Peanut Protein Film as Affected by Drying Temperature and pH of Film Forming Solution

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ABSTRACT

Films were made from peanut protein concentrate solution of pH 6.0, 7.5 or 9.0, and dried at 70, 80 or 90°C. Both total solubility and protein solubility of film decreased with increasing temperature but increased with increasing pH. Film color was darker and more yellow when pH increased. Tensile strength (TS) and elongation (E) increased but water vapor permeability (WVP) and oxygen permeability (OP) decreased as temperature increased. At pH 9 and 90°C, film had the lowest WVP and OP, and the highest TS.

Key Words: Edible film, elongation, oxygen permeability, peanut protein, water vapor

INTRODUCTION

CONSIDERABLE RESEARCH HAS BEEN REPORTED ON EDIBLE FILMS, which have many advantages over synthetic films (Donhowe and Fennema, 1994). Edible films may be produced from carbohydrates, proteins, hydrophobic-based raw materials or their combinations. Peanut seed contains high protein levels, ranging from 22-30% (Ahmed and Young, 1982). Thus, it should be a very good source for film forming materials. Three main globulin fractions in peanut protein have been isolated and identified as arachin (14S), conarachin II (8S) and conarachin I (2S) (Prakash and Rao, 1986). The main difference in arachin and conarachin is their sulfur amino acids content. Conarchin contains three times more total cystine and methionine than arachin (Woodroof, 1983). Data on peanut protein film are very limited; however, a few studies have been reported (Wu and Bates, 1973; Aboagye and Stanley, 1985). They reported production of film from peanut milk by a surface film formation method similar to that used in production of soy film (Yuba) in the orient.

The deposition technique for producing soy protein film, introduced by Jaynes and Chou (1975) could be adapted to large-scale mechanized production. Soy protein lipid film was made by casting protein isolate solution at its natural pH of 6.6 on a Teflon-coated baking pan and then drying at 100°C. Many researchers have extensively studied protein film production by the deposition technique using gluten, zein, casein, whey protein isolate, soy protein isolate and rice protein concentrate (Krochta et al., 1988; Aydt et al., 1991; Gontard et al., 1992; Mahmoud and Savello 1992; McHugh and Krochta, 1994; McHugh et al., 1994; Park et al., 1994; Shih, 1996). Brandenburg et al. (1993) made film from isolated soy protein at pH 6-12 by the deposition technique. Gennadios et al. (1993a) found that pH had an effect on soy protein isolate film formation. Our previous study confirmed the potential of film making from peanut protein concentrate by this method (Jangchud and Chinnan, 1997) but the optimum processing parameters need to be determined. This study was conducted to determine the effect of drying temperature and pH of film forming solution on peanut protein film properties.

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MATERIALS & METHODS

Defatted peanut flour (2% fat)

Defatted peanut flour was made from partially defatted flour (10% fat) (Seabrook Enterprises, Inc., Edenton, NC) by a semi-continuous hexane extraction method. The system consisted of a 5-L boiling flask, a spherical heating mantle, transformer, condenser and an extraction bowl. The extraction bowl was a 4-L, 248 mm dia, Coors porcelain Büchner-type vacuum filtering funnel. Partially defatted peanut flour (1200g) was placed in a polyester bag (mesh no. 208) and placed in an extraction bowl filled with hexane. Filter paper was used to cover the flour bag surface to uniformly distribute the hexane returned from the condenser. The extraction bowl was connected to the boiling flask (distillation unit) by a polyester tube. Temperature in the boiling flask was adjusted to provide a distillation rate of about 2 L/h. Extraction was continued for 3h with occasional stirring to facilitate extraction. Defatted peanut flour in the polyester bag was removed and transferred into an aluminum flat tray. Residual hexane in the flour was evaporated in a fume hood and the floor dried overnight in an oven at 60°C. After cooling, the defatted peanut flour (about 2% fat) was stored in a plastic bag at 4°C until used. Fat content was determined by using a Goldfisch extractor (Model 3500, Laboratory Construction Co., Kansas City, MO).

