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Research article

Characterization and Development of Venipuncture Practice Rubber Model Based for BCG Economy Framework

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Abstract: The Bio-Circular-Green (BCG) economy framework, which integrates economic, social, and environmental aspects for waste management, holds great promise for fostering growth across various sectors in Thailand. Venipuncture, a critical medical procedure, can lead to complications if not performed correctly. This study uses Thailand para latex resources and calcium carbonate extracted from recycled mollusk shells to develop an educational innovation model for venipuncture procedures. Natural rubber latex (NRL) was obtained from Chiang Rai, Thailand. Preserved latex was heated to obtain 60% concentrated latex, then combined with a sulfur solution, and calcium carbonate powder was added in various ratios. Molding used a specialized mold replicating anatomical features of the antecubital fossa, incorporating three prominent veins. The venipuncture practice rubber model was characterized for pH, moisture content, water absorption, tensile strength, and other properties. The model exhibited neutral pH, low moisture content, and notable resistance and elasticity. This study promotes the sustainable utilization of natural latex resources and recycled mollusk shells in developing innovative medical models within the BCG framework. Additional research is required to enhance the human friendliness and realism of the rubber material used in the venipuncture practice model.

Keywords: Latex; Mollusk shells; Para rubber; Practice model; Venipuncture.

1. Introduction

A Bio-Circular-Green (BCG) economy is a holistic framework that integrates the economic, social, and environmental aspects of production and consumption to implement a waste management system involving self-sustaining cycle strategies (reduction, reuse, and recycling). The BCG model is particularly relevant for Thailand as it promotes efficient utilization of natural resources by focusing on five developing sectors: food, healthcare, sustainable energy, tourism, and the creative economy [1]. The development of medical technologies and procedures continues to improve patient care, management, and healthcare outcomes [2]. Venipuncture is an invasive technique by healthcare professionals that involves either drug administration or extracting blood from a patient [3]. Poor practices of venipuncture lead to a higher risk of complications, including infection [4], nerve injury [5], and the formation of hematomas [6]. Among these complications, hematoma formation is the most commonly observed issue [6]. Previous studies have been conducted to develop a rubber arm with a fluid system for venipuncture training, aiming to enhance the effectiveness of blood drawing for medical science and nursing students. This innovation can assist students in performing the procedure with confidence by providing a better understanding of the steps involved [7, 8]. The results showed that 72.62% of students appreciated learning the procedure using an artificial arm before performing blood collection from patients [7]. Synthetic polymers for venipuncture practice offer precise structures and customizable properties. However, they can be costly and potentially skin-irritating due to chemical release. Conversely, natural polymers like natural rubber exhibit enhanced biocompatibility. These materials have gained value for artificial blood vessels and muscles due to their beneficial properties when engineered correctly. Therefore, this study utilizes Thailand's para-rubber resources and recycled mollusk shells to develop an innovative educational model for venipuncture procedures. Additionally, we aim to explore the characterization of the para-rubber model and design an initial prototype of a venipuncture model to enhance comprehensive medical education techniques.

2. Materials and Methods

2.1 Materials

The natural rubber latex (NRL) was obtained from Chiang Rai, Thailand. Commercial-grade sulfur, sodium hydroxide, zinc oxide, and methyl paraben were purchased from World Chemical Far East Co., Ltd., Chiang Mai, Thailand. Calcium carbonate was acquired from mollusk shells. The composition includes latex as the primary component, sulfur as the vulcanizing agent, ZnO as an accelerator, and NaOH and paraben as additives. Additionally, $CaCO_3$ functions as a reinforcing agent.

2.2 Preparation of calcium carbonate from mollusk shells

The fresh mollusk shells were washed with water and soaked in a 50% concentrated H_2O_2 solution for 5 days. The shells obtained were then washed, followed by a 10-day soak in a 20% w/v sodium hydroxide solution. Subsequently, the soaked shells were rinsed with water until they reached a near-neutral pH and dried at 120°C for 16 hours. Afterward, the dried shells were ground using a ball mill for 14 hours and filtered through a 150-mesh sieve to separate coarse and fine powder. The resulting coarse powder underwent multiple cycles of soaking in NaOH solution, drying, and grinding for refinement.

