

Evaluation of konjac glucomannan asymmetric membrane containing virgin coconut oil as potential wound dressing material

Meor Najmuddin Meor Suzurudin ¹, Hajaratul Najwa Mohamed ^{1*}

¹ Department of Chemistry, Faculty of Engineering Technology, University College TATI 24000 Kemaman, Terengganu, MALAYSIA.

*Corresponding author: hnajwa@uctati.edu.my

KEYWORDS	ABSTRACT
Konjac Glucomannan Virgin coconut oil Asymmetrical membrane Casting-freeze Wound dressing	<p>The wound healing process consists of a series of highly complicated and dynamic events that restore the skin's structural integrity. Most commercial wound dressings are insufficient, expensive, or may interfere with wound healing, such as adhesive wound dressings that cause skin irritation when removed. Asymmetric membranes are now one of the most promising options for wound healing owing to its unique structural similarities to the epidermal and dermal layers of the original skin. Along with its intrinsic biocompatibility, antimicrobial, hemostatic, and therapeutic characteristics, Konjac glucomannan mixed with virgin coconut oil (VCO) distinguishes out among the many ingredients utilized to create these unique layers. The casting-freeze method was used to create an asymmetric membrane of konjac glucomannan containing VCO. Fourier transform infrared spectroscopy (FT-IR), Thermogravimetric analysis (TGA), and Differential scanning calorimetry were used to characterize the membrane (DSC). The FT-IR results revealed a significant intermolecular hydrogen bond interaction between KGM-NaOH and VCO. The thermogravimetric analyses revealed that the membrane samples were thermally stable. Furthermore, DSC results reveal that VCO has improved the thermal tolerance properties of KGM asymmetric membrane when virgin coconut oil concentration at 0.1%. Based on the result, the KGM-VCO asymmetric membrane has great potential to be applied as wound dressing.</p>

1.0 INTRODUCTION

Conventional wound dressings (such as cotton bandages and gauze) absorb a significant amount of the wound's moisture, causing the wound's surface to dry up fast, hindering healing and causing discomfort while removing the dressing. Wound dressings are still used today to promote wound healing and protect damaged tissue from microorganisms and the environment. However, most commercial wound dressings are insufficient, expensive, or may disrupt wound

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healing, such as adhesive wound dressings that cause skin injury when removed. An effective wound dressing is non-adhesive, removes exudate while maintaining a moist environment for optimal healing, prevents bacterial infection and biofilm development, does not restrict healing, and ideally supports healing without encouraging scar formation (Aljghami et al., 2019). In the industry, there are many different wound dressing types and material compositions to meet the needs of various types of wounds. The basic aim of traditional wound dressings, such as gauze and tulle, is to provide a covering while enabling appropriate gaseous exchange. During the healing process, however, their strong adhesion to the wound site produces pain and further lesions (Koehler et al., 2018).

When a wound is exposed to air directly, it loses the water content and produces a scab, which keeps the wound from bacterial infection. However, a cell in a dry or low-moisture micro-environment will lose vitality and function, and may even die. Therefore, asymmetric membranes have become one of the most promising wound healing treatments. Combining an occlusive surface with a porous structure seems to be a novel way to make high-performance wound dressings. A variety of polymers in the form of films, foams, and gels have been produced to promote optimum wound healing (Rezvani et al., 2019). Konjac glucomannan mixed with virgin coconut oil (VCO) distinguishes out among the numerous ingredients utilized to create these unique layers. KGM is a hydrocolloidal dietary fibre found in konjac jelly, noodles, and tofu, and is broadly applied as a traditional medicine and food (Yang et al., 2017). KGM has also been proven to reduce triglycerides, cholesterol, blood glucose, blood pressure, and body weight in people, as well as enhance intestinal activity and immunological function (Devaraj et al., 2019).

VCO is indeed a powerful wound-healing agent (Mukhtar et al., 2017). VCO can help with a range of mild diseases, including diarrhoea, skin inflammations, gastrointestinal issues, small wounds, injuries, and swelling. The aim of this work is to use the freeze-casting process to create an asymmetrical membrane of KGM-VCO and assess its potential as a wound dressing. To analyse well-formed asymmetric membranes, Thermogravimetric Analysis (TGA), Differential Scanning Calorimetry (DSC), and Scanning Fourier Transform Infrared Spectroscopy (FT-IR) are performed.

