"Presence and analysis of different synthetic coating agents on fruits and vegetables and their health effects"

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Abstract:
Fruits and vegetables are highly demanded commodities in the market because of its nutritional value. Every year, nearly 45% of harvested fruits and vegetables are wasted due to improper handling, storage, packaging, and transportation. Hence harvested fruits and vegetables require advanced post harvest processing in order to reduce the qualitative and quantitative losses. The utilization of edible coatings and films as protective packaging techniques for the food industries has turned into a point of incredible fascination on account of their potential for improving the shelf life of fruits and vegetables and maintaining quality imputes. In order to achieve this, one of the post harvest processing techniques is coating;while at the same time coating enhances the appearance of fruits and vegetables by giving it a glossy appealing shine. Morpholine, Polyvinyl acetate, Paraffin wax, Stearic acid with glycerol and Polyethylene wax are some of the synthetic chemicals used as emulsifiers or plasticizers in the preparation of wax coatings for fruits and vegetables to help them last longer and remain fresh even during prolonged transit. They do not cause chronic toxicity. However, they are precursors for potent carcinogen namely nitrosamines for morpholine, polyethylene and polymethylene wax based coatings. Likewise, polyvinyl acetate at high levels causes gastro-intestinal blockages, paraffin wax concludes with vomiting, obstructions in liver; while stearic acid dissolved in glycerol leads to diarrhoea and irritation of gastrointestinal tract. In this systematic study, it has been reviewed to highlight the presence of different chemical agents in the wax formulation and their health impact. Coating fresh fruits and vegetables using synthetic chemicals having moderate to serious adverse effects on human beings.

Key Words: Post harvest process, Coating, Synthetic chemicals, Emulsifier, Carcinogen, edible polymers, health impacts, etc.

Introduction:

Fruits and vegetables have short shelf life due to its perishable nature. Coatings have been used for a long time as a way to preserve fruit. Indeed, the records show that the

Chinese began using coatings in the twelfth century after noticing that it slowed water loss and fermentation; Chinese citrus farmers used to pack oranges and lemons in wooden boxes filled with wax before shipping them. By the fifteenth century, the Japanese used a film made by boiling soymilk to coat their fruits before storing them. In the US, hot melt paraffin waxes were used since the 1930s to cover fruits and carnauba wax and oil in water emulsions since the 1950s to protect fruits and vegetables. Afterward, different edible films were made from various polysaccharides, proteins, and lipids.

Postharvest fruit coating is a common practice used for many years by the industry commercializing different fresh commodities. Compounds such as plasticizers, emulsifiers, antimicrobials, texture enhancers, antioxidants, flavoring agents, and nutrients can be included in coating formulations to improve coating integrity and emulsion stability and enhance functionality [6, 7].

Fruits or vegetables are usually coated by dipping in or spraying with a range of edible materials, so that a semi permeable membrane is formed on the surface for suppressing respiration, controlling moisture loss, and providing other functions (Ukai and others 1976; Thompson 2003b). A variety of edible materials, including lipids, polysaccharides, and proteins, alone or in combinations, have been formulated to produce edible coatings (Ukai and others 1976; Kester and Fennema 1986). Lipid-based coatings made of acetylated monoglycerides (AM), waxes (beeswax, carnauba, candelilla, paraffin, and rice bran), and surfactants were the 1st successful ones on whole fruits and vegetables (Paredes-Lopez and others 1974; Lawrence and Iyengar 1983; Warth 1986), used for reducing surface abrasion during handling and serving as moisture barrier (Hardenburg 1967). Colloidal suspensions of oils or waxes dispersed in water were typical early fruit-coating formulations.

Literature:

A thin film coated on the surface of certain foods, not only looks bright, beautiful, but also can adjust breath and prolong shelf life. These substances used in food appearance, shelf-life, preservation, glazing, to prevent mold erosion and water evaporation are called the ***coating agent*.**

Coating agent can be divided into two types of spray and coating type. Agent is sprayed with Polystyrene, paraffin wax, beeswax, sodium oleate, shellac formulation, ethylene oxide, higher fatty alcohols, fatty acid salts of morpholine, magnesium silicate, vinyl acetate resins and the like shellac, paraffin, liquid paraffin (white oil), morpholine fatty acid salt (fruit wax), pentaerythritol ester of rosin hexyl, octyl phenoxy poly (ethyleneoxy), dimethylpolysiloxane, carnauba wax, stearic acid are known as **Synthetic agents**. It acts as a barrier for moisture and gases during processing, handling and storage. It reduces food deterioration and enhances safety by their activity or by incorporation of antimicrobial compound. Other advantages of using edible coating is to reduce packaging waste, to extend the shelf life of fresh and minimally processed product and protect it from harmful environmental effect by maintaining the transfer of oxygen, carbon dioxide, moisture, aroma and taste compound in a food system.

