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The Impact of Formalin on Postharvest Quality, Shelf Life, and Nutritive Properties of Carrot, Papaya, Plum, Apple Plum, and Guava

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Abstract

As per the news and articles published in mass media in recent years, the usage of formalin in fruits and vegetables has become a worrisome condition in Bangladesh. In this context, this study was conducted to observe the effect of formalin on postharvest quality, shelf life, and nutritional profile of carrot, papaya, plum, apple plum, and guava. Fruits and vegetables sample were treated with different concentrations of formalin solutions (1%, 10%, 20%, and 30%) in two different modes (dipping and spraying) and stored for seven days. Physical parameters (color, texture, and flavor), weight loss, and shelf life were observed on every alternate day during the study period. Furthermore, 20% formalin-treated samples were used to find out the changes in nutritional profile (moisture, ash, carbohydrate, fat, and protein), pH, and vitamin C content. The study results revealed that different concentrations of formalin and treatment methods (dipping and spraying) did not bring up any positive effect in increasing the shelf-life and physical characteristics of selected fruits and vegetables during storage. Moreover, formalin treatment with higher concentration went in faster deterioration in color, texture, and flavor of samples compared to the control. The weight loss of fruits and vegetables is not dependent on formalin application. Formalin treatment worked negatively on the shelf life of samples. A significant reduction ($P<0.05$) trend on some nutritional parameters (carbohydrate, protein, fat, vitamin C) was observed in formalin-treated apple plum and guava when compared with the control. No significant differences

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in the pulp pH content were seen as a result of formalin treatment. The overall results suggest that formalin is not a useful preservative to improve the post-harvest qualities and shelf-life of carbohydrate-rich fruits and vegetables at any concentration and mode of application and it has also a negative effect on the nutritional properties of fruits and vegetables.

Introduction

As per the articles, news, and features published in various newspapers and other mass media in recent years, adulteration and contamination in foods have reached an extreme state in Bangladesh. A survey on food products marketed in Dhaka city conducted in 2004 by the Dhaka City Corporation reported that over 76% of food items were adulterated and food adulteration level ranges from 70% to 90%.[1] A government official statistics revealed that about 50% of food samples tested by the Institute of Public Health from 2001 to 2009 were adulterated.[2] Food items are intentionally adulterated by using various artificial colorants, hazardous chemicals, banned preservatives, and pesticides to increase the stability and storage life of products. Such as ethephon, calcium carbide, formalin, and artificial textile dye are used in fruits; formalin and artificial colorants are used in vegetables; formalin in fish; high concentration of dichlorodiphenyltrichloroethane (DDT) in dried fish; formalin, wheat flour, sorbitol, detergent in milk; toxic pesticides in banana, mango, carrot, and tomato; melamine in dried milk; urea in puffed rice; formalin and toxic red colorants are used in meat to extend storage life.[1,3] Dishonest merchants, dealers, sellers, importers, manufacturers, cultivators, and processors are applying various toxic chemicals in food to serve an attractive natural look, keep them fresh, prolong storage life, reduce economical loss, and gain financial profit finally. Mass production of seasonal food products, inadequate refrigeration, and storage facilities, growing consumer demand year-round, deficient transportation facilities, paucity of active laws, lack of appropriate implementation of existing laws by the relevant government authorities, irregular monitoring and controlling activity of regulatory authorities are the reasons why producers show the tendency of fraudulently increase the shelf life of products.[4]

In recent years, fruits and vegetables cultivation is increasing at a fast rate in Bangladesh. Vegetable farming takes up 2.57% total land area of Bangladesh, generating 3.73 million tons of produce each year.[5] However, a large portion of harvested products is thrown away every year due to a lack of storage, transport, processing, and proper marketing facilities. A recent report reveals postharvest loss of fruits and vegetables varied from 23.6% to 43.5% in Bangladesh, resulting in annual losses of thousands of crore taka. As a result, traders give priority to eliminating huge postharvest losses in various easy and cheap ways such as the use of preservatives and methanol application to extend shelf life.[6]