2.0 EXPERIMENTAL PROCEDURE

Materials

Asymmetric Konjac glucomannan membranes were produced by dissolving 0.01% (w/w) KGM in a sodium hydroxide stock solution. All membranes were pre-conditioned in a desiccator for at least two days prior to any testing (24°C, 50% relative humidity (RH)) (Silva et al., 2020). Virgin coconut oil (VCO), a commercial product, was graciously given by University College TATI. The primary saturated fatty acids' composition, as well as their percentual concentration (w/v) in VCO, were given by the manufacturer.

Preparation of the asymmetric membranes

The asymmetric membrane was formed using the casting-freeze method. To produce 2.5 % (w/v) solution, the KGM powder was mixed in water and stirred for 2 hours. After that, sodium hydroxide (KGM gelling agent) was added to the solution until it achieves a final concentration of 0.1 mol/L. Virgin Coconut oil (VCO) solutions containing 1.2% (w/v) Tween-20 were stirred at 500 rpm until the solution became clear. 60 g of KGM/NaOH solution containing VCO will be agitated at 500 rpm for 2 hours to create a stable emulsion for the asymmetric membranes. The KGM-VCO emulsion will next be casted onto a polystyrene plate with a diameter of 5.9 cm and dried at 50°C until it achieves 20% of its initial mass. The samples will then be frozen for 24 hours at 6°C. Finally, until the wipe down solution reaches a neutral pH, the asymmetric membranes will be thawed and rinsed with ultrapure water.

Thermal stability

The KGM-VCO membrane will be tested using Thermogravimetric analysis (TGA) and Differential scanning calorimetry (DSC). TGA will be done on membrane samples (6 mg) at temperatures ranging from 25 to 600 degrees Celsius. The nitrogen flow rate is 50 mL/min, with a heating rate of 10°C/min. All membrane samples have been freeze-dried overnight. Samples ranging in size from 5 mg to 10 mg will be scanned in a sealed alumina crucible and heated at a rate of 10°C to 450 °C for DSC. min⁻¹, with a flow rate of 50mL.min⁻¹, in a nitrogen environment.

Fourier transform infrared spectroscopy

Fourier Transform Infrared (FT-IR) spectra of the materials were acquired using a Nicolet 6700 Spectrometer for chemical analysis. At room temperature, potassium bromide pellets were used to produce the samples. The spectrum was obtained by averaging 32 scans with a resolution of 4 cm⁻¹, which corresponded to the spectral area of 4000–400 cm⁻¹ (Silva et al., 2020).

3.0 RESULTS AND DISCUSSION

Thermal studies

The thermal stability of konjac glucomannan powder, virgin coconut oil, and the konjac glucomannan-virgin coconut oil asymmetric membrane was tested using TGA and DSC. The Thermogravimetric analysis (TGA) method was primarily utilized to determine the thermal stability and behaviour of an asymmetric membrane. Table 1 and Figure 1 show the thermal deterioration and stability.

Table 1 and Figure 1 indicate that between 200 °C and 500 °C, and notably between 200 °C and 400 °C, KGM powder loses mass owing to decomposition. This temperature range is associated with saccharide ring breakdown and polymer chain disintegration. The TGA results are consistent with prior investigations of KGM powders, demonstrating that the asymmetric membrane manufacturing technique had no effect on the thermostability of the pure polymer (Genevro et al., 2019). Pure virgin coconut oil, on the other hand, loses weight mostly between 200 and 400 °C, while it is completely decomposed over 500 °C. For the VCO/KGM asymmetric membrane, the TGA curves exhibit distinct behavior above and below the temperature of oil breakdown. The loss of moisture was attributed to the weight loss of the membrane from 25 to 150 °C (Genevro et al., 2019). The oil appears to maintain the membrane below the temperature of oil degradation, but when the temperature is higher than the temperature of oil degradation, the oil appears to favor the opposite.

