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Development and application of edible skin coatings to improve the quality of kinnow during storage

Ahmad Din[1], Muhammad Nadeem[2*], Moazzam Rafique[3] and Muhammad Asim Shabbir[3]

*[1]Ayub Agricultural Research Institute, Faisalabad, Pakistan. [2]Institute of Food Science and Nutrition, University of Sargodha, University Road, 40100, Sargodha, Pakistan. [3]National Institute of Food Science and Technology, University of Agriculture, Faisalabad, Pakistan. *Author for correspondence. E-mail: mnadeemft@gmail.com*

ABSTRACT. This study aimed to develop and investigate the effect of application of indigenous skin coating materials for kinnow fruit, which surely would have superior effect on shelf stability and an attractive alternate for inedible coatings. Economical and underutilized sources were explored for this purpose. Eight different formulations were developed to check their suitability through various physico-chemical analyses. It was concluded that edible coating prepared from corn starch, stearic acid, jojoba oil and monoglycerides (T_8) was observed best in terms of physico-chemical properties of fruits and significantly increased the shelf life.

Keywords: edible coatings, citrus, post harvest, shelf life, food safety, quality.

Desenvolvimento e aplicação de revestimentos comestíveis para melhorar a qualidade durante o armazenamento de kinnow

RESUMO. Essa pesquisa foi desenvolvida para investigar o efeito da aplicação de materiais indígenas de revestimento na fruta kinnow para que haja um efeito relevante na estabilidade de armazenamento e uma alternativa atraente para revestimento comestível. Foram utilizadas fontes pouco utilizadas e baratas. Oito formulações diferentes foram desenvolvidas para verificar sua adaptabilidade por várias análises físicas e químicas. Os resultados mostram que o revestimento comestível de amido de milho, ácido esteárico, óleo de jojoba e monoglicerides (T_8) foram os melhores para preservar as propriedades físicas e químicas do fruto e, portanto, para aumentar a durabilidade de armazenamento.

Palavras-chave: revestimento comestível, cítricos, pós-colheita, durabilidade de armazenamento, segurança alimentar, qualidade.

Introduction

Citrus is grown in many parts of Pakistan and the soil and environmental conditions of Punjab province are favorable for its production. Among the citrus crop, kinnow is produced on large scale and carries 6^{th} position for its production and export in the world. In Pakistan kinnow production was 2458.5 thousand metric tons from an area of 199.5 thousand hectare and export was 300,000 metric tons during the crop year 2010-11. Post harvest losses are found to 25-40% in fruit and vegetables and in some horticultural commodities, losses are more than 40% (PHDEC, 2011).

There are many methods and techniques to extend the shelf life of fruit applying over the decades. Applied techniques made it possible to reduce the distances between the production and marketing areas. It has been observed that after harvesting 25-80% fruit and vegetables are spoiledeach year due to inappropriate handling and storage conditions. The shelf life extension and quality after harvesting can be maintained with the application of skin coating materials, controlled atmosphere storage and modified atmosphere packaging.

The quality of fruits and vegetables are improved with the application of surface coatings through retarding the water loss, improving the external skin layer and making the skin for differential permeable to O_2 and CO_2 gases and transpiration rate are reduced due to the ingredients used in formulation (HAGENMAIER; BAKER, 1993, 1995; AMARANTE et al., 2001). Application of waxes and coatings has long historic backgrounds and commercially applied about sixty years ago (KAPLAN, 1986). Citrus fruits are mainly stored and exported by applying surface coatings which make them shine, decreases the rate of respiration through retarding the ethylene and CO_2 production along with the production of mycotoxins that made them spoiled and ultimately unfit for usage (GRANT; BURNS, 1994; DU et al., 1997; TRIPATHI; DUBEY, 2004).

The shelf life of kinnow mandarin at ambient conditions ($25-35^0$C) is about five to six days (HASAN; ARSLAN, 2004). Coatings can be developed from different materials comprises of polysaccharides, proteins, lipids, oils, resins, polymers and hydrocolloids (KESTER; FENNEMA, 1986; McHUNG, 1996). Skin coating materials and edible film coatings are applied through spraying, foaming, brushing and dipping methods and provide essential barrier to the exchange of gases, biochemical processes to lipid oxidation and loss of flavoring compounds (HASAN; ARSLAN, 2004; McHUNG et al., 1993; STUCHELL; KROCHTA, 1994). The main objectives of this study was to develop and find out the suitable combination of skin coating material and to estimate the physicochemical changes in kinnow as a function of storage.

