Development and Optimization of Lobster-shell Derived Crude Chitosan Films Incorporated with Fish-gelatin and Oil

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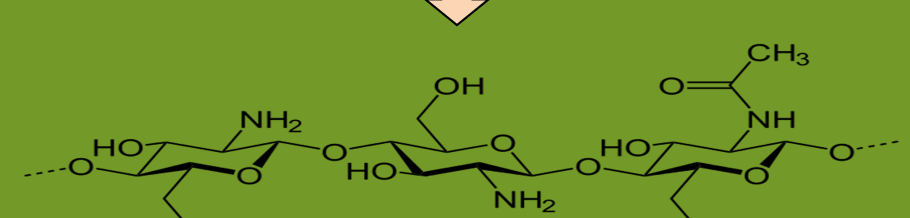
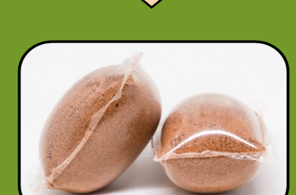
MOTIVATION

- Canada is the largest producer and exporter of lobsters around the world.
- American or Atlantic lobster (*Homarus americanus*) is the species of commercial value in the Atlantic region.
- The enormous amounts of shell waste produced and discarded during lobster processing causes several challenges
- The project aims to utilize this lobster-shell waste as a sustainable source of chitosan for the development of functional edible films with the potential to improve shelf-life of perishable food products.



Chitosan



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- S. Fakhreddin Hosseini, M. Rezaei, M. Zandi, F.F. Ghavi, Preparation and functional properties of fish gelatin-chitosan blend edible films, Food Chem. 136 (2013) 1490–1495. https://doi.org/10.1016/j.foodchem.2012.09.081.

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OBJECTIVES

- Preparation of lobster-shell derived crude chitosan films incorporated with fish-gelatin and sunflower oil.
- Optimization of these composite chitosan films for their physical, mechanical and barrier properties using response surface methodology.

METHODOLOGY

- Chitosan was extracted from lobster shells using acid-alkali extraction procedure (fig.1).

Figure 1: **Extraction of chitosan from lobster shell**

- A three-factor three-level Box-Behnken design was implemented for optimization using response surface methodology (table 1).

***Table 1*. Optimization factors and levels**

	Factors			
	Chitosan (%w/w sol)*	*Gelatin (%w/w sol) (X_1)*	*Oil (%w/w polymer) (X_2)*	*Glycerol (%w/w polymer) (X_3)*
Levels	0.5 (-)	25 (-)	0 (-)	0 (-)
	1.0 (0)	50 (0)	10 (0)	20 (0)
	1.5 (+)	75 (+)	20 (+)	40 (+)

*Dependent variable on % of Gelatin

- These composite films were prepared using solvent casting procedure (fig. 2) and were conditioned for 3 days in 52% Rh at RT before testing for their mechanical and functional properties.