Formalin, a 37-50% aqueous solution of formaldehyde (w/w) containing 10% to 12% methanol to inhibit polymerization[7] and marketed as formalin, is said to be added to foods like fruits or vegetables in Bangladesh, India, and other South-East Asian nations to improve their shelf life and storage stability by dishonest merchants.[8]

From the nutritional viewpoint, fruits and vegetables contain moisture, ash, carbohydrate, protein, crude fiber, fat, iron, phosphorous, beta-carotene, niacin, riboflavin, ascorbic acid, and antioxidants.[6,9] Fruits and vegetables are widely consumed for their rich and healthy source of valuable nutrients by consumers of all ages. Despite the lack of proper scientific information supporting formalin's usefulness in prolonging the shelf life and improving the quality of fresh fruits and vegetables, it is widely used. Regulatory organizations in Bangladesh have been using mobile courts to seize and destroy large quantities of seasonal fruits and vegetables, claiming that they are adulterated with formalin. Depending on the aforementioned issues, this study was carried out to assess the impact of formalin on the postharvest quality, and shelf life of carrot, papaya, plum, apple plum, and guava. The present study also showed the changes in the nutritive properties of fruits and vegetables after being treated with formalin. Previous studies focused on postharvest quality and shelf life of other fruits and vegetables but information on changes in nutritive properties after being treated with formalin was found limited in the literature. The outcomes of the study are expected to offer consumers and researchers authentic information regarding formalin adulteration.

Materials and Methods

The experiment was conducted under laboratory conditions at the Food Processing and Quality Control Laboratory in the Department of Food Technology and Nutritional Science (FTNS), Mawlana Bhashani Science and Technology University (MBSTU), Tangail-1902, Bangladesh from December 2020 to September 2021.

Sample Selection and Collection

Samples of plum, apple plum, guava, carrot, and green papaya were selected for formalin treatment. Plum, apple plum, and guava were collected from the Horticulture Center Folbagan, Tangail-1900 located near the MBSTU campus. Carrots and green papayas were harvested directly from the farmers' fields located at Porabari village, Tangail Sadar, Bangladesh. Manual harvesting was done carefully in the morning without physically damaging the fruits and vegetables. Various harvesting maturity indices were followed at the time of selecting the maturity of samples. With the use of the most convenient visual indices (skin color development, size, shape, length) and physical means (firmness or softness of pulp), other specific indices like aroma development, development of waxy layer on the epidermis, number of days from fruit set, watery latex, roots diameter, days after sowing seeds were also considered for selecting samples. The collected samples were then cleaned with water to remove dirt and debris and then dewatered with the use of soft tissue paper to maintain the accuracy of the study.

Sample Size

A total of 489 samples were taken for dipping method to complete necessary observations (shelf life, postharvest qualities, and nutritional parameters examination). Similarly, another 489 samples were used for the spraying method. The fruits and vegetables were assigned randomly with replication in each treatment group. The distribution of samples for each examination has been represented in Table 1.

Table 1: Distribution of total samples for each examination

For each dipping or spraying method						
	Name of Samples	**Plum**	**Apple Plum**	**Guava**	**Carrot**	**Green Papaya**
For Postharvest Qualities Examination	Shelf life	9	9	9	9	9
	Color	9	9	9	9	9
	Texture	9	9	9	9	9
	Flavor	9	9	9	9	9
	Weight Loss	9	9	9	9	9
For Nutritional Parameters Examination	Moisture	16	16	4	4	4
	Carbohydrate	16	16	4	4	4
	Protein	16	16	4	4	4
	Fat	16	16	4	4	4
	Ash	16	16	4	4	4
	pH	16	16	4	4	4
	Vitamin-C	16	16	4	4	4

Note: Values are expressed as the number of samples

Chemical Preparation and Concentration

Formalin (37% formaldehyde solution) and distilled water were collected for chemical preparation. Formaldehyde (methyl aldehyde) was purchased from Alfa Aesar, Johnson Matthey Co., Britain, United Kingdom. Distilled water was prepared at the laboratory using Steam Distillation Units, Model D1000 (FoodALYT GmbH, Bremen, Germany). Four different formalin concentrations such as 1%, 10%, 20%, and 30% were prepared. Each 1L solution of every concentration was made in a 2L glass container. The glass containers were closed with lids and then kept at room temperature (25 ± 2 ºC) in the laboratory.