2.3 Preparation of the para rubber

Preserved latex was heated to 85°C for 3 hours to obtain 60% concentrated latex. A 2% w/v sulfur solution was prepared using a 1:1:1 ratio of sulfur, sodium hydroxide, and distilled water and heated at 90°C for 50 minutes. This solution was mixed with the concentrated latex and stirred at 80°C for 30 minutes. Calcium carbonate powder from mollusk shells, particle sizes of 50 to 100 microns, was dispersed in the rubber solution in ratios of 80:20, 70:30, and 60:40. The resulting suspension was stirred at 80°C for 40 minutes. Zinc oxide and methylparaben were added at a concentration of 2 wt% each. After neutralization, the mixture was well mixed at 70°C for 20 minutes. After being placed into molds, the mixes were dried at 70°C for 48 hours and then vulcanized at 140°C for 2 hours after removal from the mold. Subsequently, the rubber model underwent characterization, determination, and the construction of prototypes before the trial phase. A diagram of methods is represented in Figure 1.

2.4 Molding and shaping of the venipuncture practice rubber model.

The venipuncture practice rubber model's molding and shaping process involved using a carefully designed mold that replicated the anatomical features of the antecubital fossa, situated on the anterior aspect of the elbow, complete with veins and skin texture. Three prominent veins were inserted on the model within this area: the cephalic, median cubital, and basilic veins [3]. During the next step, the rubber compound was poured into the mold, followed by subjecting the mold to a controlled curing process. This curing process facilitated the solidification of the rubber compound into the intended shape, resulting in a highly realistic and anatomically accurate representation suitable for venipuncture training (Figure 1).

