Reuse of Solid Waste from Juice Industry (*Citrus sinensis* peel) in the Extraction of Antioxidants with Enhanced Activity through Polymer Encapsulates for the Preservation of Skin

by

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Abstract

Bio resources are finding increasing applications in our day-to-day activities. Current research on the active ingredients of plant/fruit extracts has several applications. To widen their applications in various fields, suitable biocompatible carriers are needed which would increase the shelf life of the extracts. In this work, one such biocompatible carrier for encapsulation has been developed using PEG-Sodium alginate as a complex which will act as a model for any natural product extract viz., *Citrus sinensis* peel. The extract has been studied for its radical and nitrite scavenging activity, inhibition of β-carotene bleaching and lipid peroxidation assay, before and after encapsulation in order to quantify the antioxidant activity in presence of the carrier. From the experimental results, better encapsulation of the antioxidant have been observed with increasing molecular weight of PEG, up to 8000 Da which led to an increased shelf life and sustained release. Antioxidant-PEG-8000-SA, 20:2:1 (APS-8000) mixture has been optimized and used for preservation of goatskin. The dehydration, rehydration and hydroxyproline assays reveal that, APS-8000 would be better alternative for the conventional sodium chloride preservation.

Introduction

The growing concern among consumers about synthetic antioxidants as chemical additives has considerably increased the search for natural antioxidants.[1] Plants comprise excellent antioxidant properties and these effects are mainly attributed to their phenolic constituents.[2] Plant antioxidants are nonessential dietary components containing numerous health benefits.[3] Plant derived antioxidants are more potent, efficient and safer than synthetic antioxidants, mainly due to the bioactivity of the phenolics and their property to chelate metal, inhibit lipoxygenase and scavenge free radicals.[4] Appropriate compatible carriers for target systems with sustained release of encapsulated antioxidants are required to enhance the stability and shelf life of the antioxidants. Citrus is an important fruit crop in South Asian countries, of which, loose skin mandarins and tight skinned sweet oranges are commercially important. Citrus fruits are basically destined for the production of juices. Since the yield of juice is about half of the fruit weight, very large amount of citrus peel are generated as a byproduct of the juice industry.[5] The byproduct obtained during the processing of citrus fruits can be considered as a potential ingredient in food and meat industry for preservation.[6] Biologically active compounds such as flavonoids and phenolic acids[7] present in the citrus peels present an antioxidant and free radical scavenging abilities. Citrus peels find applications as biocatalyst, animal feed, insecticide, biofuel, bulking agent and in moisture management etc.[5]

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Addition of isolated citrus peel antioxidants can retard oxidative changes in food and thereby improve the quality and nutritional value of the food.[8] Such isolated antioxidants along with functional dietary fiber are used to generate healthy products from cooked and dry-cured sausage.[9] Darkening of the isolated peel extract reduces the functional value of the same as a food component. This is best overcome by appropriate encapsulation or crosslinking of the functional components with suitable carriers. Alginates are excellent microencapsulators as well as extremely easy to prepare and especially worthwhile for bioactive compounds.[10] Porosity in alginate carriers needs to be controlled when used as carriers. Inclusion of polyols such as polyethylene glycol, enables a better control over porosity and also improves the flexibility of the carrier.[11] PEG and sodium alginate together would also provide a polymer barrier to oxidation and helps the antioxidants in its functional needs. In the present study, the antioxidant extracted from orange peel using 70% ethanol was incorporated with PEG (different molecular weights) and sodium alginate. The resulting powder was evaluated for antioxidant potential using DPPH radical and nitrite scavenging activity, inhibition of β-carotene bleaching and lipid peroxidation assays.

MATERIALS AND METHODS

Materials

Fresh orange peels were procured from a single lot of fruits available from the citrus juice manufacturer. PEG and sodium alginate employed in this study were of analytical grade. All other chemicals for biochemical assay of antioxidants were purchased from Sigma-Aldrich India.