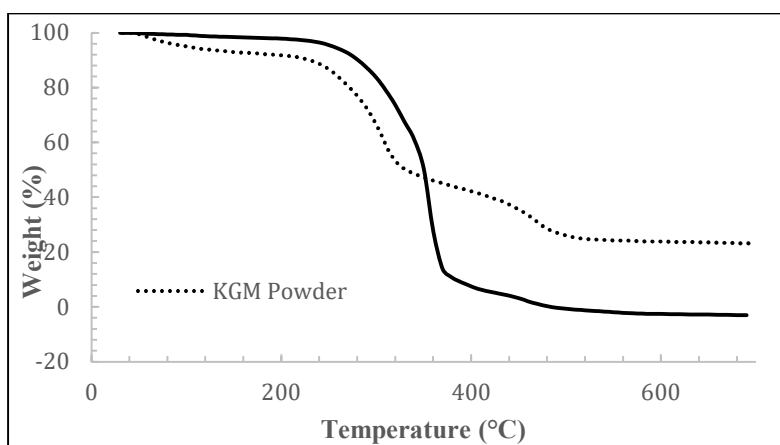


Figure 1. Thermograms of virgin coconut oil and KGM powder by using TGA methodology.

Figure 2 and Table 1 revealed weight loss up to 300°C and 400°C as a result of these observations. This indicates that the inclusion of 0.1 percent VCO improves the thermal stability of the composite membrane owing to a degree of interaction between KGM and VCO, which is related to the findings of Ismail et al (2014). For 0.5% and 1.0% VCO, the oil appears to promote the reverse, resulting in a decrease in composite membrane thermal stability. Mulyadi et al. (2019) revealed that the durability of the preservation was tested through thermal treatment of virgin coconut oil. VCO was heated to 190°C for 40 days of storage in this case. Changes in the composition of fatty acids were discovered during the course of the investigation. Heat considerably lowers the stability of VCO, according to the findings.

Table 1. Thermal analysis of KGM, VCO, and KGM/VCO asymmetric membrane in an N₂ atmosphere.

Concentration (% w/w)		% weight loss						
KGM	VCO	100 °C	200 °C	300 °C	400 °C	500 °C	600 °C	690 °C
2.5	0.0	73	86	91	92	93	93	95
	0.1	58	66	71	72	74	75	77
	0.5	66	72	87	93	96	100	100
	1.0	95	100	100	100	100	100	100
KGM powder		5	8	36	58	74	76	77
VCO		1	2	16	92	100	100	100

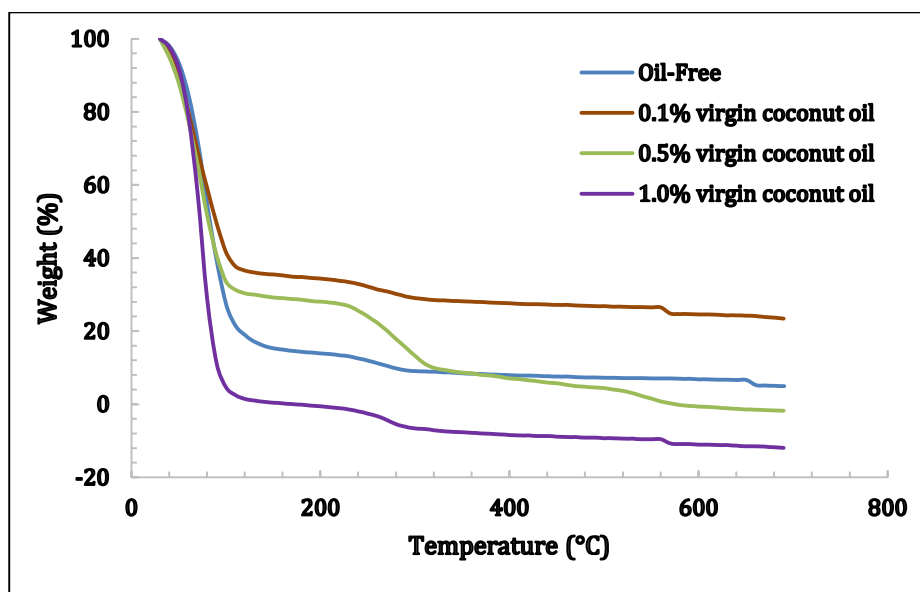


Figure 2. TGA thermograms of 2.5% (w/w) KGM asymmetric membrane containing virgin coconut oil.