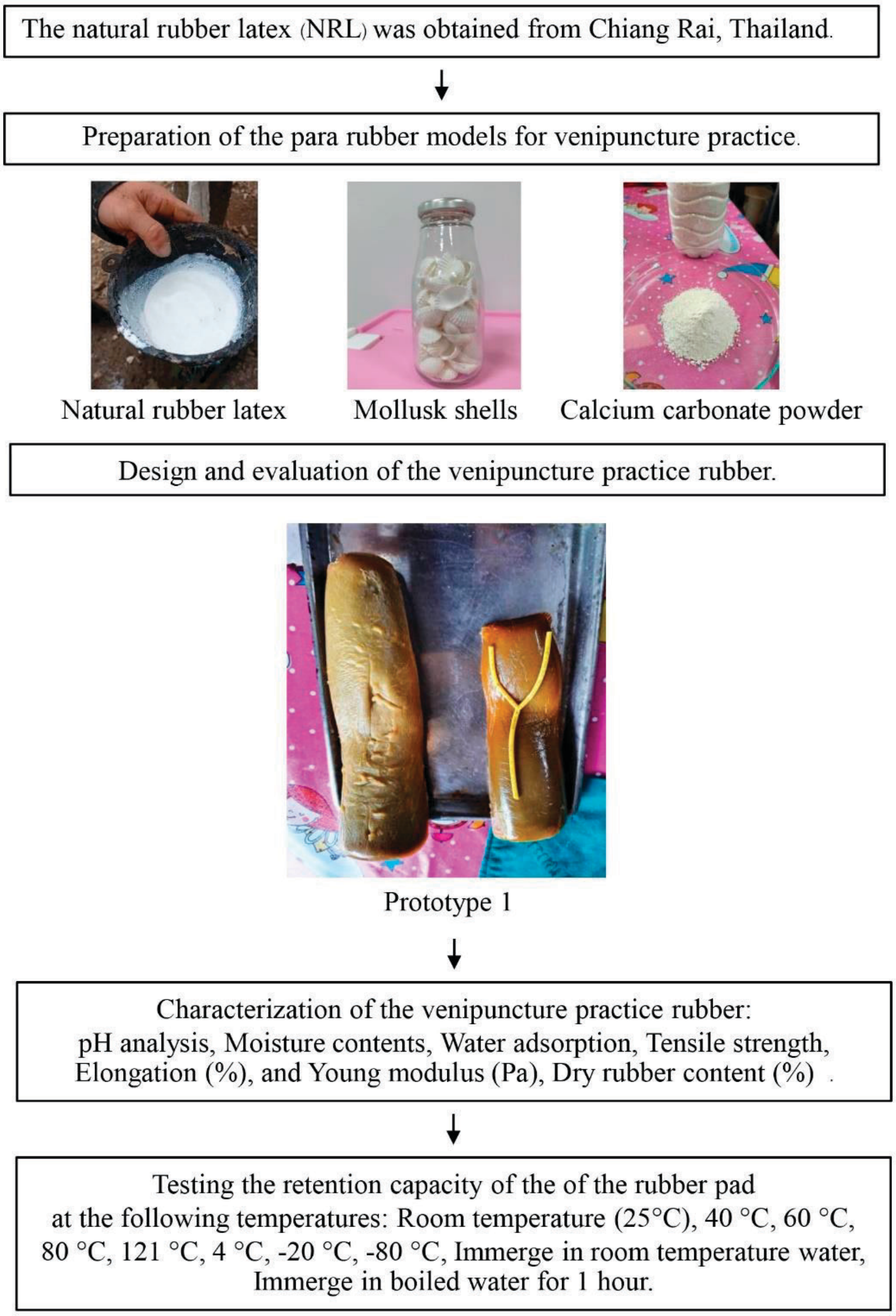

Figure 1. Diagram of developing and characterization of the venipuncture practice rubber model.

2.5 Characterization of the venipuncture practice rubber model

2.5.1 pH analysis

The pH values of the samples were determined using a waterproof pH spear tester (Oakton pH Spear Waterproof Pocket Tester EW-35634-40-Pro, Singapore). The measured ranges ranged from -1 to 15, with a resolution of 0.01, and the accuracy was within ± 0.01. Each sample was measured five times, and data were collected to calculate the average values.

2.5.2 Determination of moisture contents

The moisture content was determined using a moisture analyzer (PMB 53, ADAM, Singapore). The samples, weighing approximately 1 to 2 g with a resolution of 0.01% and sensitivity of 0.1 mg, were placed on the moisture analyzer and subjected to temperatures of 0-50°C for 4 minutes. Each sample was tested five times, and data was collected to calculate the average values.

2.5.3 Measurement of water adsorption

The samples were all precisely weighed (W1) and immersed in distilled water for 24 hours at room temperature. The swollen samples were removed, and the excess water was taken off the surface. Then, the swollen samples were reweighed (W2). The percent water adsorption of the samples was calculated using the following equations:

$$\text{Water adsorption (\%)} = (W2-W1)/W1 \times 100$$

2.5.4 Testing of tensile strength, elongation (%), and Young modulus (Pa)

The Universal Material Testing Machine (Instron 5569, US) and ASTM D638M-93 were used to test tensile strength, elongation (%), and Young modulus (Pa) with a 60N load cell. The sample size was 110 × 20 mm. The crosshead speed was set to 5 mm/min. Each sample was tested at least five times in parallel.

2.5.5 Determination of dry rubber content (%)

The dry rubber content of rubber latex was measured following the standard method of ISO 126:2005.

2.6 Assessment of the retention capacity of the rubber pad of the venipuncture practice rubber model

The rubber model was then cut into uniform square shapes. Before commencing the experiment (pre-incubation), the weight and volume of each rubber pad were measured with three repetitions for accuracy. Subsequently, the rubber pads were incubated at different temperatures: ambient room temperature (25°C), 40°C, 60°C, 80°C, 121°C, 4°C, -20°C, -80°C, room temperature water, and boiled water. Each point was incubated for one hour (incubation), and the weight and volume of each rubber pad were measured with three repetitions. Following the temperature incubation phase, the rubber samples were allowed to stabilize at room temperature for one hour (post-incubation), after which their weight and volume were measured, again in triplicate.

