Adding Value of mango and potato peels extract: A case of Edible biopolymer film for processed cheese

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ABSTRACT

Active packaging that inhibits harmful microorganisms from developing on the surface of processed cheese might extend the product's shelf life and improve its quality. In this study, whey protein isolate (WPI), potato peel extract (PPE), and mango peel extract were used to create a functional edible coating (MPE). For three months, coated processed cheese and uncoated cheese were stored in the refrigerator at 4°C. Studies were conducted on variations in total phenolic content, antioxidant activity, textural profile analysis, and microbiological count. The results showed that the processed cheese with WPI-1.5% PPE coating demonstrated the best outcomes when compared to other treatments, displaying differences in all values.

Keywords: Active coating; byproduct; antioxidant; microbial counts; eco-friendly-product.

INTRODUCTION

The packaging and food sectors focus on developing edible packaging materials to reduce waste due to the recent increase in environmental consciousness and consumers' demand for consistent, wholesome, and secure foods (Karaca et al., 2019). Edible films and coatings hold great potential as cutting-edge sustainable packaging alternatives that operate as functional barriers between food and the environment, protecting food safety and quality (Ramos et al., 2012). Whey protein, which has recently gained attention for its availability, safety, and biodegradability, and for acting as an environmentally friendly alternative to synthetic polymers, is one of the most promising edible biopolymers for food packaging (Milani and Tirgarian, 2020). Whey protein isolate and concentrate are the two primary types of whey protein utilized in producing edible films and coatings. Films/coatings made of whey proteins are colorless, odorless, elastic, and translucent, with excellent mechanical and barrier characteristics, in contrast to polysaccharides and other protein polymers. Compared to other protein films, they have high water vapor permeability, weak tensile strength, and excellent oxygen permeability. An edible whey film comprises a three-dimensional, densely interconnected network of dry polymers that resembles a gel (Di Pierro et al., 2018). Whey protein-based films/coatings have been successfully employed in numerous meals as active material transporters without substantially altering the desired features of the packaging films that provide value for subsequent industrial usage as antimicrobials, antioxidants, probiotics, etc. (Kandasamy et al., 2021).

Potato peels are a major byproduct of the potato processing industry that can be used to generate bioactive chemicals, with polyphenolic compounds attracting the most attention (Schieber and Saldaña, 2009). Therefore, potato waste is potentially an affordable and cheap source. Collecting and recycling it within the food chain might be a long-term solution to the challenges faced by the industrialized world today (Pinela et al., 2017). When bioactive components, particularly polyphenols, are extracted from potato skin using green technology, the nutritional and pharmacological characteristics, as well as the antioxidant potential of these molecules, can be retained (Durante et al., 2014). The ability of bioactive compounds isolated from potato peel waste to slow down the oxidative breakdown of various fatty food matrices was studied by Robles-Ramírez et al. (2016) and Fritsch et al. (2017). Phytonutrients and their specific functions in anti-inflammatory and anti-cancer properties have recently gained attention. As a result, mango peels are seen as a viable source of raw materials for recovering phytonutrients such as polyphenols, dietary fiber, pectin, and other substances.

Strategies were devised and tested to minimize waste volumes and make high-value compounds, particularly those in the peels, accessible for use as food and feed components regarding the use of value-added byproducts in mango processing. The application of

several prototype processing lines for food-grade byproduct stabilization to fresh peels of fully ripe mango fruits was evaluated at the food processing level (Nagel et al., 2012). The widespread usage of processed cheese may be ascribed to its many uses in our meals. Natural cheese is combined with emulsifying salts, other dairy products, and non-dairy ingredients to make processed cheese, which is then heated and mixed to produce a homogeneous product with a long shelf life (Kapoor and Metzger, 2008). According to Sorensen (2001), processed cheese, one of the most widely used types of cheese in the world, is used in various culinary preparations (processed foods and food service). Guinee (2002) states that "the functional aspects of a cheese (when used in a certain meal) relate to the performance of the cheese during all stages of food preparation and consumption, which would eventually add to the taste and aesthetic appeal of that prepared dish." Based on their end-use application, the necessary functional characteristics of processed cheese may be separated into two groups: unmelted and melted textural attributes. The widespread usage of processed cheese can be attributed to its many end uses. Processed cheese is made by combining natural cheese with emulsifying salts, other dairy products, and non-dairy ingredients. This mixture is then heated and mixed to create a homogeneous product that has a long shelf life (Kapoor and Metzger, 2008). According to Sorensen (2001), processed cheese is one of the most commonly used types of cheese worldwide and is used in various culinary preparations. Guinee (2002) states that in processed foods and food service, the functional aspects of cheese relate to its performance during all stages of food preparation and consumption, which ultimately adds to the taste and aesthetic appeal of the prepared dish. Depending on their intended use, the necessary functional characteristics of processed cheese can be categorized into two groups: unmelted and melted textural attributes. To the best of our knowledge, there is no existing literature on the potential use of potato and mango peels to extend the shelf life of minimally processed cheese.