Formalin Treatment Methods

The experiment was designed with two formalin application or treatment methods and four different concentrations of formalin solution (1%, 10%, 20%, and 30%). The dipping and spraying methods were applied for treating the fruits and vegetables in formalin solutions. Before the formalin treatment, the samples were cleaned smoothly and carefully with soft and clean tissue paper. Therefore, the skins of the samples remain intact. For the dipping method, the samples were then dipped in the formalin solutions and kept for 15 minutes so that the formalin gets ample time to infiltrate through the skin and reach the inner parts. After dipping, the samples were placed on a dry tray and allowed to dry at room temperature. The treated samples were placed at a minimum distance from each other to eliminate the possibility of any interaction. Spraying was done daily at a fixed time of the day. After the spraying process, the treated samples were observed visually and the data were recorded.

Control

The control samples were those that were not treated with formalin solutions.

Parameters Studied

Physical Appearance

Color, texture, and flavor variations between treatment and control samples were observed following the visual method described by Monira *et al.*[9] The observation was carried out daily at regular intervals at specific times of the day. Except for the first observation or primary data collection at the onset of treatment, data recordings were carried out at an interval of two days.

Color Changes

The color of fresh fruits and vegetables commodity is one of the prime quality indicators. The subjective method of evaluating color changes was used. Changes in skin color were observed visually by the human eye due to some mechanical problems shown by the Chromameter available in the laboratory. A high-resolution digital camera was also used to take snaps and observation of the changes in skin color.

Textural Changes

When fruits and vegetables ripen and mature, their textures typically alter in the opposite direction. Vegetables get more abrasive while fruits soften. For determining the textural changes in our samples, the upper surface was pressed to check softness by using the finger. The gloves were used in this investigation to eradicate any contamination.

Flavor Changes

The flavor of both fruits and vegetables are influenced by chemical makeup and structural makeups of the unripe fruits are what causes the observable changes in fruit flavor during ripening. Fruits and vegetables that are fully ripe or mature produce the best flavor and sometimes even a delectable fragrance. The samples' flavor was determined by sniffing them for fruity or vegetable scents.

Determination of Weight Loss

The weight loss of the treated samples was calculated as a drop in their weight as described by Monira *et al.*[9] The weights of the treated samples was measured every day at a one-day interval. The weight loss was calculated as a percentage of body weight. Each treated sample was separately weighted with an electric balance and preserved for the next observation. According to a previous study,9 following formula was used to compute the percentage of overall weight loss.

% of Weight Loss = (Initial Weight in g -Final Weight in g)/(Initial Weight in g) × 100

Determination of Shelf Life

Except for the first observation, the fruits and vegetables were appraised for their shelf life evaluation. Fruits and vegetables from each treatment's shelf life were investigated by counting the number of days needed for them to reach full ripeness to maintain their best marketing and eating qualities. This allowed for an evaluation of the physical characteristics of the fruits and vegetables, such as color, texture, and flavor variation.[9]

Proximate Analysis of Samples

Ash content was determined by following AOAC techniques 7.009.[10] Carbohydrate content of the selected samples was estimated by following the method of Anthrone using ethyl alcohol as a solvent.[11] Estimation of total protein content was determined by Kjeldahl method 978.04.[10] Fat content was estimated according to the method described by AOAC using petroleum ether as solvent.10 Tests were performed four times.

