Development of Novel Respiratory Face Masks Prepared from Banana Stem Fiber Against Bio-Aerosols: An Eco-Friendly Approach

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Abstract: Invisible enemy, the horror of Coronavirus, has terrified the whole world for the last few months. The panacea of absolute salvation is undoubtedly vaccine, which is still under research. Scientists have emphasized on preventive measures against Coronavirus rather than cure. The use of masks is mandatory in public places. Mask preferentially prevents the absorption of harmful airborne particles circulating in the air for prolonged periods, thus non-inhibiting the respiratory cycle. In this article, we have screened various masks and developed a novel face mask derived from bio-cellulose. The present work is deliberated on banana stem fiber extracted from banana peel by applying minimal chemical treatment in a simple laboratory protocol. The banana face mask can be recycled and biodegraded with ease. The impregnated banana face mask may act as a physical screen between the transmission of bioaerosols and the respiratory tract providing high safety, security, and economic one with respect to prevalent face masks like N95, surgical masks, and others in the market.

Keywords: banana stem-fiber; bio-mask; Coronavirus; respiratory; renewability; biodegradability; bioaerosols.

Abbreviation: HCoV; human Coronavirus; SARS; serve acute respiratory syndrome; MERS; middle east respiratory syndrome; COVID-19; coronavirus discovery in 2019; WHO; world health organization. ICTV; international committee on taxonomy of viruses. IBV; infectious bronchitis virus. PPE; personal protective equipment.

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1. Introduction

1.1. Journey with Coronavirus.

HCoV (COVID-19) caused by coronavirus-2 or SARS-CoV-2 spread almost all over the world, was declared a global pandemic by the WHO, on March 11, 2020. In late December 2019, it was first noted that a new kind of respiratory infection came into the picture in Wuhan, China [1]. This pandemic resembles(82% RNA genome similarity) to earlier breakout of Severe Acute Respiratory Syndrome Coronavirus (SERA-COV) from during 2002 - 2003, causing death to nearly 10% of the total infected people and the Middle East Respiratory Syndrome Coronavirus (MERS-CoV), approximately 36% fatality rate out of total infected [2,3] in 2012. A substantial economic meltdown occurred globally. Everyday life has almost...
paralyzed under the eclipse of this HCoV. The global financial crisis is affected the market openness. People from all sections of society are compelled to stay indoors globally for their safety and well being instead of venturing out. Thus, to address the severity of airborne infection on public health aspects, researchers stressed the significance of indigenous face masks in protecting the wearer from infection.

Furthermore, to prevent subsequent community spreading of any aerosol type diseases, toxicant exposure, use of appropriate masks, and social distancing could be the realized remedy. Various masks have differential filtration abilities hence used for different purposes [4]. Considering the dimension and severity of the HCoV, scientists and WHO have prioritized surgical grade N95 for rational public use. However, these masks are very costly, limited supply, and practically uncomfortable for more extended periods of usage. Accomplishing comfortable, cost-effective personal protective wear is a challenge for the bioenterpreneurs in the competitive. Here, we have proposed a bio-face mask prepared form banana fibber, which could be redeveloped further easily.

1.2. Etymology.

Coronavirus's microscopic image shows that the protein layers are scattered around it and an exactly look-like halo of the sun or the moon or solar corona (Figure 1). McIntosh et al. show that the particles were medium-sized (80–150 nm), pleomorphic, membrane-coated, and covered with widely spaced club-shaped surface projections [5]. WHO, officially on 11th February 2020, renamed the new disease as “COVID-19” in consultation with ICTV.

![Microscopic image of Coronavirus](image-url)

**Figure 1.** Microscopic image of Coronavirus [5]. Reprinted with permission from *Proc Natl Acad Sci USA*. 1967, 57, 933–940.

