Effects of plasticizers on sorption and optical properties of gum cordia based edible film

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Abstract The present study aimed to characterize a biodegradable film produced from the polysaccharide of an indigenous plant *Cordia myxa*. Effect of plasticizer type (Glycerol, Sorbitol, PEG200 and PEG 400) and concentration (0–30 %) was studied on sorption and optical properties of the casted film. Increase in plasticizer concentration resulted in increase in equilibrium moisture content of the film and was supported by GAB model of sorption indicating that isotherms were of Type II. The monolayer value increased with the increase in plasticizer concentration with a peak of 0.93 g.g⁻¹ for glycerol. Addition of plasticizers improved the total color (ΔE) with glycerol showing the highest effects. All films showed resistance to UV light in the range of 280–200 nm. The polysaccharide of the fruit of *C. myxa* can be used to prepare an edible film with improved properties as compared to other available edible coatings.

Keywords Gum cordia · Edible film · Sorption isotherm · Optical properties

Introduction

Plant foods for human consumption normally undergo series of post-harvest processes, transportation and storage before it reaches consumers. Hence, these processes many have significant impact on the sensory attributes such as appearance,

texture and nutritional quality of processed foods (Ruiz-Navajas et al. 2015). Preservation of such foods is made through widely used methods such as storing them in low temperature; reducing water activity, drying, preserving by chemical means and controlled packaging to minimize the mass transfer such as oxygen, aroma, moisture to the environment. Among these methods; packaging plays an important role. The packaging of foods also improves the aesthetic appeal by providing information about food and convenience in handling.

Edible films normally behave like a barrier against the transportation of water across the film (Weng and Wu 2015). However, if edible film is hydrophilic then it means that moisture could be drawn either from the outside environment or from the product inside the package, causing significant characteristic changes (Chinma and Ariahu 2015). A sorption isotherm is used to study the potential of the film to adsorb moisture from environment as a function of water activity (a_w) and can be measured in drying (desorption) or adsorption (hydration) experiment. In general, empirical sorption and desorption data is used to develop a mathematical relationship between the equilibrium moisture content and water activity (Coupland et al. 2000). Widely used equations are Bruanuer-Emmet-Teller (BET) and Guggenheim-Anderson-de Boer (GAB). BET model is limited to 0–0.5 a_w and comprises two constants; the monolayer moisture content (X_o) and net heat of sorption (C). GAB model is very close to BET model with a difference of a wider range of water activity (0.05–0.9 a_w) making it a choice for studying food systems (Timmermann et al. 2001). Along with the two constants of BET model, GAB model contains one more constant k representing the difference between properties of multilayer molecules and surrounding liquid. The sorption isotherms of various materials are classified into five different types on the basis of the Van der Waals adsorption of gases (Blahovec and

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Yanniotis 2009) namely Langmuir and Sigmoid for the first two types while the other three are unnamed. Most food materials exhibit sigmoidal isotherm (Blahovec and Yanniotis 2009).

Edible films are fabricated using biopolymers which usually form brittle films due to strong interactions between polymer chains through hydrophobic and hydrogen bonding, electrostatic forces and cross linking. Some small molecular weight compounds, known as plasticizers, reduce these interactions which result in soft and flexible film (Laohakunjit and Noomhorm 2004). The ability of a molecule to act as plasticizer depends on its molecular configuration, no of free hydroxyl groups and the configuration of the biopolymer i.e. compatibility of the plasticizer with polymer. These small molecules can significantly alter the mechanical and permeation properties of the edible film (Haq et al. 2014a). Moisture in edible films also behaves like a plasticizer affecting their physical and barrier properties (Debeaufort and Voilley 1997; Gennadios et al. 1993). Plasticizers e.g. glycerol, sorbitol and polyethylene glycol are hydrophilic and attract water in to the polymer matrix thus further enhance the plasticization activity (Zhang and Han 2006). Due to the importance of humidity dependant equilibrium moisture content, a number of sorption isotherms for edible films have been reported (Bertuzzi et al. 2007; Debeaufort and Voilley 1997; Gontard et al. 1993; Kang et al. 2015). For example, in potato peel based edible film, moisture content, water diffusivity and water vapor permeability (WVP) values were found to be higher in films with 50 % glycerol (Kang et al. 2015). Similarly, Bertuzzi et al. 2007 showed that glycerol increases the moisture and WVP of the starch films. Gontard et al. 1993 observed humidity depended puncture strength of gluten film in the presence of glycerol. Debeaufort and Voilley 1997 reported that polyethylene glycol 400 (PEG400) increases the susceptibility of the methylcellulose based edible films towards humidity dependant mechanical properties.