The DSC results for KGM powder, virgin coconut oil, and the virgin coconut oil/KGM asymmetric membrane are shown in Figures 3 and 4. The temperatures acquired with the DSC are shown in Table 2. KGM had a high exothermic peak at 100 °C, perhaps due to the evaporation of bound water from the polymers. In addition, KGM displays an exothermic peak about 230 °C, which has been assigned as the melting point. The temperatures were 70 and 275 °C at the start and end of the set, respectively. Raising the temperature over 400 °C, on the other hand, caused the material to degrade (Du et al., 2019).

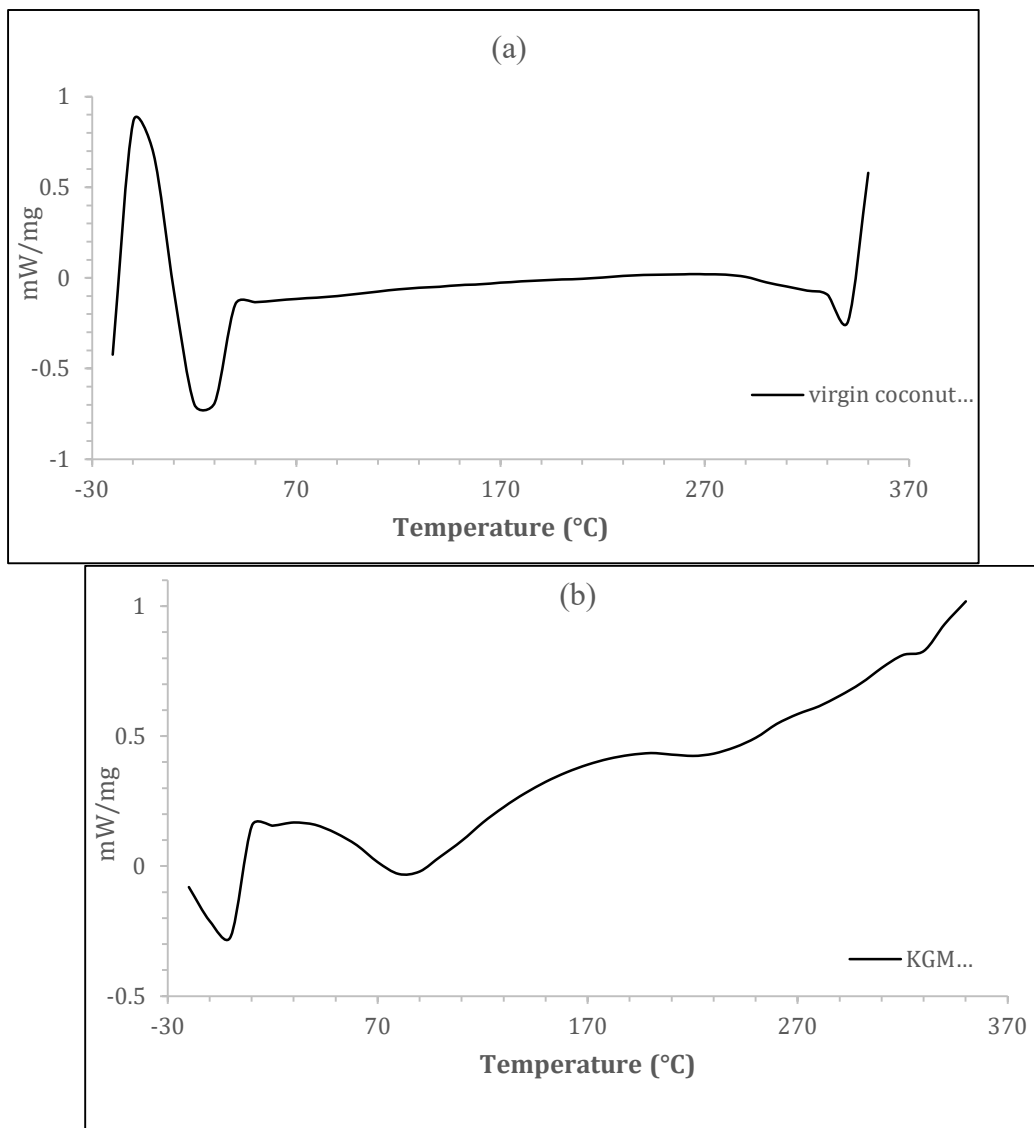


Figure 3. DSC curves for (a) virgin coconut oil and (b) KGM powder.

Table 2. DSC Temperature Measurement

Concentration (% w/w)		Temperature °C			
KGM	VCO	To	Tm	Tc	Tc - To
2.5	0.0	80	100	120	40
	0.1	60	70	110	50
	0.5	70	80	120	50
	1.0	70	80	110	40
KGM powder		40	60	80	40
VCO		10	20	30	20

Note: T_o = onset, T_c = completion, T_m = melt temperature

Concentration (% w/w)		Temperature °C	
KGM	VCO	T ₁	T ₂
2.5	0.0	-	120
	0.1	60	110
	0.5	80	120
	1.0	80	110
KGM powder		80	200
VCO		30	340

