Research Article

Exploring Plant-Based Mucilage for Edible Film Development: A Comparison with CMC

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ABSTRACT

This study investigates the preparation of natural edible thin films made from okra mucilage, flaxseed mucilage and compared with carboxymethyl cellulose (CMC) as possible coating materials for prescription tablets. The main goal is to evaluate how well they work to improve tablet stability, mask any unpleasant tastes and regulate drug release profiles. An edible film was created using each biopolymer. The mechanical strength, adhesive characteristics, moisture barrier effectiveness and disintegration behaviour of the resultant films were evaluated. Flaxseed mucilage films proved to be extremely flexible and good at masking taste. The superior moisture barrier qualities of okra mucilage films improved tablet stability. CMC is very well known film forming agent used to compare natural agent with synthetic. The results indicate that these natural polymers can function as effective, sustainable substitutes for synthetic coating agents in pharmaceutical applications, providing advantages that support patient compliance and environmental factors.

Keywords: Edible thin films, Flaxseed mucilage, Okra mucilage, Carboxymethyl cellulose (CMC), Natural polymers.

INTRODUCTION

To improve medication delivery methods, the pharmaceutical industry is always looking for new, sustainable and patient-friendly excipients. Because of their functional variety, biocompatibility and biodegradability, natural polymers have attracted a lot of attention. With advantages including taste masking, controlled drug release and environmental protection, edible thin films in particular have shown great promise as tablet coverings.[1]

Extracted from the outer layer of flaxseed shells, flaxseed mucilage (FM) is a polysaccharide-rich material recognized for its superior rheological and water-binding capabilities. Research has indicated that it may form flexible films with significant UV barrier properties, which makes it appropriate for protective uses in food packaging. These characteristics imply that it can be used in medicinal coatings, where moisture and light resistance are essential.[2]

Abelmoschus esculentus is the source of okra mucilage (OM), another naturally occurring polymer distinguished by its pectic carbohydrate makeup. Research indicates that OM can form edible films with good thermal stability and low moisture content. Its binding capabilities have been investigated in tablet formulations, showing promise as a natural binder that can enhance tablet hardness and manage disintegration time.[3]

A cellulose derivative called carboxymethyl cellulose (CMC) is frequently employed in pharmaceutical formulations because of its stability, mechanical strength and capacity to form films. CMC-based films have shown enhanced mechanical characteristics and antibacterial activity when mixed with other natural polymers, such as OM, particularly when zinc oxide nanoparticles are added. Because of these qualities, CMC is a useful ingredient in the creation of functional tablet coatings.[4]

With an emphasis on their mechanical strength, physicochemical characteristics and the suitability as tablet coating materials, this study compares edible thin films made from FM, OM and CMC. The goal of the research is to find sustainable and efficient substitutes for synthetic excipients in pharmaceutical applications by assessing these natural polymers.[5]

MATERIALS AND METHODS

Materials

1. Flax seed mucilage:

Flax seeds (Linum usitatissimum) - The main source of mucilage (Local Market)

Distilled water - For mucilage extraction and film forming (Laboratory Grade)

Plasticizer (e.g, Glycerol or Sorbitol) - To improve flexibility(Laboratory Grade)

Muslin cloth (Local Market)[6]

2. Okra mucilage:

Fresh Okra Pods - Source of mucilage (Local Market)

Distilled water - For mucilage extraction and solution preparation (Laboratory Grade)

Plasticizer - Glycerol (5-10 % of mucilage dry weight) (Laboratory Grade)

Muslin cloth (Local Market)[7]

3. Carboxymethyl Cellulose (CMC): pharmaceutical ingredient (Laboratory Grade)[6]

Methods:

Flaxseed mucilage

Extraction of Flaxseed Mucilage: Weigh flaxseeds and mix with distilled water in a 1:10 w/v ratio. Heat the mixture at 80–90°C for 1–2 hours with continuous stirring. Cool slightly and filter through muslin cloth to remove seed residues. Centrifuge the filtrate at 4000 rpm for 15 minutes to remove impurities. Collect the clear mucilage extract.

Preparation of Film-Forming Solution: Adjust mucilage concentration to about 1.5–2% (w/v). Add glycerol at 20–30% (w/w) of the dry mucilage weight as a plasticizer. Stir and heat the solution at 70°C for 20–30 minutes until homogeneous mixture form.[6]

Okra mucilage

Extraction of Okra Mucilage: Wash and chop fresh okra pods into small pieces. Boil chopped pods in distilled water at a 1:10 w/v ratio for about 30–60 minutes at 80–90°C. Cool the mixture and filter through muslin cloth to separate the viscous mucilage. Centrifuge the filtrate at 4000–5000 rpm for 10–15 minutes to purify.