This study aims to create active edible packaging materials by utilizing whey protein isolate and extracts from potato peels and mango peels. Infusions of potato peel and mango peel extracts were chosen as they provide a more realistic approach from the customers' perspective, considering water-alcohol solvents are often considered "natural." Various tests were conducted to evaluate their impact on cheese quality and shelf life. Biopolymer films were used as packaging for the processed cheese, which was stored at 4°C in cold storage for aduration of three months.

MATERIALS AND METHODS

Materials

Whey protein isolate (WPI, 95% protein) was obtained from Davisco Foods International Inc. (La Sueur, MN, USA). Anhydrous glycerol (purity, 99.5%), Folin's phenol reagent, and ethanol were supplied by Avantor Performance Materials Poland S.A. (Gliwice, Poland). Cheddar cheese (6 months old) was imported from New Zealand by Khaled Khoshala Co. for Food Industries and Cooling, Egypt. Ras cheese (1-month-old) was obtained from Mariam Co., Giza, Egypt. The Fonterra butter was obtained from Sakr Group Co., Egypt. Skim milk powder spray process grade A, nonfat dry milk made from pasteurized milk, was distributed by Dairy America, made in the USA. Egy Phos S2 emulsifying salts were obtained from The Egyptian Company for Dairy Products and Food Additives "EGYdairy" Egypt.

Methods

Extraction of Phenolic Compounds from mango and potato peels

The potato (*Solanum tuberosum* L.) cultivar was obtained from the Lion Chipsy Factory in Tanta, cleaned with tap water, and had the peel removed. Freshly processed mango (Mangifera indica L.) peel was collected (single batch) from Global Industries company, a mango processing industry, and washed with water. The underlying pulp was then removed from the mango peel using a knife. To obtain potato peel extract (PPE) powder and mango peel extract (MPE) powder, which are used in the preparation of edible coating films (Gondi and Prasada Rao, 2015), the cleaned peels of potatoes and mangos were spread in trays and dried at 45 ± 2 °C for 48 hours using a cross-flow drier (Model PTD-48E, Premium Industries Ltd., Ahmadabad, India). A measure of 10 g of each potato peel powder (PP) and mango peel powder (MP) was added to 200 mL of 80% ethanol and placed in an ultrasonicator (ultrasonication 160 W power, 40 kHz frequency, and 60% pulse) (Sonic Vibra cell USA) for 1 minute at room temperature. The samples were then centrifuged, and the supernatant was separated. The extraction procedure was conducted three times. The solvent was evaporated using a rotary

evaporator (Büchi R20, Switzerland). The residue was then dried using a freeze dryer (Labconco cooperation, Kansas City, United States) at –52°C for 48 hours under 0.1 mPa and stored at –18 °C.

Preparation of Film-Forming Solutions

The aqueous coating solution, consisting of 8%, was obtained by mixing whey protein isolate with distilled water and heating it at 80 °C for 30 minutes using a magnetic agitator rotating at 250 rpm. Glycerol, acting as a plasticizer, was added at a concentration of 50% of the protein. The powders extracted from potatoes and mango peels were added to the film-forming solution at different concentrations of 0.5%, 1%, and 1.5% (w/w). The mixtures were then homogenized for 3 minutes at 24,000 rpm. The solution without the addition of any other substances was used as a control (Soazo et al., 2013).

Manufacture of processed cheese (PCS)

The coating of processed cheese with a biopolymer solution was achieved by dipping the cheese in it. The concentrations of the required ingredients were calculated for this process, following the procedure outlined in (Ibraheem 1980) for making processed cheese at 85 °C for 8 minutes using a double jacket pan. After preparation, the cheese was filled into plastic jars at 5± 12 °C and then cut into slices. The examined blend comprised the following ingredients: 2% milk protein concentrate, 15% skim milk powder, 7% cheddar cheese, 24.5% butter, 2.8% emulsifying salt (S4), 0.8% salt, 0.1% xanthan gum, 0.1% guar gum, 0.1% myprogene, 0.1% potassium sorbate, and 0.03% nisin.

