Table 3 Effect of XG and AAG on thermal properties and crystallinity of EFYS edible films

Sample	Thermal properties			Crystallinity (%)
	T_o (°C)	T_m (°C)	T_e (°C)	
EFY starch	115.2 ± 0.36^{a}	121.8 ± 0.14^{ae}	128.9 ± 0.29^{a}	36.02 ± 0.07^{a}
AAG 0.5%	97.30 ± 0.28^{b}	113.0 ± 0.21^{b}	122.6 ± 0.65^{b}	36.63 ± 0.31^{a}
AAG 1%	114.2 ± 1.21^{c}	121.2 ± 0.56^{ae}	128.7 ± 0.92^{a}	37.12 ± 0.09^{b}
AAG 1.5%	120.3 ± 1.06^{d}	127.3 ± 0.98^{c}	135.3 ± 1.18^{c}	39.51 ± 0.22^{c}
AAG 2%	143.5 ± 0.35^{e}	150.6 ± 0.56^{d}	159.2 ± 0.71^{d}	42.79 ± 0.35^{d}
XG 0.5%	116.4 ± 0.89^{a}	121.6 ± 0.49^{e}	128.9 ± 0.57^{a}	39.06 ± 0.12^{c}
XG 1%	110.1 ± 0.78^{f}	114.2 ± 1.02^{b}	123.9 ± 0.63^{b}	38.92 ± 0.05^{ce}
XG 1.5%	115.2 ± 0.71^{ac}	120.9 ± 1.31^{a}	127.4 ± 1.07^{e}	38.66 ± 0.33^{ef}
XG 2%	127.1 ± 1.16^{g}	137.8 ± 1.20^{f}	148.0 ± 1.72^{f}	38.12 ± 0.11^{f}

Values are the means of triplicates ± standard deviations. Means in same column with different superscript letters are significantly different ($p < 0.05$)