Peanut protein concentrate

Peanut protein concentrate (PPC) was prepared from defatted peanut flour by modifying the method of alkaline extraction and acid precipitation described by Kim et al. (1992). Defatted peanut flour was extracted by mixing with distilled water in the ratio of 1:10, adjusting the pH to 9 with 1N NaOH, and stirring with a magnetic stirrer (Model 360, VWR Scientific, Atlanta, GA) at medium speed (no. 3) for 1h. After filtering through a polyester screen (mesh no. 126), the filtrate was centrifuged (Model J2-21M, Beckman Instruments, Inc.) at 0°C, 10000 RPM ($15.3 \times g$) for 30 min. Supernatant pH was adjusted to 4.5 by 1N HCl to form a precipitate and then centrifuged at 0°C, 10000 rpm ($15.3 \times g$) for 10 min. The protein concentrate was washed with a small amount (20 mL) of distilled water and centrifuged at 0°C, 10000 RPM ($15.3 \times g$) for 10 min. The isoelectric form of wet protein concentrate was then freeze dried for 24h (Freezmobile 5EL, Virtis company, Inc., Gardiner, NY), and the dry protein concentrate was ground in a Laboratory Mill (Model 4, Arthur H. Thomas Co., Philadelphia, PA) equipped with 1 mm mesh sieve. Ground peanut protein concentrate was stored in a plastic bag at −20°C until used.

Experimental design

A randomized complete block design, 3×3 factorial set of pH of film forming solution and drying temperature (pH at 6.0, 7.5, 9.0 and temperature 70, 80, 90°C) was used. Each treatment was replicated thrice. The effect of concentration (at 3 and 9%) was also tested separately on film formation at ambient temperature and at 70°C.

Film formation

Distilled water was added to the peanut protein concentrate (81.37% protein) to provide a 3% protein content in the film forming solution. The pH was adjusted to a desired value of 6.0, 7.5 or 9.0 by adding 1N NaOH during dissolution and stirring (by magnetic bar). Plasticizer was added at a protein: glycerin ratio of 3:5 (167.7% of protein) to the film forming solution and then heated to 70°C on a hot plate with magnetic stirrer. Protein to glycerin concentration was selected based on preliminary work to provide freestanding films suitable for physical testing. The solution was filtered through polyester screen (mesh no. 143), cooled for about 10 min and then poured on a nonstick plate for film formation. Film was formed at a desired temperature for 16h, then peeled off after cooling. Film samples were kept in a plastic bag in a desiccator at 0% and 50%RH for further testing.

Film testing

Conditioning. All films were conditioned prior to permeability and mechanical tests according to Standard method, D618-61 (ASTM, 1993a). Films used for testing water vapor permeability (WVP), tensile strength (TS) and elongation (E) were conditioned at 50% RH and 23±2°C by placing them in a desiccator over a saturated solution of $Mg(NO_3)_2 \cdot 6H_2O$ for 48h or more. For oxygen permeability (OP) tests, films were conditioned at 0% RH at 23±2°C by placing them in a desiccator over calcium chloride pellets for 48h or more. For other tests, films were transferred to plastic bags after peeling and placed in a desiccator.

Moisture protein and water activity. Moisture content was determined by drying samples under vacuum at 70°C and 3.4 kPa for 24h. Nitrogen content was determined using the Kjeldahl method (Egan et al., 1987). A protein conversion factor of 5.46 was used to calculate protein content. Water activity was determined at 25°C using Model CX2 (AquaLab, Decagon Devices, Inc., Pullman, WA). Saturated magnesium chloride and sodium chloride solutions were used to calibrate the instrument.

