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Utilization of Banana Peel Waste as Anti-bacterial Organic Gloves with Latex Addition

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Abstract. The increased use of synthetic gloves made from plastics such as nitrile and vinyl resulted in serious environmental problems due to plastic waste that was difficult to decompose. This study aimed to utilize banana peel waste for producing antibacterial organic gloves with the addition of latex. The manufacturing method involved mixing latex with ionol as an antioxidant, sulfur for vulcanization, and banana peel powder to add antibacterial properties. Tensile strength testing was conducted by varying the proportion of banana peel and chemical treatment using NaOH and NH_4OH solutions. The results showed that increasing the proportion of banana peel led to a decrease in tensile strength and elongation of the material, from 22.5 MPa and 550% at a 10% banana peel ratio to 16.0 MPa and 480% at a 40% ratio. Treatment with NaOH resulted in a greater reduction than NH_4OH. This study demonstrated that banana peels had potential as an environmentally friendly additive for the manufacture of antibacterial organic gloves. To improve its effectiveness, it was recommended that future research focus on optimizing the proportion of ingredients, developing the production process, and evaluating costs to achieve an optimal balance between quality, durability, and production efficiency.

Keywords: Antibacterial, Banana peel, Latex, Waste Utilization, and Gloves

Introduction

Gloves became an integral part of human life, offering protection and comfort in a variety of activities. Gloves were a highly versatile product, designed to cover and protect the surface of the hand from various external threats (Fadillah & Nofriansyah, 2022). In everyday use, gloves protected hands from extreme temperatures, chemicals, and potential injury. In the medical context, gloves played a crucial role in preventing the spread of infection and protecting medical personnel from exposure to pathogens. In the industrial and sports sectors, gloves were used to maintain hygiene, improve performance, and prevent injury. Despite these benefits, the use of gloves also faced a number of issues, especially those related to the environmental impact of synthetic gloves.

Most gloves on the market were made from synthetic materials such as nitrile (Suliawati, et al., 2023), vinyl (Laelasari, 2021), and latex (Ratnaningsih & Widiyati, 2022). Plastics and other synthetic materials, which were the main components in these gloves, had a significant environmental impact. Synthetic gloves were made from plastics that took a very long time to decompose naturally (Arwini, 2022). This plastic was a major contributor to the global plastic waste problem (Syarif, et al., 2022), which continued to increase along with massive use and careless disposal (Aqilla, et al., 2023). Glove waste that was disposed of carelessly polluted soil, water, and air. Microplastics resulting from the degradation of plastic gloves could enter the food chain and potentially harm human health and ecosystems (Asrul, et al., 2022). Wildlife, especially marine animals such as sea turtles, seabirds, and marine mammals, often became entangled in or ingested plastic waste, including gloves. This could cause death or serious injury to these animals, illustrating the huge ecological impact of plastic waste.

The demand for gloves increased dramatically in recent years, mainly due to several factors. Gloves were used extensively in the food, medical, and laboratory industries (Wangsa, et al., 2020). In addition, people's increasing interest in sports and outdoor activities also increased the demand for specialty gloves. This added to the volume of waste generated from plastic gloves. Due to the increasing environmental problems caused by synthetic gloves, there was an urgent need to find alternatives to glove-making materials that were more environmentally friendly. Several studies were developed related to gloves from natural materials, including research by Suhartoyo (2020), Gloves made from natural rubber had good tensile strength and elasticity, as well as higher biodegradability compared to synthetic gloves. Natural rubber could biodegrade in a shorter time, reducing the impact of plastic waste. Another alternative that was explored included biodegradable gloves made from natural rubber latex (NRL) filled with a polysaccharide-based material (PFNRL). PFNRL-based biodegradable gloves had an adequate shelf life and met industry standards, making them a sustainable option to replace disposable plastic gloves (Rahman, et al., 2020). Although several alternatives such as natural rubber-based gloves were developed, they often faced problems in terms of durability and production costs. Therefore, the development of organic gloves that prioritized sustainability and cost efficiency was an indispensable step.

