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Analysis of Research Works on Coating and Packaging in Citrus

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Introduction

Citrus fruit is one of the major horticultural crops grown worldwide, and they are the most traded horticultural commodity in the world. Brazil, the Mediterranean countries, China, and the United States account for about two-thirds of the total citrus production. Oranges occupy the major portion of world citrus production followed by mandarins. About one-third of the citrus fruits produced globally are used for processing. Citrus fruits constitute a crucial source of vitamin C, folic acid, and carotenoid content. Besides the essential vitamins and minerals, limonoids and flavonoids have been associated with many disease-preventive properties such as anticancer, lipid-lowering, and cardiovascular-protective activities. Citrus fruits provide a wide range of photochemical that are beneficial for human nutrition and exherts antioxidant properties. Major postharvest losses of citrus fruit are caused by weight loss, fungal diseases, physiological disorders, and quarantine pests. The development of novel natural edible films and coatings with antimicrobial properties is a technological challenge for the industry and a very active research field worldwide (Palou et al.2015). Citrus fruits are the first fruit crop in international trade in terms of value. Several species and their hybrids, considered under the more general term citrus, are of great commercial interest: eg., lemons (*Citrus lemon* (L.) Burn), limes (*Citrus aurantifolia* (Christm.) Swing), sweet oranges (*Citrus sinensis* (L.) Osb.), mandarins(*Citrus reticulata* Blanco), satsumas (*Citrus unshiu* (Mak.) Marc), clementines (*Citrus clementina* Hort.), grape fruits (*Citrus paradisi*Macf.), and pummelos (*Citrus maxima* (L.) Osb) (UNECE, 2010). According to the FAO (FAOSTAT, 2012), there are 140 citrus-producing countries. Around 70% of the world's total marketable citrus are grown in the Northern Hemisphere, in particular Brazil, countries around the Mediterranean, and the United States. There are two clearly differentiated markets in the citrus sector: the fresh citrus fruits market, with a predominance of oranges and mandarins, and the processed citrus products market, mainly for orange

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and grapefruit juice. Brazil is the highest citrus production in the world and India ranks 3rd. State wise Andhra Pradesh (1.91mmt), Maharashtra(1.76mmt), Madhya Pradesh(1.24mmt)(2019). In Nagaland, about 18.1% is citrus production. The recommended varieties are Khasi mandarin, Eureka and assam Lemon. The region has a suitable climate, grown in almost all districts.

Post Harvest Handling in Citrus

- **Cleaning and sorting** – fresh from the field after the fruits are harvested, these are kept at room temperature and the fruits are cleaned manually of any debris or unwanted leaves attached.
- **Washing-** It is said to remove soil and dirt particles, disease spores and field spraysurface residues. Washing disturbs the natural wax layer of fruit however, water spraysat high pressure are sometimes used to clean pests (such as red scale) and diseases (such as sooty mould) from fruit. Recirculated water in particular is more likely to become contaminated with disease spores and should be treated with a sanitiser.
- **Grading**- Fruit are graded on the packing line to remove blemished or damaged fruit and to grade fruit according to market specifications. Any fruit that will not be packed should be sorted and removed from the line prior to waxing. Fruit is normally sized mechanically (using belts or rollers), electronically or by weight.
- **Waxing** - Waxing is used to improve the appearance of fruit, protect the fruit surface, slow down the development of some rind disorders and most importantly reduce water loss from the fruit. Waxes used on fruit should be suitable for human consumption. It is done prior to packaging. There are several different wax formulations commercially: Carnauba (a natural wax extracted from palm leaves); shellac based waxes; polyethylene based waxes and resin based waxes.
- **Packaging** - Fruit can be packed either as "loose fill " or pattern packed depending on the market being targeted. Pattern packing can be either "open pocket" or "closed pocket". Each package of fruit should be graded to have a similar size, shape, colour and condition (blemish level).
- **Storage**- Citrus are non-climacteric fruit and have low respiration rates. They are therefore able to be stored for long periods of time. Storage is a very essential

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component. It has the possibility of achieving higher market prices when local fruit is in short supply. With an ambient temperature and humidity citrus fruits can be successfully stored for long duration with any loss in flavour and quality. A lot of fruits have shown successful outcomes while stored in Modified Atmospheric or Controlled Atmosphere conditions.

- **Transportation -** The packed and stored fruits are then ready for the market when the supply is in demand. Transport can be through trucks, rail, tempos, air or by water ways depending the distance of the market.

Post harvest losses

The degradation in both quantity and quality of a food production from harvest to consumption. Quality losses include those that affect the nutrient/caloric composition, the acceptability, and the edibility of a given product while quantity losses refer to those, in the loss of the amount of a product. Loss of quantity is more common in developing countries Kitinoja and Gorny, 2010.