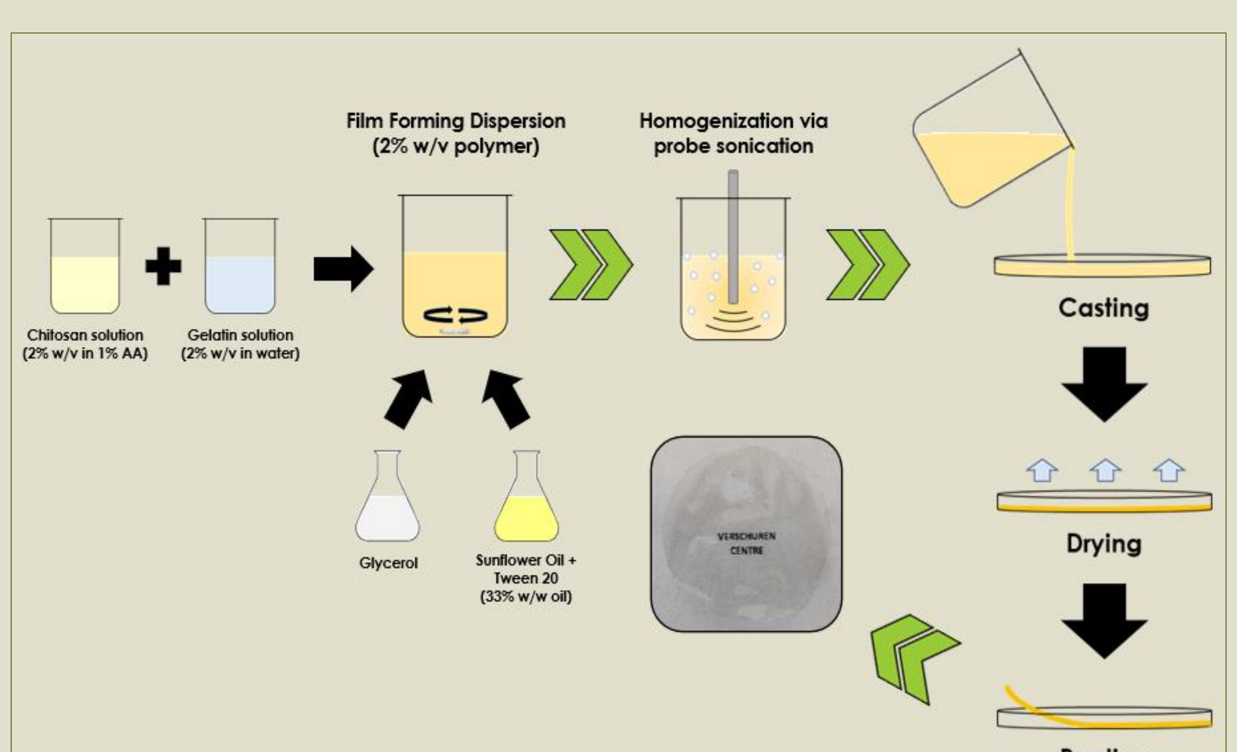

***Figure 2**: Preparation of* **chitosan-gelatin composite films**

RESULTS

***Table 2*. Box-Behnken design matrix and response sheet**

Runs	Variables				Responses							
	Chitosan %w/w	Gelatin (X_1)%w/w	Oil (X_2)%w/w	Glycerol (X_3)%w/w	Thickness (μm)	Moisture Content (%)	Swelling Power (%)	Water Solubility (%)	Tensile Strength (MPa)	Elongation at Break (%)	Contact Angle (°)	Water Vapor Permeability (g.mm/Kpa.h.m2)
1	75	25	0	20	64.00	18.21	77.68	17.04	44.15	64.97	39.27	0.89
2	25	75	0	20	46.40	15.83	97.85	23.57	27.49	40.00	28.27	0.67
3	75	25	20	20	89.20	13.62	55.61	16.33	41.52	63.84	32.70	0.85
4	25	75	20	20	79.38	11.27	79.62	15.96	13.47	38.00	9.22	0.60
5	75	25	10	0	66.30	10.94	135.02	18.13	79.26	20.60	51.89	0.57
6	25	75	10	0	58.40	5.72	177.67	25.84	30.91	6.01	53.00	0.41
7	75	25	10	40	77.70	31.42	63.32	14.13	29.31	78.52	51.23	1.21
8	25	75	10	40	57.10	27.58	81.90	16.11	15.09	99.66	30.87	1.05
9	50	50	0	0	51.80	9.73	230.00	32.13	79.10	7.41	42.94	0.54
10	50	50	20	0	82.55	4.04	101.47	23.75	62.85	10.94	36.35	0.49
11	50	50	0	40	65.50	25.22	65.50	21.81	34.52	96.25	43.02	1.25
12	50	50	20	40	84.30	23.29	63.66	21.11	25.96	82.99	35.26	0.82
13	50	50	10	20	67.80	15.15	61.05	22.03	33.76	57.52	51.70	0.84
14	50	50	10	20	67.40	13.82	70.25	22.33	31.23	48.61	49.66	0.82
15	50	50	10	20	64.20	12.00	60.89	23.25	34.07	55.41	54.73	0.82
16	50	50	10	20	65.00	12.18	62.99	22.12	38.89	45.24	50.88	0.83
17	50	50	10	20	69.90	12.86	64.83	24.17	36.70	48.13	56.55	0.84

