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Preparation and Characterisation of Gellan Gum Hydrogel containing Curcumin and Limonene

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Abstract. Success in wound treatment requires careful assessment on the wound and suitable wound dressing. In this project a novel incorporation of both curcumin and limonene into gellan gum hydrogel have been done. This system is believed to have a better permeation of curcumin to the target area. The samples prepared are denoted as GGTF for gellan gum thin film, Cur-GGTF for curcumin gellan gum thin film. Samples of Cur-GGTF incorporated with limonene with three different concentrations of 0.0005 M, 0.0006 M and 0.0007 M are known as CurLim-GGTF05, CurLim-GGTF06 and CurLim-GGTF07, respectively. The hydrogels were crosslinked by calcium ion. From the FTIR analysis, all of the expected functional groups from the gellan gum, curcumin and limonene were found present in the hydrogel samples. The TGA-DTG analysis has proven that the incorporation of limonene into hydrogels has decreased the thermal stability of the hydrogels. The addition of limonene has caused a hike in the gel fractions of the hydrogels. The water vapour transmission rate (WVTR) and swelling test showed that the introductions of high concentrations of limonene into the hydrogels have hampered the absorption of water molecules thus causing the swelling degree to decrease.

1. Introduction
Hydrogel is a polymer in three dimensional networks which is hydrophilic and capable of assimilating vast amount of biological fluids and water [1]. Due to their adjustable physical and chemical characteristics, the hydrogels have evolved as crucial substance for wound healing and management. The hydrogel adhesives act as a boundary against bacterial infection by adhering to the tissues and staying intact by acquiring plentiful mechanical strength. In addition, the wound exudates are being absorbed by the hydrogels and subsequently the moisture of the wound are kept for an accelerated cure. These cater the wound an outright protection and healing process [2]. The utilisation of hydrogel minimises the wound area with the increasing duration of wound healing [3].

Gellan gum is a polysaccharide produced by Pseudomonas elodea, a Gram-negative bacterium which is non-pathogenic [4]. High acyl and low acyl forms of gellan gum are obtainable commercially. The low acyl gellan gum latterly has been the choice of interest in wound care and tissue engineering fields. This is due to the resemblance of the low acyl gellan gum as the natural extracellular matrix and it is biologically inert [5]. High acyl gellan gum is less stable than low acyl gellan gum due to the presence of bulky acyl group which produce a weaker gel by disrupting the gelling process. Due to the high stability and optimum stiffness properties of low acyl gellan gum, it makes a promising material for wound dressing application [6].
Curcumin is a phytochemical agent in the spice, turmeric that is responsible for the distinctive taste and yellow colour of Indian curry. Traditional Indian medicine also vastly used curcumin. The antiinflammatory and antioxidant properties of curcumin have been the reason for it being used as a medium of wound healing and treatment of various diseases for millennia [7]. Curcumin is a primary curcuminoid, which is a group of phenolic compounds isolated from the rhizome of Curcuma longa L, turmeric from the Zingiberaceae family [8]. Curcuminoid is referred as a group of compounds such as curcumin, demethoxycurcumin, bis-demethoxycurcumin and cyclic curcumin. Curcumin is the major component and cyclic curcumin is the minor component out of these compounds [9]. Chemically, curcumin is termed as diferuloylmethane and the IUPAC name is 1,7-bis(4-hydroxy-3-methoxyphenyl)1,6 heptadiene-3,5-dione [10]. Curcumin provides protection to skin by decreasing any inflammation and extinguishing free radicals off the skin. In addition, it is found that curcumin elevates fibroblast and vascular density in wounds, enhance collagen deposition and consequently, minimize the time taken for wound healing. Besides, curcumin is a powerful non-toxic agent for curing skin disorders. The proangiogenic property of curcumin induces accumulation and angiogenesis of extracellular matrix, which continues through the remodeling phase of wound healing [11].