Preparation of Lyophilized Powders

Fresh orange peels were finely ground and extracted with 70% ethanol (sample to solvent ratio 1:10) at room temperature for 72 hours with several agitations as described earlier.[8] The extracts were filtered using Whatman No. 4 filter paper. Ethanol in the orange peel extract was removed using a rotary vacuum evaporator. The aqueous extract obtained was assayed for total phenolic content. Different extract formulations were prepared using polyethylene glycol (PEG) of various molecular weight with sodium alginate. The ratio of aqueous extract, PEG and sodium alginate was maintained at 20:2:1 and the blends were prepared by stirring in the additives (PEG followed by sodium alginate). The samples were named APS-X where A, P, S stands for antioxidant, PEG and sodium alginate, respectively. X denoted the molecular weight of PEG employed (1000, 2000, 4000, 6000, 8000 and 10000 Da). Samples were then lyophilized at 1×10^{-2} Torr (1.33 Pa) and -73°C for 48 hours. The lyophilized samples were stored at 4°C. The experiments were carried out in triplicates.

Reduced Viscosity Measurement Studies

Stock solution of homopolymers and blends of PEG/sodium alginate of different compositions viz., 10/90, 20/80, 30/70, 40/60, 50/50, 60/40, 70/30, 80/20, 90/10 by weight percentage were prepared in aqueous extract. The viscosity measurements at 30±0.5°C were carried out using an Ubbelohde suspended level viscometer.

Color Measurement

CIE illuminant D65 was used in all color measurement. The transmittance was measured and the light was bombarded using a fibre optic spectrophotometer carrying a LS-1 tungsten halogen lamp from ocean optics. Barium sulphate was employed as white standard. Color difference meter was used for color analyses of orange peel powder. The Hunter color L* (lightness), a* (redness) and b* (yellowness) values were obtained through a computerized system using spectra magic software. 'L*' indicates the lightness of the sample where 0 represents black and 100 represents white. Negative and positive value of 'a*' indicates green and magenta respectively. Negative and positive value of 'b*' indicates blue and yellow respectively. CIE Lab color space was employed to determine the L*, a*, b* values.

Total Phenolic Content

The total phenolic content of 1% aqueous solution was estimated colorimetrically using the folin–Ciocalteu method.[4,12,13] To 1 mL of extract solution 1 mL folin–Ciocalteu reagent (2N) was added and allowed to stand for 5 minutes. Then 1 mL of saturated sodium carbonate solution (10%) was added to the mixture and adjusted to 10 mL with distilled water. The reaction was kept in dark for 90 minutes, after which the absorbance was read at 700 nm using a UV-visible spectrophotometer. Quantification was done based on a standard curve generated with gallic acid.

2,2-diphenyl-1-picrylhydrazyl (DPPH) Radical Scavenging Activity

DPPH radical scavenging activity of the aqueous solution (1%) of orange peel extract was estimated.[8] 200 ml of aqueous solution of 1% peel extract was added to 300 mL of water and 500 mL of 0.2 mM methanolic DPPH solution. The mixture was vortexed and left to stand at room temperature for 30 minutes. A test tube containing 500 mL of distilled water and 0.2 mM methanolic DPPH served as control. The absorbance of the solution was measured spectrophotometrically at 517 nm. The percentage of DPPH scavenging was obtained from the equation

$$\text{Radical scavenging activity (\%)} = [(A_{control} - A_{sample})/ A_{control}] \times 100$$

Inhibition of β – Carotene Bleaching

The antioxidant activity of peel extract powder was evaluated by the β-carotene linoleate model system.[14] A solution of β-carotene was prepared by dissolving 2 mg of β–carotene in

10 mL of chloroform. 2 mL of this solution was pipetted into a 100 mL round-bottom flask. After the chloroform was removed at 40°C under vacuum for 5 min, 40 mg of linoleic acid, 400 mg of tween 80 emulsifier and ~ 97 mL distilled water were added to the flask (to 100 ml final volume) with vigorous shaking for 1 min. Aliquots (4.8 mL) of this emulsion were transferred into different test tubes containing 0.2 mL of peel extracts. The tubes were shaken and incubated at 50°C in a water bath. As soon as the emulsion was added to each tube, the zero time absorbance was measured at 470 nm using a spectrophotometer. Absorbance reading was then recorded at 30 minutes interval until the control sample had changed color. A blank, devoid of β–carotene, was prepared for background subtraction. Antioxidant index (AI) is reported as percentage protection of β–carotene against oxidation, based on the calculation using the equation:

$$AI = (A_{s\,(120)/}\, A_{s\,(0)}) \times 100$$

where $A_{s(120)}$ = Absorbance of sample after 120 minute and $A_{s(0)}$ = Absorbance of sample at 0 minute.