1. Physical and environmental losses

- Excess or insufficient heat, gases, humidity, chilling injuries.

2. Mechanical losses

- During loading/unloading
- Dropping of the product on hard surfaces
- Sudden jerks during transportation
- Puncturing the fruits
- Over packing
- Weak crates

3. Biological and microbiological losses

- Caused due to infestation by rodents, birds, bacteria, molds etc**.**

4. Biochemical and physiological losses

- The undesirable reactions between chemical compounds, includes the contamination with certain pesticides.

Coating and packaging in reducing the post harvest losses:

- Reducing permeability to water loss

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- Reducing permeability to respiration
- Creation of a modified atmosphere for coated fresh produce and effect on ripening
- Checks weight loss and surface desiccation
- Maintaining original structural integrity and quality
- Replacing/recovering of the surface natural wax lost during cleaning and sanitation after harvest.
- Reducing decay and delays scenescence.
- Maintains freshness of the product for a longer period.
- It enhances the marketability.
- Easy to handle and transport the packaged products.
- Protects the product from pests and many other diseases.

Research Findings

Coatings in citrus

Kanetis *et al.*,(2007) – A fungicidal coating trial(1,200 mg/liter for azoxystrobin and fludioxonil, 1,000 mg/liter for imazalil and pyrimethanil) was carried out in managing green mold of lemon fruit. Fruits were wound-inoculated with conidia of Penicillium digitatum (20 µl of 10 6 conidia/ml) of an imazalil/thiabendazole-sensitive isolate and treated after 13 to 15 h with : A, a diluted storage fruit coating; B, a packing fruit coating; or C, water with applications followed by packing fruit coating treatments. The incidence of fruit decay was evaluated after 6 to 7 days of incubation at 20°C. Among the fungicides, Azoxystrobin and Fludioxonil applied in water or storage fruit coating, respectively, provided the best anti-sporulation activity. Storage fruit coating improved the activity of both fungicides. Pyrimethanil was the least effective fungicide in suppressing sporulation of the pathogen on decaying fruit. Overall, among the mixtures, azoxystrobin-fludioxonil and TBZ-fludioxonil had high anti-sporulation activity in aqueous and storage fruit coating applications.

Arnon *et al.*,(2014)- A study carried out on the efficacy of a newly developed polysaccharide-based edible bilayer coating comprising carboxymethylcellulose (CMC) and chitosan in preserving postharvest quality in 'Or' and 'Mor' mandarins, 'Navel' oranges, and 'Star Ruby' grapefruit after simulated storage and marketing. In allcitrus species, it was found that the CMC/chitosan bilayer coating was equally effective as the commercial polyethylene wax in enhancing fruit gloss.

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Furthermore, the CMC/chitosan bilayer coating slightly increased fruit firmness, especially of oranges and grapefruit, but was mostly not effective in preventing post-storage weight loss. Both the CMC/chitosan bilayer coating and the commercial wax had no significant effects on juice, TSS and acidity levels. Application of the commercial wax, and the CMC/chitosan bilayer coating, resulted in a gradual decrease in flavor acceptability of 'Or' and 'Mor' mandarins because of increased perception of off-flavors.CMC/chitosan bilayer edible coating sufficiently enhanced fruit gloss, but was not effective in preventing postharvest weight loss. Flavor quality was slightly impaired in mandarins but not in oranges and grapefruit.

Arnon *et al.*, (2015) conducted a study on Biodegradable coatings for citrus fruits that can replace the currently used polyethylene-based waxes. Methylcellulose (MC), hydroxypropyl methylcellulose (HPMC), carboxymethyl cellulose (CMC) and chitosan (CH) coatings were examined on the most sensitive citrus fruit model: mandarins. Among the examined polysaccharides, CMC provided mandarins with the best firmness, lowest weight loss and satisfying gloss, while not affecting natural flavour and the respiration process. To enhance coating performance, glycerol, oleic acid and stearic acid were added; however, mandarin quality generally deteriorated with these additives. Then, a layer-by-layer (LBL) approach was applied. LbL coatings, based on a combination of two polysaccharides, CMC as an internal layer and chitosan as an external layer, gave the best performance. Different concentrations of chitosan were examined. The LbL coatings notably improved all quantified parameters of fruit quality, proving that polysaccharide based edible coating may offer an alternative to synthetic waxes