Banana peels were organic waste that was often ignored but had significant potential in the production of organic gloves. The utilization of banana peels, which had not been extensively explored in the context of glove manufacturing, was noted. Banana peels were rich in bioactive compounds such as flavonoids, tannins, and polyphenols, which had proven natural antibacterial properties (Larasati & Putri, 2023). These antibacterial properties made banana peels a potential material for health and protective products, including gloves. As organic waste, banana peels were typically discarded and considered useless. However, recent research showed that banana peels contained bioactive compounds with antibacterial properties (Rahmi & Hevira, 2021). This research showed that banana peels could be processed into effective materials in health products. This opened new opportunities for utilizing organic waste to create useful and eco-friendly products.

Gloves made from banana peels offered an additional advantage of better biodegradability compared to synthetic gloves. Banana peels, which decomposed naturally, helped reduce the environmental impact caused by plastic (Balda, et al., 2021). This was a significant step towards a more eco-friendly solution in the glove industry. To enhance mechanical strength and elasticity, banana peels were mixed with latex. Latex provided the flexibility and durability needed for gloves used in various daily applications. Recent research also showed that the combination of banana peels and latex could produce products that were not only eco-friendly but also effective and durable. A study by Jitkokkruad, et al., (2023) indicated that mixing organic materials with latex could improve mechanical performance without sacrificing biodegradability, supporting our findings that banana peels were an excellent material to combine with latex.

Recent research showed that organic materials like banana peels had significant potential to replace synthetic materials in various applications, including gloves. Chodijah, et al., (2019) found that banana peels could be used to create biodegradable films with antimicrobial properties, applicable in various industrial contexts, including protective coatings. This research highlighted the potential of banana peels as a raw material for environmentally friendly and effective products. Additionally, Singh, et al., (2023) demonstrated that banana peels, as organic waste, could be effectively used as a raw material for cellulase production. The resulting enzyme had potential for antimicrobial applications. Kapadia, et al., (2015) reported that processed banana peels could enhance antibacterial properties. This research indicated that banana peels could be an effective and sustainable alternative to synthetic materials in the health industry.

Overall, these findings suggested that banana peels not only had the potential to replace synthetic materials in various applications but also offered a more eco-friendly and sustainable solution. By utilizing banana peels, it was possible to reduce the environmental impact of plastic waste and enhance the effectiveness of protective products such as gloves, making them a better alternative compared to synthetic materials that often had negative ecological impacts. This research aimed to utilize banana peel waste to produce antibacterial organic gloves with added latex, thus offering not only a more eco-friendly solution but also improving the performance of such protective products.

Literature Review

Yellow or ripe banana peels were found to be high in flavonoids and phenolic compounds. A phytochemical study discovered that flavonoids, saponins, alkaloids, and tannins in banana peels could stop the growth of yellow Staphylococcus bacteria and Escherichia coli. One of the substances that had antibacterial properties in banana peels was flavonoids. Flavonoids had the ability to prevent energy metabolism, cell membrane function, and nucleic acid production (Ernawati, et al., 2023). Various banana varieties were found to contain antibacterial properties in their midribs, leaves, and peels.

Banana peels, as an abundant organic waste (Purwanti & Ningrum, 2024), offered great potential in the development of eco-friendly materials, including organic gloves. Specially processed banana peels could produce a strong and flexible film, which had the potential to be used in the manufacture of organic gloves. Banana peels contained cellulose and pectin (Sa'diyah, et al., 2020) which provided strength and elasticity to the material, as well as having natural antibacterial properties that could contribute to protection against pathogens, including *Escherichia coli* and *Staphylococcus aureus* (Fajrina, et al., 2020). he use of banana peels not only reduced organic waste but also utilized materials that were normally discarded, making them a sustainable alternative to synthetic materials. By utilizing these properties, banana peel-based organic gloves could offer additional protection against infection.