Film solubility (total soluble matter). A method modified from Stuchell and Krochta (1994) was used to measure film solubility. Film pieces 20 mm × 20 mm were dried at 70°C and 3.4 kPa in a vacuum oven for 24h, then weighed to the nearest 0.0001g for the initial dry weight. Films were immersed in 20 mL of distilled water in 50 mL-screw top centrifuge tubes containing 0.01% potassium sorbate. The tubes were capped and placed in a shaking water bath for 24h at 25°C. The solution (4 mL) was removed and set aside for later testing of protein solubility. The remaining solution and film piece was poured onto (Whatman #1) qualitative filter paper, rinsed with 10 mL distilled water, and dried at 70°C in a vacuum oven for 24h and the dry weight of film was determined. Triple measurements were done for each treatment replicate. Total soluble matter was calculated from the initial gross weight and final dry weights.

Protein solubility. Samples set aside from the total soluble matter tests were analyzed for protein content using the bicinchoninic acid (BCA) protein assay (Smith et al., 1985). A protein assay kit (No. BCA-1, Sigma Chemical Co., St. Louis, MO) was used for analysis, and the protein determination reagent was prepared from 4% (w/v) copper (II) sulfate pentahydrate solution and bicinchoninic acid solution at ratio of 1:50. Then 200 μL of test solution was placed in a test tube 4 mL of protein determination reagent was added and vortexed thoroughly. Samples were heated to 37°C for 30 min in a water bath, then cooled to 23±2°C. Absorbance at 562 nm was determined by diode array spectrophotometer (Hewlett Packard Model 8451A, Avondale, PA). A standard curve was developed using bovine serum albumin.

The protein solubility (%PS) was calculated as follows:

$$\%\ PS = \text{Wt of protein in 20 mL solution} \times 100 / \text{Initial wt of film} \times (\%\ \text{protein in film}) \times (\%\ \text{dry matter of film})$$

Color. Hunter color parameters (L*, a*, b*), were measured by a Chroma meter (Model CR-200, Minolta Corp., Osaka, Japan). Color value was recorded as L* (lightness, 0=black, 100=white), a* (−a*=greenness, +a*=redness), and b* (−b*=blueness, +b*=yellowness). Yellow standard plate (calibration plate CR-A47, L*= 85.45, a*= −0.15, b*=+54.55) was used as a standard. Film specimens were placed on the black plate when measurements were performed. Total color difference (ΔE^*_{ab}), hue angle (H) and chroma (C) were calculated from the following equations:

$$\Delta E^*_{ab} = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{0.5}$$
$$C = [(a^*)^2 + (b^*)^2]^{0.5}$$
$$H = \tan^{-1}(b^*/a^*)$$

where ΔL*, Δa* and Δb* referred to differences between standard and sample color values.

Film thickness. Film thickness was measured with a digital micrometer (Digitrix-Mark II, Cole Palmer Instrument Company, Nile, IL) to the nearest 0.001 mm at 5 locations. Mean thickness for each sample was calculated and used in WVP, OP and TS determinations.

Water vapor permeability (WVP). WVP was determined by a specific WVP instrument (Permatran-W1A, Modern Controls, Inc., Minneapolis, MN). The testing method as described by Standard Method F1249-90 was used (ASTM, 1993b). Film samples were double masked by manufacturer supplied aluminum foil masks with effective film test area 5 cm^2. Testing was performed at 37.8°C and 50%RH. WVP was estimated by multiplying water vapor transmission rate (WVTR) by the thickness and dividing by WVP gradient across the exposed film.

Oxygen permeability (OP). OP was determined with a MOCON unit (Ox-Tran 100A, Modern Control, Inc., Minneapolis, MN) according to Standard Method D3985-81 (ASTM, 1993c). Film samples were double masked by aluminum foil with an effective film test area of 50 cm^2. Testing was performed at 30°C and 0%RH. OP was calculated by multiplying oxygen gas transmission rate (OGTR) by the thickness and dividing by partial pressure difference of oxygen across the film surface.