Khorram *et al.,(*2017)-Effect of different edible coatings on quality of 'Kinnow' mandarin was studied. Different coating materials: 1% carboxymethyl cellulose (CMC), 5% gum Arabic (GA), 1% Persian gum (PG), 0.5% beeswax (BW), 1% carnauba wax (CA) (w/v) and commercial wax were applied and the results were compared with those of uncoated (control) fruit. Fruits were stored for 3 weeks at 5 °C and 90–95% RH. The fruit firmness, weight loss, total soluble solids (TSS), titratable acidity (TA), pH, and TSS/TA ratio were examined. The results showed that all coatings could reduce the weight loss as compared to the control. GA and CA treatments showed the highest and the lowest pH values, respectively. Samples treated with CMC had the highest TSS/TA. An increase in storage time

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led to a decrease in the firmness and an increase in the TSS, TA, and weight loss. Glossiness was just observed in CMC and PG coatings. Based on the results, PG was the best coating.

Palou *et al.,* (2015) did a study on Chitosan and other edible coatings formulated by adding antifungal agents to composite emulsions based on polysaccharides or proteins and lipids was carried out. The most important antifungal ingredients are selected for their ability to control major citrus postharvest diseases like green and blue molds, caused by *Penicillium digitatum* and *Penicillium italicum*, respectively, and include low-toxicity or natural chemicals such as food additives, generally recognized as safe (GRAS) compounds, plant extracts, or essential oils, and biological control agents. It was suggested that chitosan with citral/lemon grass oil(3ml/L or 4ml/L)reduced mycelia growth and spore germination.

Hayat *et al.*,(2017) The study was conducted to assess the effect of different wax coating materials and Modified Atmosphere Packaging (MAP) on storage life and quality of Kaghzi lime. The fruits were harvested at light yellow skin color stage and treated with different wax coating materials: T1= Citrus Wax (wood resins18%, Imazalil 0.3%, Thiabendazloe 0.5%), T2= PHRC SCM Wax [9% total solids (castor and shellac based wax)]; T3= Modified Atmosphere Packaging (MAP), and T0= The fruit without any treatment were used as control. The fruits were stored at 10°C for 45 days and RH was maintained at 90%. The coating treatments significantly ($P \leq 0.05$) reduced PWL, increased shelf life and maintained the quality of fruits. Citrus Wax proved best because it maintained relatively higher levels of acidity, flavor, vit.C and fruit firmness. Most of the quality parameters such as PWL, TSS, juice percentage, titratable acidity, vit.C, taste, flavor, external color and firmness remained stable for the lime fruits treated with Citrus Wax. Similarly, disease incidence was also considerably lower compared with untreated lime fruits; therefore Citrus Wax can be utilized on commercial scale to enhance the shelf life and to maintain the quality of lime fruits.

Chen *et al.*,(2019) A study on Xinyu tangerines were done to reduce the losses caused by fungal deterioration of harvested fruit, a polysaccharide-based edible coating, containing natural antimicrobial agents (e.g., plant extracts) and the effects of Ficus hirta Vahl. fruits extract(FFE)–incorporated chitosan (CS) edible coating on Xinyu tangerines during cold storage at 5 ^{o}C. Results showed FFE has efficacy as an antifungal against P. italicum in a dose-dependent mannerin vivo. It was found that the edible coating of FFE–CS exhibited a

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higher reduction of TSS, TA and AsA content by reducing the fruit decay rate, weight loss, respiration rate, and malondialdehyde (MDA)content. Moreover, the activities of protective enzyme such as superoxidedis mutase (SOD), peroxidase (POD), and phenylalanine ammonia-lyase (PAL), which have been linked with reactive oxygen species (ROS) and the phenylpropanoid pathway, were higher in the FFE–CS-coated fruits. FFE–CS edible coating could reduce postharvest loss and enhance the storability of Xinyu tangerines due to the in vivo antifungal activityof FFE.

Nasrin *et al.*,(2020) An experiment was conducted to assess the influence of coconut oil and beeswax coating and MAP on postharvest storage quality of lemon at ambient storage. Lemons wee coated with coconut oil and beeswax mixture(90:10 or 80:20) or only coconut oil and lemons were kept open in crates or in MAP and stored at ambient condition. The effectiveness of edible coating and MAP in extending the shelf life of lemon with quality was evaluated by determining weight loss, respiration rate, ethylene production rate, firmness, shrinkage, yellowing, decay incidence, TSS, pH, ascorbic acid, juice content and also organoleptic quality were assessed periodically during storage. The results revealed that coconut oil only and mixtures with beeswax (both formulations) coating especially with MAP had immense effect on retaining greencolour, reducing respiration, ethylene production, weight loss and shriveling, preserving firmness and moisture content of lemon throughout the storage.