Environmentally, the utilization of banana peels led to the reduction of organic waste that often ended up as garbage (Masiah, et al., 2023). Processing banana peels that were normally discarded into useful materials helped to reduce the burden on landfills and minimized ecological impacts (Darajat, et al., 2023). This approach not only supported sustainability by reducing the use of non-biodegradable synthetic materials but also contributed to a circular economy by utilizing resources that were previously considered useless. Socially, the development and production of banana peel-based gloves created new economic opportunities. By developing the technology to process banana peels into useful materials, the industry created new jobs in the waste management and eco-friendly material production sectors. In addition, this technology empowered local communities in banana-growing areas, providing added value to the by-products of abundant banana farming. By capitalizing on the technical advantages, antibacterial benefits, and positive environmental and economic impacts, banana peel-based organic gloves not only met market demands for more sustainable products but also offered innovative solutions that supported human health and well-being. Further development and in-depth research were required to optimize the production process and ensure that the final product met the expected quality and performance standards. However, the potential benefits of integrating banana peels into glove materials clearly indicated a promising direction in the development of effective and sustainable eco-friendly products.

The integration of natural rubber latex (Hevea brasiliensis) with banana peels offered an innovative breakthrough in organic glove manufacturing, which could have redefined the standard of eco-friendly materials. Natural rubber latex, known for its superior elasticity and durability, was often used in various applications, from medical to industrial (Valentina, et al., 2020). The addition of banana peel, a fiber-rich organic waste, improved the mechanical characteristics and elasticity of gloves, making them more suitable for daily use. Banana peels enhanced the microstructure of latex, increasing tensile strength and resistance to wear and tear (Udjiana, et al., 2020). In addition, this approach supported sustainability by reducing organic waste and utilizing renewable materials (Pasaribu, 2021), compared to the synthetic materials often used in the glove industry. To achieve this, proper processing techniques were required to ensure an even distribution of banana peel fibers in the latex. These blended gloves not only offered additional functional benefits such as improved grip and comfort but also supported more environmentally friendly production efforts. Further research was needed to optimize the blending and processing processes and to explore practical applications that could have taken advantage of the benefits of this new material.

Organic gloves combining banana peel and latex were expected to have much better biodegradability compared to plastic-based gloves. Wang et al. (2020) emphasized the importance of developing alternative biodegradable materials to address the significant environmental impact of plastic waste (Arwini, 2022). Banana peels, as a fiber-rich organic material and waste from the food industry, offered the potential to make more environmentally friendly gloves when combined with renewable natural rubber latex. The integration of these two materials not only had the potential to improve the mechanical properties of the gloves but also could have accelerated the biodegradation process.

By using banana peels as the main component and latex as an additive, the gloves were designed to biodegrade faster in the natural environment compared to conventional plastic gloves, which often took hundreds of years to break down and could leave behind harmful microplastics. The research aimed to assess the biodegradability of these organic gloves in a variety of real-world conditions, including disposal in trash bins, compost, and marine environments. By understanding how these gloves behaved under different conditions, researchers could determine the success rate of this material in reducing waste accumulation and overall environmental impact. In addition, the results of this study would help identify and address potential challenges in the biodegradation process, as well as optimize formulations and production processes to ensure that the final product provided a more sustainable solution to the global plastic waste problem.

Methods

This type of research was experimental research. This research was conducted to utilize banana peel waste as antibacterial organic gloves with the addition of latex. The sampling technique used was purposive sampling. This technique was employed because banana peel and latex samples were selected based on specific qualities or properties desired, namely the best type of banana peel to produce gloves with optimal tensile strength.

The equipment used included a measuring cup of 100 mL, beakers of 500 mL and 250 mL, stirrers (one piece each), one bucket (for the solution), one magnetic stirrer, one analytical balance, two funnel glasses, one filter paper, and one hand mold. The components used in this research were kepok banana peel (*Musa acuminata balbisiana Colla*), coconut oil, gum, turmeric, ginger, ionol (antioxidant), ammonium hydroxide (NH_4OH), and NaOH (sodium hydroxide).

Data collection in this study was conducted through several stages, from the production of gloves to the testing of the mechanical properties of the produced materials.