Nitrite Scavenging Activity

The interaction of 1% aqueous peel extract with nitric oxide was assessed by nitrite scavenging method.[8] One mL of the sample was added to 1 mL of nitrite solution (1 ppm) and made up to 10 mL. The pH was adjusted to 1.2 using 0.1 N HCl and 4.2 and 6.0 using a 0.2 M citrate buffer. The reaction mixture was incubated at 37°C in a water bath for one hour. A 1 mL aliquot of sample combined with 5 mL of 2% acetic acid and 0.4 mL of Griess reagent (1:1 solution of 1% sulfanilic acid in 30% acetic acid and 1% of napthylamine in 30% acetic acid) was vortexed and kept at room temperature for 15 minutes. The amount of residual nitrite in the reaction mixture was measured spectrophotometrically at 520 nm. The nitrite scavenging effect (NSC) was calculated out as follows:

$$NSC\ \% = \{1 - (S_{(Abs)} - B_{(Abs)})\}/C_{(Abs)} \times 100$$

Where $S_{(Abs)}$ is the absorbance of the reaction mixture containing sample extracts, $B_{(Abs)}$ is the absorbance of the reaction mixture containing sample extracts minus the Griess reagent and $C_{(Abs)}$ is the absorbance of the reaction mixture alone.

Inhibition of Lipid Peroxidation in Fish Meat Homogenate

The inhibition of lipid peroxidation of salmon fish homogenate by 1% aqueous solution of peel powder was assayed.[6] Fresh salmon flesh was obtained, skin removed and 10% homogenate in distilled water prepared using a homogenizer. 5ml of sample homogenate was transferred to a test tube to which 500 µL of aqueous solution of the citrus peel powder was added. Tubes containing 500 µL distilled water served as a control. Tubes were incubated in a water bath at 37°C for 0, 30, 60 and 90 minutes. After incubation, lipid oxidation was determined as 2-thiobarbituric acid reactive substances (TBARS) value.[15] 50 µL of butylated hydroxyl anisole (7.2%) and 5 mL of TBA/TCA solution (20 mM thiobarbituric acid in 15% trichloroacetic acid) were added to the test tube. Tubes were heated in boiling water bath for 15 minutes, cooled and then centrifuged at 6000 rpm for 15 minutes. Absorbance of the supernatant was measured at 532 nm compared to the initial value (0 minute) and used for calculation of increase in TBARS values.

Application of Optimized Antioxidant Powder Formulation for the Skin Preservation: Dehydration Studies

Three raw goatskins were cut into two sides, were trimmed and washed immediately. The washed sides were allowed to drain for 15 min and then fleshed. The fleshed sides were made into half sides by equally cutting across the backbone. Half sides were numbered and weighed individually. Each experimental preservation trial was carried out using two half sides of the goatskins. The optimized powder formulation was applied on the fleshed side of each goatskin at an offer of 1% (w/w). Other four half skins were used for control preservation trial. Skins were preserved by conventional method of drying at room temperature and another half side, were treated with sodium chloride 40% (w/w) for control preservation trials.[16] Moisture content of the goat skins were determined at different intervals for a period of 80 h using the standard procedure.[17] The preserved goat skins were stored at room temperature.

Rehydration Studies

Rehydration assays for the preserved samples were carried out in triplicate, by immersing the control and experimental preserved hide sample in water. Approximately, 10 g preserved sample was put in 100 mL distilled water at room temperature in a 250 mL beaker. At pre-determined sampling periods, the samples were removed from the beaker and gently blotted on the tissue paper to remove surface water and then weighed by an electronic balance with an accuracy of ±0.0001g. The preserved goatskins were evaluated for rehydration characteristics with respect to the rehydration ratio, from the weight before and after the rehydration.