Limonene (4-isopropenyl-1-methylycloclohexene) is a monoterpene which can be found in lemons, grapefruits, oranges, limes and other citrus fruits. Terpene is a large group of unsaturated hydrocarbons found in essential oils of plants especially in citrus trees [12]. There are two isomers of limonene which are D-limonene and L-limonene. Yet, D-limonene is the prime active form of limonene [13]. Dlimonene is the main flavour compound in citrus oil. It has been utilised numerous as food flavouring and tumor treating agent [14]. Besides, it has been discovered to be used in chemotherapy as an antimicrobial agent and antioxidant against cancer [15]. By certain cellular mechanisms, the growth of tumor can be inhibited by limonene. The prevention of the development of new blood vessels by angiogenesis process is one of them which aids in the reduction of inflammation [16, 17]. Above all, the tissue-repair properties of D-limoenene have been proved significantly due to the remarkable antiinflammatory effects in wound-healing [17]. Nonetheless, the skin absorption of inadequately permeable drugs can be escalated by incorporating limonene, which is an effective enhancer into the system [18]. On top of that, burn wound antimicrobial treatment could be enriched by limonene via the amplification of drugs’ permeation [19].

2. Materials and methods
2.1 Material
Low-acyl gellan gum (Gelzan™ CM), glycerin, calcium chloride, CaCl₂ were obtained from Sigma Aldrich. Curcumin and Limonene were purchased from Acros Organic. All materials were used as received. No further purification was required.

2.2 Preparation of Samples

2.2.1 Preparation of Gellan Gum Thin Film (GGTF)
GGTF was prepared by dissolving 0.5 g of gellan gum powder in 30 mL deionized water (18 MΩ cm⁻¹). Then, the solution was mixed with 2.5 mL of glycerin which acts as a plasticizer. Next, 5 mL of 0.03 M of calcium chloride, CaCl₂ was added dropwise to establish the physical crosslinking process. The solution was then stirred using magnetic stirrer on hot plate set at temperature of 80 °C for a total mixing of 2 hours. After 2 hours, the solution was placed in a petri dish and left in the oven drying at 72 hours and 35°C. Finally, the GGTF was stored in the desiccator at room temperature for further characterizations.

2.2.2 Preparation of Curcumin Gellan Gum Thin Film (Cur-GGTF)
The same method to prepare the GGTF was adapted here as mentioned in 2.2.1, only that 2.1 g of curcumin was added to form 0.06 M Cur-GGTF.
2.2.3 Preparation of Curcumin–Limonene Gellan Gum Thin Film (CurLim-GGTF)

The same method to prepare the Cur-GGTF was adapted here as mentioned in 2.2.2, only that 5 mL of limonene solution of 0.0005 M, 0.0006 M and 0.0007 M were added into the mixture solution.

2.3 Characterization

The prepared GGTF, Cur-GGTF and CurLim-GGTF were characterized by using few analytical techniques. The techniques involved were Fourier Transform Infrared (FTIR) spectroscopy and Thermogravimetric Analysis-Differential Thermogravimetric Analysis (TGA-DTG).

2.3.1 Fourier Transform Infrared (FTIR) Spectroscopy

Fourier Transform Infrared (FTIR) spectroscopy was used to determine the functional groups which are present in the GGTF, Cur-GGTF, CurLim-GGTF, curcumin and limonene. The instrument used was Perkin Elmer Fourier Transform Infrared (FTIR) spectrometer model 100 Series which used the Universal Attenuated Total Reflection (UATR) accessory (single-bounce beam path, 45 ° incident angle, 16 scans, and 4 cm⁻¹ resolution). All samples were tested in the transmission range of 400 to 4000 cm⁻¹. Infrared spectrum obtained from the analysis is used as a verification to determine the incorporation of gellan gum, curcumin and limonene.

2.3.2 Thermal Analysis (TGA-DTG)

Thermal analysis (TGA-DTG) for GGTF, Cur-GGTF, CurLim-GGTF, curcumin and limonene was carried out at 10°C/min heating rate from 50 °C to 1000 °C under nitrogen flow using a Q5000 (TA Instruments) thermo balance. Based on the thermograms obtained, the decomposition and mass change over time of GGTF, Cur-GGTF, CurLim-GGTF, curcumin and limonene were determined.