1.3. History of HCoV discovery.

By 1930, a new type of viral disease, the acute respiratory infection, was found in domestic chickens caused by the infectious bronchitis virus (IBV), a new RNA virus [6]. This new group of RNA viruses was named Coronavirus [6]. In the 1940s, two more animal coronaviruses were detected; those are transmissible gastroenteritis coronavirus (TGEV), which infects pig [7], and mouse hepatitis coronavirus (MHV) [8]. Human coronaviruses were...
first isolated in the 1960s [9]. In 1965, Tyrrel and Bynoe, working at British Medical Research Council, successfully cultivated the first HCoV through human embryonic tracheal and nasal organ culture, and they named this new group of viruses B814 [9]. Around the same time, Harme and Procknow at the University of Chicago have isolated a new type of virus, called 229E. The morphological similarities of B814, 229E, and IBV were characterized under an electron microscope [9]. All three are detected or isolated in common cold conditions and tended to attack the respiratory problem. Scientists from the National Institute of Health during 1965-66 could isolate a new strain of virus stressing upon the organ culture [5]. The first global epidemic occurred with coronaviruses during 2002-2003 (SARS-CoV) and MERS-CoV in the year 2012.

1.4. Classification of HCoV.

Coronaviruses constitute the family Coronaviridae, belonging to Nidovirals order [10]. Coronaviride further classified into four genera: Alphacoronaviruses (HCoV-229E [11], HCoV-NL63 [12], TGEV [13], PEDV [14], FIPV [15], CCoV [16]), Betacoronaviruses (MHA (Nedellec) [17], BCoV [18], SARS-CoV [19], MERS-CoV [20]), Gamacoronaviruses and Deltacoronaviruses.

1.5. Structure of coronaviruses.

Cyro-electron predicts that corona virion is spherical, and the diameter is approximately 125 nm [21]. Coronaviruses are adapted by the largest member of the single-strand positive-sense RNA virus. They have an unusually large genome among all RNA genomes, ranging between 27 to 32 kilobase (kb). The genome typically contains a 5'cap with 3'poly tail—the 5'end allows RNA for the replication and transcription. The 3'end plays a crucial role in replicating RNA and synthesis of viral RNA [22-23]. It consists of mainly four structural proteins: the nucleocapsid proteins (N), the membrane proteins (M), the enveloped proteins (E), and the spike proteins (S) [23]. The N-terminal protein resides in the nucleocapsid having two terminal ends: N-terminal domain (NTD) and C-terminal domain (CTD). Both domains can bind RNA protein and eventually contribute to optimal RNA binding using a different mechanism. The affinity towards the viral character of RNA is enhanced due to structural changes upon phosphorylation [24]. Binding of N protein is facilitated with the viral RNA [25, 26]. The M-protein molecular weight is ~25-30 kDa in coronavirus virion. It has a tiny N terminal glycosylated ectodomain and a big C terminal endodomain, reaching 6-8 nm into viral particle [27, 28]. Preprint studies suggest that M protein may acquire two different conformation types, which facilitate binding nucleocapsid after promoting the membrane curvature and M protein subsist as a dimer in the virion [29]. The highly divergent E-protein is found in small quantities within the coronavirus virion (~8-12 kDa). It constitutes of N terminal ectodomain and a C terminal endodomain topologically and shows activity through the ion channel. It regulates the assembly and release of the virus [30]. The spike protein is one of the important parts that mediates coronavirus entry into host cells. It consists of three segments: a large ectodomain, a single-pass transmembrane anchor, and a short intracellular tail [31]. The ectodomain contains two parts: receptor binding sub-unit S1 and membrane fusion sub-unit S2 [32]. S1 helps the virus to hold on the surface of the receptor. S2 quickly fuses the host and allowing viral genomes to penetrate host cells [32]. The spike protein formed two structurally distinct conformations, pre-fusion, and post-fusion; the transition from pre-fusion to post-
fusion leads to membrane fusion by triggering the protein; hence host cells is affected by viruses [33-34].

1.6. Mode of replication.

The Spike protein of Coronavirus (SARS-CoV-2) acted as a molecular machine and forced Coronavirus entering the host cell. Coronavirus enters into the respiratory tract of humans. After binding, HCoV hijacks cellular machinery to make more and copies of itself. Hence, it can spread the surroundings cells [34].