Packagings in Citrus

Bhattarai and Shah (2017) - Five treatments viz plastic (20 µ) wrapping (T1), plastic (20 µ) with 5 holes wrapping (T2), plastic (20 µ) with 10 holes wrapping (T3), Newspaper wrapping (T4), Jute wrapping (T5), no packaging materials (control) (T6) were conducted. And plastic (20 µ) with 5 holes wrapping (T2) was found best. This provides suitable environment for gaseous exchange and lowers transpiration and moisture loss rate and increases shelf life of fruits. The maximum shelf life (45 days) was recorded in T2. Weight loss was maximum in T6 followed by T4 and T5. Among the various packaging material treatments Plastic (20 µ) with 5 holes wrapping was found effective in improving shelf life and higher marketability.

Jadhao *et al.,* (2008)- An experiment was conducted on storage of kagzi lime in perforated polyethylene and non-perforated polypropylene bags of 100, 200 and 300 gauges

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and with different treatments *viz*., chemicals and wax emulsion. The fruits stored in 200 gauged perforated polypropylene bags recorded minimum pH, TSS, brix/acid ratio and maximum content of acidity and ascorbic acid at the end of 70 days in cold storage condition. However, it revealed that, fruits packed in 200 gauged perforated polypropylene and polyethylene bags exhibited shelf life up to 70 by slowed down biochemical changes.

Bangulzai *et al.*,(2015) - An experiment was conducted on the packaging material in citrus fruits. Sweet oranges and grape fruit packed in gunny bags, wooden crates, paper boxes and plastic bags. Gunny bags and plastic bags showed quality deterioration in fruit. It was concluded that regardless the citrus varieties, paper box packing proved to be most suitable for citrus fruit storage, which maintained the better fruit quality and lesser fruit weight loss than rest of the packing materials. Sweet orange remained in acceptable quality up to six days of storage under room temperature while grape fruits remained in acceptable quality up to 9 days after storage later the fruit quality was deteriorated.). The stored citrus fruits packed in paper box revealed better performance. The stored citrus fruits packed in wooden crates ranked 2nd for quality attributes for sweet orange and grape fruits.

Anmol and Shailesh Kumar(2020)- Among different packaging materials, LDPE (low density polyethylene), HDPE (high density polyethylene), Clingfilm and Shrink film are widely used as packaging materials. LDPE (low density polyethylene) is characterized by high permeability tocarbon di-oxide and other gases, HDPE (high density polyethylene) has high tensile strength, Shrink film packaging materials can reduce shrinkage and mechanical damage to fruits while Cling film is plastic stretch film which protects the fruits from loss of moisture and severely restrict the ventilation. It was found out that cellophane 30 mic showed best results in extending the shelf life of lemon.

Gomez *et al.*,(2020) - Studies on the influence of a controlled release of essential oils (EOs) from an active packaging(including _-cyclodextrin-EOs inclusion complex) was done on the mandarin quality stability, comparing different sized cardboard trays and boxes, either non-active or active, at the pilot plant scale (experiment 1; commercialization simulation at room temperature after a previous simulation of short transportation/storage of 5 days at 8 ^{0} C). Then, the selected package was further validated at the industrial scale (experiment 2; cold storage at ^{0}C up to 21 days). Among package types, the active large box (10 kg fruit per box) better maintained the mandarin quality, extending the shelf life from two weeks (non-

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active large box) to three weeks at room temperature. Particularly, the active large box highly controlled microbial growth (up to two log units), reduced weight losses(by 1.6-fold), reduced acidity, and increased soluble solids (highly appreciated in sensory analyses),while it minimized colour and controlled firmness changes after three weeks. The mandarin's shelf life with this active cardboard box format was extended more than one week at 8^0C.

Conclusion

After a thorough study and comparison among all the above research findings, it is found that the biodegradable coatings instead of polyethylene based waxes and application of natural edible/ polysaccharide based coatings instead of commercial synthetic waxes are an increasing interest due to human health issues and environmental protection, recently. Hence, more research in this particular area is needed. Layer by layer approach coatings notably improved all quantified parameters of fruit quality, proving that polysaccharide based edible coating may offer an alternative to synthetic waxes. Edible coatings such as chitosan, plant extracts, essential oils etc used are recognised safe for consumption.Interestingly, organic materials like, coconut oil has been found to show good performance in maintaining the quality and shelf life in citrus. More research in such is essential. Proper packaging is a very important step in providing quality products to the consumers. Among the citrus fruits, mandarin is found out to be the most sensitive fruit mainly due to the thin rind.Coatings along with packaging have shown to have innumerable benefits in post harvest handling. Therefore, encourage the use of more eco-friendly and consumer safe coating and packaging materials.

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