Film Formation: Pour the film-forming solution onto a clean casting surface (glass or Teflon tray). Spread evenly and dry at room temperature for 24–48 hours or in a hot air oven at 40–50°C. Peel off the dried film carefully for characterization or preliminary coating tests.[7]

Carboxymethyl cellulose

Preparation of CMC Solution: Weigh CMC (1–3% w/v) depending on the desired film thickness. Slowly disperse the CMC powder into distilled water while stirring vigorously to avoid clumping. Stir continuously at room temperature or mild heating (40–50°C) for 30–60 minutes until fully dissolved and viscous. Add plasticizer (15–30% w/w of CMC) to improve film flexibility and adhesion.

Film Formation: Pour the solution onto a clean, flat glass or Teflon surface. Allow to dry at room temperature for 24–48 hours or in an oven at 40–50°C. Peel off the film for mechanical and physicochemical analysis.[8]

Casting of Film: Pour a fixed volume (e.g., 20–25 ml) of the film solution onto a leveled glass or Teflon plate. Spread evenly to avoid air bubbles and ensure uniform thickness.[6]

Drying and Storage: Dry the film at ambient temperature (25–30°C) for 24–48 hours or in a hot air oven at 40–50°C. Once dried, peel the film carefully from the plate. Store the film in a desiccator or sealed container at room temperature until further use.[6]

Characterization of Films:

1. **Thickness:** Thickness uniformity demonstrates a pleasing physical look. It displays a consistent distribution of the contents. The thickness of thin films was measured with a vernier caliper at three separate places and the average values were calculated.[9-11]

2. **Moisture Content:** Determine the thin film's initial weight prior to drying. Dry the film for a predetermined amount of time at a predetermined temperature (for example,100–120°C) in an oven or vacuum chamber. To stop the film from absorbing moisture again, cool it in a desiccator. Once the film has dried, weigh it one more time (final weight). Use the following formula to determine the moisture content:[9,10,12]

$$\text{Moisture Content (\%)} = \frac{\text{Initial Weight} - \text{Final Weight}}{\text{Initial Weight}} \times 100$$

Where,

Initial Weight = weight of the sample before drying

Final Weight = weight of the sample after drying

3. **Water Solubility:** 2 cm × 3 cm pieces of each film were cut and stored in a desiccator with silica gel for 7 days. Samples were weighed and placed into test beakers with 80 ml of deionized water. The samples were maintained under constant agitation at 200 rpm for 1 h at 25 °C. The remaining pieces of film were then collected by filtration and dried again in an oven (at 60 °C for 24 h) to constant weight. The percentage of total soluble matter (% solubility) was calculated as follows:[9,14,15]

$$\text{Water Solubility (WS)} = \frac{Wi - Wf}{Wi} \times 100$$

Where,

Wi= Initial dry weight of the sample

Wf = Final dry weight of the sample

4. **Water Vapour Permeability (WVP) Test:** For water vapor transmission studies glass vials of approximately equal diameter were used as transmission cells. These transmission cells were washed thoroughly and dried to constant weight in an oven. About 1 g of fused calcium chloride as a desiccant was taken in the vials and the polymeric films were fixed over the brim with the help of an adhesive tape. These pre-weighed vials were kept in a chambers filled with saturated salt solutions to achieve the required humidity conditions for a period of 24 h. Different saturated salt solutions are used to maintain the desired humidity condition like Potassium chloride (90 % RH), Sodium chloride (75 % RH), Potassium carbonate (45 % RH). The weight gain was determined after a period of 24 h and water vapor transmission rate was calculated. Water vapor transmission (Q) usually expressed as number of grams of moisture gain per 24 h per square centimeter. It was calculated as follows:[9,10,13,14]

$$WVP = \frac{WVTR \times X}{\Delta P}$$

Where,

X = film thickness (m)

ΔP = water vapour pressure difference across the film (Pa)

5. **Tensile strength:** Tensile strength, which can be calculated from the highest stress applied to a point at which the specimen breaks, applied load at rupture and the film's elongation, as indicated by the equation that follows. Tensile strength measurement provided a straightforward way to ascertain the mechanical properties of the polymeric films. A manually created tensile strength measurement tool was used to ascertain the films' tensile strength. A 25 mm wide by 50 mm long film was cut, secured between two clamps, and weighted on the other side of the pan until the film broke. Tensile strength and the weight needed to shatter the film were recorded. [9,10,12]

$$TS = \frac{F_{Max}}{A}$$

Where,

TS = Tensile strength (MPa)

F_{max} = Maximum force at break (N)

A = Cross-sectional area of the film (mm²)

