Developmental prospectives of new generation super absorbent wound dressing materials from sulfated polysaccharide of marine red algae

Amruth P[1, 2], Rosemol Jacob M[1, 2], Suseela Mathew[1] and Anandan R[1]

[1]Biochemistry and Nutrition Division, ICAR-Central Institute of Fisheries Technology, Cochin-682029, Kerala, India

[2]Faculty of Marine Sciences, Cochin University of Science and Technology, Cochin-682022, Kerala, India

*Corresponding author

Dr. Suseela Mathew

Principal Scientist & Head of the Division

Biochemistry and Nutrition Division

ICAR-Central Institute of Fisheries Technology

Matsyapuri P.O., Willingdon Island

Cochin-682029, Kerala, India

Telephone number: +91 9446218958

Email: suseela1962@gmail.com

Abstract

Wound healing remains as a dynamic process and the type of dressing material significantly affects the efficacy of healing. The identification of ideal dressings to use for a particular wound type is an important requisite facilitating the entire process of healing. Chronic, high exudate wounds are dynamic in presentation and remain as a major health care burden. Researchers have sort to design and optimize biodegradable wound dressings that focuses to optimize moisture retentiveness, as superior character in the healing process. In addition, dressings have been designed to visualize the wound bed by improving the optical property, target and kill infection-causing bacteria, with the incorporation of antimicrobial agents, nanomaterials and numerous other measures. For the practitioners, choosing the optimal dressing decreases time to healing, provides cost-effective care and improves patient quality of life. The current mini review highlights the ideal characters of wound dressing materials and presents insights on the superior characters of carrageenan biocomposites for prospective advancements in research in the area of wound care and management.

Introduction

Natural polymers like polysaccharides (chitin, alginates, chitosan, heparin and chondroitin), proteoglycans and proteins (fibrin, collagen, gelatin, silk fibroin, keratin and egg shell membrane) are broadly used for the treatment of wounds and burns management [Mogosanu and Grumezescu, 2014].Carrageenan, a natural polymer is having wide prospective in the area of wound care and management. According to the recent advancements in science and technology, suitable materials for wound dressings are available for different wounds. Natural polymers based dressings gain critical significance due to the biodegradability and biocompatibility offered by them. Choosing ideal dressing material remains as a challenge for wound care practitioners. To accomplish appropriate wound healing, the preference amongst different wound healing products for a specific wound is crucial. Studies related to the mechanisms of wound healing has improved potential to heal chronic wounds at a faster phase by using moisture-retentive dressings [Lawrence et al., 1995].

Semi-permeable film dressing remain as an important class of interactive wound dressing. They align to the patient's body with ease, transparent nature aids visualization of wounds and gas permeability in turn accelerate angiogenesis. These class of dressings are impermeable to liquid and bacteria [Dhivya et al., 2015]. Additionally, with regard to their film structure, they are semi occlusive in nature and trap considerable moisture; they permit autolytic debridement of necrotic wounds and provides moist healing background for

granulating wounds [Henghoven et al., 2017]. The hydrophobic nature of semi-permeable dressings imparts resistance to absorb moisture among the other classes of dressing. Hence, these are advisible for epithelializing, shallow, superficial wound and with low exudates, e.g. Tegaderm™, Opsite™, Biooclusive ™. Commercially available film dressings differ in terms of properties such as vapour permeability, adhesive characteristics, conformability and extensibility [Thomas et al., 1988]. The characters of ideal wound dressing are depicted in (Table 1.) [Scales et al., 1956; Dhivya et al., 2015].

Figure 1: Characteristics of dressing material for wound healing applications

The drawback of film dressing (eg. Polyurethane) for its lower moisture retentive potential have been avoided by the practitioners on treating high exudate wounds. Therefore, research has been advanced in search of novel biomaterials especially with moisture retentive property aimed at chronic high exudate wound healing applications.