The exothermic peaks between 10 and 50 °C are most likely caused by the breakdown of VCO and fatty acids into smaller chains, whilst the series of peaks beyond 250 °C is caused by the decomposition of these compounds into even smaller chains (Kimura et al., 2016).

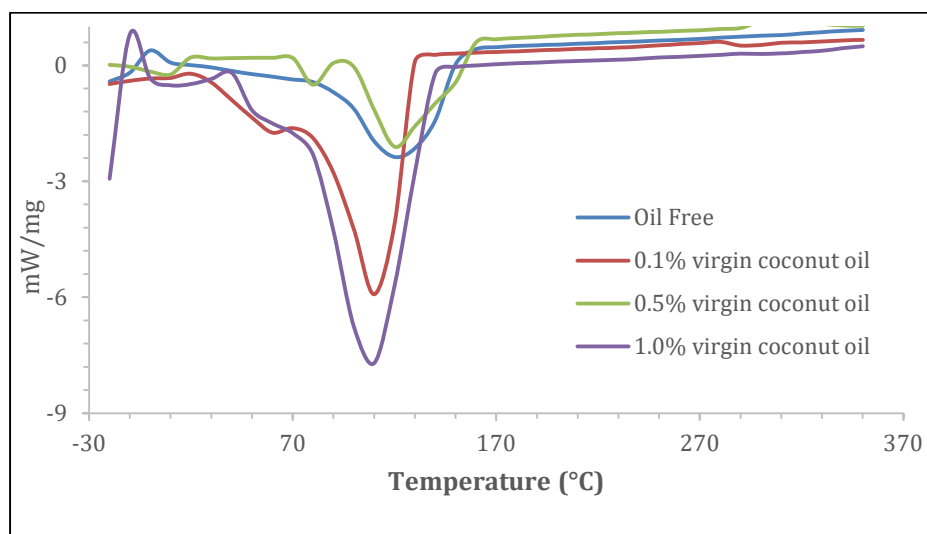


Figure 3.4. DSC run curves for 2.5% (w/v) KGM membrane containing virgin coconut oil.

The loss of water molecules enclosed during the drying process caused an exothermic peak in the DSC thermogram for pure KGM membrane at $T = 120^{\circ}\text{C}$. When compared to pure KGM-*virgin coconut oil*-free asymmetric membrane, the melting point (T_m) values of the KGM-*virgin coconut oil* asymmetric membrane increased. Furthermore, broad endothermic peaks appeared for the KGM-*virgin coconut oil* asymmetric membrane, with an increased range ($T_c - T_o$) of temperature onset (T_o) and temperature completion (T_c), indicating that the addition of VCO increased the crystallization of the sample and improved the thermal properties of the asymmetric membrane for 0.1% and 0.5% *virgin coconut oil*, respectively.