Coatings block the pores on the produce skin, reducing **fruit** water loss. **Wax** is commonly used in many **fruits** such citrus, tomato, bell pepper, and cucumber to improve **fruit** appearance and reduce transpiration; however, the effect of the **wax** on reducing **fruit** transpiration is limited (about 30% reduction).

- Synthetic coatings should be applied on fruits and vegetables by different methods. These methods are

a) Dipping

b) Brushing

c) Extrusion

d) Spraying

e) Solvent casting

Now days the dipping method is used widely for applying **edible synthetic coatings** on fruits and vegetables, in this method **Fruits and Vegetables** are dipped in coating solution for 5-30 sec. [99]. It is easy to apply on mostly fruits. While Brushing method gives good result, Edible Coatings applied on generally, Beans and highly perishable Fruits and Vegetables such as strawberry, berries. Other three methods spraying, extrusion and solvent castings are also used in food industry. Extrusion method depends on thermoplastic properties of edible coatings; it is best technique for applying of EC for industrial purpose as compared to other methods [99].

Gap in Research:

Every day, people are developing these edible coatings. They want to use environmentally-friendly material rather than synthetic chemicals, which are polluting in nature. The main advantages gained by using edible coatings are:

- Reduction in weight loss and an improvement in fruits' firmness.
- Reduction in respiration rates and ethylene production, which delay senescence.
- Prevention of injuries related to chilling and storage.
- Encapsulation of aroma compounds, antioxidants, and pigments that stop browning reactions.
- Reduction of the use of packaging material.
- Improvement of external appearance by providing an extra shine in the surface of the fruit.

Even though it is possible to develop new waxes from a wide selection of available materials, both synthetic and natural, it is paramount to ensure that the products can fulfill their role; protect food products from deterioration processes, including oxidation, moisture absorption/desorption, chemical reactions, and microbial growth, as well as to improve their physical strength, reduce particle clustering, and possibly improve visual and tactile properties of food product surfaces (Pirozzi et al, 2020).

Edible coatings have some disadvantages [27, 70].

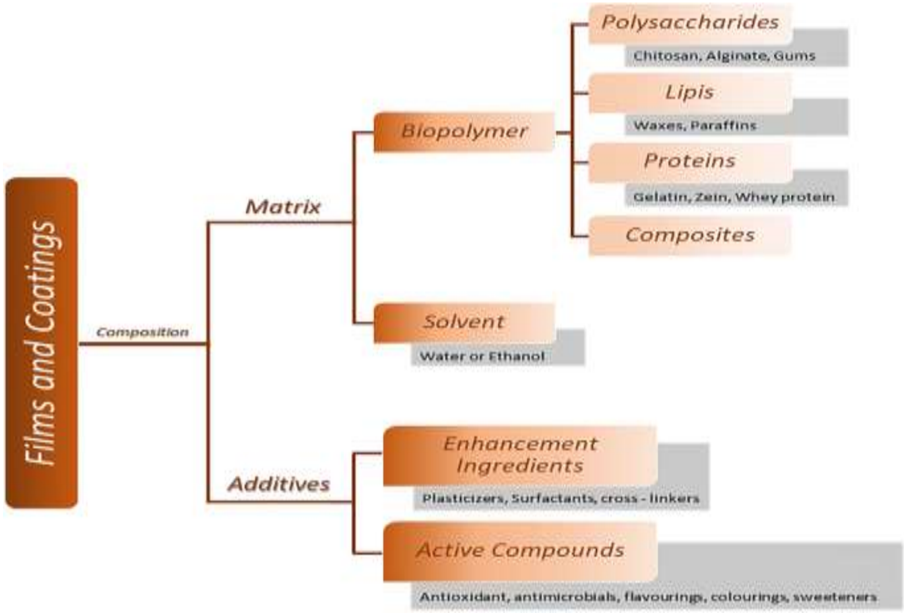
- Thick coating can prohibit O_2 exchange, causes off- flavor development.
- Edible coatings have good gas barrier properties which causes anaerobic respiration due to this normal ripening process is disturbed in fruits and vegetables.
- Some edible coatings are hygroscopic in nature, which helps to increase microbial growth.

For example: →

Modern coatings are made from a mixture of resins, beeswax, sugarcane, carnauba, and other substances, and they accomplish two tasks, preserving the fruit and making it look appealing. According to researchers from McGill University, modern coatings can be made of up to 50 different components, most of which are in the esters chemical category. Among the most commonly used ingredients in current waxes are carnauba wax that comes from the leaves of a Brazilian palm, shellac extracted from the Indian lac bug, and candelia wax that originates from a desert plant. Commonly used synthetic esters are made by mixing sucrose and fatty acids. Polyethylene can also be applied in a fine layer, as an alternative ethylene derived from corn ethanol can be used.

The edible polymers can be comprised in any of the four categories:

(1) Hydrocolloids, (2) polypeptides, (3) lipids, (4) synthetic and composite edible polymers.