Carrageenan is a negatively charged, hydrophilic, sulphated polysaccharide extracted from marine red algae. It has the efficacy to form transparent, moisture-retentive films and hence are expected ideal for wound healing [Boateng et al, 2013; Farhan and Hani, 2017; Sedayu et al., 2019]. Carrageenan films offer other properties like good tensile strength (TS), water vapor retention rate (WVTR) and gaseous exchange [Farhan and Hani

2017;Harumarani, 2016] requisite for wound healing process, especially significant for healing chronic, high exudate wound. To comprehend the specific sorts of modern interactive wound dressing, the current review gives insights to researchers and wound care professionals to explore the possibility of using carrageenan films with manipulated properties. These films can be explored as wound dressings by presenting their superior functional and rheological properties, likely to remain abreast with the latest technological advancements in the area of wound care management.

Properties of carrageenan films

Property of carrageenan films can be enhanced by manipulating film with effective, plasticizers, cross-linkers, hydrophobic fillers, natural polymers, nano materials and numerous others. The ideal properties of manipulated carrageenan film are summarized in the Table 2.

Properties	**Reference**
Transparency	[Park 1996;Paula et al., 2015;Sedayun et al, 2019; Farhan and Hani ,2017; Fouda et al., 2015;Ye et al.,2017; Boateng et al.,2013]
Thickness	[Shojaee-Aliabadi et al.,2014;Farhan and Hani,2017;Oun and Rhim,2017]
Moisture retention	[Abdou and Sorour,2014;Farhan and Hani,2017;Khazaei et al.,2014]
Solubility	[Shojaee-Aliabadi et al.,2014;Boateng et al.,2013; Farhan and Hani, 2017]
Tensile strength[TS]	[Farhan and Hani 2017;Harumarani, 2016]
Elongation at Breaks[EAB]	[Farhan and Hani 2017;Harumarani, 2016]
Water vapor transmission rate [WVTR]	[Farhan and Hani 2017; Khazaei et al.,2014]
Heat seal strength	[Farhan and Hani 2017]
Gas barrier	[Rhim and Wang 2013]
Anti-microbial	[Shankar et al.,2015; Soni et al.,2006]

Table 2: Ideal properties of manipulated carrageenan films

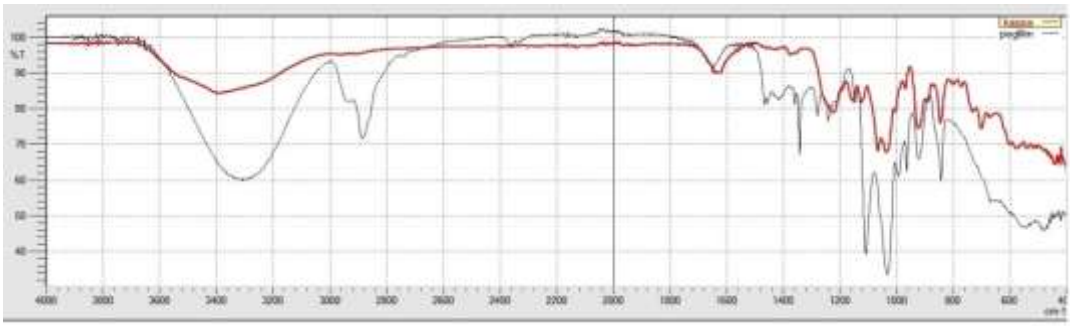

Fig 2: FTIR-spectra of manipulated carrageenan film compared with carrageenan from Sigma Pvt. Ltd.

(Source: From the protocol of carrageenan extraction, ICAR CIFT, Cochin)

Properties of carrageenan film V/s Semi-permeable film

Semi permeable wound dressings are thin transparent polyurethane adhesives, which are gas permeable and impermeable to bacteria and liquid. They are elastic, conformable, and painless on removal and transparent allowing inspection of the wound [Salemark, 2000]. Manipulated carrageenan films are also adhesive, thin, transparent and pervious to gas and are impervious to liquid and bacteria [El-Fawal, 2017; Sedayu et al., 2019].Semipermeable dressings are non-absorbent and therefore, they pose the limitation of healing highly exudation wounds [Rubio 1991] whereas manipulated carrageenan films have the potential to retain moisture [Ousey et al., 2011], which is a critical parameter for healing highly exudation wounds. Besides these functional properties, carrageenan biofilms have good heat seal strength, therefore are ideal for wound dressing.