Determination of pH

The pH of the fruits and vegetables was measured with a pH meter (Sension+ PH31, HachsensION+, USA) by the AACC method.[12]

Determination of Vitamin C Content

The technique described by AOAC was used to determine the vitamin C content.[10] Dye factor was calculated according to the equation used by Mazumdar and Majumder.[13]

Vitamin C content (mg/100g) = $(e \times d \times b)/(c \times a) \times 100$
Where, a = sample's weight; b = volume with meta-phosphoric acid; c = aliquot volume used to estimate; d = factor of dye, e = burette reading

Statistical Analysis

The SPSS (Statistical Package for Social Science, SPSS Inc., Chicago, Illinois, U.S.A)) version 26.0 was used to evaluate the data generated from the study. Mean data were subjected to analysis by one-way Analysis of Variance (ANOVA) followed by Duncan's Multiple Range Test (DMRT). Statistical significance was shown at the confidence level of 95%. The significance of differences was tested at $P < 0.05$.

Results and Discussion

Effect of Formalin on Physical Characteristics of Fruits and Vegetables

After being treated with different concentrations of formalin, there were no appreciable benefits on plums in terms of changes in their physical characteristic over the control (Table 2). With increasing storage period (Day 5 and 7) of all treated samples, the plum's color turned into characteristics brown color, and the flesh texture became soft in both treatment method were observed. Throughout the whole storage period (up to the 7th day), the control samples of apple plum were in acceptable condition (Table 3). The appearance of the treated samples changed from reddish-green to dark brown and developed black spots. Additionally, the texture of treated samples of both methods gradually changed from slightly soft on day 3 to soft on days 5 and 7. The light green color of the control guava remained stable for up to 3 days (Table 4). The control guava's characteristically hard texture became softened and the flavor increased on the 7th day due to ripening. The color of treated guava slightly changed at 3 days in both applying methods but on the 5th and 7th day, brown green and brown color was observed in samples treated with the dipping method. In terms of texture, no change was observed on 3rd day but treated guava samples were turned slightly soft from the 5th day to soft on the 7th day. The reddish-orange color and characteristics texture of the control carrot remains unchanged up to 3rd day but the pale color and softness in texture developed from 5th day (Table 5). In treated samples of both applying methods, pale color was observed in all carrot samples from 3rd day. In the dipping method, a soft texture was observed from the 5th day except for 1% formalin-treated carrot samples. Table 6 showed the physical changes of green papaya after being treated with formalin and stored for 7 days. The control samples' color was unchanged up to the 5th day. Slightly softness in texture was observed on 3rd day. Compared to controls, treated samples have an unpleasant flavor of all fruits and vegetables. Observation showed that the flavor of the control sample of all fruits and vegetables became offensive on the 5th day except for the guava sample and the increased flavor was observed on the 7th day. Dipping of plum, apple plum, carrot, and papaya in 10%, 20%, and 30% formalin solution developed offensive flavor on 3rd day. The spraying method gave increased flavor on the 5th day and ripen flavor on the 7th day at 10, 20%, and 30% formalin solution. Acceptance results revealed that the control samples of plum, apple plum, guava, and papaya were acceptable on the 4th day and only guava samples were extended to the 5th day. Formalin-treated samples of plum, guava, and carrot with different concentrations were in acceptable condition on 3rd day. Application of formalin solution on papaya and apple plum indicated that shelf life was decreased at high concentrations (10%, 20%, and 30%) than low (1%).