Edible films interact with electromagnetic spectrum in visible and ultraviolet (UV) regions. This is reflected in two important optical properties, color and transparency. The transmittance of visible light through the film to reveal the products color is a characteristic feature consumer appreciates (Yang and Paulson 2000). One the other hand, the transmittance of ultra violet light is detrimental to food product (Akhtar et al. 2012).

The major bulk of edible film is made up of proteins from animal source such as collagen, gelatin, fish myofibril, milk such as casein, whey, egg such as egg white or protein from plant source such as corn zein, wheat gluten, soy and peanut protein (Azam et al. 2013; Bhat and Karim 2014; Guldass et al. 2010; Lim et al. 1999; Tao et al. 2015). Other bulking agents include carbohydrates or lipids. However, these materials have limited utilization due to the high cost associated and limitation in functionality (Vieira et al. 2011). Current

approach includes exploring new biological materials to develop edible films of superior quality and low manufacturing cost. Our previous work explored a new plant specie *Cordia myxa*, a tree of plant family Boreginaceae, which grows nearly all over the Indo-Pak subcontinent but has limited medicinal uses (Haq and Azam 2015). The ripe fruits contain thick sticky material mostly anionic polysaccharides suggesting its use as biodegradable films and coatings (Haq et al. 2013; Haq et al. 2014a). The purpose of this study is to evaluate the effectiveness of plasticizer in biodegradable films prepared from the anionic polysaccharide extracted from *C.myxa* for the improvement of sorption isotherm and optical properties.

Material and methods

Film fabrication

Gum was extracted and purified from the fruits of *C.myxa* by hot water and acid precipitation (Haq et al. 2014b). Films were prepared by solution casting method as previously described by our group (Haq et al. 2014a). Briefly, gum (10 g) was added to about 800 ml water, 0.1 N NaOH was then slowly added with mixing till the pH was achieved to 7.0. The solution was then made up to 1 L. Then the plasticizers (glycerol, sorbitol, polyethylene glycol 200 or polyethylene glycol 400) were added in to gum solution at the rate of 0–30 % based on the weight of the gum by mixing. The solutions were poured into clean and smooth glass petri dishes and dried at 40 °C and 10 % RH for 48 h in a controlled environmental chamber (Lab Tech Model LCT 1075C, Korea). The samples were conditioned to 58 % RH for 72 h before measurements taken unless otherwise specified.

Sorption properties

The effect of environmental humidity on equilibrium moisture content (sorption isotherm) was determined by gravimetric method. Films were cut in squares (20 × 20 mm) and dried at 90 °C for 72 h before placing them into desiccators under controlled humidity (Table 1). The humidity was adjusted by placing a slush of various salts in desiccator at 25 ± 0.2 °C (Greenspan 1977). The films were exposed to the environment created by slush having a_w of 0.11 to 0.90 for three days, sufficient to saturate the films with environment as determined by reweighing the film on 5th and 6th day with no change in weight. The films were weighed in an analytical balance with a least count of 0.01 mg. The mathematical model, Guggenheim- Anderson-de Boer (GAB), was applied to experimental data.

Table 1 Saturated salt solutions used to control the water activity

S.N	Chemical Name	Chemical Formula	a_w at 25 °C
1.	Lithium Chloride	LiCl	0.112
2.	Magnesium Chloride	MgCl ₂	0.328
3.	Potassium Carbonate	K ₂ CO ₃	0.432
4.	Magnesium Nitrate	Mg(NO ₃) ₂	0.529
5.	Sodium Bromide	NaBr	0.576
6.	Sodium Nitrate	NaNO ₃	0.709
7.	Sodium Chloride	NaCl	0.753
8.	Barium Chloride	BaCl ₂	0.902

This model is described by the following equation;

$$X = \frac{CkX_o a_w}{[(1-ka_w)(1-ka_w + Cka_w)]} \quad (1)$$

Where:

X is the equilibrium moisture content on dry basis (g g⁻¹).

a_w is the water activity.