In a recent study, carrageenan and polyethylene oxide based solvent cast films have been developed as dressing to deliver drugs to the wound. They posed good transparency and elastic modulus that caused augmented flexibility to the films [Boateng et al, 2013]. Flexibility characteristic imparted to the dressing is indispensable, especially for orthopedic wounds that are predisposed to swelling and have a bigger risk of friction exerted between the wound and dressing [Peles and Zilberman, 2012]. Here are some of the observations of few relevant studies depicted in table 3 to substantiate the mechanical property enhancements of manipulated carrageenan films as reference.

Tensile strength (TS)	**Remarks**	**Reference**

	The increased TS of the SRC films are achieved with effective plasticizers (e.g. Glycerol/sorbitol) ascribed to the strong polymer plasticizer interaction formed by hydrogen bonding between carrageenan matrix chain and plasticizer molecules.	(Farhan and Hani 2017; Harumarani, 2016)
Elongation at breaks (EAB)	**Remarks**	**Reference**
	Semi refined carrageenan films plasticized with effective plasticizers exhibited good flexibility and stretch ability to the films and achieves higher elongation at breaks (EAB) value.	(Farhan and Hani 2017; Harumarani, 2016)
Water vapor transmission rate (WVTR)	**Remarks**	**Reference**
	Inclusion of plasticizers to carrageenan polymer increases the water vapour permeability (WVP) owing to the reorganization that occur in the hydrocolloid polymer structure which surges the free volume and segmental motion of the polymer network enabling water molecules to penetrate	[Khazaei et al.,2014 Farhan and Hani 2017]

	effortlessly through the membrane	

Table 3: Mechanical properties of manipulated carrageenan film

Future prospective of carrageenan films

Carrageenan is a promising bioactive compound well documented for its numerous applications in the area of food, pharmaceutics and biomedicine [Sedayu et al., 2019]. Studies related to wound healing applications are very scant. Modulation of physical, physico-chemical, rheological, surface-active and biological property of carrageenan would be able to optimize effective wound dressing materials for advanced healing therapy. Manipulating carrageenan with polymers advances the mechanical strength as well as ease of removal for the flexible films [Alves et al., 2006; Campo et al., 2009] Transparency remains as a critical parameter concerning a wound dressing, aids the physician to visualize the wound bed without disturbing the dressing material [Boateng et al., 2008]. Carrageenan based films are transparent, flexible, and uniform films due to the viscoelastic property offered by them [Pawar et al., 2013]. This ideal character gain attention in the design of transparent dressings.

Poor absorbency as well as impermeability is noticed among most of the wound dressing as a disadvantage. In such dressings, wound exudate gathers underneath the dressing and as a consequence, skin maceration and bacterial multiplication happens and there is threat of infection. Consequently, there exist requisite for regular changes after incorporation which remain as a reason for patient's discomfort. Therefore, moisture retention remains as a critical parameter especially with regard to high exudation wounds. High exudate wounds are very difficult to treat and are challenging. Moisture retentive property in dressings enhances angiogenesis and accelerates wound healing. Therefore, moisture vapor transmission rate (MVTR) remains as significant parameter for an optimal dressing focused against chronic high exudate wounds. Manipulated carrageenan films are demonstrated to pose good transparency and moisture retentive properties [Sedayu et al., 2019].

Conclusion

Wound healing is a multi-phases and multi-factorial physiological process. The complexity of this phenomenon makes the healing process very difficult and painful due to several abnormalities. Since, wound dressing remains as the main external effectors during

the healing process of wounds, the market demand for biodegradable wound dressing is experiencing remarkable growth over the few decades and expected to continue. The shortcomings of the polyurethane films in terms of its efficacy on healing highly exudate wound due to its lower moisture absorption potential have drawn attention from wound care practitioners and researchers to find suitable alternatives to film dressing's inexistence. Carrageenan, the commercially exploited marine sulphated polysaccharide, gain attention especially in the area of wound care due to its remarkable physico-mechanical properties like good texture, transparency, gas permeability, tensile strength (TS), elongation at breaks (EAB) and water vapour transmission rate (WVTR) which is desirable properties for an ideal film based dressing.

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