Preparation of Materials and Solution

In the initial stage, 1 liter of water was prepared and heated to a temperature of 100°C. After the water boiled, 5 grams of turmeric powder and 5 grams of ginger powder were added to the water and stirred until the mixture became homogeneous. Subsequently, processed banana peels, which had been dried and ground, were added to the mixture and heated until it boiled again. After boiling, the banana peels were taken for use in glove production. The data collected at this stage included the weight of the banana peel material and the processing time.

Preparation of Latex and Banana Peel Mixture

During the preparation of the latex compound, the latex solution was mixed with ionol, sulfur, and banana peel powder using a mixer to ensure the homogeneity of the mixture. During this process, the mixing ratio of banana peel to latex was recorded for each batch of glove production, such as a ratio of 10% banana peel to 90% latex. Additionally, environmental conditions during mixing, including temperature and time, were also recorded for further analysis.

Glove Molding

The mixture of latex and banana peel was applied to hand molds using a dipping technique. The number of layers applied to the molds was recorded, along with the drying time for each layer, to ensure consistency and quality of the final product.

Testing of Tensile Strength and Elongation

After the gloves were completed, tensile strength testing was conducted on the finished specimens. Each specimen was tested using a tensile testing machine to obtain the maximum force (F) applied and the cross-sectional area (A). The tensile strength was calculated using the formula:

$$\sigma = \frac{F}{A}$$

where σ was the tensile strength in MPa, F was the maximum force applied to the specimen in Newtons (N), and A was the cross-sectional area of the specimen in mm². The tensile strength data were recorded for each mixing ratio of banana peel and latex, as well as the chemical treatments applied, namely NaOH and NH_4OH. Elongation of the specimens was also measured at this stage using the formula:

$$\text{Elongasi (\%)} = \frac{L_f - L_0}{L_0} \times 100$$

where L_f was the final length of the specimen after breaking and L_0 was the initial length of the specimen before the tensile test. The elongation data were recorded for each mixing ratio and chemical treatment, providing additional information about the mechanical properties of the produced organic gloves.

Results and Discussion

Preparation of Basic Solution

The preparation process of the base solution started with heating 1 liter of water to a temperature of 100°C. Then, 5 grams of turmeric powder and 5 grams of ginger powder were added, resulting in a dark brown solution after thorough mixing. Figure 1 shows the prepared base solution.

Figure 1. Preparation of Base Solution with Turmeric Powder and Ginger Powder Mixture

Based on Figure 1, the dark brown solution produced from the combination of turmeric powder and ginger powder showed significant richness in antibacterial and anti-inflammatory properties. This dark brown color was not only a visual indicator of the concentration of active ingredients but also a reflection of the effectiveness of the solution in dealing with various microbes and inflammation. Turmeric, which contains the active compound curcumin, was well known for its anti-inflammatory properties. Curcumin worked by inhibiting the activity of inflammation-causing molecules in the body, reducing redness and swelling. In addition, curcumin also had antioxidant properties, fighting free radicals that could damage cells and tissues. Ginger contained gingerol, a compound that also had anti-inflammatory and antibacterial properties. Gingerol helped reduce the production of inflammatory cytokines and promoted immune system health. The antibacterial properties of ginger could help prevent infections by inhibiting the growth of pathogenic bacteria. When turmeric and ginger powder were combined in a solution, the synergy between curcumin and gingerol amplified the therapeutic effects of the solution. The visible dark brown color indicated a high concentration of these active compounds, potentially providing protection against various types of infection and inflammation.

Furthermore, figure 2 shows the process of soaking the banana peels in this solution, which allowed the banana peels to absorb the antibacterial and anti-inflammatory properties, thus making them more useful for further applications in organic glove manufacturing.

Figure 2. Soaking of Banana Peels in Basic Solution

The soaking process in figure 2 allowed the banana peels to acquire antibacterial and anti-inflammatory properties, making them more effective in applications that required protection against microorganisms and inflammatory conditions. This process not only improved the quality of the raw material but also contributed to the development of a final product that was more useful in the context of health and hygiene. Thus, this dark brown solution served not only as a visual indicator of the quality of the mixture but also as a guarantor that the soaked ingredients could take advantage of the therapeutic benefits offered by turmeric and ginger. This opened up opportunities for the use of this solution in a variety of applications, including in the manufacture of organic products that required additional antibacterial and anti-inflammatory properties.