Determination of Hydroxyproline

Approximately 25 g of control and experimental preserved samples were taken and soaked with 900% water for 8 h in water shaker and spent solution was collected. Hydroxyproline was determined using the method of Woessner, after acid hydrolysis of the sample.[18] The amount of hydroxyproline was calculated by multiplying the concentration (mg/L) with volume of spent liquor (L) per kg of raw goat skin (dry weight basis).

RESULTS AND DISCUSSION

The aqueous extract from citrus peel was incorporated into a polymer carrier, then it was lyophilized resulting in light colored powder. The yield was 30 ± 5 g for every 100 g of fresh orange peel.

Reduced Viscosity Measurement Studies

In order to quantify the miscibility of PEG and sodium alginate in aqueous extract, interaction parameter μ and α

$$\mu = \frac{\Delta B}{\{[\eta]_2 - [\eta]_1\}^2}$$

where $[\eta]_1$ and $[\eta]_2$ are the intrinsic viscosity of the pure components and ΔB is given as

$$\Delta B = \frac{b - \bar{b}}{2w_1w_2}$$

Where w_1 and w_2 are the weight fractions of the PEG and sodium alginate. $\bar{b} = w_1b_{11} + w_2b_{22}$, where b_{11} and b_{22} are the slopes of the viscosity plots for the components of sodium alginate and PEG which are related to Huggins coefficient K_H as;

$$b = K_H [\eta]^2$$

For the ternary system,

$$b = w_1^2 b_{11} + w_2^2 b_{22} + 2w_1w_2 b_{12}$$

Where, b_{12} is the slope for the blend solution. If $\mu \geq 0$ then the blend is miscible and immiscible when $\mu < 0$.

$$\alpha = K_m - \frac{k_1[\eta]_1^2[w]_1^2 + k_2[\eta]_2^2[w]_2^2 + 2\sqrt{k_1k_2[\eta]_1[\eta]_2w_1w_2}}{\{[\eta]_1w_1 + [\eta]_2w_2\}^2}$$

Where, k_1, k_2 and k_m are the Huggins constants for individual component 1, 2 and blend, respectively. The long range hydrodynamic interactions are considered while deriving the equation. The polymer blend is miscible if $\alpha \geq 0$ and immiscible when $\alpha < 0$.

PEG/SA blend is miscible in aqueous extract. The interaction parameters were computed to probe the miscibility of sodium alginate and polyethylene glycol in aqueous extract and values tabulated in Table I. From Table I, it can be seen that, μ and α values are positive for blends greater than 60 and 40% polyethylene glycol.

Color Characteristics of Orange Peel Powder

The comparative color values of orange peel powders are shown in Table II. From Table II, it could be observed that, for all the powder formulations, L*> 90, implying lighter color. The positive value of 'b*' for all the powders indicate, presence of yellow tinge which arises either from the aqueous extract of orange peel or due to the incorporation of alginate. Lyophilized citrus peel powder has been reported to have an 'L*' value of 64.50 ± 0.88 without carrier.[8] An increase in the L value in presence of PEG and sodium alginate confirms the role of carrier on color reduction possibly by mere adsorptive effects.

TABLE I
Interaction parameters *μ* and α of 1% (w/v) SA/PEG blend in aqueous extract at 30°C.