The addition of *virgin coconut oil* has small effect on the temperature T_2 for membrane breakdown. The heat generated by the degradation of KGM is reduced by *virgin coconut oil*, supporting the higher thermal stability of the membrane seen in the TGA measurements. The inclusion of VCO increased the heat tolerance qualities of the KGM asymmetric membrane by 0.1% *virgin coconut oil* concentration, according to these findings (Ismail et al., 2014). Figure 5 additionally depicts both front and top views of the Konjac glucomannan/VCO asymmetric membrane.

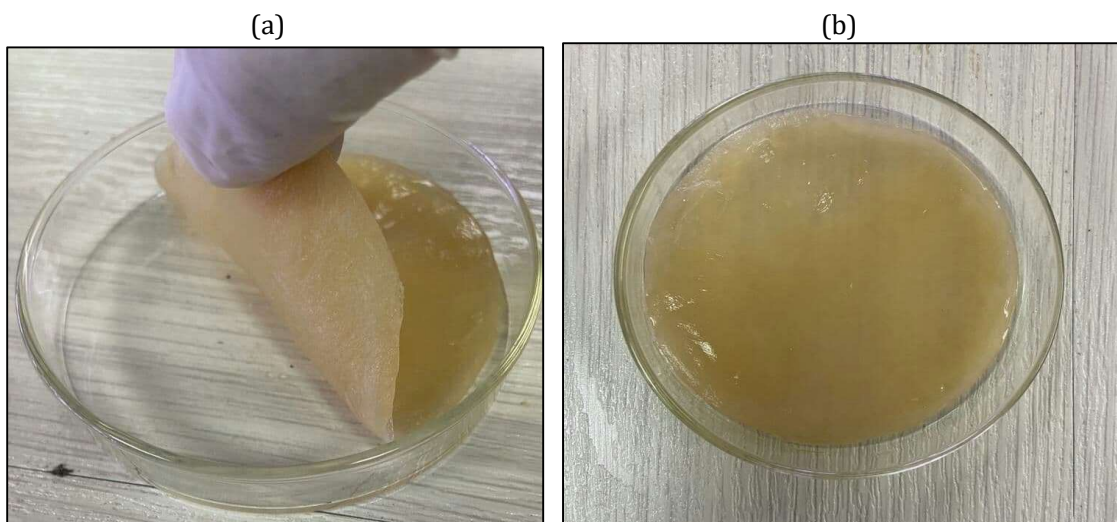


Figure 5. Konjac glucomannan/VCO asymmetric membrane (a) front view (b) top view

Fourier transform infrared (FT-IR) spectroscopy

The FTIR technique was utilized to analyse the structural changes that occurred throughout the development of the KGM-VCO asymmetric membrane (Figure 6). The FTIR spectra of a VCO-loaded KGM-based asymmetric membrane at various concentrations are shown in Figure 6. The broad adsorption band at $3000\text{-}3700\text{ cm}^{-1}$ was formed by the free stretching vibration of inter-molecular and inter-molecular hydroxyl groups, which was seen in all membranes. The infrared spectra of KGM revealed a broad, sharp peak about 3368 cm^{-1} , indicating hydroxyl group stretching (Liu et al., 2021).