1.7. Mode of transmission.

Presently, the rapid growth of the number of infected patients with time suggests that the virus must be transmitted through the air. Roy Anderson and Robert introduced the concept reproductive number (R\textsubscript{0}) in their book1992. If R\textsubscript{0} = 1 means one infective person infects exactly one new person. If R\textsubscript{0} = 2 means one infective person infects two new persons, and so on (Figure 2) [35]. An average human can inhale particles up to 100 μm in dimension, and the aerosol is relatively smaller than this. Usually, the virus spread when people cough, sneeze, and tiny droplets containing the virus are released. These droplets can undergo other person's nose, eyes, and finally enters into the host cell. A new person finally gets affected [36]. Preprint data showed that SRAS-CoV-2 remained viable in aerosol for up to 3 hours and was stable in the plastic surface up to 72 hours and 48 hours on stainless steel surface [37]. Mostly environmental sampling is undertaken in diverse establishments like malls, hospitals, govt. offices and departmental stores. To date, except for supportive treatment, no permanent solutions are available. Therefore, proper protection and awareness is the only way to survive.

![Figure 2](https://nanobioletters.com/)  
**Figure 2.** A plot Number of person (N) and Time. R\textsubscript{0} > 1, Rapid growth of case; R\textsubscript{0} = 1, no. of an infected person remain constant; R\textsubscript{0} < 1, will lead to outbreak ending.

1.8. Masks as a PPE.

In the current situation, although we have focused on the corona, it has no hesitation in saying that the mask is not just to protect the corona but to further protect from other air pollutants. As the population grows, factories are growing to meet their needs, and the number of vehicles is increasing. The aerosols, solid, liquid, and gaseous particle suspended in air, originated from factories, cars, and fossil fuel burning. An ambient air pollutant is high and demands a high risk for people, especially among children and patients with heart diseases, cardiovascular diseases. People have trouble breathing problems to dust, yard work. For these global issues like dust allergies or asthma-related health problems, face mask choice is best [38-40]. Over the past few decades, scientists have relied on face masks to protect from disease. During the world war period, the influenza epidemic between 1918-1920, wearing a face mask
was mandatory for health workers and police and people attached to epidemic care issues [41]. The history of masks uses very old. The travelogue of the Italian traveler Marco Polo wrote the use of masks in China in 13th century (https://www.globaltimes.cn.). “Brownian motion” named after Scottish researcher Robert Brown, in 1827, invented that the protective efficacy of masks on dust (https://www.globaltimes.cn.). To walk the path along with the epidemic, it is essential to wear a face mask as a PPE. The main objective behind face masks is to block them from spreading in air through droplets. Being an asymptomatic syndrome, it is impossible to understand whether he or she is affected or not. Hence, it is necessary to wear face masks for every people for their safety and community safety.

1.9. Parameter selection.

It is important to select parameters for designing and synthesizing a mask. The mode of action and stability of aerosol is different, and it varies with the size. The most important parameter is that the filtration ability should be the same or smaller size than aerosolized droplets [42, 43].

1.10. Types of masks.

Cloth masks are very common, cheap, and easy to make in the home. Generally, people sitting in a rural area or those who have a shortage of proper masks choose cloth masks as protection. Many preprint studies suggest that cloth masks with two to three-layer are better than a single layer. Further, It is not better but helps protect from movable larger particles in the air [43]. Masks with activated carbon coating are capable of filtrate NO\textsubscript{x}, SO\textsubscript{x}, CO\textsubscript{x} like toxic gases from the air [44]. Copper coating masks are generally used to protect from influenza by using the potent biocidal properties of copper [45]. At least 95% of solid or liquid aerosols can block under N95 receptor capacity. Therefore, the number say 90, 95, 96 refers to the minimal percentage of aerosols filtered under test conditions [46]. Even the above-mentioned respirator can make it more difficult for the wearer to breathe due to the building up of carbon dioxide, which may reduce oxygen intake, as consequences increased breathing rates and heart rates. Exposure to the fire zone can outweigh the benefits of the mask.