PEG/SA% Wt Content	APS 1K blend		APS 2Kblend		APS 4K blend		APS 6K blend		APS 8K blend		APS10K blend	
	μ	α	*μ*	A	*μ*	α	*μ*	α	*μ*	A	*μ*	α
10/90	-0.93	-0.54	-0.74	-0.48	-0.65	-0.46	-0.61	-0.56	-0.55	-0.39	-0.62	-0.33
20/80	-0.89	-0.39	-0.76	-0.41	-0.62	-0.40	-0.59	-0.50	-0.45	-0.25	-0.55	-0.27
30/70	-0.82	-0.24	-0.67	-0.36	-0.58	-0.35	-0.55	-0.45	-0.41	-0.21	-0.51	-0.21
40/60	-0.73	-0.12	-0.55	-0.25	-0.51	-0.22	-0.48	-0.32	-0.37	-0.18	-0.46	-0.15
50/50	-0.67	-0.75	-0.45	-0.15	-0.41	-0.19	-0.35	-0.29	-0.22	-0.12	-0.38	-0.11
60/40	-0.57	0.22	-0.15	0.02	-0.16	0.02	-0.22	0.10	-0.13	0.08	-0.26	-0.08
70/30	0.06	0.59	0.16	0.25	0.17	0.15	0.02	0.25	0.09	0.15	0.10	0.17
80/20	0.09	1.01	0.36	0.90	0.26	0.20	0.19	0.30	0.33	0.86	0.29	0.55
90/10	0.36	1.54	0.47	1.13	0.50	1.33	3.23	1.83	0.57	1.88	0.43	1.26

TABLE II
Hunter color values of the powders from the orange peel extract.

Sample	L	a	b
APS-1000	93.56 ± 0.18	1.8 ± 0.01	21.4 ± 1.8
APS-2000	93.73 ± 0.12	-0.03 ± 0.01	39.93 ± 0.76
APS-4000	95.79 ± 0.18	-0.69 ± 0.16	48.9 ± 1.1
APS-6000	99.23 ± 0.33	-0.31 ± 0.07	57.4 ± 0.37
APS-8000	97.64 ± 0.26	-0.6 ± 0.04	53.85 ± 0.34
APS-10000	95.26 ± 1.3	5.19 ± 0.08	13.21 ± 0.34

TABLE III
Total phenolic content, DPPH radical scavenging and β – carotene bleaching assay of 1% powder sample.

Sample	Phenolic content as gallic acid equivalents (mM)	Radical scavenging activity (%)	Antioxidant index %
APS-1000	1.30 ± 0.01	55.65 ± 2.10	14.1 ± 0.36
APS-2000	1.41 ± 0.03	61.68 ± 1.56	14.7 ± 0.59
APS-4000	1.58 ± 0.01	64.56 ± 1.26	17.2 ± 0.42
APS-6000	1.71 ± 0.08	69.29 ± 1.98	22.1 ± 0.98
APS-8000	1.79 ± 0.01	72.92 ± 1.12	24.3 ± 0.74
APS-10000	1.60 ± 0.12	67.65 ± 1.31	17.1 ± 0.29

Total Phenolic Content

The phenolic content of the aqueous solution of orange peel extract has been estimated as 15±0.5 mM. The phenolic content of 1% aqueous solution of various powder formulations are shown in Table III. From Table III, it could be inferred that, samples APS-6000 and APS-8000 show higher phenolic content in terms of gallic acid equivalents. This could be due to the incorporation of more phenolic compounds by PEG 6000 and PEG 8000, when compared to other product formulations. This in turn indicates that APS-6000 and APS-8000 would show improved antioxidant activity, when compared to other formulations. Up to a molecular weight of 8000 for PEG, the increase in phenolic content with molecular weight is an indication of the higher encapsulation efficiency.[19] However, at higher molecular weight of PEG, the phenolic content was found to decrease, this is possibly due to the poor miscibility of alginate and PEG in the aqueous peel extract, similar to the observations made in the case of starch and PEG elsewhere.[20] As well as higher molecular weight PEGs are solid at ambient conditions, which leads to poor miscibility in the aqueous peel extract.[20]

DPPH Radical Scavenging Activity

DPPH free radical scavenging activities of powder formulations of orange peel extract are tabulated in Table III. The radical scavenging activity increases with an increase in the molecular weight of PEG used as polymer carrier, up to PEG 8000.Further increase in molecular weight of PEG 8000 to 10000 shows a decreasing trend, which can be understood from sample APS-8000 and APS-10000 showing 72.92±1.12 and 67.65±1.31% radical scavenging, respectively.