❖ **Edible Polymers for coating Fresh Fruits/veggies with use of synthetic polymers as linking or binding agents:**

➢ **Following table shows edible polymers/natural hydrocolloids/biopolymers or composite polymers that are used in general for coating post-harvested fresh fruits and vegetables having one of the ingredients as synthetic fiber in the form of solvent or linking agents or enhancement ingredients or active compounds etc…**

Sr. No.	**Fruits**	**Synthetic linking with Coating Agent/agents**	**Applied method for coating agents**	**Health impact**	**Analysis method**
1.	Cherry	1.Sodium Caseinate 2. Chitosan	Dipping in a Chitosan coating solution (Chitosan Ascorbate/ O-Sulfated N-Acetylchitosan/ N-Carboxybutyl Chitosane)	Chitosan might cause mild stomach upset, constipation, or gas and can cause irritation.	Acid hydrolysis, Glucosamine derivatization, and high performance liquid (HPLC) chromatograp hy.
2.	Kiwi fruit	Chitosan hydrochloride	hypobaric treatment, gas fumigation and modified atmosphere packaging	**Chitosan** ca n cause irritation, mild stomach upset, constipation, or gas; when	Acid hydrolysis, Glucosamine derivatization, and high performance liquid (HPLC) chromatograp

				applied to the skin	hy.
3.	Apples, Red grapes	Chitosan-methyl cellulose	Dipping	• irritable bowel syndrome, severe stomach cramps, rectal bleeding; or • No bowel movement within 3 days after using **methyl cellulose**.	FT-IR spectroscopy
4	Peach	Calcium caseinate	Dipping/spreading	Stomach pain and bloating. Alkalis may curb and damage the nutrient-absorbing capacity of your digestive system. Consumption of this protein may lead to headaches, chest pain, nausea, weakness, heart palpitations, etc.	Sedimentation techniques/ultracentrifugation/indirect analysis.
5	Peach/ blueberry/ strawberry	Petroleum Jelly/ raisin/ beewax/	spraying	Wax coated apples can lead to	High temperature gas

		shellac/ carnauba wax		health hazards like respiratory issues, ulcers or even infections.	chromatography
6	Sapota	Sodium Caseinate	Dipping/spreading	It could trigger an allergic reaction. The exact allergic response varies between people but may include symptoms like diarrhea, vomiting, pale skin, and weight loss	Sedimentation techniques/ultracentrifugation/indirect analysis.
7	Strawberry	Sodium alginate-Calcium chloride	Dipping	Systolic **blood pressure** increased. They are considered as potential sensitizers to the skin and the respiratory tract.	DLS (Dynamic light scattering)

❖ SYNTHETIC COATING AGENTS:

The following table shows different synthetic coating agents that are used to coat perishable fruits and vegetables, as well as their applied method on fresh fruits and vegetables; and health impacts on human beings; analysis of these coating agents from the sample.

Sr. No.	Synthetic coating agents	Vegetables	Application methods	Health Impacts	Analysis methods
1	**Paraffin Wax**	citrus, tomato, bell pepper, and turnip, cucumber, sweet potatoes, egg plant	Blended paraffin waxes applied as oil or pastes are often used on vegetables.	**Eating** a lot **of paraffin** can lead to intestinal obstruction, which can cause abdominal pain, nausea, vomiting, and possible constipation. dye may develop tongue and throat swelling, wheezing, and trouble breathing.	High temperature gas chromatography
2.	**Poly vinyl polyacetate**	Tomatoes/ capsicum- bell paper, citrus fruits, apples	A synthetic resin prepared by the polymerization of vinyl **acetate**. Dipping or rolling the fruits and vegetables	High levels can cause fatigue, irritability, disturbed sleep, dizziness and lightheadedness. ***Vinyl Acetate** may affect the heart, nervous system and liver. May be harmful if swallowed. May cause gastrointestinal blockage.	-High-Performance Liquid Chromatography–Evaporative Light Scattering Detector and Pyrolyzer–Gas Chromatography–Mass Spectrometry
3	**Diethanolamine/t**	Apples,	Hot air	Diethanolamine	Ion Exchange

	riethylamine/ morpholine (Glazing agents)	Avocados, Bell peppers, Cantaloupes, Cucumbers, Eggplants, Grapefruits, Lemons, Melons, Oranges, Peaches, Pineapples, Pears, Pumpkins, Sweet potatoes, Tomatoes, Turnips, Almonds	treatment and liquid wax spray.	may affect the liver and kidneys. All three compounds may potentially transform to their toxicologically critical N-nitroso-derivatives leads to carcinogen.	Chromatography, Gas chromatography
4	**Stearic acid +glycerol** (a glazing agent)	Papaya, Tomato, Guava, Nuts and Seeds	Dipping Glycerol as plasticizer.	May cause gastrointestinal irritation with nausea, vomiting and diarrhea. The toxicological properties of this substance have not been fully investigated. Aspiration of material into the lungs may cause chemical pneumonitis, which may be fatal. May be harmful if swallowed.	FTIR analysis
5	**Polymethylene wax**	Citrus, apples,	Spraying	A genotoxin carcinogen and	X-ray diffraction