Chemical analysis

Proximate chemical composition

The potato and mango peels' moisture, protein, fat, fibre, and ash contents were determined according to the methods of (AOAC, 2010). The difference calculated total carbohydrates. All proximate composition experiments were performed in triplicate and expressed as g/100 g.

Starch determination

Ultraviolet-visible (UV-VIS) spectrophotometry method is a method with the principle of colour formation in analytes with reagents used so that it can absorb light at specific wavelengths specifically. Using colour-forming reagents will increase sensitivity, so the detection limit is low. Several studies have successfully measured amylose in analogue rice based on flour and purple sweet potato starch. The principle of this method is to prove that in the validation of the analysis method, several parameters must be considered, including accuracy, precision, the limit of detection (LOD), the limit of quantitation (LOQ), and linearity.

Determination of total phenolic content:

Total phenolic content (TPC) was determined by measuring the complex of antioxidants with Folin-Ciocalteau reagent at 765 nm (DU 530, Beckman Coulter Inc., Brea, USA) using the procedure described in (Soliman and Nasser 2022). The results were expressed as a per cent.

Determination of antioxidant properties activity (DPPH)

Each sample's radical scavenging capacity estimation was performed using 2, 2-diphenyl-1- picrylhydrazyl radical (DPPH•, Sigma Aldrich) according to the method of, (**Soliman *et al.*, 2022**). 500 μg was taken from each sample and mixed with DPPH• reagent, 1,000 μL (0.1 mM), for 30 min. Each mixture was read at 517 nm in a double-beam Ultraviolet-Visible spectrophotometer (Thermo Scientific, AQ8000, USA).

High-Performance Liquid Chromatography

An Agilent 1260 series was used for high-performance liquid chromatography (HPLC) analysis. An Eclipse C18 column (4.6250 mm i.d., 5 m) was utilized for the separation. At a flow rate of 1 mL min G1, the mobile phase was composed of water (A) and 0.05% trifluoroacetic acid in acetonitrile (B). The mobile phase was set in the following order: 0 min (82% A), 0–5 min (80% A), 5–8 min (60% A), 8–12 min (60% A), 12–15 min (85% A), and 15–16 min (82% A). The multiwavelength detector was monitored at 280 nm. For each of the sample solutions, the injection volume was 10 L. The temperature in the column was kept constant at 35◦C (Soliman et al., 2022).

Texture Profile analysis of processed cheese

The Texture Profile Analysis (TPA) of processed cheese was performed using a texture analyzer (mecmesin limited, Slinfold, West Sussex, UK). Experiments were carried out by a compression test that generated a plot of force (gf) versus time (sec). Samples were double-compressed at a compression speed of 2 cm/min. The analysis was carried out at room temperature. Hardness (gf), springiness (mm), chewiness (gf*mm), gumminess (gf),

and cohesiveness were evaluated as described by (El-Kholy *et al.,* 2019).

Microbiological analysis of processed cheese

The microbiological methods outlined in the standard methods for the examination of dairy products (Marshall, 1992)

Were employed for the Determination of the following specific bacterial groups:

Total bacterial count (nutrient agar).

spore-forming bacterial count (Mannitol Egg Yolk Polymyxin (MYP) agars).

Coliform bacterial count (macconkey agar).

Yeasts and moulds count (potato dextrose agar).

RESULTS AND DISCUSSION

Chemical composition of mango and potato peels

Table 1 shows the chemical composition of mango and potato peel powder. The data reveals that mango peel powder had higher values of fat, fiber, and carbohydrate contents (%) than potato peel powder, at 3.28%, 19.13%, and 64.35%, respectively. On the other hand, potato peel powder had higher contents of moisture, protein, ash, and starch, with values of 6.39%, 10.16%, 4.01%, and 29.63%, respectively. Similar studies in the literature have reported values of 0.7-2.9%, 11.1-17.2%, 68-88%, and 28% for the contents of fat, protein, glucose, and starch in potato peels, respectively (Mohdaly et al., 2009 and Sampaio et al., 2020). Our research also yielded results within these ranges. The slight variations could be attributed to environmental factors that affect the nutritional content of potato peels, such as variety, harvest season, ripening stage, and weather conditions (Ezekiel et al., 2013, Akyol et al., 2016). The measurements for mango peel powder were comparable to those reported by Ashoush and Gadallah (2011).