Inhibition of β - Carotene Bleaching

The presence of antioxidants hinders the extent of bleaching by neutralizing the linoleate free radical formed in the system. Hence, the extent of decrease in discoloration indicates the activity. Antioxidant studies by β-carotene bleaching method showed that all samples are comparable (Table III, Figure 1). A higher antioxidant index of 24.3 and 22.1% is obtained from sample APS-8000 and APS-6000 respectively.

Nitrite Scavenging Activity

Nitrite scavenging activity of 1% solution of powder formulations is shown in Figure 2. At pH 1.2, 4.2 and 6.0 nitrite scavenging for Sample APS-8000 was 84.53, 62.5 and 16.91%, respectively, which shows its antioxidant ability to reduce nitrite. Sample APS-6000 shows a similar scavenging property with 78.41, 56.76 and 16.85% for pH 1.2, 4.2 and 6.0, respectively. The order of nitrite scavenging activity of various samples can be shown as

APS-8000 > APS-6000 > APS-10000 ≥ APS-4000 > APS-2000 > APS-1000.

Inhibition of Lipid Peroxidation Using Thiobarbituric Acid Reactive Substances (TBARS)

In the present study, ability of orange peel powder to inhibit lipid oxidation in salmon meat homogenate incubated at 37°C has been estimated. Salmon is a fatty fish and the meat is more sensitive to oxidative deterioration due to its high polyunsaturated fatty acid content. Homogenization results in disruption of muscle cell membrane, which establishes the possible interaction of unsaturated fatty acid with pro-oxidant substances such as non-heme iron and thereby accelerating lipid oxidation that leads to the rapid development of rancidity.

Oxidative degradation of PUFA generates a number of degradation products including malondialdehyde, which is a major component measured as an index of lipid peroxidation. 2-thiobarbituric acid reactive substances (TBARS) production in a mildly accelerated condition is the measurement of secondary lipid oxidation products. Results of TBARS analysis in salmon fish meat homogenate system is shown in Figure 3. Inhibition of lipid peroxidation in sample APS-8000 is more predominant than other samples. Sample APS-6000 is comparable with sample APS-8000 in the inhibitory activity against lipid peroxidation. The order of inhibition of lipid peroxidation of various powder formulations follows the same order of nitrite scavenging activity.

From the above studies, it could be understood that the loading efficiency of different molecular weight of PEG plays an important role in the powder formulation of antioxidants. Alginate as microencapsulate has very good compatibility with both PEG and polyphenolic compounds. PEG of molecular weight ranging from 6000 to 8000 is a better protecting carrier for antioxidants than those of lower molecular weight. Molecular weight higher than 8000 has shown a decreasing trend in total phenolic content that is reflected in subsequent antioxidant potential, mainly due to the immiscible character of PEG above molecular weight of 8000. APS-8000 produced the best formulation.

Application of Optimized Antioxidant Powder Formulation for the Skin Preservation

Underlying Principle of APS as a Preservative

Alginates are excellent microencapsulates and the porosity of alginate carriers controlled using PEG. PEG is used to remove water from the skin matrix through hydrostatic pressure, through which it helps to create unfavorable condition for the growth of microorganism on skin matrix. At the same time, the plant polyphenols are released slowly, which also prevents the microbial action on the skin. This combination (PEG and sodium alginate) provides a polymer barrier against oxidation of antioxidants and helps to retain its activity against microbial action on skin. Further, the APS will coat the individual fiber bundles thereby avoiding the fiber cohesion of the hide matrix. These fiber bundles could rapidly rehydrates when it is subjected to rehydration process.

Dehydration and Rehydration Studies

Dehydration and rehydration rate for control and experimentally preserved skin matrix are given in Figure 4a. Dehydration process is rapid for drying based preservation process on the other hand sodium chloride and APS preservations are slower and comparable. The rate of rehydration of control and experimentally preserved skin matrix are given in Figure 4b. It is known that the rehydration of skin matrix preserved by drying is difficult due to the fiber cohesion during the drying process.[16] Skin matrix preserved with APS provides faster rehydration of skin matrix compared to sodium chloride preservation and drying. Rate of dehydration and rehydration of skin matrix are faster for APS compared to drying at ambient and sodium chloride preservation methods. This is primarily due to combined effect of polymers (PEG and SA) and citrus peel antioxidants.