		mature green tomatoes, cucumbers and other vegetables such as asparagus, carrots, radish		allergen causes kidney cancer.	(XRD)
6	**Polysterene (Polysterene sulfonates)**	Cucumbers, Mangoes.	Spreading	Styrene primarily exhibits its toxicity to humans as a neurotoxin by attacking the central and peripheral nervous systems. Chronic functional impairment of the nervous system.	Dispersion and polar component spreading techniques
7	**Polyethylene**	Oranges, sweet lime, Peach, Sapodilla (Chickoo)	Spreading, film formation.	Cancer development, skin problems, menstrual and pregnancy issues,	Dispersion and polar component spreading techniques

Analytical Data of Major Synthetic agents:

Analytical data on synthetic and glazing agents in India refers to scientific, laboratory-tested information quantifying chemicals (like morpholine, paraffin wax, or polyvinyl acetate) applied post-harvest to fruits and vegetables to enhance shine, prevent moisture loss, and extend shelf life. This data identifies, measures, and monitors residues for safety compliance.

Sr. No.	Synthetic agents	Analysis method with principle	Reference
1.	Polysterene (Polysterene sulfonates)	Dispersion and polar component spreading techniques : The assembly of sodium polystyrene sulfonate (Na+ -PSS) at the surface of single-walled carbon nanotubes (SWNTs) in pH 3 aqueous solution is described. Rather than forming linear or sheet-like chain morphologies over SWNT surfaces, Na+ -PSS adopts a spherically collapsed conformation believed to be the result of cation (either Na+ or H+) condensation onto the ionized polymer chain. It is well reported that cations (and also anions) adsorb preferentially onto single-walled and multi-walled carbon nanotube surfaces leading to an increased ion concentration in the near surface regions relative to the bulk solution. It is believed that the ultrasonic agitation drives cations into the small spaces between SWNT bundles and coulombic potential attracts the PSS to those regions.	Ariga, K.; Hill, J.P.; Lee, M.V.; Vinu, A.; Charvet, R.; Acharya, S. Challenges and Breakthroughs in Recent Research on Self-Assembly. Sci. Technol. Adv. Mater. 2008, 9, 014109
2.	Polymethylene wax	X-ray diffraction (XRD) XRD patterns of CA (a), paraffin wax (b), and CA-wax composite.(polymethylene wax) X-ray diffraction (XRD) patterns of the samples were performed on a powder	https://www.researchgate.net/figure/RD-patterns-of-CA-a-paraffin-wax-b-and-CA-wax-composite_fig12_262338218

		diffractometer (PANalytical, X'Pert3) with Cu Ka radiation (l ¼ 1.54056 A). ° Porosimetry measurements were carried out using a highresolution 3Flex Micromeritics adsorption instrument. The 3Flex Micromeritics was equipped with a high-vacuum system, and three 0.1 Torr pressure transducers. The densities of the CAs were calculated by measuring the weight and volume of the samples. The electrical conductivity of the CAs was measured with a two-probe method using an ADM-930 Digital Multimeter (0.1 U to 40 MU).	**V. V. Tyagi, N. L. Panwar, N. A. Rahim and R. Kothari, Renewable Sustainable Energy Rev., 2012, 16, 2289–2303.**
3.	**Stearic acid +glycerol (a glazing agent)**	**To develop solid lipid nanoparticles (SLNs) with stable lipid matrix structures for the delivery of bioactive compounds, a new class of SLNs was studied using propylene glycol monopalmitate (PGMP) and glyceryl monostearate (GMS) mixtures and carvacrol as a model lipophilic antimicrobial. Stable SLNs were fabricated at PGMP:GMS mass ratios of 2:1**	**https://www.researchgate.net/figure/Fluorescence-spectra-of-Car-SLNs-with-a-carvacrol-loading-at-30-mass-of-lipids-and-a_fig3_335176509 Kumar, S.; Randhawa, J.K. High melting lipid based approach for drug delivery: Solid lipid nanoparticles. Mater. Sci. Eng. C 2013, 33, 1842–1852. [CrossRef] [PubMed] Li, Q.; Cai, T.; Huang, Y.; Xia, X.; Cole, S.P.C.; Cai, Y. A Review**