X_o is the monolayer moisture content i.e. the water required to saturate all primary adsorption sites by single water molecule.

C is the Guggenheim constant and represents the energy difference between the water molecules attached to primary sorption sites and those adsorbed to successive sorption layers and.

k is a correction factor which represents the difference between the properties of multilayer molecules with respect to the bulk liquid.

Optical properties

Color of the films was analyzed by spectrophotometer (Model, V-670, JASCO, Tokyo, Japan) with 2° standard observer and D65 light source against a white background plate having $L^*a^*b^*$ value 97.39, 0.03 and 1.42 respectively. Total color difference between the white background and film samples was calculated using the following equation

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (2)$$

Where; ΔL^* , Δa^* and Δb^* are the differentials between the color parameter of the film samples and the color parameter of the white standard plate.

For the assessment of the UV and visible light barrier properties, the film samples were mounted on a film holder and scanned for transmittance (200–800 nm). Transparency of the film was calculated by following equation;

$$\text{Transparency} = \frac{A_{600}}{\text{Thickness}} \quad (3)$$

Experimental design and statistical analysis

Full factorial experimental design with randomized order using single factor at 21 levels (4 plasticizer in 5 concentration = 20 plus one without plasticizer) was used. Each experiment was performed in triplicate. Analysis of variance (ANOVA) followed by Duncan multiple range test was used to distinguish the treatments at $p < 0.05$ using statistical package for social scientists (SPSS version 17). For sorption parameters, data (water activity and moisture content) was fitted on GAB model using non linear regression analysis option of SPSS.

Results and discussions

Sorption isotherm

The representative moisture sorption isotherms of gum cordia films containing different plasticizers at a level of 10 % are presented in Fig. 1. For all films equilibrium moisture content was increased slowly till about 0.7 a_w followed by rapid increase. All isotherms curve are sigmoidal in shape as described for most food commodities (Blahovec and Yanniotis 2009) and food polymers (Gontard et al. 1993). The order of sensitivity of the films for a_w was found in the order of Glycerol > Sorbitol > PEG 200 > PEG 400 > Control.

Effect of concentration of plasticizer on equilibrium moisture content is given in Fig. 2. For all plasticizers, approximately linear increase in equilibrium moisture content was observed with respect to concentration except at very low a_w (0.11). At this a_w , the equilibrium moisture content was found decreasing with increase in concentration of plasticizer. This phenomenon is observed because of hydroxyl groups in plasticizer, saturating the adsorption sites of polymer under low humidity conditions (Debeaufort and Voilley 1997), but subsequently replaced by water at elevated humidity (Baik and

Fig 1 Representative sorption isotherm of gum cordia film, the concentration of all plasticizers is 10 % based on gum cordia weight

Fig. 2 **a** Effects of plasticizer type and concentration on equilibrium moisture content of gum Cordia films at different water activities **a.** 0.11 aw, **b.** 0.33 aw, **c.** 0.43 aw **d.** 0.53 aw. **(2b)** Effects of plasticizer type and concentration on equilibrium moisture content of gum Cordia films at different water activities **e.** 0.58 aw, **f.** 0.70 aw, **g.** 0.75 aw **h.** 0.90 aw

Table 2 Effect of plasticizer type and concentration on GAB equation parameters of gum cordia film

Plasticizer	Concentration (%)	X_0	C	K	R^2
None	None	0.039	120.677	0.799	0.985
Glycerol	10	0.069	6.935	0.958	0.996
	15	0.071	6.090	0.957	0.974
	20	0.075	5.152	0.967	0.991
	25	0.085	4.952	0.953	0.985
	30	0.093	4.057	0.951	0.975
Sorbitol	10	0.047	20.676	0.965	0.967
	15	0.049	18.577	0.942	0.977
	20	0.051	15.564	0.965	0.986
	25	0.052	12.566	0.975	0.992
	30	0.054	10.647	0.967	0.995
PEG 200	10	0.044	18.546	0.946	0.996
	15	0.045	17.565	0.965	0.967
	20	0.048	16.465	0.986	0.997
	25	0.049	15.453	0.976	0.995
	30	0.053	12.356	0.946	0.996
PEG 400	10	0.039	20.556	0.965	0.985
	15	0.040	20.556	0.986	0.983
	20	0.041	18.564	0.946	0.997
	25	0.045	17.564	0.975	0.995
	30	0.049	15.564	0.996	0.992

Chinachoti 2001). This is also consistent with our finding where among all plasticizers, glycerol showed sharp changes at lower humid conditions due to highest number of hydroxyl groups per unit mass. The moisture adsorption was further increased due to increase in free volume of polymer allowing the matrix to adsorb more water and promoting water clustering at successively higher hydration levels.