3. Results and Discussion

3.1 Characterization of the venipuncture practice rubber model

The physiochemical and mechanical properties of the venipuncture practice rubber model are shown in Table 1. The pH values of the venipuncture practice rubber model were 7.92 ± 0.15. The pH value was neutral and did not cause skin irritation while being used. The percentage of moisture content value was 0.14 ± 0.05%, indicating that there would be only minimal bacterial growth. The recorded water absorption was 9.12 ± 0.02%, owing to the formation of pores during the preparation of the rubber compound. After the drying procedure, the sample underwent a controlled evaporation process that led to the residual presence of porous regions, thereby giving rise to the occurrence of closed or open pores. Calcium carbonate was added to increase the hardness and tensile strength of the venipuncture practice rubber model (2.54 ± 0.054 MPa). The elongation, Young modulus, and dry rubber content values were 669.5 ± 1.94%, 1.51 ± 0.35 Pa, and 36.37%, respectively. Sulfur increased the hardness of the rubber, and zinc oxide was the catalyst for the cross-linking reaction. These chemical combinations helped the rubber to have less stretch and higher resistance to tensile strength. It confirmed that the dry rubber content of the sample met the quality criteria of field latex. According to a previous study, natural latex had remarkable mechanical characteristics because of its distinctive hierarchical structures, including strong tensile and tear strength, high cracking growth resistance, good elasticity, and low heat buildup. Natural rubber latex particles have a core-shell structure consisting of a polyisoprene hydrophobic core encircled by either a layer of mixed proteins and phospholipids or a layer of lipid monolayers below a protein monolayer [9]. Our results indicated that para rubber is suitable for developing rubber materials used in venipuncture practice.

Table 1. Characterization of the venipuncture practice rubber model**.**

Physiochemical and mechanical properties	Venipuncture practice Rubber
pH	7.92 ± 0.15
Moisture content (%)	0.14 ± 0.05
Water adsorption (%)	9.12 ± 0.02
Tensile strength (MPa)	2.54 ± 0.054
Elongation (%)	669.5 ± 1.94
Young modulus (Pa)	1.51 ± 0.35
Dry rubber content (%)	36.37

After molding and shaping the venipuncture practice rubber model, the artificial blood was poured into the tubes embedded in the model. We successfully drew artificial blood from the venipuncture practice rubber model in the conducted trials phase. However, it should be noted that this study was a preliminary investigation of the characteristics of the rubber model. The study of qualification and satisfaction surveys to align with human friendliness, realism, and a lifelike blood collection simulation mimicking practical human situations should be investigated in further study.

3.2 The retention capacity of the rubber pad of the venipuncture practice rubber model

The gross appearance of the rubber pad did not change after incubation in different temperature environments (Figures 2 and 3). However, the venipuncture pad changed to a pale color and became bloated when exposed to a temperature of 121°C and immersed in boiled water (Figures 2 and 3). The weight and volume of the rubber pad remained unchanged across the various incubation time points (pre-incubation, incubation, and post-incubation) under different temperature exposures, except for incubation of rubber in boiled water (> 200 °C) (Figures 4A and 4B). The rubber pad displayed a notable retention capacity and returned to its original state after exposure to various temperatures. As seen in previous studies, the hyperelastic mechanical response and deformation of rubber were influenced by temperature [10, 11]. In Thailand, rubber models used for medical and health studies were frequently employed in challenging environments with varying temperatures. Fluctuations in temperature due to seasonal changes can lead to significant changes and deformity of the mechanical characteristics of rubber, especially in the summer. Consequently, the effects of temperature on the mechanical properties of the rubber model should be a significant point of concern in developing the rubber model. Understanding how weight and volume change with temperature variations would help refine the model's design and manufacturing, ensuring optimal performance and quality during use. A limitation of our study was the lack of a scanning electron microscope to further examine the mechanical properties and fracture mechanism of rubber pads under different temperature exposures.

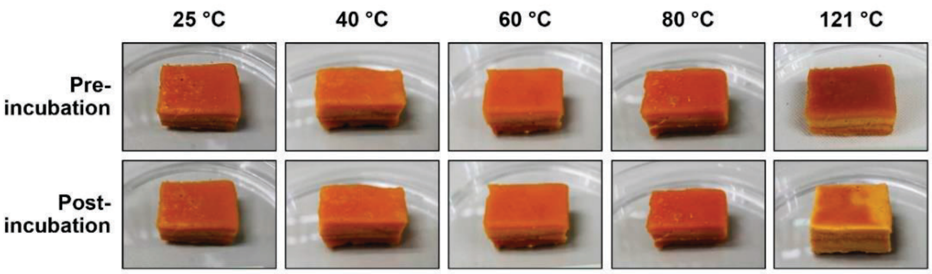

Figure 2. Testing the retention capacity of the rubber pad at various temperatures: 25°C, 40 °C, 60 °C, 80 °C, 121 °C, before and after incubation for 1 hour.