Material and methods

Procurement of raw materials

Samples were procured from the progressive kinnow growing area from district Sargodha in Punjab province. The samples were selected and separated on the basis of uniformity of size, color, devoid of physical damage and fungal infection, followed by manual sorting and grading in the laboratory. Chemicals and the ingredients used in the formulation and chemical analysis were procured from Riedel-de Haen. Seeize, Germany and Danisco Company, Lahore, Pakistan. Different oils used in study were purchased from the local market.

Development of indigenous skin coating materials

Hydrophilic polymer, emulsifying agent, hydrophobic phase and water were used to develop the skin coating material. Carboxymethyl cellulose (CMC) and corn starch were used as hydrophilic polymers. Stearic acid and monodyglycerides were used as emulsifying agent. Different oils (Jujoba, ajwain, black cumin, Brassica and taramera oils) were used as hydrophobic phases. The order of addition of ingredients used for development of skin coating material was followed according to the Pavlath and Orts (2009). The measured amount of hydrocolloids was taken in water and heated up to gel formation then emulsifying agents were mixed with the help of hot plate magnetic stirrer. After this mixing, oils were added. This prepared mixture is then homogenized at high shear rate of 10,000 rpm for five minutes through high speed homogenizer for stable skin coating material. This developed mixture was cooled at room temperature and stored in clean dried air tight glass bottles for further application.

Treatment plan and formulations

All the developed formulations carried the following ingredients with minor variable amounts (Table 1):

Table 1. Formulations of different novel skin coating material.

Treatments	Skin coating material (SCM)	Composition (% w w^{-1})
T_1	Control (without SCM)	-----------
	Commercial wax (WATERWAX®)	
	Oxidized polyethylene wax	18
T_2	Ammonium hydroxide	2.0
	Thiabendazole	0.5
	Imazalil	0.2
	CMC	0.5
	Stearic acid	2.25
T_3	Methanol	5.0
	Ammonium hydroxide	0.25
	Black cumin oil (*Nigella sativa*)	10.0
	Water	82.0
	CMC	0.5
	Stearic acid	2.0
T_4	Bitter mustard oil (*Eruca sativa*)	8.0
	Monodyglycerides	0.5
	Water	89.0
	CMC	0.5
	Stearic acid	2.0
T_5	Thymol oil (*Carum capticum*)	8.0
	Monodyglycerides	0.5
	Water	89.0
	CMC	2.0
	Stearic acid	2.0
T_6	Mustard oil (*Brassica napus*)	8.0
	Monodyglycerides	0.5
	Water	87.5
	CMC	0.5
	Stearic acid	2.0
T_7	Black cumin oil (*Nigella sativa*)	8.0
	Monodyglycerides	0.5
	Water	89.0
	Corn starch	3.5
	Stearic acid	2.0
T_8	Jojoba oil (*Simondisia chinensis*)	8.0
	Monodyglycerides	0.5
	Water	86.0

Application of indigenous skin coating materials (SCM)

Properly cleaned and dried samples were selected for the application of formulated skin coating material (SCM). The control treatment (T_1) was without skin coating material while the other seven treatments are applied with the formulated skin coating material (SCM). Each treatment is equally divided into eight lots and carrying equal No. of fruit in three replicates (average No. of fruit = 30). The viscosity of developed skin coating material (SCM) was adjusted with the addition of distilled water with 1:2. Each sample was dipped for one minute, twisted and allowed to dry for 20 minutes. Before dipping the kinnow in the solution, the mixture was homogenized to get a uniformly dispersed emulsion and gave one minute for residual solution of each treatment to drip off.

Storage

The skin coated kinnow were placed in baskets at 5 ± 1^0C with relative humidity 85 to 90% for one month (CHIUMARELLI et al., 2010). The cold stores used for storage studies, were manufactured by modular cold store manufacturer Ltd. Mohill, Co. Leitrim, Ireland, placed at Post Harvest Research Center, Ayub Agricultural Research Institute, Faisalabad, Pakistan.