The compatibility of the plasticizer and its hydrophilic nature made it helpful to determine the equilibrium moisture content of the film in a wide range of a_w . The sorption of water is related to hydroxyl groups on the molecule and its molecular weight. At lower a_w (0.11) and low plasticizer concentration, the sorbitol plasticized film showed highest water sorption while glycerol plasticized film showed highest sorption at higher a_w . Glycerol being smaller in size penetrated better into the polymer increasing available – OH to interact with water (Donhowe and Fennema 1993). In comparison to sorbitol, glycerol containing more hydroxyl groups per unit mass exhibited highest equilibrium moisture content. This is also in agreement with PEG 400 having lowest hydroxyl groups per unit mass showed minimum water sorption.

The GAB equation was found to fit well on experimental data (Table 2). The coefficient of multiple determination (R^2) was found to be greater than 0.98. Similarly the GAB equation parameter, k was found to be <1 and $C > 2$, indicating that isotherms were of Type II (Blahovec and Yanniotis 2009). The monolayer value varied with type and concentration of plasticizer. The monolayer value increased by increasing plasticizer

Table 3 Effect of type and concentration of plasticizer on CIE color parameters of gum cordia film

Plasticizer	Concentration (%)	L^*	a^*	b^*	ΔE
None	None	77.05 ± 1.08 ^{ab}	−1.76 ± 0.13 ^a	20.91 ± 0.04 ⁿ	28.22 ± 0.79 ^j
Glycerol	10	78.07 ± 1.59 ^{abcd}	−1.74 ± 0.10 ^a	15.89 ± 0.11 ^j	24.22 ± 1.29 ^{fg}
	15	78.60 ± 0.99 ^{abcdef}	−1.33 ± 0.08 ^b	12.89 ± 0.31 ^d	22.06 ± 0.91 ^{bc}
	20	80.20 ± 1.07 ^{fg}	−0.91 ± 0.09 ^{de}	9.97 ± 0.12 ^c	19.23 ± 0.99 ^a
	25	80.25 ± 0.63 ^{fg}	−0.78 ± 0.06 ^{ef}	9.50 ± 0.11 ^b	18.96 ± 0.58 ^a
	30	81.15 ± 0.68 ^g	−0.66 ± 0.05 ^{fg}	9.05 ± 0.14 ^a	17.96 ± 0.66 ^a
Sorbitol	10	77.74 ± 1.07 ^{abc}	−1.29 ± 0.06 ^{bc}	16.19 ± 0.24 ^k	24.63 ± 0.93 ^{fg}
	15	78.29 ± 0.83 ^{abcdef}	−1.26 ± 0.06 ^{bc}	15.50 ± 0.28 ⁱ	23.76 ± 0.74 ^{efg}
	20	79.78 ± 1.04 ^{defg}	−1.32 ± 0.11 ^{bc}	14.92 ± 0.15 ^h	22.25 ± 0.88 ^{bcde}
	25	79.84 ± 0.71 ^{efg}	−1.21 ± 0.05 ^{bc}	14.58 ± 0.24 ^g	21.96 ± 0.67 ^b
	30	80.00 ± 0.54 ^{efg}	−1.13 ± 0.06 ^c	14.44 ± 0.11 ^{fg}	21.76 ± 0.45 ^b
PEG 200	10	76.90 ± 0.36 ^{ab}	−1.15 ± 0.09 ^c	15.50 ± 0.07 ⁱ	24.89 ± 0.31 ^{fg}
	15	78.28 ± 0.83 ^{abcdef}	−0.90 ± 0.11 ^{de}	15.61 ± 0.14 ^{ij}	23.82 ± 0.72 ^{fg}
	20	78.59 ± 1.11 ^{abcdef}	−0.71 ± 0.08 ^{fg}	15.61 ± 0.26 ^{ij}	23.56 ± 0.92 ^{cdef}
	25	79.37 ± 1.08 ^{cdef}	−0.63 ± 0.07 ^{fg}	14.24 ± 0.22 ^f	22.13 ± 0.90 ^{bcd}
	30	79.41 ± 1.12 ^{cdef}	−0.64 ± 0.04 ^g	12.79 ± 0.14 ^d	21.29 ± 0.96 ^b
PEG 400	10	76.69 ± 1.58 ^a	−1.70 ± 0.09 ^a	18.11 ± 0.16 ^m	26.67 ± 1.27 ^h
	15	77.41 ± 0.43 ^{ab}	−1.60 ± 0.09 ^a	16.95 ± 0.22 ^l	25.36 ± 0.45 ^{gh}
	20	77.18 ± 1.18 ^{ab}	−1.61 ± 0.01 ^a	15.87 ± 0.17 ^j	24.92 ± 0.96 ^{fg}
	25	77.83 ± 1.00 ^{abc}	−1.15 ± 0.10 ^c	14.69 ± 0.16 ^{gh}	23.69 ± 0.82 ^{def}
	30	78.71 ± 1.20 ^{bcdef}	−0.63 ± 0.07 ^{fg}	13.44 ± 0.05 ^e	22.23 ± 1.02 ^{bcde}