			of the Structure, Preparation, and Application of NLCs, PNPs, and PLNs. Nanomaterials 2017, 7, 122. [CrossRef] [PubMed]
4.	**Poly vinyl polyacetate**	**HPLC method for quantitative analysis of PVAc, the linearity of the calibration curve was determined using the PVAc standards with a concentration range of 200–1000 µg/mL. The calibration curve showed excellent linearity (R2 > 0.999). In addition, the LOD and LOQ were calculated using statistical methods and were found to be 22.2 µg/mL and 67.3 µg/mL, respectively (Table 1) [14,15].**	**KoSFoST (Korean Society of Food Science and Technology). Polyvinyl Acetate, Food Science and Technology Dictionary. Available online: https://terms.naver.com/entry.nhn?docId=296974&cid=602-62&categoryId=60262 (accessed on 4 August 2019)**
5.	**Diethanolamine / Triethylamine/ Morpholine**	**The derivative was extracted with dichloromethane and determined by gas chromatography-mass spectrometry. The linearity range of morpholine was 10–500 g·L^{-1} with good correlation, and limits of detection (LOD) and limits of quantification (LOQ) were 7.3 g·L^{-1} and 24.4 g·L^{-1}, respectively. Low, medium, and high concentrations of morpholine were added in apple juices and ibuprofen samples to evaluate standard recovery rate and relative standard deviation. The spiked recovery rate ranged**	**D. Velasco, C. Elvira, and J. S. Román, "New stimuli-responsive polymers derived from morpholine and pyrrolidine," *Journal of Materials Science: Materials in Medicine*, vol. 19, no. 4, pp. 1453–1458, 2008. View at: Publisher Site | Google Scholar**

		from 94.3% to 109.0%, and the intraday repeatability and interday reproducibility were 2.0%–4.4% and 3.3%–7.0%, respectively.	
6.	**Polyethylene**	**Microplastics analysis and counting by Scanning Electron Microscopy (Cambridge Instruments Mod. Stereoscan 360) combined with an X Energy Dispersion Detector (SEM-EDX) (Diffractometer Rigaku Miniflex) using Inca software The criterion of calculation was applied to an overall reading area within 1 mm^2 of stub, examining 228 fields at 1500 K magnification.**	**1.Bosker et al., 2019 T. Bosker, L.J. Bouwman, N.R. Brun, P. Behrens, M. G. Vijver Microplastics accumulate on pores in seed capsule and delay germination and root growth of the terrestrial vascular plant Lepidium sativum 2. Chemosphere, 226 (2019), pp. 774-781 Procedural Manual, 16th Edition, Codex Alimentarius Commission Joint FAO/WHO Food Standards Programme, FAO, Rome (2006) 2006**

❖ Synthetic Glazing agents & Animal study data:

A food additive, which when applied to the external surface of a food, imparts a shiny appearance or provides a protective coating. Glazing agents provide a shiny appearance or protective coating to foods.

Types of glazing agent:

i. Coating agent
ii. Film forming agent
iii. Glazing agent
iv. Polishing agent
v. Sealing agent
vi. Surface-finishing agent.

Manufacturers are using glazing agents in confectionery segments mainly cakes, pastries, chocolates, and draggers in order to enhance their appearance and extend their product life cycle. These agents are expected to expand the demand in functional food and bakery application segment.

The bakery was the second largest application that accounted for 21.8% of the revenue share in 2015. The segment is expected to gain momentum owing to changing lifestyle and increase in consumption of packed food items. Food-glazing agents are exclusively used in bakery products to provide perfect texture, shiny surfaces, customized designs, and enhanced taste.

Fruits & vegetables application sector is on the medium growth rate-medium market penetration side. Food glazing agents are expected to explore opportunities in the segment as vendors are using these items to add a shiny look to fruits and vegetables sold in their stores. In addition, these agents help in maintaining the freshness of the product.

Here are some animals data discussed in relation to different glazing agents used on fruits and vegetables.

A. Hydrogenated poly-1-decene:

❖ **Short-term studies of toxicity of hydrogenated poly-1-decene on Rats:**

A 28-day range-finding study was conducted to establish an appropriate range of doses for a 90-day study in rats. Diets containing 0, 8000, 20 000, or 50 000 mg/kg (0, 0.8, 2, and 5%)hydrogenated poly-1-decene (32% trimer, 47% tetramer, 17% pentamer, 4% hexamer) were fed to groups of five male and five female Fischer 344 rats for 29 days, resulting in intakes of test material equal to 0,1000, 2500, and 6200 mg/kg bw per day for males and 0, 1000, 2500, and 6800 mg/kg bw per day for females, respectively. Five animals of each sex were housed per cage, observed twice daily for clinical signs, and palpated weekly; body weights were measured twice weekly, and mean weekly food consumption was measured for each cage. Gross autopsy at sacrifice included an extensive inventory of the weights of the kidney, liver, heart, spleen, and mandibular and mesenteric lymph nodes from all animals; the liver and mesenteric lymph nodes of all controls and all animals at the high dose were examined histologically but with no special staining techniques or use of polarized light to allow visualization of accumulated material.