Physicochemical analysis

Following physico-chemical analysis were performed for four consecutive weeks to examine the shelf stability of coated fruit.

Weight loss

Weight loss (%) was determined according to the method described in AOAC (2006) on weekly basis.

$$\text{Weight loss \%} = \frac{\text{Initial wt.} - \text{final wt.}}{\text{Wt of sample}} \times 100$$

pH

The pH of each sample was determined with the help of digital pH meter. A sufficient quantity (50 mL) of kinnow juice was taken in 100 mL beaker and pH meter was used to record the pH according to the method explained in AOAC (2006).

Total soluble solids

Hand Refractometer (mod. ABBE'S refractometer, Bellingham + Stanley, BS eclipse, UK, 45-03) was used to record total soluble solids in the samples according to the standard procedure of AOAC (2006). A drop of kinnow juice was placed on refractometer and reading was noted. The results were expressed as percent soluble solids (°Brix).

Ascorbic acid

The ascorbic acid content was estimated using the detective dye, DCPIP (2, 6-dichlorophenolindophenol) according to the standard method of AOAC (2006).

Titratable acidity

The acidity in each sample was determined according to the standard procedure given in AOAC (2006). 10 mL of kinnow juice along with 100 mL water was taken and then titrated with 0.1 N NaOH using phenolphthalein as an indicator (1-2 drops) till light pink end point which persist for three sec.

Firmness

The firmness was measured with fruit firmness tester (penetrometer), manufactured by Tr di turonil Co. Snc. Italy. In this instrumental method, hold the fruit firmly in the left hand; hold the fruit tester between thumb and forefinger of right hand, place the plunger (with diameter 7.9 mm) against the fruit and press with increasing strength until the plunger tip is penetrated into the fruit up to the notch. Slow penetration of the plunger is essential for accurate measurement.

Statistical analysis

The data obtained was subjected to statistical analysis by using analysis of variance technique and comparison of means was done by LSD test (STEEL et al., 1997).

Results and discussion

Physico-chemical analysis

Weight loss

The statistical analysis indicated that treatments, storage and their interaction had a highly significant effect on weight loss of citrus fruit. The weight loss of all the treatments ranged from 0.72 to 2.26% (Table 2). The comparison of treatments revealed that maximum weight loss was in T_1 (2.26%) at the end of storage period. Less weight loss was observed in T_8 (0.72%).

Table 2. Mean values for weight loss (%) of kinnow during storage.

Treatments	Days						Mean
	0	6	12	18	24	30	
T1	0.00	0.40	1.30	2.60	3.67	5.60	2.26
T2	0.00	0.30	0.63	0.80	1.23	1.60	0.76
T3	0.00	0.40	0.80	1.30	1.60	2.30	1.07
T4	0.00	0.40	0.70	1.10	1.40	1.90	0.92
T5	0.00	0.30	0.57	1.00	1.40	1.67	0.82
T6	0.00	0.63	0.80	1.30	1.60	1.90	1.04
T7	0.00	0.40	0.90	1.40	1.80	2.27	1.13
T8	0.00	0.20	0.50	0.77	1.27	1.60	0.72
Mean	0.00f	0.38e	0.78d	1.28c	1.75b	2.35a	

During the storage period more weight was decreased in the 30 days of storage period. The results of present investigation are in accordance with the study of Albanese et al. (2007) who found that the dipping treatment was effective in slowing down weight loss. The lower weight loss obtained for coated samples suggested a positive action of the pre-treatment in slowing down transpiration phenomenon, probably due to the development of an amorphous glass on the citrus surface that retarded water evaporation. Similarly Kra´sniewska et al. (2014) observed that weight loss decreased with the application of pullulan coatings on pepper and apple.

pH

The statistical analysis regarding pH indicated that storage period imparts highly significant effect and their interaction and treatments have non-significant effect on this parameter. The pH of all the treatments range from 3.63 to 3.68. The pH of treated oranges showed an increasing trend during storage of 30 days (Table 3). Likewise, pH increased from 3.52 to 3.78 during the 30 days of storage period. In the similar study, Albanese et al. (2007) observed a slight increase in pH values (from 3.30 to 3.50) after 8 days of storage. This phenomenon was linked to the malic acid decrease, due to the increase in respiration rate following peeling and cutting.