1.11. Filtering efficiency of facemasks.

\[
FE = \frac{X_u - X_d}{X_u} \times 100
\]

FE, filtering efficiency of face mask. \(X_u\), upstream air, \(X_d\), downstream air [47].

2. Materials and Methods

The banana stem was stripped manually and then shaken under the mixer mechanically. It was then subjected to treat under 1% NaOH solution and washed thoroughly with 1% CH\textsubscript{3}COOH solution. It was then washed thoroughly with water and dried afterward. The dry mass was added to a little surfactant or starch solution and shacked several times. The fine nano bed is developed, and it was placed in 100°C - 120°C for 4 hours or under sunlight for 1-2 days. Similar techniques are employed to synthesize cellulose nanofibers from banana peel from chemical treatment [50]. Nano range of 90 nm – 150 nm is attained in the nanofibers [Figure 3]. The stepwise procedure has been shown in figure 4 (A-F). It is noteworthy that nanofiber has been separated from banana peel by pretreatment, chemical treatment, mechanical
treatment, and disintegration methods like sonication, cryo-crushing, and dissolution previously [48 - 55].

Figure 3. TEM images of the acylated cellulose nanofibers [51]. Reprinted with permission from IOSR-JAC 2017, 10, 15-19.

Figure 4. (A) Separation of banana bark from a Banana tree; (B) Separation of Banana Stem from banana bark or banana tree; (C) Banana peel cutting; (D) Banana stem dust; (E) Banana mask sheet wait; (F) Banana mask sheet dry.

Figure 5. Degradation of the stem through alkaline hydrolysis.

The main chemical compositions of banana fiber are cellulose (60%-62%), hemicellulose (19%), lignin (5-7%), and others [56]. Cellulose is a naturally occurring fiber.
consisting of a D-anhydroglucopyranose unit linked together with \( \beta- (1\rightarrow4) \) glycosidic bond. They are joined with each other by hemicelluloses. The whole structure is covered through lignin [56]. Alcoholic degradation with stream explosion breaks the hemicellulose bond, disrupting lignin structure and the linkage between others cellulose or carbohydrate and making solid bio-mass into smaller ones and for a further subsequent process (see Fig. 5).

3. Results and Discussion

The mask was first tied to the vacuum cleaner's end, and maximum dust particles accumulated on the mask surface. The same experiment was repeated several times and showed similar results. Furthermore, the experiment was carried out with NaCl; it was found that maximum NaCl was adsorbed on the mask's surface. Few particles were found in the reservoir of the vacuum cleaner. The presence of maximum dust or NaCl on the mask's surface indicates the quality of the filtering efficiency of the mask. The newly invented bio mask has primarily experimented as field trial among the people in the remote area of West Bengal, India, and no adverse effect regarding respiration was found with the face mask use. A schematic diagram of the mask is shown in figure 6A-6B, and Figure 6C depicts the final face mask prepared from banana.

![Figure 6. A. Front view of face mask. B. Side view of face mask. C. 2D view of the face mask from banana peel.](image-url)

4. Conclusions

The evolution of the industrial benefits of banana peel as a renewable source to prepare a face mask would greatly impact our society. The newly developed bio mask would be competitive in the mask market, having better efficiency. It can help healthcare workers and common people, protecting them from viral infection and transmission. The development is very consistent with the most fundamental appeal that has grown in recent time to sustain a safe environment and a clean environment. The recent worldwide epidemic has shown the crisis of money, environmental protection, won protection. The central crisis is financial stability; the problem can be solved through sustainable implications among rural people and a renewable source of raw material. This waste plant material usability would boost employment generation, adding value to an agriculture waste and environmental benefits.

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https://nanobioletters.com/1999
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**Conflicts of Interest**

The authors declare no conflict of interest.

**References**