6. **Transparency:** The transparency of a mucilage film, was calculated by using a UV-Vis spectrophotometer. The film is cut into a rectangular shape, placed in a cuvette, and its light transmittance at a specific wavelength (like 540 or 600 nm) is measured. The transparency value is then calculated by multiplying the transmittance percentage by the film thickness. Higher transparency values indicate more opaque films. [16,17]

$$\text{Transparency Value: } \frac{A600}{x}$$

Where,

A600: is the absorbance of the film at 600 nm

x: is the thickness of the film in millimeters

RESULT AND DISCUSSION

The films prepared from flaxseed mucilage, okra mucilage and CMC were evaluated based on physical, mechanical and barrier properties. The findings are summarized below:

Table 1: Comparative Properties of Edible Films from CMC, Flaxseed Mucilage, and Okra Mucilage

Property	Flaxseed mucilage	Okra mucilage	CMC
Thickness (mm)	0.095 ± 0.003	0.102 ± 0.004	0.085 ± 0.002
Moisture Content (%)	10.5	12.2	8.1
Water Vapor Permeability (g/m²/24h)	1.58	2.01	1.24
Tensile Strength (MPa)	28.2	21.7	35.6
Transparency (Absorbance at 600 nm)	0.41	0.36	0.28
Film Appearance	Slightly rough, amber-tinted	Opaque, slightly sticky	Smooth, glossy, clear

1. **Thickness:**

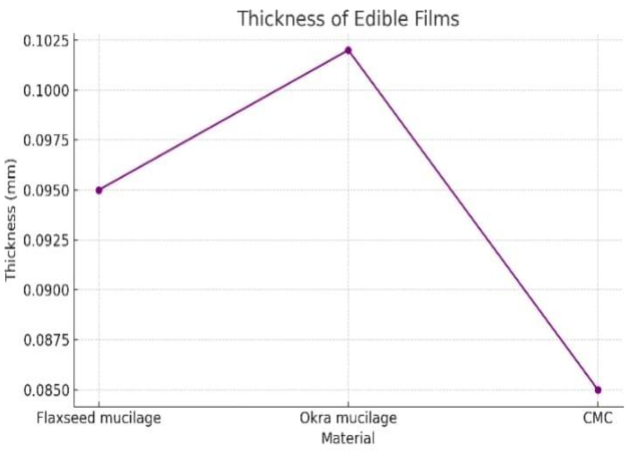

Figure 1: Thickness Graph

The graph presents the thickness of edible films from different materials. Okra mucilage films are the thickest (~0.102 mm), followed by flaxseed mucilage (~0.095 mm), while CMC films are the thinnest (~0.085 mm). Although CMC forms thinner films, the slightly higher thickness of natural films does not hinder their suitability. In fact, the moderate thickness of natural films like flaxseed and okra mucilage may enhance barrier properties, supporting their use in sustainable edible packaging.

2. **Moisture Content**:

The graph displays the moisture content of edible films, which is crucial for tablet coating performance: Okra mucilage has the highest moisture content (~12.2%), which may lead to stickiness or affect tablet stability. Flaxseed mucilage shows moderate moisture content (~10.5%), offering better stability. CMC has the lowest moisture content (~8.1%), making it ideal for coatings where low moisture uptake is critical. While CMC is optimal for moisture-sensitive drugs, natural polymers like flaxseed and okra mucilage can still be considered for coating due to their biodegradable and non-toxic nature, especially in applications where slight moisture absorption is acceptable.

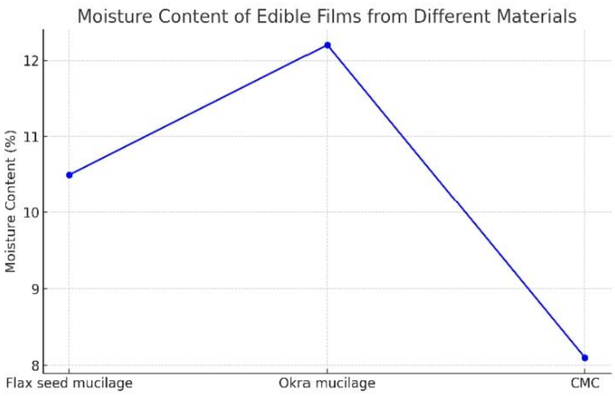

Figure 2: Moisture Content Graph

3. Water Solubility:

Flaxseed mucilage film shows moderate solubility, providing controlled disintegration and protection. Okra mucilage film exhibits moderate to high solubility, allowing faster release while still offering some barrier. CMC film has high solubility, making it ideal for quick-release coatings. Overall, while CMC ensures rapid solubility, natural films like flaxseed and okra mucilage offer a balance between solubility and sustainability, making them suitable for eco-friendly coating applications.