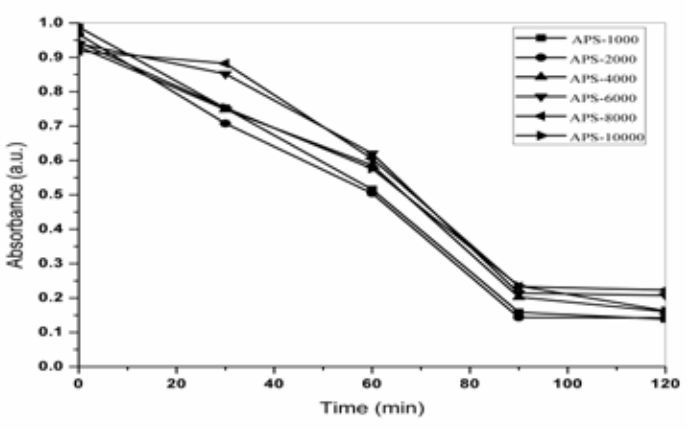

Figure 1. Antioxidant activity of powder samples using a β – carotene bleaching assay.

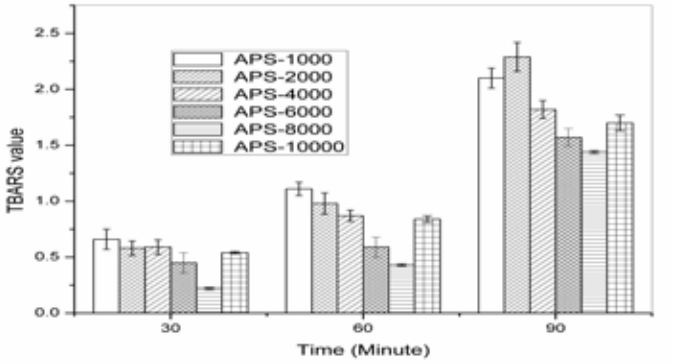

Figure 2. Nitrite scavenging activity of powder formulations.

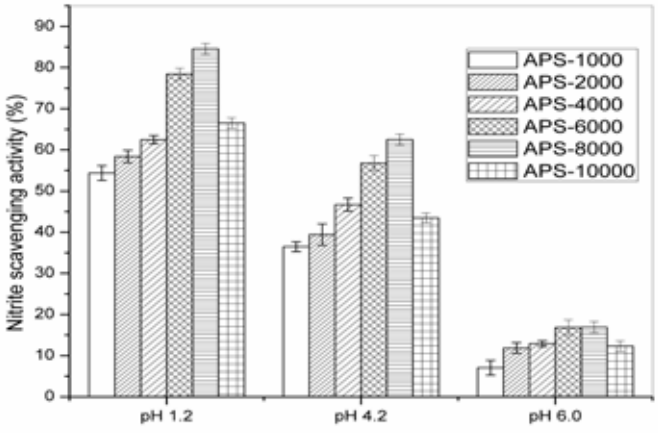

Figure 3. Increase in TBA reactive substances in salmon fish homogenate at 37°C for various powders.