Data is presented as mean ± standard error, $n = 3$

Means with different superscript alphabets in the columns are significantly different ($P < 0.05$)

concentration. The highest monolayer value was found at be 0.93 g.g^{-1} in glycerol plasticized film. The C parameter decreased with increase in plasticizer content and was found lowest for glycerol. This parameter represents the energy difference between the water molecules attached to primary sorption sites and those adsorbed to successive sorption. The parameter k , of GAB model was found independent of the type and concentration of plasticizer. These results are in agreement with previously reported values for biopolymers (Mali et al. 2005).

Optical properties

The gum cordia film was transparent and yellowish in color. The yellowish nature of the film is represented by b^* parameter of CIE color space and measured in the range 9–20 depending upon the type and concentration of plasticizer (Table 3). This parameter also contributed largest in total color difference (ΔE), which was found at 17–28. The addition of plasticizer decreased ΔE . This effect was most pronounced in films plasticized with glycerol. The incorporation of colorless plasticizers in film matrix resulted in the dilution of the colored film forming polymer thus decreasing the total color measured. Additionally, the increase in plasticizer concentration slightly enhanced light reflection from the film surface, i.e. increased in L^* value. This effect

was more pronounced at higher concentrations specifically in glycerol plasticized films. The difference in the ability of plasticizers to decrease the color may be due to the difference in the physical structure of the film. These observations are consistent with previously findings relating to the effect of plasticizer on color of edible film. (Jongjareonrak et al. 2006) reported decrease in ΔE and increase in L^* value for gelatin based film plasticized with glycerol, sorbitol, ethylene glycol, PEG200 and PEG 400. Similarly, Paschoalick et al. 2003 observed a linear decrease in ΔE of edible film made from muscle proteins of Nile Tilapia by increasing the concentration of glycerol. Color of the gum cordia film ($L^*a^*b^*$: 81–76, -1.7–0.6, 20–9) is comparable to some of the other biopolymer based films e.g. soy protein ($L^*a^*b^*$: 88, -1.3, 3), mesquite gum (89, 1.5, 20), mustard based biopolymer (75, 1.3, 30) and chitosan ($L^*a^*b^*$: 45, 0.8, 7) (Guerrero et al. 2011; Hendrix et al. 2012; Osés et al. 2009; Singh and Chatli 2015). However, the gum cordia film was more colored than some of the most commonly reported edible films including gelatin (95, -0.35, 1.6), tapioca starch films (85, -1.08, 5) and whey protein isolate films (95, -0.05, 2) (Flores et al. 2007; Jongjareonrak et al. 2006; Osés et al. 2009).

The light transmission (%) and transparency ($A_{600/\text{mm}}$) of the gum cordia films is shown in Table 4. The films restricted the transmission of the UV light in the range of 280–200 nm.