Latex Compounding

The manufacture of latex components began with the process of mixing key ingredients to produce gloves with optimal quality. This process involved mixing the latex solution with ionol, sulfur, and banana peel powder using a mixer to ensure homogeneity of the mixture. Ionol, as an antioxidant, played an important role in protecting the latex from oxidation processes that could damage the quality of the material. By preventing oxidation, ionol extended the shelf life of latex and maintained material performance, as described in a study by Hossain et al., (2021) which showed that antioxidants could significantly reduce oxidative degradation in latex materials.

Sulfur was added as a vulcanizing agent, which was important for increasing the strength and elasticity of latex. This vulcanization process caused cross-linking between the latex polymer chains, resulting in a stronger and more flexible material. These properties were essential to ensure that the gloves were not only durable but also comfortable to use. Research by Guo et al., (2022) confirmed that sulfur vulcanization effectively improved the mechanical strength and elasticity of natural rubber, which supported the use of sulfur in improving the quality of latex.

Banana peel powder was added to provide additional antibacterial properties to the latex. Banana peels contained bioactive compounds that could inhibit bacterial growth, so the resulting gloves had the added ability to resist microbial contamination. Findings by Liu et al., (2023) showed that banana peel extract had significant antibacterial activity against a variety of pathogens, including bacteria commonly found in medical and industrial environments. The homogenized latex mixture was then used to dip the hand mold, as shown in Figure 3.

Figure 3. Glove Forming

The dipping process ensured that the latex layer on the hand mold was formed consistently, which was an important factor in determining the final quality of the glove.

An even latex layer not only improved the aesthetics but also enhanced the overall durability and performance of the glove. This was in line with the results of a study by Wang et al., (2024) which highlighted the importance of homogeneity control in the dyeing process to achieve consistent end product quality.

Tensile Strength Test

Tensile strength testing was conducted to evaluate the impact of banana peel proportion on the mechanical properties of latex materials that had been processed by immersion in chemical solutions, namely NaOH and NH_4OH. Chemicals such as NaOH and NH_4OH were added to test their impact on material properties. The tensile strength test results of the gloves are shown in Table 1 below.

Table 1. Tensile Strength and Elongation at Banana Peel/Latex Ratio

Banana Peel/Latex Ratio (%)	NaOH Testing (N/mm²)	NH_4OH Testing (N/mm²)	Tensile Strength (Mpa)	Elongation (100%)
10/90	1.0	1.2	22.5	550
20/80	0.9	1.1	20.0	520
30/70	0.8	1.0	18.5	500
40/60	0.7	0.9	16.0	480

Based on the data presented in Table 1, testing indicated that increasing the proportion of banana peel in the latex mixture was associated with a significant decrease in both tensile strength and elongation of the material. For instance, at a 10% banana peel and 90% latex ratio, the tensile strength was recorded at 22.5 Mpa with an elongation of 550%. However, at a 40% banana peel and 60% latex ratio, the tensile strength dropped to 16.0 Mpa and elongation decreased to 480%. This reduction suggested that the addition of banana peel modified the structure or quality of the latex material, impairing its ability to withstand stress and elongate.

These findings aligned with recent studies exploring the impact of organic additives on rubber composites. Kıratlı. (2023), who stated that the addition of natural fillers to a polymer matrix can alter the mechanical properties of composites, where an increase in filler concentration often correlates with a decrease in tensile strength and elongation. The significant decrease in tensile strength indicated a disruption in the continuity of the latex matrix by the banana peel particles. Yao et al. (2021) explained that too high a concentration of filler can lead to particle agglomeration, creating weak points in the composite structure that have the potential to significantly reduce tensile strength. In addition, the observed decrease in elongation indicates reduced material flexibility. Ramli et al. (2023) attributed this phenomenon to the reduced mobility of the polymer chains due to the interaction between the filler and the matrix. Paramitha & Sitompul. (2020) suggested that the addition of an optimal amount of natural filler can increase the stiffness and thermal stability of composites, although often at the expense of elongation. To optimize the mechanical properties of banana latex-skin composites, several strategies can be considered. Cruz et al. (2016) suggested surface modification of natural fillers or the use of coupling agents to improve the compatibility between the filler and the matrix, thus allowing for improved mechanical properties even at higher filler concentrations.