Tensile strength and elongation (TS&E). TS was determined with an Instron universal testing instrument (Model 1122, Instron Corp., Canton, MA) as per Standard Method D882-91 (ASTM, 1993d) using 5 samples, 2.54 cm×12 cm, cut from each film. Initial grip separation and cross head speed were set at 50 mm and 500 mm/min, respectively. TS was calculated by dividing the maximum force at break by the thickness, and percent elongation at break was calculated as follows:

$$E = 100 \times (d_{after} - d_{before}) / d_{before}$$

where d was the distance between grips holding the specimen before or after the break of the specimen.

Statistical analysis

Statistics on a completely randomized design were determined using the GLM procedure in SAS (SAS Institute, Inc., 1988). Duncan's multiple-range test ($p \leq 0.05$) was used to determine significance of differences between means.

RESULTS & DISCUSSION

Effect of film forming concentration and drying temperature

Effect of concentration of film forming solution on film properties was determined in a preliminary study. That study involved two levels of protein content (3% and 9%) at room temperature and 70°C to observe the formation of film. Results showed film could not be formed at room temperature and 3% protein, but could be formed at 9% protein at room temperature (23°C) after 48h of drying. However, the surface of film was moist and sticky. At 70°C and 16h drying, film could be formed at both 3% and 9% protein contents. This result could

be explained by the theory of film formation reviewed by Banker (1966) which states that at low concentration (3%), the cohesive strength may be low, resulting in inability to form strong bonds at room temperature. At high drying temperatures (70 to 90°C), the cohesive strength increased and film was formed. At the high protein concentration (9%), the cohesive strength was high enough to form a strong bond between polymers at room temperature. Reported edible protein films from materials other than peanuts, have been formed at room temperature or slightly higher (23 to 40°C). For example, soy protein isolate (SPI) film was formed at 5% (w/w), 23±2°C, 30–40% RH for 30h (Stuchell and Krochta, 1994), gluten film at 11.4% (w/v), 32±2°C in an air circulating oven for 15h (Gennadios et al., 1993b), rice protein concentrate film at 27.3% (w/v), room temperature, 65% RH for 48h (Shih, 1996), and whey protein isolate (WPI) film at 5% (w/v), 37°C for 5h and followed by drying at room temperature overnight (Mahmoud and Savello, 1992).

Effect of pH and temperature

Results from analysis of effects of pH, temperature and interactions were compared an film chemical properties (Table 1), color (Table 2) and mechanical properties (Table 3). All factors except protein, L*, a*, ΔE^*_{ab} had coefficients of determination (R^2) >70%. The coefficient of variance (CV) of all models was <30% except for OP. Temperature had an effect on moisture content, color (b* and chroma), WVP, OP, TS and E; whereas, pH had an effect on film color (L* and a*) and E. The temperature and pH interaction effects were only observed on water activity, film solubility, protein solubility and hue angle. Mean values of each treatment (each combination) and main effect (pH and temperature) were compared on film chemical properties (Table 4), color (Table 5) and physical properties (Table 6). Duncan multiple range test (DMRT) was performed on the main factors when interaction was not significant. When interaction was significant, data were analyzed by temperature and then DMRT was performed (lower case and upper case letters, Tables 4, 5, 6, signify differences in means where DMRT was performed).