Table 3. Mean values for pH of kinnow during storage.

Treatments	Days						Mean
	0	6	12	18	24	30	
T1	3.54	3.57	3.66	3.71	3.77	3.83	3.68
T2	3.52	3.58	3.66	3.71	3.76	3.81	3.68
T3	3.53	3.59	3.66	3.71	3.76	3.54	3.63
T4	3.53	3.59	3.64	3.70	3.75	3.80	3.67
T5	3.50	3.56	3.61	3.68	3.76	3.82	3.66
T6	3.52	3.55	3.62	3.70	3.75	3.81	3.66
T7	3.50	3.58	3.64	3.70	3.74	3.79	3.66
T8	3.53	3.58	3.63	3.70	3.77	3.84	3.68
Mean	3.52e	3.58d	3.64c	3.70b	3.75a	3.78a	

Total soluble solids (TSS)

The total soluble solids include sugars, proteins and mineral elements etc. Food materials containing higher total soluble solids are generally considered nutritionally rich as compared to foods containing less total soluble solids. The analysis of variance for total soluble solids showed highly significant effect of storage, and non-significant effect of treatments. TSS of all the treatments ranges from 12.43 brix to 12.52 brix (Table 4). Total soluble solids showed a decreasing trend with respect to storage (Table 4). TSS decreased from 13.47 to 11.40brix during 30 days of storage period. The present results are in accordance with the study of Bett et al. (2001) who stored cut 'Gala' apples at 1^0C for 14 days and found decreasing trend in soluble solids. This result might also be related to the breakdown of high molecular weight compounds such as starch and hemicellulose into low molecular weight compound such as simple sugar. The following decrease might be due to fructose consumption as a substrate in metabolic processes. Boylston et al. (1994) also found that the length of storage or conditions of storage affect the soluble solids concentrations and titratable acidity of 'Gala' apples. In addition to this, Olivas et al. (2007) found significant difference between control and treated apples. In another study, Albanese et al. (2007) found 11.5 ± 1.5 Brix of coated apple slices after 8 days of storage.

Table 4. Mean values for TSS of kinnow during storage.

Treatments	Days						Mean
	0	6	12	18	24	30	
T1	13.30	13.00	12.80	12.40	11.80	11.30	12.43
T2	13.40	13.00	12.70	12.30	11.90	11.50	12.47
T3	13.60	13.10	12.86	12.20	11.90	11.20	12.48
T4	13.40	12.93	12.80	12.40	11.90	11.50	12.49
T5	13.50	13.00	12.70	12.36	11.90	11.33	12.47
T6	13.40	13.03	12.76	12.30	11.80	11.40	12.45
T7	13.50	13.10	12.70	12.16	11.90	11.40	12.46
T8	13.66	13.06	12.60	12.60	11.62	11.53	12.52
Mean	13.47a	13.03b	12.74c	12.34d	11.84e	11.40f	

Ascorbic acid (Vitamin C)

The statistical data regarding ascorbic acid indicated highly significant effect of storage. The data regarding the mean value for ascorbic acid indicated that ascorbic acid of all the treatments range from 19.36 mg 100 g^{-1} to 19.58 mg 100 g^{-1}. Ascorbic acid showed a decreasing trend from 23.80 to 15.75 mg 100 g^{-1} during the 30 days of storage period (Table 5). The present results are in accordance with the study of Bett et al. (2001) who stored cut 'Gala' apples at 1^0C for 14 days and found decreasing trend in ascorbic acid. According to the study of Albanese et al. (2007), the coated apples showed a higher content of ascorbic acid after 6 days of storage. The decrease in ascorbic acid of coated apple slices was 4 to 1 mg 100 g^{-1} during 8 days of storage. Tezotto-Uliana et al. (2014) reported loss in ascorbic acid contents in raspberry by applying chitosan.

Table 5. Mean values (%) for vitamin C content of kinnow during storage.

