In the experiment, natural resources were precisely applied to hair follicles and strands on microscope slides using pipettes. This method, followed by sealing and incubation, allowed for a controlled assessment of the direct impact of these substances on hair health and growth. The participants aged 16 will be referred

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to as Participant A, the 36-year-old male as Participant B, and the 65-year-old female as Participant C for clarity in the following descriptions of the experimental results.

Collection of hair samples

The hair follicles and hair strands were all collected from a dermatology clinic. The center sent the hair follicles and hair strands in the form of prepared microscope slides from the distributor, hBARSCI. Each slide was labeled with the corresponding ethnicity and age of the individual from whom the samples were obtained. The center also provided instructions on how to insert the appropriate resources into the slide. In total, we had 30 slides that we used for each component of our experiment.

Setup of the experiment

The table was divided into three sections, in which the hair follicles were individually housed in designated sections, specifically arranged to align with the parameters of the experiments. The hair follicles, along with their connected hair strands, that were tested to promote hair growth, were placed into the "Keratin Growth Promoting Natural Resources Group" section. The hair follicles, along with their connected hair strands, that were tested to reduce hair growth, were placed into the "Products Reducing Keratin Growth Group" section. The third section was the control group, in which one hair follicle and one hair strand connected to their respective hair follicles were placed. The experiment was done at room temperature. For the castor oil and coconut oil, we placed enough of the oils so that we would later use them. We made the turmeric and baking soda mixture and the sugar, honey, and lemon mixture out of natural ingredients.

To make the turmeric and baking soda mixture, we first purchased fresh wild turmeric from our local grocery store. For the baking soda, we acquired it at a nearby retail store. The baking soda brand was Sanar Natural. We then grated the turmeric until it turned into a powdery state. Next, we measured 12 grams of turmeric powder and 6 grams of baking soda to be able to make enough mixture for the 12 slides. We placed the turmeric powder in a sterile container and added 6 grams of baking soda. We thoroughly blended the ingredients using a sterile spatula to achieve a homogeneous mixture. The prepared mixture was labeled in a sterile container with an airtight seal to prevent contamination. Before using, we verified the mixture for consistency and the absence of any clumps. We adjusted the quantities based on the number of slides. For this, we added exactly 1.5 grams of the mixture to each sterile container.

To make the sugar, honey, and lemon mixture, we purchased ingredients from our local grocery store, which included pure granulated sugar, all-natural honey, and organic lemons. First, we mixed approximately 12 teaspoons of sugar and 6 teaspoons of honey in the sterile container. We mixed it until there were minimal clumps in the mixture. Then we squeezed a lemon until all the lemon juice came out, and we continued to mix until smooth. We then put the mixture into a pipette, where each sterile container got exactly 1.5 teaspoons of the mix.

Treatment of the hair

We started by precisely adding 1.5 teaspoons and grams of the respective mixtures to the designated area of the slide, ensuring that the mixture corresponded to the specific part of the hair being tested. For example, if the slides were intended for hair strand testing, the mixture was applied exclusively to the area assigned for the hair strand. The substances were added to the hair so that they were lightly coated, but enough to last a week. The design of the microscope slides made it possible to insert the respective substances into the slides. We carefully put the substances into the slide using a pipette and made sure no leakage of the mixtures was observed. After the mixtures were put in the slides, we closed the opening of the slides and let them rest for 10 minutes before we placed them into Petri dishes and put them in the VEVOR lab incubator. We set up the incubator at 98 degrees Fahrenheit, and we ensured the incubator's ventilation system was working to keep the heat distribution equal throughout the incubator. The control group slides were kept in the same condition as the other test groups. The slides were checked daily to see if any disruptions occurred during this process.

Measurement of the hair

The study spanned a week, during which we monitored changes in hair growth, recording both the initial and final measurements of hair follicle and hair strand lengths. We carefully removed the microscope slides from the incubator to measure the hair length. A total of 168 hours elapsed for incubation, and each incubation cycle lasted 24 hours during the seven days. We put the slides with their respective Petri dishes under the microscope for measurements. Our AmScope binocular biological compound microscope had a calibrated eyepiece, which allowed us to measure the growth of the hair follicles and hair strands under the microscope. We began first by measuring the original length of the hair follicles and hair strands in the microscope slides from the base to the top of the hair follicles or strands. This was used for both the control groups and the test groups. For slides that were testing hair follicle growth or shrink, we measured the hair follicle's length from the base to the highest point of the hair follicle every day. The same method was used for the hair stand, where we measured the length from the base of the hair strand to the highest point of the strand. Each day, we measured the hair follicles and hair strands in the same routine to ensure the consistency of our findings. We recorded the data to compare findings with the original length. We also noted the health and characteristics of the hair and hair follicles. In our context, healthy hair was distinguished by the steady growth of the hair, no abrupt changes in texture or color, and the hair follicle not having any structural changes.

On the other hand, abnormal traits were classified by stunted growth of the hair, structural damage to any part of the hair, and physical irregularities such as sudden changes in the color of the hair follicle. With the noticeable pattern from both the hair follicle slides and the hair follicles connected to their respective hair strands slides, we anticipated observing either hair growth or reduction in length based on their role in the hair during that week. At the end of the measurement process, we put the microscope slides back into the incubator and repeated the process.

We calculated all metrics for the experimental groups relative to those of the control. This was done to facilitate a clearer assessment of whether there was growth, decline, or no change at all compared to the control group. For instance, we reported the hair strand length growth of 3.8 mm for

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Participant C, and then we calculated the difference between their growth and that of the control group (2.1 mm), resulting in a growth difference of 1.7 mm. The same methodology was used for the hair strands as well.

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