Moisture content and a_w. Temperature had an effect ($p \leq 0.01$) on moisture content of film after peeling. Mean moisture content of films (Table 4) prepared at 70°C was 32.57% (db) higher than for those prepared at 80°C (23.84% db) or 90°C (14.79% db). Peanut protein film had a somewhat higher moisture content than that reported for other protein-based films. This may be due to the high amount of glycerin used in film forming solution (167% of protein content). Mahmoud and Savello (1992) reported that the moisture content in WPI films increased when the concentration of glycerin increased. Such increase is hypothesized to be attributed to the hydrophilic nature of glycerin which dilutes and loosens the structure of films, resulting in an increased water holding capacity and water transmission. However, WPI film formed at room temperature had moisture contents ranging from 26.3 to 26.5% even when its glycerin content (1.5%) was much lower than in peanut protein film. Noted that this same film would have a much lower moisture content when the drying temperature was comparable to that we used. Although interaction between pH of film forming solution and drying temperature was found for water activity (Table 1), the relation between pH and temperature was not significant. Film at the highest drying temperature (90°C) showed the lowest water activity (0.120 – 0.134) which indicated that the films should be stable to microbial growth which generally require water activity >0.7.

Protein content, film solubility and protein solubility. The protein content of these films was 49.07±3.03% (db) and the film did not dissolve or break apart after 24h of incubation. This confirmed that the protein polymer network was highly stable and that only small molecules (small peptide, monomers and nonprotein material) were soluble (Stuchell and Krochta, 1994).

Temperature and pH interaction was significant both for film solubility and protein solubility. Minimum values were observed at each temperature at the low pH (6.0). Film solubility increased significantly at each temperature when pH was increased from 6.0 to 7.5 but, with the exception of the 70°C treatment, no difference was found when pH was further increased to 9.0. Protein solubility, increased with increasing pH, and declined with increasing temperature. The solubility of peanut protein film (32.17 – 55.27%) was higher than

Table 1—Analysis of variance (F-statistics), coefficient of determination (R^2) and coefficient of variance (CV) of temperature and pH effects on film chemical properties

	Source	df	Moisture content MC (%db)	a_w	Film solubility (%db)	Protein solubility (%db)
F-statistics						
	Model	8	5.22**	15.72**	62.07**	30.8**
	Temp	2	19.17**	51.15**	128.01**	38.15**
	pH	2	0.34	1.36	108.64**	75.93**
	Interaction	4	0.69	5.20**	5.81*	4.55*
R^2	Model		0.70	0.82	0.98	0.97
CV	Model		25.68	11.61	3.00	11.03

**significant at $p \leq 0.01$, *significant at $p \leq 0.05$

Table 2—Analysis of variance (F-statistics), coefficient of determination (R^2) and coefficient of variance (CV) of temperature and pH effects on film color

	Source	df	L*	a*	b*	ΔE^*_{ab}	Hue angle	Chroma
F-statistics								
	Model	8	2.21	3.59*	5.53**	1.00	6.09**	5.15**
	Temperature	2	1.34	2.67	5.92**	2.00	9.13**	15.53**
	pH	2	4.49*	10.89**	2.54	0.03	9.31**	1.91
	Interaction	4	1.51	0.40	1.84	0.98	2.96*	1.58
R^2	Model		0.50	0.61	0.71	0.31	0.73	0.70
CV	Model		2.40	17.03	25.75	1.80	11.16	23.15

**significant at $p \leq 0.01$; *significant at $p \leq 0.05$.

Table 3—Analysis of variance (F-statistics), coefficient of determination (R^2) and coefficient of variance (CV) of temperature and pH effects on film permeabilities and mechanical properties

	Source	df	Water vapor permeability (g.mm/(m^2.d.Kpa))	Oxygen permeability (cc.μm/(m^2.d.KPa))	Tensile strength (Mpa)	Elongation (%)
F-statistics						
	Model	8	11.97**	10.41**	32.23**	12.15**
	Temp	2	45.94**	39.45**	126.78**	28.73**
	pH	2	1.40	0.82	0.87	17.64**
	Interaction	4	0.27	0.68	0.64	1.12
R^2	Model		0.84	0.82	0.93	0.84
CV	Model		23.98	35.73	25.67	20.06