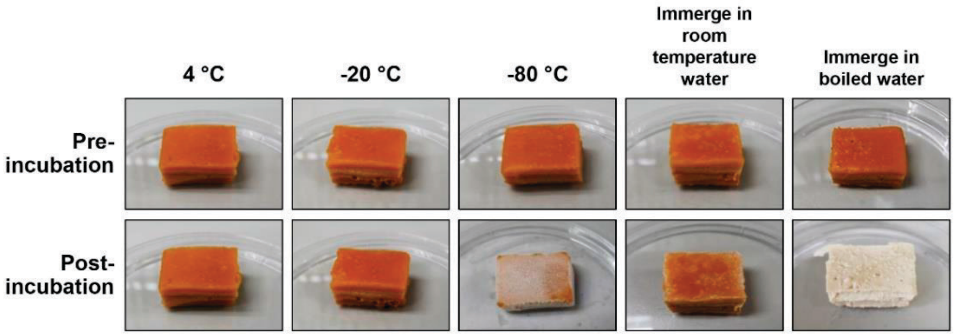

Figure 3. Testing the retention capacity of the rubber pad at various temperatures: 4 °C, -20 °C, -80 °C, after immersion in room temperature water, in boiled water, before and after incubation for 1 hour.

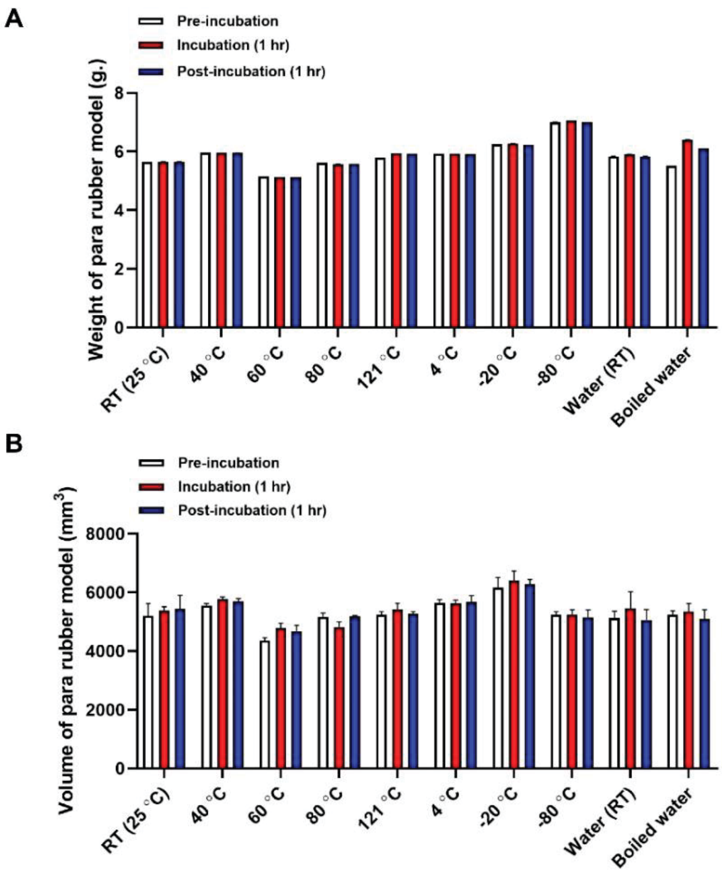

Figure 4. The graph of weight and volume changes of the rubber pad at various temperatures (A and B). Pre-incubation means the initiation time point that measures the weight and volume of the rubber pad. Incubation means the time after incubating the rubber pad at various temperatures for 1 hour (hr.). The rubber pad was then measured to establish its weight and volume. Post-incubation means the time after incubation, leaving the rubber pad at room temperature for 1 hour (hr.) and immediately measuring its weight and volume—RT; room temperature.