T_o-onset temperature, T_m-mid/melting temperature, T_e-end temperature

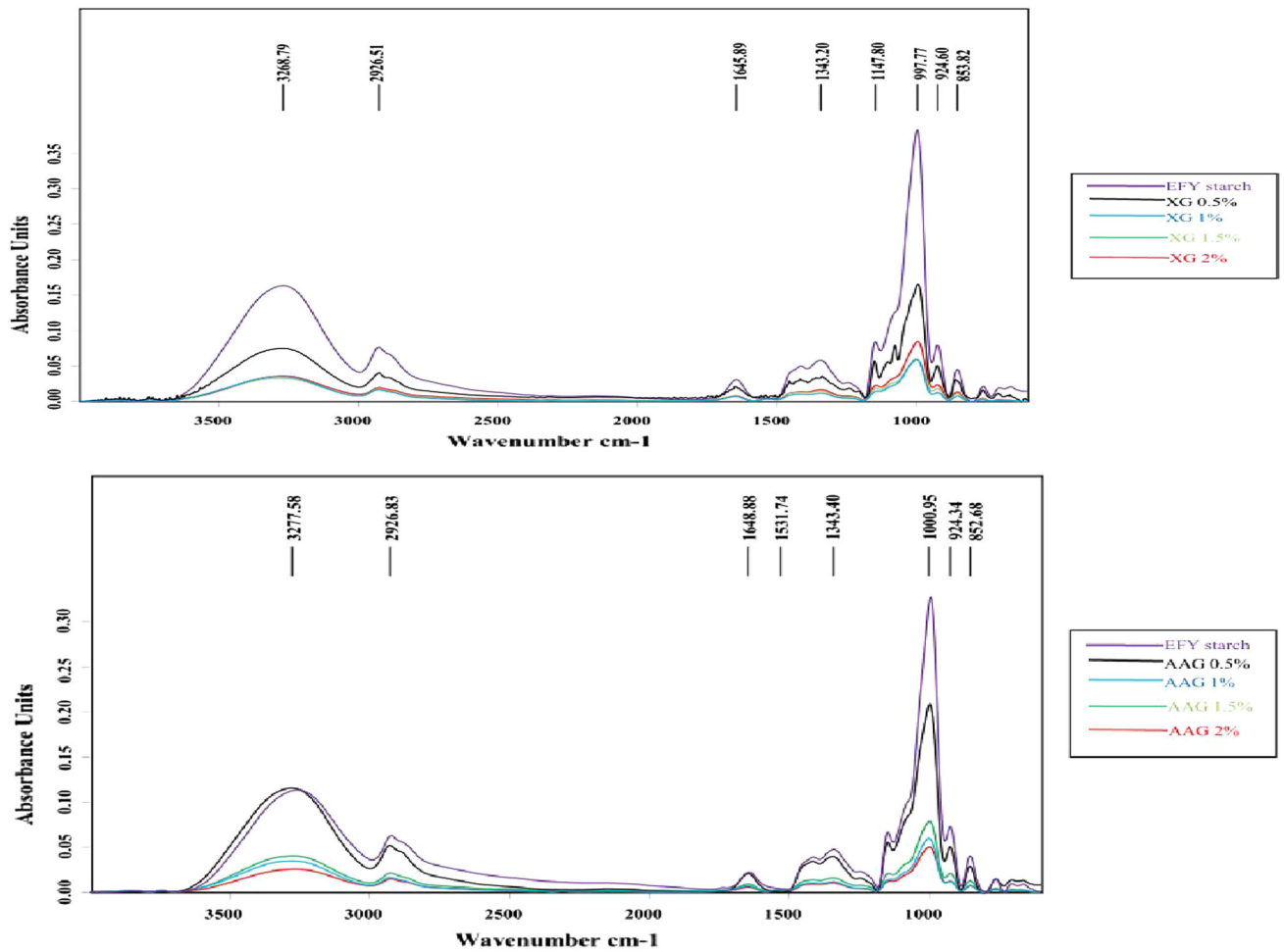

Fig. 1 FTIR spectrum of EFY starch/XG/AAG film (where, *EFY* elephant foot yam starch, *XG* Xanthan gum, *AAG* agar–agar)

The addition of XG and AA had shown the same characteristics in FTIR spectra with respect to various chemical compounds but exhibited differences in peak absorbance and intensity of broad band. The peak absorbance was observed to be higher for both XG and AA at 0.5% and 1% concentration level, whereas peak absorbance for EFYS control and higher concentration levels of AA and XG was found lower. The shift in absorbance of –

Table 4 Mechanical properties of EFYS with different concentration of AAG and XG

Sample	Tensile strength (TS, MPa)	Maximum elongation percentage at break (EAB, %)	Young modulus (YM, MPa)
EFYS	15.81 ± 0.90^{a}	23.96 ± 3.87^{a}	54.08 ± 4.16^{a}
AAG 0.5%	17.30 ± 1.38^{ab}	19.75 ± 1.85^{a}	60.81 ± 11.15^{b}
AAG 1%	17.64 ± 2.15^{a}	15.36 ± 1.67^{a}	63.43 ± 4.39^{b}
AAG 1.5%	17.85 ± 0.65^{b}	13.62 ± 1.16^{a}	65.08 ± 6.48^{b}
AAG 2%	20.14 ± 0.63^{ab}	13.34 ± 0.57^{a}	58.03 ± 2.99^{ab}
XG 0.5%	19.27 ± 0.22^{ab}	21.52 ± 1.38^{a}	56.15 ± 6.02^{ab}
XG 1%	19.10 ± 0.66^{b}	17.40 ± 1.18^{a}	58.28 ± 2.71^{ab}
XG 1.5%	19.34 ± 0.92^{ab}	15.36 ± 0.79^{a}	64.03 ± 5.54^{b}
XG 2%	19.48 ± 0.96^{b}	14.69 ± 0.39^{a}	69.77 ± 0.84^{b}

Values of mechanical properties are the means of triplicates ± standard deviations. Means in same column with different superscript letters are significantly different ($p < 0.05$)

(EFYS film) to 17.30–20.14 MPa and 19.27–19.48 MPa with the addition of AA and XG, respectively. These trends are in line with mango kernel starch-gum composite films (Nawab et al. 2017) and tapioca starch/xanthan gum composite films (Arismendi et al. 2013). The improvement in TS may be due to the development of intermolecular H-bonds and the cohesive molecular structure of the films after addition of hydrocolloids (AA/XG). However, the negative trend for maximum elongation percentage at break (EAB) was observed with the addition of hydrocolloid. EFYS film had maximum EAB (23.96%), which reduced to 19.75–13.34% and 21.52–14.69% with the addition of AA and XG from 0.5 to 2%, respectively. Similar findings were reported by Nawab et al. (2017) and Arismendi et al. (2013) for the mango kernel starch-gum composite films and tapioca starch-xanthan gum composite films, respectively. The reduction in EAB could be explained by a synergistic interaction between the EFYS and hydrocolloid molecules that produces a more unfolded network due to weaker amylose–amylose interaction forces (Saberi et al. 2017).

The Young Modulus (YM) signifies the stiffness of the film and was significantly ($p < 0.05$) varied with the addition of hydrocolloids. The YM of EFYS film was 54.08 MPa and increased in the range of 60.81–65.08 MPa and 56.15–69.77 MPa with the increase in concentration of AA (0.5–1.5%) and XG (0.5–2%), respectively. The increase in YM with the addition of hydrocolloid may be due to increase in cohesiveness which offers greater resistance against the deformation. In addition to that, the enhanced H- bonding, ordering polymer alignment and improve structural orientation during retrogradation also contributed to YM. Results were also supported by Nawab et al. (2017) for mango kernel starch-gum composite films.

Conclusion

Elephant foot yam starch based edible film was developed. Moisture content, thickness and density of the EFYS film increased with the increase in hydrocolloids. Film exhibited better interaction with AA compared to XG, in terms of mechanical and thermal properties. The highest mechanical strength (20.14 MPa) and glass transition temperature (150.6 °C) was observed for film having highest percent of agar–agar (i.e. 2%). Good mechanical properties of film may prevent the stored products from mechanical stress. and also explores its possibility for the replacement of plastic packages. Film made from 1.5% agar–agar possessed lowest barrier properties (oxygen permeability), making it apt for storing fruits and vegetables which require higher transmission rate.

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