**significant at $p \leq 0.01$; *significant at $p \leq 0.05$.

Table 4—Chemical properties of film as related to pH of film forming solution and drying temperature[a]

		pH			
	Temp (°C)	6.0	7.5	9.0	Mean
Moisture content (%db)	70	36.60	32.45	28.65	32.57a
	80	24.17	23.14	23.84b	
	90	14.50	12.72	17.14	14.78c
Mean		25.09	23.12	22.97	
a^w	70	0.240A	0.229A	0.168A	0.212
	80	0.133A	0.147A	0.143A	0.141
	90	0.120A	0.131A	0.134A	0.129
Mean		0.146	0.155	0.144	
Film solubility	70	41.16C	55.27A	48.09B	48.17
(% db)	80	33.72B	42.68A	41.52A	39.31
	90	32.17B	39.86A	40.02A	37.35
Mean		35.68	45.94	43.21	
Protein solubility	70	9.98B	22.61A	20.09A	16.55
(% db)	80	6.21B	12.47A	16.99A	11.89
	90	5.43B	10.37A	12.37A	9.39
Mean		7.20	13.66	16.48	

[a]Means with the same lower case letter in a column are not significantly different (p>0.05). Means with the same upper case letter in a row are not significantly different (p>0.05).

Table 5—Color of film as related to pH of film forming solution and drying temperature[a]

		pH			
	Temp (°C)	6.0	7.5	9.0	Mean
L*	70	39.12	37.28	38.38	38.26
	80	38.42	37.55	36.81	37.59
	90	38.20	38.12	36.87	37.73
Mean		38.58A	37.65B	37.35B	
a*	70	1.38	1.10	0.98	1.15
	80	1.34	1.10	0.84	1.09
	90	1.13	0.90	0.85	0.96
Mean		1.28A	1.03B	0.89B	
b*	70	1.71	3.39	4.15	3.08b
	80	2.97	3.69	4.21	3.62b
	90	6.30	5.05	5.97	5.78a
Mean		3.66	4.04	4.78	
ΔE^*_{ab}	70	70.38	69.68	69.03	69.69
	80	69.89	69.88	70.19	69.99
	90	68.06	68.97	69.52	68.85
Mean		69.44	69.51	69.58	
Hue	70	45.39B	71.99A	75.94A	64.44
angle	80	63.39A	73.14A	77.33A	71.29
	90	79.82A	79.89A	82.07A	80.59
Mean		62.87	75.01	78.45	
Chroma	70	2.28	3.56	4.28	3.37b
	80	3.30	3.85	4.31	3.82b
	90	6.40	5.13	6.04	5.86a
Mean		4.00	4.18	4.88	

[a]Means with the same lower case letter in a column are not significantly different (p>0.05). Means with the same upper case letter in a row are not significantly different (p>0.05).

Table 6—Physical properties of film as related to pH of film forming solution and drying temperature

		pH			
	Temp (°C)	6.0	7.5	9.0	Mean
Water vapor					
permeability	70	38.98	39.73	33.71	37.47a
g·mm/(m²·d·KPa)		(0.1911)[a]	(0.1995)	(0.1692)	
(thickness, mm)	80	26.80	32.96	27.44	29.07b
		(0.1568)	(0.1684)	(0.1508)	
	90	10.42	11.80	8.83	10.35c
		(0.1099)	(0.1252)	(0.1006)	
Mean		25.40	28.16	23.33	
Oxygen					
permeability	70	16.80	13.12	16.29	15.40a
cc·µm/(m·d·KPa)		(0.1714)	(0.1793)	(0.1703)	
(thickness, mm)	80	9.45	10.10	7.76	9.10b
		(0.1548)	(0.1670)	(0.1594)	
	90	3.69	1.53	1.16	2.13c
		(0.1204)	(0.1204)	(0.1053)	
Mean		9.98	8.25	8.40	
Tensile strength, Mpa	70	0.31	0.39	0.50	0.40c
(thickness, mm		(0.1892)	(0.1704)	(0.2033)	
	80	1.18	1.31	1.70	1.40b
		(0.1714)	(0.1703)	(0.1579)	
	90	4.27	3.68	4.10	4.02a
		(0.1227)	(0.1460)	(0.1459)	
Mean		1.92	1.79	2.10	
Elongation, %	70	40.67	72.22	107.33	73.74b
(thickness, mm		0.1892)	(0.1704)	(0.2033)	
	80	98.79	177.83	190.62	155.75a
		(0.17814)	(0.1703)	(0.1579)	
	90	121.51	147.46	170.50	146.49a
		(0.1227)	(0.1460)	(0.1459)	
Mean		86.99B	132.84A	156.15A	