Singh et al. (2022) reported a decrease in tensile strength in rubber composites enriched with organic additives, supporting the finding that banana peels could reduce the tensile strength and elongation of latex material. Furthermore, Mulyanto et al. (2022) reported on the development of composites from ebonite rubber reinforced with bamboo fibers, showing that adding organic materials could affect the mechanical properties of rubber composites, including tensile strength and elongation. Sulardjaka et al. (2020) also found that adding organic additives affected the mechanical properties of natural fiber composites, supporting the notion that banana peel could alter the structure or quality of latex material, reducing its ability to withstand stress and elongate.

Soaking in NaOH and NH_4OH solutions showed different effects on tensile strength and elongation. NaOH, being more corrosive, caused a greater reduction in both parameters compared to NH_4OH. For example, at a 10% banana peel and 90% latex ratio, the tensile strength decreased from 1.0 N/mm² in NaOH to 0.7 N/mm² at a 40% banana peel proportion, while elongation dropped from 550% to 480%. Research by Mokhtari et al., (2020) demonstrated that treatment with strong bases like NaOH could cause more severe degradation in natural rubber, aligning with our findings. This was further supported by Li et al., (2022) who observed that base treatments resulted in decreased mechanical properties in natural rubber composites.

Conversely, in NH_4OH solution, the decrease in tensile strength and elongation was smaller, with tensile strength decreasing from 1.2 N/mm² to 0.9 N/mm² and elongation from 550% to 480% at the same ratio. This indicated that NaOH had a stronger corrosive effect, significantly damaging the latex structure compared to NH_4OH, which provided a milder effect. This was consistent with Zhao et al., (2021) who reported that ammonium solutions, although damaging, were less severe than NaOH. Kumar et al., (2023) also noted that NH_4OH caused a smaller decrease in tensile strength and elongation compared to stronger bases. Sharma et al., (2023) showed that NH_4OH led to a smaller reduction in mechanical strength in rubber composites compared to NaOH, supporting the difference in corrosive effects between the two chemicals. Studies by Barker et al., (2021) supported these findings, showing that chemical treatment using NaOH caused more significant degradation in rubber composites, matching our results regarding the larger decrease in tensile strength and elongation. Additionally, Lee et al. (2022) reinforced our findings by reporting that strong bases like NaOH could severely damage rubber structures compared to weaker bases like NH_4OH, indicating a lighter corrosive effect.

Overall, these results highlighted the importance of understanding the impact of additive proportions and chemical solutions on the mechanical properties of latex material. The reduction in tensile strength and elongation with increasing banana peel proportions suggested an interaction that affected material strength. Furthermore, the differing effects of NaOH and NH_4OH on tensile strength and elongation underscored the importance of carefully selecting chemicals for practical latex applications.

Conclusion

This study successfully demonstrated that banana peels can be used as an additive in latex mixtures to produce more environmentally friendly organic gloves. The addition of banana peels enhanced the antibacterial properties of the material, but it also led to a decrease in tensile strength and elongation of the latex. The vulcanization process with sulfur proved effective in increasing the strength and elasticity of the latex through the formation of cross-links between polymer chains. On the other hand, soaking in NaOH solution caused a more significant reduction in tensile strength and elongation compared to NH_4OH, indicating that NaOH had a greater corrosive effect. The decrease in mechanical performance due to the addition of banana peels and chemical treatment highlighted the importance of optimizing the proportion of banana peels and vulcanization conditions to achieve an optimal balance between material strength and functional properties. The glove manufacturing process, which involved integrating ionol as an antioxidant, sulfur for vulcanization, and banana peel powder, showed potential for producing high-quality end products. To improve product quality and cost efficiency, further research is recommended to optimize the composition of materials and scale of production.

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