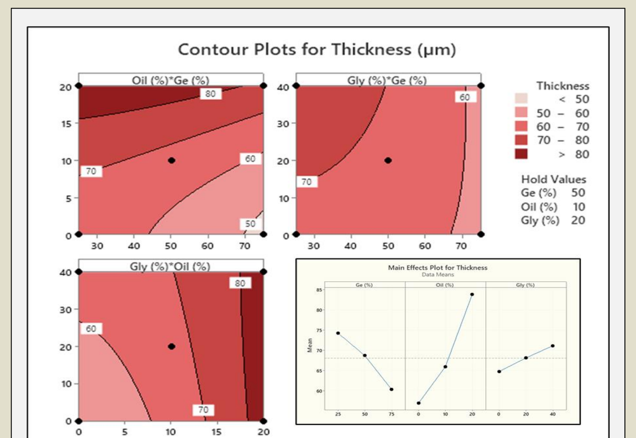

Figure 3: **Contour and Main Effect Plots for Film Thickness (T)**

T (μm) *= 56.36 + 0.032* X_1**+ 0.352* X_2** + 0.661* X_3** – 0.003* X_1^2 *+ 0.045* X_2^2** – 0.001* X_3^2 *+ 0.008* X_1X_2 *– 0.006* X_1X_3** – 0.015* X_2X_3**;* $R^2 = 0.98$

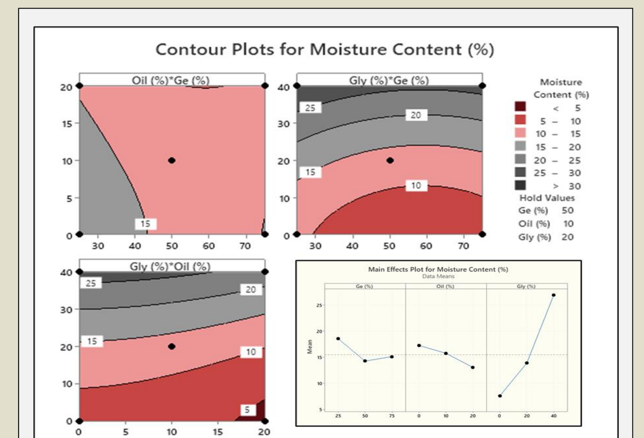

Figure 4: **Contour and Main Effect Plots for % moisture content (MC)**

MC (%) *= 21.23 – 0.459* X_1** – 0.028* X_2** + 0.154* X_3** + 0.004* X_1^2** - 0.009* X_2^2 *+ 0.008* X_3^2**;* $R^2 = 0.97$