[a]Values in parentheses represent film thickness (mm).Means with the same lower case letter in a column are not significantly different (p>0.05). Means with the same upper case letter in a row are not significantly different (p>0.05).

that reported for SPI film (28 – 30%) (Stuchell and Krochta, 1994). However, the protein solubility in both types of films was quite similar. The higher concentration of glycerin used in peanut protein film may have contributed to the higher film solubility.

Appearance and color of film. Films formed at higher pH (7.5 and 9.0) and higher temperatures (80 and 90°C) were not moist and sticky at the surface when peeled. These desirable characteristics were not found in films formed at lower pH and lower temperature. Film formed at pH 6.0 was a lighter yellow and appeared more opaque and dull than film formed at pH 9.0 where the film was dark yellow because of alkalinity and heat reaction and rather clear because of fewer insoluble components. These results were comparable to the SPI film study of Brandenburg et al. (1993). Instrumental color parameters L* and a* decreased with increasing pH which influenced darkness of the film (Table 5). Values for b* and chroma increased with an increase in temperature only, and this made the film appear more yellowish. Temperature and pH interaction was significant on hue angle because hue angle is derived from a* and b*.

Water vapor permeability. Increasing the film drying temperature decreased WVP (Table 6) but pH had no effect. Gennadios et al. (1993a) reported no effect due to pH (6.0 to 9.0) in studies on SPI. The effect of drying temperature was not reported as most protein edible films have been formed at room temperature. In our study, we hypothesized that reduction in WVP due to increased temperature was from greater cross linking resulting in a tight and compact protein network and structure.

Oxygen permeability (OP). The effects of pH and temperature on OP was similar to those on WVP. On a percentage basis, OP decreased two times more than WVP. Mean OP decreased from 15.40 to 2.13 cc. m/(m²·d·KPa) when temperature increased from 70 to 90°C.

Tensile strength (TS) and percent elongation (E). TS increased from 0.40 to 4.02 MPa and E from 73.74 to 146.49%, when film forming temperature increased from 70 to 90°C. This was attributed to protein denaturation at higher temperature which was also probably due to tighter compact protein networks and structures.

The increase in E with increase in pH was assumed to be due to protein-protein interactions and the isoelectric point (pI) of peanut protein (4.5). When the pH of the film forming solution was closer to pI, a greater interaction of protein could result in more condensed (Kinsella and Phillips, 1989) and less elastic film structure. Gennadios et al. (1993a) reported that TS of SPI was unaffected by pH from 6.0 to 9.0, but was affected by more acidic or alkaline conditions. Elongation of SPI film increased slightly when pH of the film forming solution increased from 6.0 to 9.0.

CONCLUSIONS

FILM DRYING TEMPERATURE AND PH OF FILM FORMING SOLUTION affected physico-chemical and permeability properties of films. Those films produced at high temperature (90°C) exhibited low moisture content and water activity. Film color varied from pale-yellow to dark-yellow depending on pH and drying temperature. Film solubility and protein solubility decreased when temperature increased, but increased with pH. Water vapor permeability and OP decreased with increased temperature while TS and E increased. pH had no effect on WVP, OP and TS, but E increased with increases in pH. The extreme conditions of film formation at pH 9.0 and 90°C gave films with the lowest permeabilities.

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