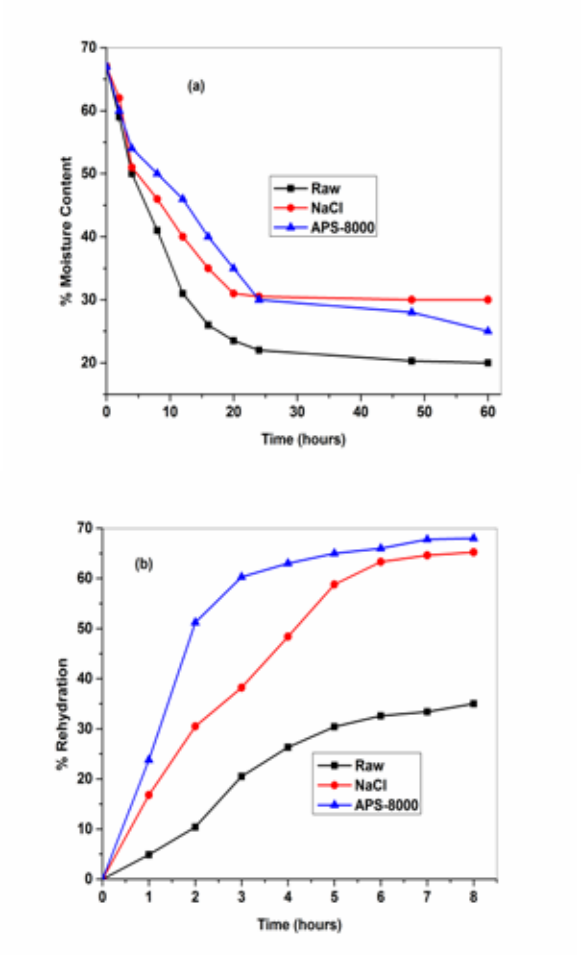

Figure 4. (a) Dehydration curves of raw goat skin during preservation by APS-8000, NaCl and drying at room temperature, (b) Rehydration behaviors of goat skins preserved by APS-8000, NaCl and drying at room temperature.

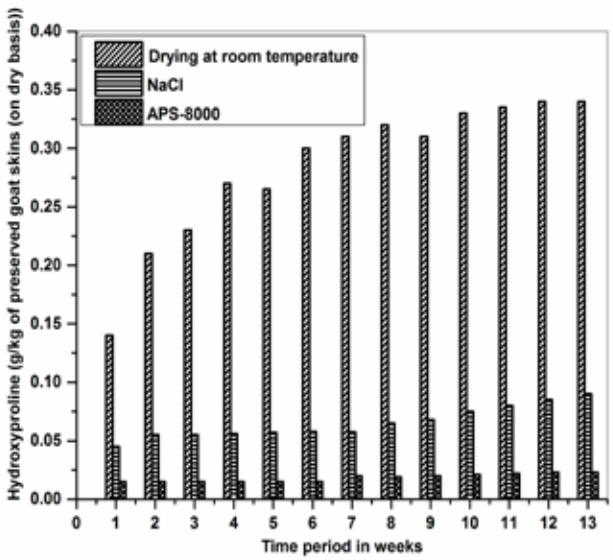

Figure 5. Effectiveness of preservation method by APS-8000, NaCl and drying at room temperature.

Comparison of the Effectiveness of Preservation Method Based on APS-8000 and Salt

Effectiveness of preservation process was assessed through the determination of loss of leather making protein during the storage of preserved skin samples for 90 days. It is known that estimation of hydroxyproline in spent soak liquor is used as a potential marker to identify the degradation of leather making protein.[16] It is observed from Figure 5 that the hide sample preserved by drying shows significant degradation of skin matrix compared to sodium chloride and APS-8000 based preservation. The degradation of skin matrix preserved by APS-8000 is slightly higher compared to the sodium chloride based preservation of skin. Hence, APS-8000 based preservation is found to be more efficient as compared to salt based preservation.

CONCLUSION

PEG-Sodium alginate polymer system was developed as a possible carrier for natural antioxidants from orange peel. A powder formulation with high stability and shelf life was formed at 20:2:1 weight ratios (Aqueous extract: PEG: sodium alginate) with the phenolic content of 15±0.5 mM. The powder formulation prepared using PEG of molecular weight 6000 – 8000 Daltons gave a good sustained release pattern. The color measurement values indicate that the formulated power was lighter in color, which is needed for a preservative. This formulated powder may also find application in food industry for preservation. Antioxidant-PEG-8000-SA, 20:2:1 (APS-8000) mixture has been optimized and used for preservation of goat skin. The dehydration, rehydration and hydroxyproline assays reveal that, APS-8000 would be better alternative for the conventional sodium chloride preservation.

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