Table 1. Acute toxicity of hydrogenated poly-1-decene (carbon chains)

Species	Route	Chain length	LD_{50} (mg/kg bw)
Rat	Oral	C10-11	> 10 000
Rat	Oral	C11-13	> 10 000
Rat	Oral	C9-11	> 34 600
Rat	Oral	C10-13	> 34 600
Rat	Oral	C9-12	> 25 000
Rabbit	Dermal	C10-11	> 3 200
Rabbit	Dermal	C11-13	> 3 200
Rabbit	Dermal	C9-11	15 400
Rabbit	Dermal	C10-13	15 000
Rabbit	Dermal	C9-12	> 5 000

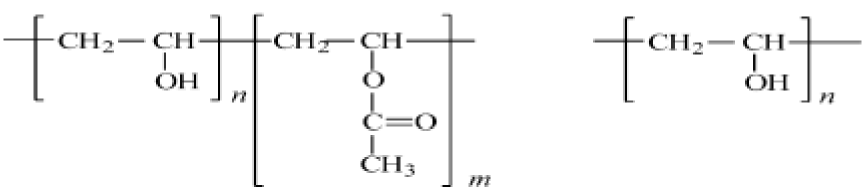
From Mullion et al. (1990)

Observations:- The oral and dermal acute toxicities of MCP 1602 and 1-decene, homopolymer, hydrogenated were low in rats and rabbits, respectively. An acute inhalation toxicity study was not presented for MCP 1602 but the LC50 for 1-decene, homopolymer, hydrogenated as an aerosol was greater than 2.5 mg/L which suggests that inhalation toxicity may also be low. As the notified substance (an oil) is non-volatile FULL PUBLIC REPORT 15 and has a high boiling point it is not expected to be inhaled. Both analogues were slight skin irritants in rabbits. Ocular exposure to MCP 1602 caused slight to moderate irritation in rabbits; exposure to 1-decene, homopolymer, hydrogenated caused slight irritation. Dermal exposure to either analogue did not result in skin sensitisation in guinea pigs. Rats exposed dermally to repeated doses of 2 000 mg/kg had increased incidences of hyperplasia of the sebaceous glands, hyperplasia/ hyperkeratosis of the epidermis and dermal inflammation. In general, these symptoms subsided after two weeks. Males from this dose group had decreased bodyweight gain and altered serum chemistry parameters. Rats exposed at up to 20 000 ppm in a 90-day feeding study to 1-decene, homopolymer, hydrogenated did not exhibit any clinical signs of systemic toxicity. Marginal effects on clinical chemistry parameters (glucose and ALT in males; sodium, phosphorus and calcium in females) were observed.

B. **Polyvinyl Acetate:**

Polyvinyl alcohols (PVA) (CAS no. 9002-89-5) are synthetic polymers used in a wide range of industrial, commercial, medical andfood applications. The purpose of this review,this critical evaluation of the available information on PVA, is to support the safety of PVA as a coating agent for pharmaceutical and dietary supplement products. All the available information on PVA gleaned from a comprehensive search of the scientific literature was critically evaluated. Orally administered PVA is relatively harmless. The safety of PVA is basedon the following: (1) the acute oral toxicity of PVA is very low, with LD50s in the range of 15–20 g/kg; (2) orally administered PVA is very poorly absorbed from the gastrointestinal tract; (3) PVA does not accumulate in the body when administered orally; (4) PVA is not mutagenic or clastogenic; and (5) NOAELs of orally administered PVA in male and female rats were 5000 mg/kg body weight/day in the 90-day dietary study and 5000 mg/kg body weight/day in the two-generation reproduction study, which was the highest dose tested. A critical evaluation of the existing information on PVA supports its safety for use as a coating agent for pharmaceutical and dietary supplement products.

(A) (B)



(A) partially hydrolyzed; (B) fully hydrolyzed.)

Acute oral LD_{50} of PVA

Species	LD_{50} (mg/kg)	Reference
Rat	>20,000*	Zaitsev et al., 1986
Rat	21,500	Hazleton, (CIR), 1959; Clydesdale, 1997a
Mouse	147,000	Zaitsev et al., 1986
Mouse	>4000*	Burford and Chappel, 1968
Dog	20,000	Hazleton, (CIR), 1959; Clydesdale, 1997a

* Highest dose administered.

Repeated oral dose studies with PVA

Mouse	100–1500 mg/kg	One mouse in 1500 mg/kg dose group died. No other mortalities or abnormalities	JSCI, 1968
Mouse	500 mg/kg/day for 20 days	No mortalities or abnormalities	JSCI, 1968
Mouse	100, 500, 1000 mg/kg/day for 26 weeks	No mortalities or abnormalities	JSCI, 1968
Rat	2200–4400 mg/kg for 2–4 weeks	No gross changes. Hepatic hydropic changes eosinophilic infiltrations of gastric submucosa and myeloid marrow.	Hueper, 1939
Rat	0.5% PVA for 8 weeks (~500 mg/kg/day)	Two mortalities prior to end of test period. Five surviving rats showed inflammatory lesions of the lungs.	DuPont Chemical, 1936
Cat	0.5, 1.0 g/kg/day for 8 weeks	No abnormalities during test period but autopsy revealed vacuolar degeneration in liver and renal tubular epithelium. (Only two cats used)	DuPont Chemical, 1936
Dog	? mg/kg for 20 days[a]	HNEL (NOAEL)=10,000 mg/kg. No effects reported.	Clydesdale, 1997b
Dog	? mg/kg for 180 days[a]	LEL (LOAEL)=800 mg/kg. Diarrhea, emesis	Clydesdale, 1997c

[a]Details not provided.