2.3.3 Gel Fraction

The thin film samples were cut into 20mm x 20mm square piece, sealed with aluminium foil and parafilm in a beaker, and dried at room temperature for 24 hours. The samples were weighed and immersed in 10 mL of deionized water at room temperature for 24 hours. Then, the samples were removed from the solution and oven dried at 50 °C for 24 hours. The samples were then weighed again and the gel fraction was calculated as shown below:

\[ \text{Gel fraction (\%)} = \left( \frac{W_f}{W_i} \right) \times 100 \]  

Where,
- \( W_i \) = initial weight of samples
- \( W_f \) = final weight of samples

2.3.4 Water Vapour Transmission Rate (WVTR)

The WVTR procedure was carried out using ASTM E96 international standard method. The thin film samples were cut into 30 mm x 30 mm and put as a cap on a glass vial with diameter of 23 mm that contains 10 mL of deionized water. Then, the samples were weighed and left in the desiccators for 24 hours. The silica gel was oven dried for 24 hours before they were used. After 24 hours, the samples were weighed again. The value of water vapour transmission rate (WVTR) was calculated as shown below:

\[ \text{WVTR (gm}^{-2} \text{d}^{-1}) = \frac{\Delta m}{A \cdot t} \]  

Where,
- \( \Delta m \) = the change in weight of sample system
- \( A \) = the area of glass vial opening
- \( t \) = the time in days
2.3.5 Swelling Test
The dried samples with a dimension of 2cm x 2cm were immersed in a properly sealed 100 mL beaker that contains 20 mL of pseudo-extracellular fluid (PECF) buffer solution of pH 5.5 that resembles human skin condition at a controlled temperature of 37 °C in an oil bath shaker with a medium shaking frequency for the duration of 24, 48 and 72 hours. The wet samples were weighed after drying them using a tissue paper. The swelling data for GGTF, Cur-GGTF and CurLim-GGTF of different concentrations were recorded. The swelling percentage for each sample was calculated using the equation as shown below:

\[
\text{Swelling Percentage (\%)} = \left[ \frac{(M_f - M_i)}{M_i} \right] \times 100
\]

Where,

\(M_f\) = weight of sample after swelling
\(M_i\) = initial weight of the sample

3. Results and Discussion
3.1 Fourier Transform Infrared (FTIR) Spectroscopy
The FTIR spectrum obtained for GGTF, curcumin, limonene, Cur-GGTF, CurLim-GGTF05, CurLimGGTF06 and CurLim-GGTF07 were shown in Figure 1. Based on the GGTF spectrum analysis, a broad absorption band at 3317 cm\(^{-1}\) is observed indicating the presence of O-H, hydroxyl group. At wavenumber of 2943 cm\(^{-1}\), C-H bending group has shown absorption. The absorption band at 2887 cm\(^{-1}\) attributed to the carboxyl, COOH group is witnessed. Then, carbonyl, C-O group from the glycosidic bond showed strong absorption band at 1639 cm\(^{-1}\). The peak at 1037 cm\(^{-1}\) demonstrates the presence of ester, C-O-C group [20, 21]. For curcumin, the absorption peak at 3510 cm\(^{-1}\) consisting of aromatic hydroxyl, O-H vibration group could be observed. Then, C-H alkane group showed a peak of absorption at 2918 cm\(^{-1}\). An absorption band is noticed at 1625 cm\(^{-1}\) which indicates the carbonyl, C=O stretching group.

The strong and sharp peak of the carbonyl group is due to the large dipole of the bond. At wavenumber of 1600 cm\(^{-1}\), alkene C=C group has been identified [22]. Subsequently, the symmetric aromatic benzene group, C\(_6\)H\(_5\) is noted at the absorption peak of 1427 cm\(^{-1}\). The resonance effect in the benzene ring lowers the stretching frequency. An alkoxy group, which is methoxy O-CH\(_3\),
Figure 1. FTIR spectra for GGTF, curcumin, limonene, Cur-GGTF, CurLim-GGTF05, CurLimGGTF06 and CurLim-GGTF07 exhibited an absorption peak at 1203 cm\(^{-1}\) [23]. In the limonene, alkane C-H group is denoted at absorption peak of 2917 cm\(^{-1}\). Moreover, at 1645 cm\(^{-1}\) absorption band, the appearance of alkene C=C group is marked. Besides, an alkenyl C=CH\(_2\) group is displayed in a strong absorption peak manner at 885 cm\(^{-1}\) [24]. In the Cur-GGTF, the hydroxyl O-H group has been detected at the absorption peak of 3298 cm\(^{-1}\). The shift in this peak compared to that of in GGTF and curcumin shows that the incorporation of these compounds were successful. In addition, the absorption peak at 2939 cm\(^{-1}\) and 1602 cm\(^{-1}\) were discovered for C-H alkane and C=C alkene groups respectively. There is a shift in absorption band of
COOH carboxyl group from that of in the GGTF which is from 2887 cm\(^{-1}\) to 2885 cm\(^{-1}\) [20]. Then, carbonyl C=O group showed up at wavenumber of 1623 cm\(^{-1}\), 1427 cm\(^{-1}\) and 1205 cm\(^{-1}\) which are referred to aromatic benzene ring, C\(_6\) H\(_5\) and methoxy group, O-CH\(_3\), respectively with some alteration in the peaks due to the assimilation of the compounds [23]. Ester C-O-C group has shown a shift to the peak from that of GGTF at 1037 cm\(^{-1}\) to 1031 cm\(^{-1}\) after the integration of both GGTF and curcumin. On top of that, the absorption peaks and functional groups present in the samples with the incorporation of GGTF, curcumin and limonene which are CurLim-GGTF05, CurLim-GGTF06 and CurLim-GGTF07 are listed in Table 1. All of the functional groups existed in the GGTF, curcumin and limonene were found in the prepared samples with some perceived shifts in the absorption peaks. This has proven that there are interactions between the compounds and the incorporation of curcumin and limonene into GGTF were successful [20].