Table 4 Effect of type and concentration of plasticizer on light transmission (%) and transparency ($A_{600/\text{mm}}$) of gum cordia films

Plasticizer	Conc. (%)	Wavelength (nm)								Transparency
		200	280	350	400	500	600	700	800	
None	None	0.1	0.2	16.3	36.5	59.5	65.4	73.8	74.2	2.61 ± 0.05^k
Glycerol	10	0.1	0.3	16.3	39.3	61.6	68.3	73.0	75.5	2.13 ± 0.08^{ghij}
	15	0.1	0.3	16.4	39.5	62.0	68.5	73.4	75.9	2.04 ± 0.06^{efg}
	20	0.1	0.3	16.5	39.8	62.3	68.7	73.8	76.3	1.79 ± 0.09^{cd}
	25	0.1	0.3	16.7	40.2	63.1	69.3	74.7	77.3	1.57 ± 0.10^{bcd}
	30	0.1	0.2	16.9	40.6	63.6	69.9	75.4	78.0	1.39 ± 0.14^a
Sorbitol	10	0.1	0.3	16.2	39.0	61.2	67.1	72.5	74.9	2.25 ± 0.10^{ij}
	15	0.1	0.3	16.3	39.2	61.4	67.2	72.7	75.2	2.15 ± 0.14^{ghij}
	20	0.1	0.3	16.3	39.3	61.6	67.2	73.0	75.5	1.94 ± 0.04^{ef}
	25	0.1	0.3	16.5	39.6	62.1	67.8	73.6	76.1	1.70 ± 0.11^{bc}
	30	0.1	0.3	16.6	40.0	62.7	68.2	74.3	76.9	1.67 ± 0.07^{bc}
PEG 200	10	0.1	0.3	16.3	39.2	61.5	66.8	72.9	75.3	2.21 ± 0.04^{hij}
	15	0.1	0.3	16.5	39.7	62.2	67.4	73.7	76.2	2.18 ± 0.07^{ghij}
	20	0.1	0.3	16.7	40.1	62.9	68.0	74.5	77.1	1.90 ± 0.04^{de}
	25	0.1	0.3	16.7	40.3	63.2	68.3	74.9	77.5	1.68 ± 0.06^{bc}
	30	0.1	0.3	16.7	40.3	63.1	68.2	74.8	77.4	1.66 ± 0.05^{bc}
PEG 400	10	0.1	0.3	16.2	39.0	61.2	66.0	72.5	74.9	2.28 ± 0.13^{ij}
	15	0.1	0.3	16.4	39.4	61.8	66.7	73.2	75.7	2.17 ± 0.09^{ghij}
	20	0.1	0.3	16.5	39.8	62.4	67.3	73.9	76.4	2.14 ± 0.10^{ghij}
	25	0.1	0.3	16.7	40.2	63.0	67.9	74.6	77.2	2.08 ± 0.04^{fgh}
	30	0.1	0.3	16.7	40.3	63.2	68.1	74.9	77.5	2.10 ± 0.07^{gh}

Data is presented as mean $\pm$ standard error, $n = 3$

Means with different superscript alphabets in the columns are significantly different ($P < 0.05$)

This is consistent with proportion of protein in gum cordia. The amino acids especially tyrosine, phenylalanine and tryptophan absorb UV light strongly (Guerrero et al. 2011). Similar protective strength has been reported for some protein based edible films e.g. soy protein (Guerrero et al. 2011), whey protein isolate (Gounga et al. 2007) and fish myofibrillar proteins (Shiku et al. 2003). The transparency (A600/mm) of the gum cordia film was recorded as 1.39–2.61 depending upon the type and concentration of plasticizer as observed for total color, suggesting that the film is clear enough to use without affecting the appearance of product coated. This value is comparable to previously reported transparency values for edible films e.g. gelatin (1.1–2.4), soy protein (1.4), fish myofibrillar proteins (6–36) and pea starch (1.1–2.7) (Guerrero et al. 2011; Jongjareonrak et al. 2006; Shiku et al. 2003; Zhang and Han 2006).

Conclusion

Anionic polysaccharide from *C. myxa* can be used to form film using plasticizers. The resultant films had improved sorption isotherm and optical properties as compared to other available edible coatings. The effectiveness of various plasticizers for film forming was evaluated by varying their concentrations. The glycerol was found to be the best for making edible film. Gum cordia films exhibited sigmoidal shape isotherms curves which can be modeled using GAB equation. Plasticizers decreased the energy required to attach the water molecule to sorption sites in polymer. Incorporation of plasticizer to gum cordia decreased the total color of the film. Gum cordia formed transparent films with all plasticizers. Gum cordia films were excellent barrier to UV light.

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