The **acute** oral **toxicity** is low in **rats** and **mice** (LD50 > 8000 mg/kg body weight), although it appears to be more **toxic** in the dog.

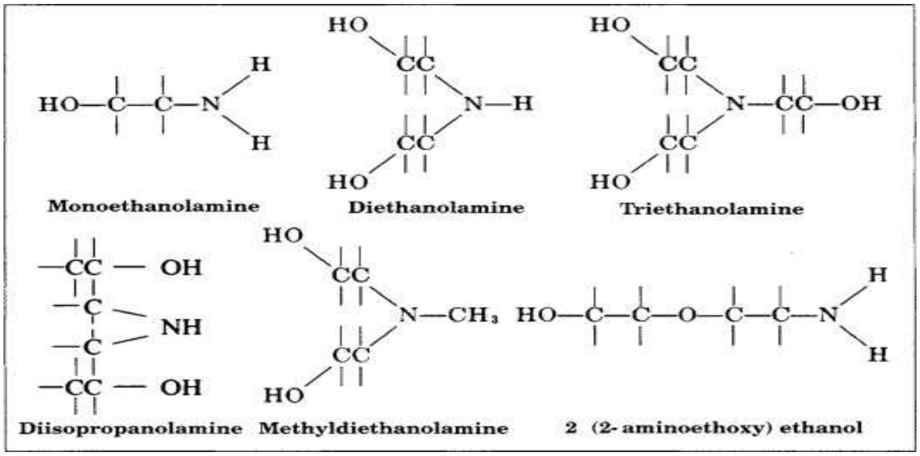
There are no reported chronic toxicity or carcinogenicity studies of orally administered PVA.

c. Morpholine:

Pilot studies conducted by us also indicate presence of morpholine in some fruits and vegetables purchased from local super market in Hyderabad, India. There are different analytical methods of estimation of morpholine [20, 21, 22, 23]. In the present study, the average concentration (in duplicate) of morpholine was estimated in these fruits and vegetables; 0.171 mg/kg of tomato, 1.831 mg/kg of carrot and 0.342 mg/kg of capsicum as per spectrophotometric method [24, 25] as shown in figure 3. Although the amounts of morpholine in these fruits and vegetables are below the acceptable range of 0.48 mg/kg body weight/day [26], it does not rule out the risk of formation of NMOR if consumed directly and continuously. Considering the fact that formation of NMOR may lead to cancer over a period of time it is certainly not a situation to be ignored.

Sr. No.	Animal Model	Route	Dose	Effects Observed	References
1.	Rat	Inhalation up to 42 hr	1200 or 1800 ppm	Liver and kidney necrosis	[28]
2.	Guinea pigs	Oral, 30 days	0.5 g/kg bw	Necrosis of liver and renal tubules	[27]
3.	Guinea-pigs and rabbit	Dermal application	0.9 g/kg bw	Necrosis of liver & tubules of the kidney	[27]
4.	Guinea-pigs and rats	Single oral administration	0.1-10g/kg bw	Hemorrhages in stomach and small intestine	[27]

D. Diethanolamine:



Diethanolamine was tested for carcinogenicity by dermal application in one study in mice and in one study in rats. In the mouse study, there was a treatment-related increase in the incidences of both hepatocellular adenomas and carcinomas in both males and females, as well as an increase in the incidence of hepatoblastomas in males. There was also a marginal increase of renal tubule adenomas in males. In rats, no treatment-related increase in the incidence of tumours was seen in either males or females. In a Tg.AC transgenic mouse model using similar doses to the first mouse study, there was no treatment-related increase in the incidence of skin tumours after skin application.
Animal studies indicate that exposure to diethanolamine by intravenous injections can cause increasedblood pressure, pupillary dilatation, and salivation. At very high doses in animals, sedation, and coma may result.
Acute animal studies have shown that dermal exposure to diethanolamine may burn skin, and eye contact with the chemical may impair vision. Acute animal tests in rats have shown diethanolamine to have moderate acute toxicity from oral exposure.
Animal studies have reported effects on the liver, kidney, blood, and CNS from chronic oral exposure to diethanolamine.
Skin lesions were observed in mice following daily topical administration of diethanolamine. EPA has not established a Reference Concentration (RfC) or a Reference Dose (RfD) for diethanolamine. The California Environmental Protection Agency (CalEPA) has established a chronic reference exposure level of 0.02 milligrams per cubic meter (mg/m) for diethanolamine based on effects on the blood in rats. The CalEPA reference exposure level is a concentration at or below which adverse health effects are not likely to occur. It is not a direct estimator of risk but rather a reference point to gauge the potential effects. At lifetime exposures increasingly greater than the reference exposure level, the potential for adverse health effects increases.