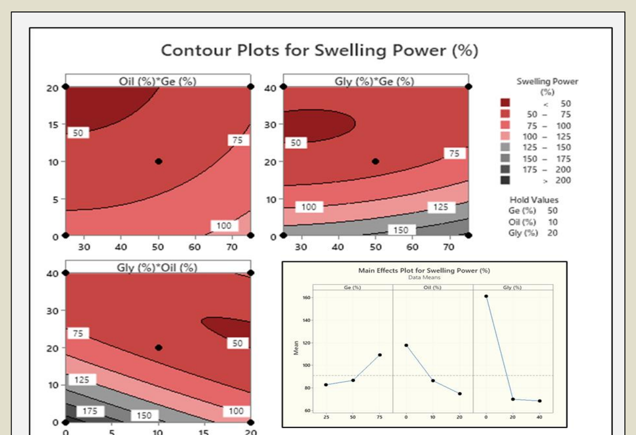

Figure 5: **Contour and Main Effect Plots for % Swelling Power (SP)**

SP (%) *= 203.9 – 0.31* X_1** – 6.93* X_2** – 7.69* X_3** + 0.01* X_1^2 *+ 0.072* X_2^2 *+ 0.11* X_3^2** + 0.004* X_1X_2 *– 0.012* X_1X_3 *+ 0.158* X_2X_3**;* $R^2 = 0.96$

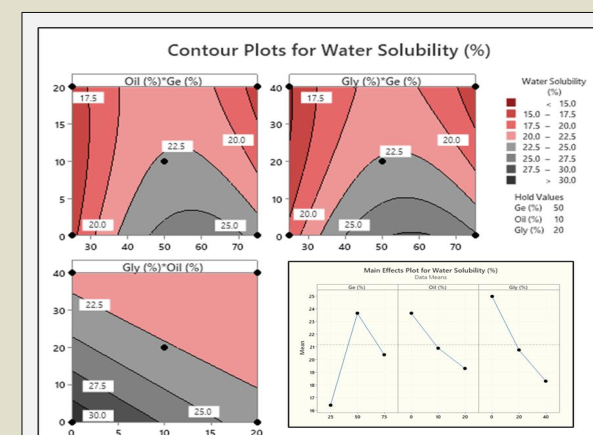

Figure 6: **Contour and Main Effect Plots for % Water Solubility (WS)**

WS (%) = 0.45 + 1.06 X_1* – 0.224 X_2* – 0.23 X_3* – 0.009 X_1^2* + 0.008 X_2^2 + 0.003 X_3^2* – 0.007 X_1X_2* – 0.003 X_1X_3* + 0.01 X_2X_3*; $R^2 = 0.98$

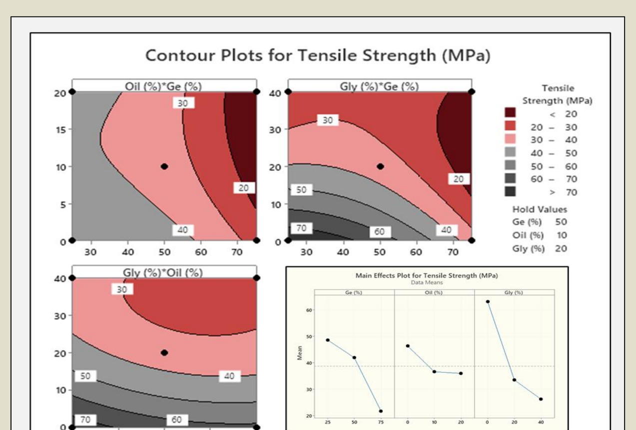

Figure 7: **Contour and Main Effect Plots for Tensile Strength (TS)**

TS (MPa) *= 83.83 + 0.455* X_1** – 1.01* X_2** – 3.003* X_3** – 0.012* X_1^2** + 0.044* X_2^2 *+ 0.028* X_3^2** – 0.01* X_1X_2 *+ 0.017* X_1X_3** + 0.01* X_2X_3*;* $R^2 = 0.98$