4. Conclusions

In conclusion, the venipuncture practice rubber model was characterized by favorable physiochemical and mechanical properties. The model exhibited neutral pH, low moisture content, and notable resistance and elasticity. The model's retention capacity was evident, maintaining its weight and volume across varying temperatures, except for exposure to extreme conditions. Our research suggested that para rubber can create materials specifically for venipuncture procedures. However, this study needs further improvement to enhance human friendliness and realism, aligning the model more closely with lifelike blood collection simulations in practical scenarios.

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References

[1] Cheng, H.Y.; Lu, C.Y.; Huang, L.M.; Lee, P.I.; Chen, J.M.; Chang, L.Y. Increased frequency of peripheral venipunctures raises the risk of central-line associated bloodstream infection in neonates with peripherally inserted central venous catheters. *Journal of Microbiology, Immunology and Infection*. **2016**, *49*(2), 230-236. https://doi.org/https://doi.org/10.1016/j.jmii.2014.06.001

[2] Edyvean, R.G.J.; Apiwatanapiwat, W.; Vaithanomsat, P.; Boondaeng, A.; Janchai, P.; Sophon-thammaphat, S. The Bio-Circular Green Economy model in Thailand-A comparative review. *Agriculture and Natural Resources*. **2023**, *57*(1), 51–64. https://li01.tci-thaijo.org/index.php/anres/article/view/258253

[3] Fu, X.; Wang, Z.; Ma, L.; Zou, Z.; Zhang, Q.; Guan, X. Temperature-Dependence of Rubber Hyperelasticity Based on the Eight-Chain Model. *Polymers*. **2020**, *12*(4), 932. https://doi.org/10.3390/polym12040932

[4] Horowitz, S.H. Venipuncture-Induced Nerve Injury. *Journal of Neuropathic Pain & Symptom Palliation*. **2005**, *1*(1), 109-114. https://doi.org/10.3109/J426v01n01_17

[5] Jarintanan, F.; Chanprasert, K.; kongwan, W.; Ratanawiboolsook, N.; Pawinwongcha, J.; Liemmanee, W. Rubber arm with fluid system for venipuncture training, new model in clinical skills tutors. *Progress in Applied Science and Technology*. **2016**, *6*(1), 212-220. https://ph02.tci-thaijo.org/index.php/past/article/view/243173

[6] Kimori, K.; Konya, C.; Matsumoto, M. Venipuncture-Induced Hematomas Alter Skin Barrier Function in the Elderly Patients. *SAGE Open Nursing*. **2018**, *4*, 2377960818782050**.** https://doi.org/10.1177/2377960818782050

[7] Lew, K. *3.05 - Blood Sample Collection and Handling*. In J. Pawliszyn (Ed.), Comprehensive Sampling and Sample Preparation (pp. 95-121). Academic Press. **2012**, https://doi.org/https://doi.org/10.1016/B978-0-12-381373-2.00068-5

[8] Rey, T.; Chagnon, G.; Le Cam, J.B.; Favier, D. Influence of the temperature on the mechanical behaviour of filled and unfilled silicone rubbers. *Polymer Testing*. **2013**, *32*(3), 492-501. https://doi.org/10.1016/j.polymertesting.2013.01.008

[9] Saengpayab, Y.; Kongsri, W.; Chongsereecharoen, E.; Pratummasoot, N.; Akkarapattanapong, V.; Jarintanan, F. Venipuncture training assists using electrical sensors in a rubber arm system. *Journal of Physics: Conference Series*. **2021**, *1719*(1), 012025. https://doi.org/10.1088/1742-6596/1719/1/012025

[10] Thimbleby, H. Technology and the future of healthcare. *J Public Health Res*. **2013**, *2*(3), e28. https://doi.org/10.4081/jphr.2013.e28

[11] Wei, Y.; Zhang, H.; Wu, L.; Jin, L.; Liao, S. A review on characterization of molecular structure of natural rubber. *MOJ Poly Sci*. **2017**, *1*(6), 197-199. https://doi.org/10.15406/mojps.2017.01.00032