Acceptable Daily Intake (ADI) but accumulation of NMOR by daily intake of coated fruits/vegetables is a serious threat to health and in the long term, impacting the quality of life. In order to overcome this problem, we strongly suggest the mantra of 3W (Wipe, Wash and Soak in Water for a longer time) and also caution that consumers should not fall prey to bright and dark color of fruits and vegetables.

Conclusion:

Plasticizers are mixed in solution of edible coating for increase mechanical property. These contain low molecular weight, it is mixed with protein coating material for enhance and change its structural ability [45, 91]. Water is also natural and effective plasticizer. The most common plasticizers added in coatings are Glycerol, fatty acids, Sorbitol, propylene glycol, sucrose polyethylene glycol and monoglycerides [45, 44, 91]. Edible coatings are used from many years for storage of Fruits and Vegetables in food industry. Different coating materials are used for coating such as hydrocolloids, waxes, protein. Researchers have produced new edible coatings; it is safe and environment friendly and safely eaten with Fruits and Vegetables. According to this review, Synthetic Coatings extends shelf life, reduce water and moisture loss, delayed ripening process and also prevent microbial growth specifically in fresh fruits and vegetables; but harmful to human beings in different ways, as well as pollutes environment.

The health risks associated with regular consumption of artificially wax coated fruits include,

- Risk of Cancer. Morpholine/ Diethanolamine/ Triethylamine are used commonly as solvents and emulsifiers in making the wax coatings for fruits and vegetables. ...
- Risk of Liver and Kidney Damage. ...
- Allergies.

In edible coating, recently a new concept has been introduced and it is herbal edible coating. It gives better results and health benefits. Herbal edible coated Fruits and Vegetables contained nutrients and act as medicines. Edible coating is biodegradable. It's eco-friendly. It's toxically safe. It's regarded as a GRS, Generally Regarded as Safe, from the FAO, the FDA and several other food legislations. It also reduces water losses. It delays ripening. It enhances aesthetic and sensory attributes. It slows down gas exchange by providing a semi-permeable barrier. It prevents mechanical injury. It also preserves the vital chemicals and anti-oxidants in the fruits.

Future Recommendations: (Future study needs)

The numbers of flexible films available for packaging have proliferated in recent years. Among the substitutes recently considered to replace the application of synthetic (petroleum-derived) polymers against postharvest diseases and shelf life extension, gums and their derivatives have been considered as promising biocontrol products. Polysaccharide gum coatings provide a semi permeable barrier on the surface of produce to reduce respiration rate, weight loss and maintain the nutritional value.

The major desirable characteristics of films considered while selecting for MAP (Modified Atmospheric Packaging) of fresh fruits and vegetables are listed as follows (Kader et al., 1989; Mangaraj et al., 2009): 1) required permeability for the different gases, 2) good transparency and gloss, 3) the physical properties of machinability, high tear strength, elongation, clarity and durability, 4) integrity of closure (heat sealing), fogging of the film as a result of product respiration, 5) low temperature heat-sealability, 6) non toxic, nonreactant with produce and chemically inert, 7) good thermal and ozone resistant, 8) water vapour transmission rate, 9) resistance to chemical degradation, 10) printability, 11) commercial suitability with economic feasibility, and 12) ease of handling.

Herbal edible coating is a new technique for food industry. It is made from herbs or combination of other edible coatings and herbs, most common herbs used in Edible coatings are such as Aloe vera gel, Neem, Lemon grass, Rosemary, Tulsi and Turmeric. Herbs have antimicrobial properties, it consists vitamins, antioxidants and essential minerals [20]. As recently Aloe vera gel is widely used in coating on Fruits and Vegetables, because of its antimicrobial property, it also reduces loss of moisture and water. Ginger International Journal of Scientific Research and Modern Education (IJSRME) ISSN (Online): 2455 – 5630 (www.rdmodernresearch.com) Volume I, Issue I, 2016 198 essential oil, clove bud oil, turmeric neem extract, mint oil, other essential oil and extracts are also used in edible coating of Fruits and Vegetables. Herbs are natural source of vitamins, minerals, antioxidants, beneficial for health act as a nutraceutical and medicines [15, 54, 63].

A continued development of functionality and processing was needed for a commercial breakthrough. In a scenario where petroleum-based polymers were replaced by biopolymers, edible biopolymers from food crops would primarily be used in food applications, whereas other biopolymers could well cover the demand for commodity polymers. Protein based nanoparticles have the advantage of greater stability during storage and were easy to scale up as compared to other delivery systems [94].

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