**Table 1.** List of functional groups and absorption peaks for CurLim-GGTF05, CurLim-GGTF06 and CurLim-GGTF07.

| Symbol | Functional Group | CurLim-GGTF05(cm\(^{-1}\)) | CurLim-GGTF06(cm\(^{-1}\)) | CurLim-GGTF07(cm\(^{-1}\)) |
|--------|------------------|----------------------------|----------------------------|----------------------------|
| A      | Broad hydroxyl, O-H | 3309                       | 3305                       | 3304                       |
| B      | Alkane, C-H       | 2941                       | 2940                       | 2940                       |
| C      | Carboxyl, COOH    | 2884                       | 2885                       | 2887                       |
| D      | Carbonyl, C-O     | 1600                       | 1602                       | 1601                       |
| E      | Alkene, C=C       | 1427                       | 1426                       | 1425                       |
| F      | Benzene, C\(_6\) H\(_5\) | 885                        | 884                        | 882                        |
| G      | Alkoxy (methoxy), O-CH\(_3\) | 1203                      | 1203                      | 1203                      |
| H      | Ester, C-O-C     | 1025                       | 1026                       | 1024                       |
| I      | Alkenyl, C=CH\(_2\) | 885                        | 884                        | 882                        |

**3.2 Thermal Analysis**

Figure 2 shows the DTG for GGTF, curcumin, limonene, Cur-GGTF, CurLim-GGTF05, CurLimGGTF06 and CurLim-GGTF07. The DTG provide the percentage and peak temperature of sample mass change. As given in Table 2, there are two stages of samples decomposition, part A which occurred at 50 -200 °C and part B which occurred at 130-450 °C. Part A is the first stage which represents the loss of plasticizers, low molecular weight and volatile liquid components in the samples. Part B is the second stage indicates the loss of polymer chains in the samples [25]. The introduction of limonene definitely has an effect on the thermal behavior of the hydrogels. The weight loss decreases as the concentration of limonene increases in the hydrogels indicating there is an interaction between the limonene molecule, curcumin and gellan gum. Consequently, the weight loss in part B increases as the concentration of limonene in the hydrogel increases due to the successful incorporation of limonene onto the polymer chains. The weight loss in part A in the limonene sample is the highest due to its nature of being in a liquid state. This causes the liquid to be evaporated easily with the presence of heat. Moreover, there is no weight loss in part A for curcumin as there is no volatile liquid exists in the sample.
Figure 2. DTG curves for GGTF, curcumin, limonene, Cur-GGTF, CurLim-GGTF05, CurLimGGTF06 and CurLim-GGTF07

Table 2. The data obtained from DTG for all the samples GGTF, curcumin, limonene, Cur-GGTF, CurLim-GGTF05, CurLim-GGTF06 and CurLim-GGTF07.