HPLC to identification and quantification of phenolic compounds in the peel wastes (mango and potato)

HPLC was used to perform an initial assessment of the MPE and PPE to establish which components were responsible for their remarkable antioxidant and antibacterial properties. Tables 2a and 2b depict the information for 15 identified components for MPE and 14 identified components for PPE. Total phenolic compounds of mango peels were presented in (Table 2a). Syringic acid, gallic acid, mangiferin, ferulic acid, chlorogenic acid, caffeic acid, kaempferol, p-coumaric acid, protocatechuic acid, iso mangiferin, myricetin, apigenin, quercetin, ethyl gallate, and catechin were all found in the extract when it was analyzed by high-performance liquid chromatography (HPLC). Table 2a shows the findings of a comparison between the retention times of the compounds in question and those found in the extract. According to Ribeiro and Schieber (2010), the main substances in Mangifera indica peels were gallic, mangiferin, myricetin, ferulic, protocatechuic, coumaric, and ellagic acid. According to data in Table (2a), myricetin represented the most significant proportion of all phenolic compounds, contributing roughly 16.73%. The methanol extract of mango peels, gallic acid and mangiferin contributed 16.23% and 12.91%, respectively. Caffeic acid was in the minor proportion, making up roughly 0.15% of phenolic compounds.

Table 2b presents the total phenolic components of potato peel extract (PPE), which scored 774.38 mg/kg of peel extract. Moreover, PPE includes pyrogallol, chlorogenic, iso-ferulic, gallic, coumaric, protocatechuic, catechin, caffeic, ferulic, and catechol acids, as well as coumarin, vanillin, and caffeine. Gallic acid (201.67 mg/kg), vanillic acid (183.5 mg/kg), and catechin (126.7 mg/kg) are all found in relatively high concentrations in the PPE. These percentages amount to 16.36%, 23.69%, and 26.04%, respectively. P-Coumaric acid makes up around 0.54% of all phenolic compounds, representing the lowest concentration. Caffeic acid, gallic acid, pyrogallol, benzoic acid, and chlorogenic acid are some of the phenolic chemicals discovered in the methanol extract of potato peels by Mohadli in 2010. The phenolic chemicals gallic acid, caffeic acid, chlorogenic acid, and protocatechuic acid were shown to be the most abundant in potato peel extract (Sello, 2011).

Total phenolic content and antioxidant activity of processed cheese coated with edible films

The processed cheese covered with edible films demonstrated total phenolic and antioxidant activity after storage at 4 °C for three months, according to the data in Table 3. Throughout the three months of storage, it was found that the treatment with WPI-1.5% PPE had a greater level of phenolic compounds. The results were 99.75, 101.05, 102.19, and 102.78 mg GAE/g, whereas the control sample had lower values of 5.19, 6.15, 7.12, and 7.25 mg GAE/g. These values were followed by

those after WPI-0.5% MPE treatment, which were 72.85, 73.63, 74.25, and 74.59 mg GAE/g. Antioxidant activity was lower in the control samples. However, during storage, treatments with WPI-1.5% PPE showed more significant total antioxidant activity (AA), with values of 199.27, 203.24, 205.85, and 207.18%, respectively, than treatments with WPI-0.5% MPE, with values of 76.19, 78.25, 79.59, and 81.09%. During storage, the values were 23.75, 29.25, 30.95, and 31.67%. The antioxidant activity of cheese after storage given peptides with low molecular weight has been confirmed by Chen & Guangqing (2010) and Ramos et al. (2022).