The higher the concentration of formalin in the treated samples, the faster the deterioration of color and texture. The most likely causes of deterioration in color and texture include a high rate of respiration, enzymatic processes, and microbial infection. The physical changes in the treated samples against control samples of plum and guava are depicted in Figures 1 and 2. The onset of physiological and biochemical mechanisms such as browning reactions, which cause losses or changes in flavor, odor, and nutritional value, are generally triggered by all phenomena like cutting, shock, loss of stiffness, etc.[14] According to certain research, pre-harvest stress decreases fruit quality after harvest.[15] Color grew darker and texture grew soft and the presence of dark spots in samples (plum and green papaya) along with increasing formalin concentrations was noticed. It might be due to the additional pigment produced when formalin reacts with organic materials on the surfaces of the samples. The physical change seen in samples treated in both methods could be the presence of formalin, the respiration of fruits and vegetables, or the reaction of formalin solution with sample composition. No samples treated with different amounts of formalin showed any noticeable advantages over the control for the entire period of storage in our investigation. Instead, the treated samples underwent quicker deterioration. This is the opposite of the general perception of people of using formalin in extending the shelf life of fruits and vegetables.[9] A previous study on the impact of formalin on the quality of mango showed that the surface color of mangoes treated with 10, 100, and 1000 mg/ L formalin solutions was turned to visible dark spots. The color of mango gradually became worse and shrinkage of skin was reported.[9] The color of the mushroom becomes white to brown, texture become elastic after being treated with formalin.[16] The color of the litchis and mangoes treated with formalin deteriorated as the storage progressed. The color of the treated samples turned green to yellowish green with dark spots, and the texture grew soft into glorious day by day reported by Antora and her colleagues.[16]

Table 2: Changes in physical parameters of formalin-treated plum

Formalin Solution Strength	Formalin Treatment Method	Obser vation Para meters	Observation Period (Days)					Accep tance Period (Days)
			0	1	3	5	7	
Control (0%)	-	Color	Yellowish Green	NC	Brown	Brown	Brown	4
		Texture	Characteristic	NC	Slightly Soft	Soft	Soft	4
		Flavor	Characteristic	NC	Not Changed	Offensive	Offensive	4
1%	DM	Color	Yellowish Green	NC	Brown	Brown	Brown	3
		Texture	Characteristic	NC	Soft	Soft	Soft	3
		Flavor	Characteristic	NC	Offensive	Offensive	Offensive	3
	SM	Color	Yellowish Green	NC	Brown	Brown	Brown	3
		Texture	Characteristic	NC	Slightly Soft	Soft	Soft	3
		Flavor	Characteristic	NC	Not Changed	Offensive	Offensive	3
10%	DM	Color	Yellowish Green	NC	Brown	Brown	Brown	3
		Texture	Characteristic	NC	Not Changed	Soft	Soft	3
		Flavor	Characteristic	NC	Offensive	Offensive	Offensive	3
	SM	Color	Yellowish Green	NC	Brown	Brown	Brown	3
		Texture	Characteristic	NC	Slightly Soft	Soft	Soft	3
		Flavor	Characteristic	NC	Not Changed	Offensive	Offensive	3
20%	DM	Color	Yellowish Green	NC	Brown	Brown	Brown	3
		Texture	Characteristic	NC	Not Changed	Soft	Soft	3
		Flavor	Characteristic	NC	Offensive	Offensive	Offensive	3
	SM	Color	Yellowish Green	NC	Brown	Brown	Brown	3
		Texture	Characteristic	NC	Slightly Soft	Soft	Soft	3

		Flavor	Characteristic	NC	Not Changed	Offensive	Offensive	3
30%	DM	Color	Yellowish Green	NC	Brown	Brown	Brown	3
		Texture	Characteristic	NC	Not Changed	Soft	Soft	3
		Flavor	Characteristic	NC	Offensive	Offensive	Offensive	3
	SM	Color	Yellowish Green	NC	Brown	Brown	Brown	3
		Texture	Characteristic	NC	Slightly Soft	Soft	Soft	3
		Flavor	Characteristic	NC	Not Changed	Offensive	Offensive	3