| Sample          | A            | B            |
|-----------------|--------------|--------------|
|                 | Temperature range ( ºC) | Weight loss (mg) | Percentage of weight loss (%) | Temperature range ( ºC) | Weight loss (mg) | Percentage of weight loss (%) |
| GGTF            | 58-136       | 4.08         | 25.59         | 136-380       | 11.01         | 69.05         |
| Curcumin        | -            | -            | -             | 136-451       | 6.30          | 75.60          |
| Limonene        | 57-200       | 39.51        | 99.33         | -             | -             | -             |
| Cur-GGTF        | 52-125       | 2.86         | 17.56         | 125-540       | 11.22         | 68.78         |
| CurLim-GGTF05   | 54-117       | 0.91         | 10.49         | 118-363       | 6.74          | 78.10         |
| CurLim-GGTF06   | 53.6-109.8   | 0.70         | 6.11          | 110-544       | 9.12          | 79.65         |
| CurLim-GGTF07   | 53-103       | 0.46         | 2.13          | 102-545       | 9.87          | 80.16         |
Cur-GGTF exhibited decomposition temperature slightly higher than that of GGTF but lower than curcumin. Hence, after the curcumin was incorporated into the hydrogel, it exhibits the physical property of the curcumin. This has verified the interaction has occurred between the curcumin and gellan gum.

In addition, for the samples of CurLim-GGTF05, CurLim-GGTF06 and CurLim-GGTF07, the decomposition temperature decreases respectively as the limonene concentration gets higher in the hydrogel. This means that the thermal stability of the limonene incorporated hydrogels decline accordingly with the surge of limonene concentration in the hydrogels [26]. CurLim-GGTF07 can withstand maximum temperature of 220.95 °C before it started to decompose. According from the previous research, lowering of the decomposition temperature of a delivery system can cause significant escalation in the transdermal permeation of the compounds or drugs from the system to the skin [27]. Therefore, even though the thermal stability of the CurLim-GGTF incorporated with limonene were lowered than that of without limonene, better permeation of drugs and chemical compounds to the wound area could be expected. Thus, limonene has been verified to increase the penetration of drugs for better wound treatment. The decomposition temperatures for the all of the samples are given in Table 3.

### Table 3: The decomposition temperatures for all of the samples, GGTF, curcumin, limonene, CurGGTF, CurLim-GGTF05, CurLim-GGTF06 and CurLim-GGTF07

| Sample         | Decomposition Temperature (°C) |
|----------------|---------------------------------|
| GGTF           | 233.83                          |
| Curcumin       | 392.96                          |
| Limonene       | 149.66                          |
| Cur-GGTF       | 239.25                          |
| CurLim-GGTF05  | 228.63                          |
| CurLim-GGTF06  | 222.13                          |
| CurLim-GGTF07  | 220.95                          |

### 3.3 Gel Fraction

Gel fraction is a measure of crosslinking degree in a polymer which indicates the crosslinking between the gellan gum, curcumin and limonene. Figure 3 demonstrate the gel fraction percentage obtained for all the samples. The gel fraction for the samples of CurLim-GGTF05, CurLim-GGTF06 and CurLimGGTF07 increases as the concentration of limonene increases. This is due to the intensified compactness of the hydrogel structure in which resulted to denser packing of the incorporated molecules, curcumin and limonene into the gellan gum hydrogel. Furthermore, Cur-GGTF has higher gel fraction than GGTF but lower than that of in the CurLim-GGTF05, CurLim-GGTF06 and CurLim-GGTF07. This is due to the presence of gellan gum and curcumin molecules which makes the packing is less tight when compared to hydrogel containing both curcumin and limonene. The existence of curcumin molecules in Cur-GGTF has occupied the space in the hydrogel structure causing it to have a higher gel fraction than GGTF. Moreover, GGTF has the least gel fraction percentage due to the unoccupied space of other molecules which makes it to have a less dense structure thus having the lowest degree of crosslinking. In a nutshell, higher number of molecules present in a hydrogel causes the crosslinking degree to be amplified. This leads to an increment in the gel fraction percentage in the hydrogel [28].
3.4 Water Vapour Transmission Rate

Water vapour transmission rate (WVTR) is crucial in wound dressing application. WVTR controls the depletion of body fluid caused by the exudation and evaporation. The loss of body fluid causes reduction in the body temperature which results in the escalation of metabolism rate. This will enhance the wound healing process. However, the WVTR value less than 76 g m\(^{-2}\) d\(^{-1}\) is not suitable for wound dressing as the accumulation of exudates can occur which leads to bacterial growth [29]. This will decelerate the wound healing process.