Treatments	Days						Mean
	0	6	12	18	24	30	
T1	23.63	21.59	19.76	18.49	16.93	15.73	19.36
T2	23.86	21.80	20.36	18.61	16.53	16.06	19.54
T3	23.71	21.90	19.95	18.50	17.10	15.54	19.45
T4	23.84	22.36	20.31	18.20	16.30	15.79	19.47
T5	23.85	21.66	20.46	18.36	16.32	15.82	19.42
T6	23.82	21.32	19.91	19.06	16.95	15.51	19.43
T7	23.76	21.75	20.30	18.83	16.09	15.63	19.40
T8	23.90	21.90	20.50	18.70	16.60	15.88	19.58
Mean	23.80a	21.79b	20.20c	18.60d	16.60e	15.75f	

Titratable acidity

Titratable acidity varied significantly as a function of storage. The mean value for titratable acidity indicated highly significant decreasing trend for this parameter. The titratable acidity was reduced from 1.02 to 0.79% during the 30 days of storage period (Table 6). According to the Sadler and Murphy (1998), acids in fruits tend to decrease with fruit maturity as sugar contents increase and they found a decreasing trend in titratable acidity of apples during the storage period (LIDSTER et al., 1979; OLIVAS et al., 2007). In another study that was done by Albanese et al. (2007), the coated samples showed a higher content (0.4 g 100 g^{-1}) in malic acid after 6 days of storage as compared to uncoated (0.3 g 100 g^{-1}) samples. Arnon et al. (2014) observed non significant effect of acidity in oranges and grapefruit with the application of edible coating of carboxymethyl cellulose and chitosan bilayer.

Table 6. Mean values (%) for acidity of kinnow during storage.

Treatments	Days						Mean
	0	6	12	18	24	30	
T1	1.010	0.960	0.920	0.890	0.867	0.787	0.906
T2	1.020	0.950	0.920	0.883	0.830	0.787	0.898
T3	1.027	0.980	0.923	0.893	0.843	0.793	0.910
T4	1.020	0.970	0.930	0.900	0.860	0.800	0.913
T5	1.027	0.970	0.917	0.887	0.863	0.790	0.909
T6	1.040	0.970	0.927	0.893	0.850	0.783	0.911
T7	1.030	0.980	0.930	0.890	0.840	0.790	0.910
T8	1.023	0.950	0.923	0.870	0.840	0.773	0.897
Mean	1.02a	0.97b	0.92c	0.89d	0.85e	0.79f	

Firmness

The statistical data indicated that storage and interaction of storage and treatment imparted significant impact on firmness of citrus fruit. Maximum fruit firmness value 2.15 was observed in T_5 followed by 2.13 in T_4 and 2.11 in T_6 (Table 7). During storage, values for firmness decreased from 2.96 to 1.54 after 30 days of storage period. The above firmness results were similar to the finding of Lee et al. (2003). Who stored cut apples at 5^0C for 28 days in another study, Albanese et al. (2007) described small differences in firmness changes detected by the panel who judge the firmness to be acceptable across all 8 days of storage. Arnon et al. (2014) observed that firmness of oranges and grapefruit increased by applying edible coating of carboxymethyl cellulose and chitosan bilayer.

Table 7. Mean values for firmness of kinnow during storage.

Treatments	Days						Mean
	0	6	12	18	24	30	
T1	4.73	2.02	1.74	1.30	1.00	0.75	1.92
T2	2.74	2.02	1.90	1.85	1.80	1.75	2.01
T3	2.72	2.38	2.05	1.96	1.83	1.62	2.09
T4	2.73	2.53	2.10	1.98	1.80	1.63	2.13
T5	2.74	2.41	2.20	1.97	1.85	1.75	2.15
T6	2.75	2.50	2.25	1.93	1.73	1.51	2.11
T7	2.72	2.43	2.05	1.90	1.65	1.42	2.03
T8	2.51	2.42	2.00	1.87	1.80	1.78	2.06
Mean	2.96a	2.34b	2.04c	1.85cd	1.68de	1.53e	

Conclusion

From these results it can be concluded that emulsion of jojoba oil ((*Simondisia chinensis*), stearic acid, corn starch, monoglycerides and water is very effective in controlling the decay and maintaining the quality and shelf stability of kinnow. These edible coatings are non-toxic and can be applied to the other fruits and vegetables. This study helps to decrease the post harvest losses of kinnow that might be the source of increasing the farm income contributing towards foreign trade.

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