4. Water Vapour Permeability:

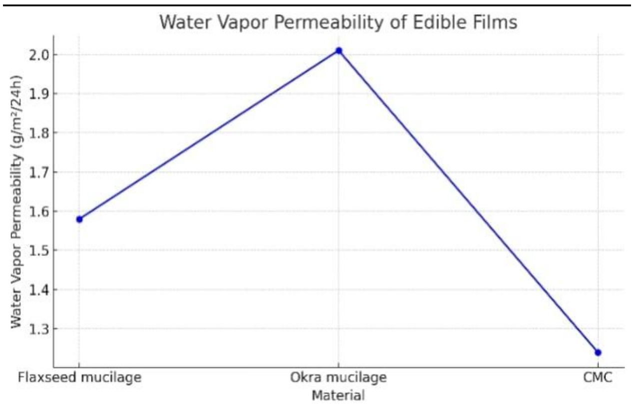

Figure 3: Water Vapour Permeability Graph

The graph shows the water vapor permeability (WVP) of edible films. Okra mucilage has the highest water vapor permeability (~2.0 $g/m^2/24h$), which may result in lower moisture protection. Flaxseed mucilage provides moderate permeability (~1.58), offering a better barrier than okra. CMC shows the lowest permeability (~1.25), making it most effective for moisture protection. While CMC offers superior moisture barrier properties ideal for tablet stability, natural polymers like flaxseed and okra mucilage remain suitable for use in tablet coatings due to their biodegradability, non-toxicity, and natural origin, aligning with clean-label and eco-friendly pharmaceutical trends.

5. Tensile Strength:

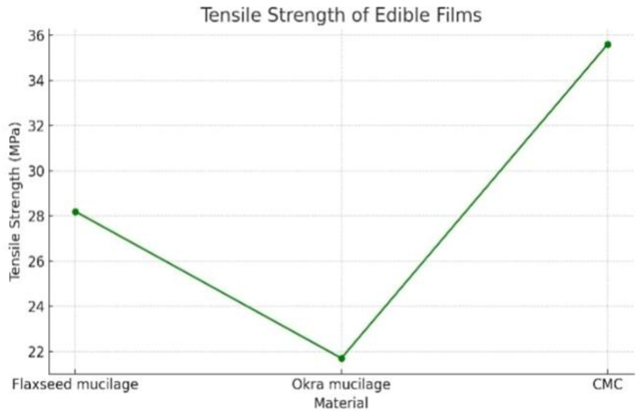

Figure 4: Tensile Strength Graph

The graph shows the tensile strength of edible films made from different materials. CMC exhibits the highest tensile strength (~35.6 MPa), followed by flaxseed mucilage (~28.2 MPa), while okra mucilage has the lowest (~21.5 MPa). Although CMC shows superior mechanical strength, natural films like flaxseed and okra mucilage still offer adequate strength along with eco-friendly and biodegradable properties, making them promising alternatives for sustainable coating solutions.

6. Transparency:

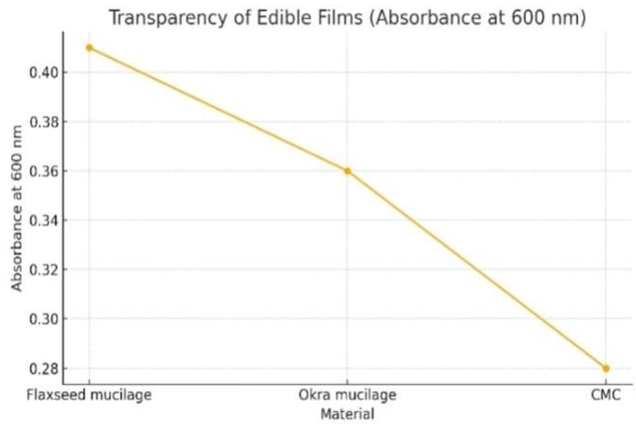

Figure 5: Transparancy Graph

The graph illustrates the transparency of edible films made from different materials, measured by their absorbance at 600 nm. Transparency is inversely related to absorbance; lower absorbance indicates higher transparency. Among the three materials tested: Flaxseed mucilage exhibited the highest absorbance (~0.41), indicating the lowest transparency. Okra mucilage showed intermediate absorbance (~0.36), suggesting moderate transparency. CMC (Carboxymethyl Cellulose) had the lowest absorbance (~0.28), reflecting the highest transparency. Although CMC is more transparent, natural films are still preferable due to their biodegradability and eco-friendly nature, making them better choices for sustainable edible coating.

CONCLUSION

From the above discussion it is concluded that the analysis of edible films derived from okra, flaxseed, and carboxymethyl cellulose (CMC) reveals clear variations in their characteristics that affect how well suited they are for coating applications. Flaxseed and okra mucilage films offer environmentally safe, biodegradable substitutes for CMC films, which are perfect for pharmaceutical coatings that are sensitive to moisture due to their excellent mechanical and barrier qualities. To better fit particular uses, their qualities can be further enhanced by mixing or chemical changes.

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