Figure 4 shows the WVTR for all of the samples. The WVTR for GGTF is the highest because of the hydrophilicity property of gellan gum that allows more water molecules to be transmitted through the thin film. The presence of hydrophobic compound, curcumin in Cur-GGTF has caused the WVTR value to be slightly less than that of GGTF. For the samples of CurLim-GGTF05, CurLim-GGTF06 and CurLim-GGTF07, the values of the WVTR decreased as the concentration of limonene in the thin film increases. This is due to the higher number of limonene molecule per unit volume that present in the thin film which has interrupted the diffusion of water molecules through the thin film. Thus, the tight packing of limonene which has increased as the concentration of limonene in the thin film increases causes the rate of water vapour transmission across the film to decline accordingly. Subsequently, higher concentration of limonene causes a hike in the gel fraction which affects the WVTR values to decrease accordingly. The higher gel fraction which indicates a stronger structure of the hydrogel results in a reduction of the WVTRs. The optimum WVTR for wound dressing is in the range of 76 to 9360 g m\(^{-2}\) d\(^{-1}\) [29]. Hence, the WVTR values obtained for all the samples are suitable for wound dressing purpose.
Swelling degree is the measure of water uptake by the hydrogel. This is an essential in vivo study for the wound management. Figure 5 show the swelling pattern and percentage of swelling at 24, 48 and 72 hours for GGTF, Cur-GGTF, CurLim-GGTF05, CurLim-GGTF06 and CurLim-GGTF07. The percentage of swelling for all of the samples, GGTF, Cur-GGTF, CurLim-GGTF05, CurLim-GGTF06 and CurLim-GGTF07 increases with the time frame of 24, 48 and 72 hours. The swelling percentage of GGTF is the highest due to the hydrophilic behaviour of the gellan gum hydrogel. Hence, it can absorb and conserve a large amount of water. This has caused the swelling degree of GGTF to be the most highest. The percentage of swelling decreases accordingly from GGTF to CurLim-GGTF07 due to the increase in the crosslinking magnitude of the hydrophobic molecules which are curcumin and limonene in the thin films. This affects the water absorption by the hydrogels which caused the swelling percentage to decrease with the presence of curcumin in the hydrogel. Moreover, the decreased in the swelling degree from CurLim-GGTF05, CurLim-GGTF06 to CurLim-GGTF07 is due to the concentration of limonene that gets amplified, respectively. High concentration of limonene denotes a large quantity of limonene molecule present per volume of hydrogel. Consequently, the crosslinking of the hydrogel is enhanced and the assimilation of water molecule into the hydrogel is diminished. This crosslinking effect has minimised the mobility of the polymer chains in the hydrogels which eventually lessen the swelling degree [1]. Hence, the addition of higher concentration of limonene causes higher gel fraction that restricts the swelling potential of the hydrogels. Thereafter, an immense amount of water absorption by the hydrogels can make them to be highly swollen. A highly swollen hydrogel can be fractured easily and disintegrate before the healing of the damaged tissues or wound on the body. Therefore, the incorporation of limonene into curcumin gellan gum thin film will make a better wound dressing material.

3.5 Swelling Test

Figure 4. Water Vapour Transmission Rate for GGTF, Cur-GGTF, CurLim-GGTF05, CurLim-GGTF06 and CurLim-GGTF07
4. Conclusion
GGTF, Cur-GGTF containing only 0.06 M curcumin and Cur-GGTF containing 0.06 M curcumin with three different concentrations of limonene of 0.0005 M, 0.0006 M and 0.0007 M has been successfully prepared. From all of the characterizations that have been done, it has been proven that the incorporation of curcumin and limonene into gellan gum hydrogel was successful. Subsequently, the lowering of the decomposition temperature after the incorporation of the curcumin and limonene could lead to a pathway for a higher permeation of curcumin. This is expected to enhance the wound healing process. Moreover, WVTR study has verified the suitability of all the prepared hydrogels for wound dressing purpose. The swelling test has resulted that the hydrogels incorporated with limonene have lesser absorption of moisture in which makes it a better option for wound dressing as it is less likely to be broken and tear apart during body movement. The incorporation of curcumin and limonene into gellan gum hydrogel has shown high capability to be applied as good wound dressing material.

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