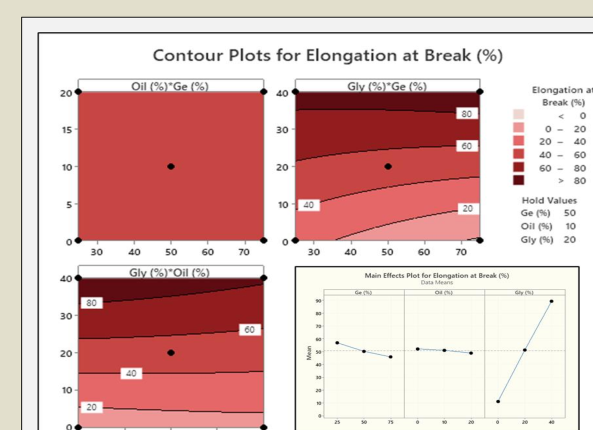

Figure 8: **Contour and Main Effect Plots for % Elongation at Break (EAB)**

EAB (%) *= 37.7 - 0.57* X_1 *+ 0.303* X_2 *+ 1.269* X_3** – 0.001* X_1X_2 *+ 0.018* X_1X_3** – 0.021* X_2X_3*;* $R^2 = 0.96$

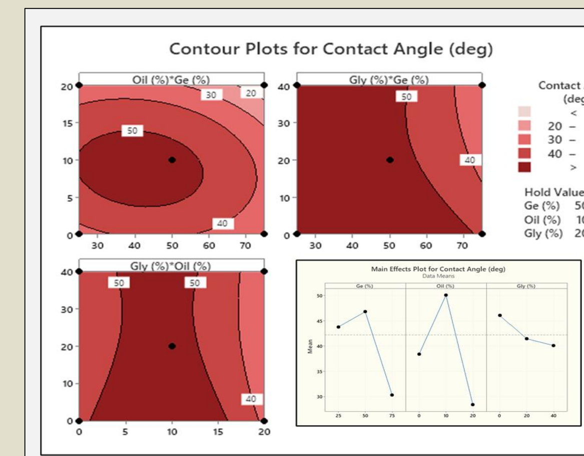

Figure 9: **Contour and Main Effect Plots for Surface Contact Angle (CA)**

CA (°) *= 24.8 + 1.17* X_1** + 2.77* X_2** – 0.452* X_3 *– 0.014* X_1^2** – 0.166* X_2^2** + 0.008* X_3^2*;* $R^2 = 0.88$

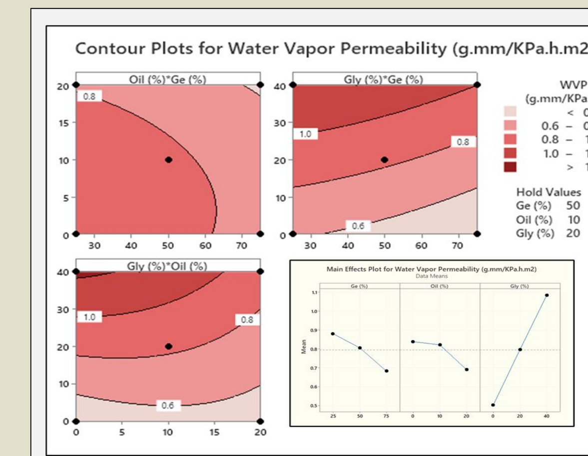

Figure 10: **Contour and Main Effect Plots for Water Vapor Permeability (WVP)**

WVP (g.mm/KPa.h.m²) *= 0.775 – 0.004* X_1** – 0.007* X_2** + 0.015* X_3**;* $R^2 = 0.91$

DISCUSSION

- All fitted models were statistically significant ($p<0.001$) and had high R^2 values (>0.85).
- Incorporation of fish-gelatin significantly reduced film strength and elongation but enhanced their vapor barrier properties.
- Incorporation of oil increased the hydrophobicity of the films while not significantly affecting their mechanical properties.
- Glycerol was found to have the most significant affect on the mechanical as well as barrier properties of the films.

CONCLUSIONS

- The presented study gave crucial insights on the effect of incorporation of fish-gelatin, oil and glycerol in lobster-shell derived chitosan films.
- While this optimization model is limited to chitosan-gelatin composite films, it covers wide ranges of response values for the studied parameters and hence will be helpful in tailoring edible films with specific properties for various food packaging applications.
- Further studies on the antimicrobial nature of these films can widen their scope of applications.

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