Texture profile of processed cheese coated with edible films

The textural profile analysis of processed cheese that was coated with edible films and stored at 4 °C for three months is shown in Table 4. The hardness values of the control sample were 409.78 gf on the first day and 1098.55 gf after three months, greater than those of other treatments. The treatments with WPI-1.5% PPE had the lowest values, which were 402.97 gf at zero time and 545.35 gf at the end of storage. During storage, the hardness values of the cheese samples all increased significantly ($p < 0.05$). A coating's presence, kind, and method of manufacture were all shown to significantly affect hardness. Coating and storage time had a significant impact on springiness; values decreased in every situation. Low values (as low as 0.64–0.62) were seen in the WPI-0.5% MPE treatment, but the WPI-1.5% PPE treatment showed higher values (0.70-0.65). When the sample was fresh, and after three months of storage, the control sample exhibited higher values (0.79-0.69). Cohesiveness data indicated that the control sample had a lower value of 0.40 and that Treatment with (WPI-0.5% MPE) had a higher value (0.52) at zero time, followed by Treatment with (WPI-1.5% PPE) (0.43). "Gummi" is a term used to describe the following condition. After three months, the values climbed to 624.69, 347.18, and 232.90, respectively, from the initial values of 171.31 for the control sample, 206.59 for treatment with (WPI-0.5% MPE), and 184.71 for treatment with (WPI-1.5% PPE). Chewiness values increased during storage, from 120.66 to 134.65.

Microbial aseptic of processed cheese coated with edible films

The microbiological analysis of processed cheese coated with edible films during storage at 4 °C for three months is shown in Table 5, with the data presented in log CFU/g. The data showed that the control sample had higher total bacterial counts than those of other treatments; values ranged from 3.27 log CFU/g on day one to 3.68 log CFU/g at the end of storage. These values increased from 3.27 log CFU/g on day one to 3.35 log CFU/g after one month and to 3.55 log CFU/g after two months. The counts of cheese coated with edible films were dramatically reduced. During the storage period, the treatment with WPI-0.5% MPE had counts of 3.21, 3.30, 3.47, and 3.59 log CFU/g, respectively, but the treatment with WPI-1.5% MPE had lower counts with values of 3.15, 3.29, 3.45, and 3.55 log CFU/g, respectively. The same table showed that the spore-forming bacterial counts in the control sample were 1.94 log CFU/g and 1.96 log CFU/g in the second and third months, respectively, whereas spore-forming bacteria first emerged in the treatment group receiving WPI-0.5% MPE in the third month and were recorded at 1.48 log CFU/g. There were no spore-forming or previous bacteria after the treatment with WPI-1.5% PPE. These findings were consistent with those of Varga (2007) and Hasanain (2013) and are consistent with the Egyptian Specifications for processed cheese from 2005. All samples were free of coliforms and had no detectable counts of molds and yeasts.

CONCLUSION

We conclude from this work that the use of potato peel and mango peel extracts, with whey proteins as a biopolymer, had an effective impact in raising the antioxidant level of processed cheese, prolonging the preservation period, and reducing the number of microbes and spores.

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Table 1: Chemical composition of mango and potato peels (g/100g) on dry weight basis

Constituent	Mango peel	Potato peel
Moisture	5.97	6.39
Protein	3.78	10.16
Fat	3.28	2.55
Fiber	19.13	16.55
Ash	3.49	4.01
Carbohydrates	64.35	60.34
Starch	7.52	29.63

Table 2a: Fractionation of total phenolic compounds of mango peels methanol extract**:**

Phenolic compounds	Mango peels		t_R
	Concentration (mg/ kg)	Percentage (%)	Min
Gallic acid	516.2	16.23	5.2
Ferulic acid	6.9	2.16	7.2
Chlorogenic acid	264.8	8.32	8.5
Syringic acid	335.6	10.55	11.8
Quercetin	317.2	9.97	12.9
Caffeic acid	4.9	0.15	13.0
Kaempferol	187.2	5.88	13.6
P-Coumaric acid	188,6	5.93	14.5
Protocatechuic acid	78.6	2.47	15.2
Iso Mangiferin	12.6	0.39	17.1
Myricetin	532.2	16.73	17.4
Apigenin	142.4	4.47	18.2
Mangiferin	410.8	12.91	19.8
Ethyl gallate	34.7	1.09	21.2
Catechin	147.3	4.63	22.4

t_R Min: retention time

Table 2b: Fractionation of total phenolic compounds of potato peels methanol extract

Phenolic compounds	Potato peels		t_R
	Concentration (mg/ kg)	Percentage (%)	Min
iso-ferulic	11.2	1.44	6.2
α-Cuumaric	6.04	0.77	7.1
Gallic acid	201.67	26.04	8.4
Catechin	126.7	16.36	9.2
pyro gallol	98.4	12.70	11.2
Chlorogenic acid	15.67	2.02	11.4
Caffeic acid	28.56	3.68	12.3
Protocatechuic acid	23.2	2.99	13.5
Ferulic acid	12.89	1.66	15.2
Catechol	11.7	1.51	17.1
P-Coumaric acid	4.2	0.54	18.3
Coumarin	31.2	4.02	18.6
Vanillic	183.5	23.69	20.2
Caffeine	19.45	2.51	23.4

t_R Min: retention time

Table 3: Total phenolic content and antioxidant activity of processed cheese coated with edible films during storage at 7 °C for 3 months:

Cheese treatment	Storage period	Total Phenolic Content (mg GAE/g)	Antioxidant activity (mMol Trolox/g sample)
Control	Fresh	5.19 ± 1.15	23.75 ± 0.82
	1 month	6.15 ± 0.95	29.25 ± 0.75
	2 months	7.12 ± 0.87	30.95 ± 0.85
	3 months	7.25 ± 0.85	31.67 ± 0.56
WPI-0.5 % MPE	Fresh	72.85 ± 1.95	76.19 ± 1.73
	1 month	73.63 ± 0.98	78.25 ± 1.25
	2 months	74.25 ± 1.19	79.59 ± 1.23
	3 months	74.59 ± 0.85	81.09 ± 1.52
WPI-1.5 % PPE	Fresh	99.75 ± 1.67	199.27 ± 1.25
	1 month	101.05 ± 1.45	203.24 ± 1.23
	2 months	102.19 ± 1.95	205.85 ±1.68
	3 months	102.78 ± 1.89	207.18 ± 1.75

Table 4: Texture profile analysis of processed cheese coated with edible films during storage at 4°C for 3 months

Cheese treatment	Storage period	Hardness (gf)	Springiness (mm)	Cohesiveness	Gumminess (gf)	Chewiness (gf*mm)
Control	Fresh	409.78	0.79	0.40	171.31	134.65
	3 months	1098.55	0.69	0.57	624.69	431.04
WPI-0.5 % MPE	Fresh	397.85	0.64	0.52	206.59	132.46
	3 months	535.76	0.62	0.65	347.18	214.01
WPI-1.5 % PPE	Fresh	402.97	0.70	0.43	184.71	120.66
	3 months	545.35	0.65	0.46	232.90	162.05

gf: gram force, mm: millimetre,

Table 5: Microbiological analysis of processed cheese coated with edible films during storage at 4°C for 3 months (log CFU/ g)

Cheese treatment	Storage period	Total bacterial count	Spore Formers count	Coliform group	Yeast Moulds
Control	Fresh	3.27	ND	ND	ND
	1 month	3.35	ND	ND	ND
	2 months	3.55	1.94	ND	ND
	3 months	3.68	1.96	ND	ND
WPI-0.5 % MPE	Fresh	3.21	ND	ND	ND
	1 month	3.30	ND	ND	ND
	2 months	3.47	ND	ND	ND
	3 months	3.59	1.48	ND	ND
WPI-1.5 % PPE	Fresh	3.15	ND	ND	ND
	1 month	3.29	ND	ND	ND
	2 months	3.45	ND	ND	ND
	3 months	3.55	ND	ND	ND

WPI: whey protein isolate; MPE:mango peel extract; PPE:potato peel extract; ND= not detect; CFU: colony forming unit

القيمة المضافة لمستخلصات قشور المانجو والبطاطس : حالة غشاء بولمرى حيوي صالح للاكل للجبن المطبوخ

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الملخص العربى

قد يؤدي استخدام العبوات النشطة لمنع الكائنات الحية الدقيقة الضارة من النمو على سطح الجبن المعالج إلى زيادة مدة الصلاحية وتحسين جودتها. يهدف هذا البحث إلى تطوير غشاء صالح للأكل من عزل بروتين مصل اللبن (WPI) ومستخلص قشر البطاطس (PPE) ومستخلص قشر المانجو (MPE).تم حفظ الجبن المطبوخ والجبن المطبوخ بدون غشاء في الثلاجة عند 4 درجات مئوية لمدة ثلاثة أشهر. تمت دراسة الفروق في نشاط الفينوليات الكلية ومضادات الأكسدة وقوام الملمس والعدد الميكروبي. وجد أن هناك اختلافات ملحوظة في جميع القيم بين المعالجات لفائدة العينات باستخدام-WPI 1.5٪ PPE .

الكلمات الاسترشادية : فيلم صالح للأكل، قشور البطاطس، قشور المانجو، مضادات الأكسدة، عدد الميكروبات.