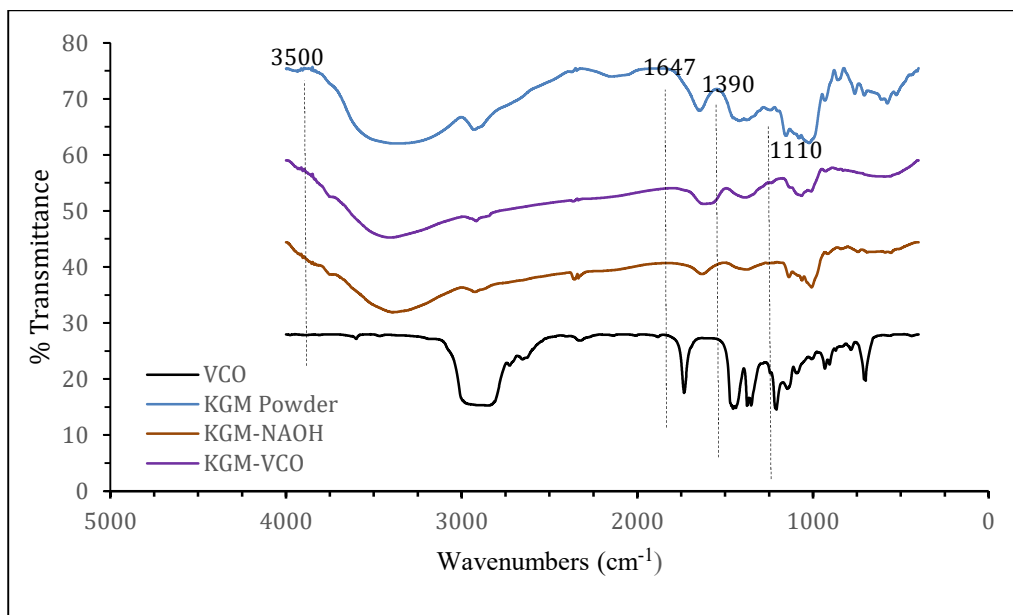


Figure 6. KGM and VCO FT-IR spectra with varying DS

The stretching vibration of -OH corresponds to the significant absorption at 3368 cm^{-1} . The C-H stretching vibrations in the -CH_2 or -CH_3 groups were responsible for the peak at 2928 cm^{-1} . The stretching vibration of the carbonyl at 1647 cm^{-1} matched to the KGM molecules' distinctive acetyl groups (Li et al., 2018). The C-O stretching vibrations associated to -OH absorption band at 1647 cm^{-1} was identified (Ye et al., 2017). C-O-C vibrations were responsible for the absorption peak at 1023 cm^{-1} (Wang et al., 2020).

The hydroxyl group absorption peak of the pure KGM asymmetric membrane was shown at 3397 cm^{-1} , however the absorption peaks of the VCO-loaded asymmetric membrane were observed at a higher frequency at 3400 cm^{-1} , with the strength of the peaks increasing dramatically. This discovery showed that the insertion of VCO had an effect on the hydrogen bonding contact between the polymers (Xue et al., 2019). The FTIR spectra of the emulsion membranes revealed projecting peaks at 1623 , 1389 , and 1064 cm^{-1} , which corresponded to carboxylic (C=O) bending of methylene (CH_2), bending of methyl (CH_3), and stretching of esters (C-O), respectively. These peaks are proportional to the amount of VCO present (Silva et al., 2020).

Furthermore, the chemical structures of KGM asymmetric membrane and KGM-VCO asymmetric membrane matched those of native KGM. When compared to the KGM-VCO spectra, the peak at 3400 cm^{-1} in KGM native got noticeably broader, showing that the -OH vibrations were marginally influenced. Furthermore, the peak in native KGM at 3368 cm^{-1} changed to 3397 cm^{-1} in KGM asymmetric membrane, which might be attributable to the complicated vibrational stretches associated with free, inter-, and intramolecular hydroxyl groups (Wang et al., 2015). We anticipate that the positively charged groups of KGM and the negatively charged free fatty acids from VCO can interact within the emulsion system via coulombic forces, resulting in stable emulsions and, eventually, asymmetric membrane emulsions.

4.0 CONCLUSION

The KGM-VCO membranes produced using the unique freeze-casting technique have an asymmetric structure with a flat film on top and a porous structure on the bottom. The FT-IR results demonstrated that KGM-NaOH and VCO have a significant intermolecular hydrogen bond interaction, indicating that KGM-NaOH loaded with VCO is compatible. The membrane samples

had a good temperature stability, according to the thermogravimetric analyses. Furthermore, DSC results show that VCO content increases the heat durability capabilities of the KGM asymmetric membrane.

As a result of its thermal stability and bio-compatibility, the asymmetric membrane of KGM/VCO is a promising material for wound dressing applications. Future pre-clinical and clinical research, however, are encouraged to give evidence-based medical results addressing the routine use of KGM/VCO asymmetric membrane as wound dressings in clinical settings.

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