Note: DM = Dipping Method, SM = Spraying Method, NC = Not Changed

Table 3: Changes in physical parameters of formalin-treated apple plum

Formalin Solution Strength	Formalin Treatment Method	Observation Parameters	Observation Period (Days)					Acceptance Period (Days)
			0	1	3	5	7	
Control (0%)	-	Color	Reddish Green	NC	Brown	Dark Brown	Dark Brown	4
		Texture	Characteristic	NC	Slightly soft	Soft	Soft	4
		Flavor	Characteristic	NC	Not Offensive	Offensive	Offensive	4
1%	DM	Color	Green	NC	Greenish Brown	Brown	Brown	3
		Texture	Characteristic	NC	Slightly Soft	Soft	Soft	3
		Flavor	Characteristic	NC	Not Offensive	Offensive	Offensive	3
	SM	Color	Green	NC	Brown	Brown	Brown	2
		Texture	Characteristic	NC	Slightly soft	Soft	Soft	2
		Flavor	Characteristic	NC	Not Offensive	Offensive	Offensive	2
10%	DM	Color	Reddish Green	NC	Greenish Brown	Brown	Dark Brown	1
		Texture	Characteristic	NC	Slightly Soft	Soft	Soft	1
		Flavor	Characteristic	NC	Not Offensive	Offensive	Offensive	1
	SM	Color	Green	Green with black spot	Greenish Brown with a black spot	Brown	Brown	1
		Texture	Characteristic	NC	Slightly Soft	Soft	Soft	1
		Flavor	Characteristic	NC	Offensive	Offensive	Offensive	1
20%	DM	Color	Green	Greenish Brown	Brown	Brown	Brown	1
		Texture	Characteristic	NC	Slightly Soft	Soft	Soft	1
		Flavor	Characteristic	NC	Offensive	Offensive	Offensive	1
	SM	Color	Yellowish Red	Yellowish Brown	Reddish Brown	Brown	Brown	1
		Texture	Characteristic	NC	Slightly Soft	Soft	Soft	1
		Flavor	Characteristic	NC	Offensive	Offensive	Offensive	1
30%	DM	Color	Reddish Green	NC	Yellowish Brown	Brown	Brown	1
		Texture	Characteristic	NC	Slightly soft	Soft	Soft	1

		Flavor	Characteristic	NC	Offensive	Offensive	Offensive	1
	SM	Color	Yellowish Green	Yellowish Brown	Brown	Brown	Brown	1
		Texture	Characteristic	NC	Slightly soft	Soft	Soft	1
		Flavor	Characteristic	NC	Offensive	Offensive	Offensive	1

Note: DM = Dipping Method, SM = Spraying Method, NC = Not Changed

Table 4: Changes in physical parameters of formalin-treated guava

Formalin Solution Strength	Formalin Treatment Method	Observation Parameters	Observation Period (Days)					Acceptance Period (Days)
			0	1	3	5	7	
Control (0%)	-	Color	Light Green	NC	Slightly Changed	Yellowish Green	Not Changed	5
		Texture	Characteristic	NC	NC	Slightly Soft	Soft	5
		Flavor	Characteristic	NC	NC	Not Changed	Increased	5
1%	DM	Color	Light Green	NC	Slightly Changed	Yellowish Green	Brownish Green	3
		Texture	Characteristic	NC	NC	Not Changed	SlightlySoft	3
		Flavor	Characteristic	NC	NC	Not Changed	Increased	3
	SM	Color	Light Green	NC	Slightly Changed	Brownish Green	Not Changed	3
		Texture	Characteristic	NC	NC	Slightly Soft	Slightly Soft	3
		Flavor	Characteristic	NC	NC	Not Changed	Increased	3
10%	DM	Color	Light Green	NC	Slightly Changed	Brownish Green	Brown	3
		Texture	Characteristic	NC	NC	Slightly Soft	Soft	3
		Flavor	Characteristic	NC	NC	Increased	Ripen	3
	SM	Color	Light Green	NC	Slightly Changed	Brownish	Brown Green	3
		Texture	Characteristic	NC	NC	Slightly Soft	Soft	3
		Flavor	Characteristic	NC	NC	Increased	Ripen	3
20%	DM	Color	Light Green	NC	Slightly Changed	Brownish Green	Brown	3
		Texture	Characteristic	NC	NC	Slightly Soft	Soft	3
		Flavor	Characteristic	NC	NC	Not Changed	Ripen	3
	SM	Color	Light Green	NC	Slightly Changed	Brown	Brown	3
		Texture	Characteristic	NC	NC	Slightly Soft	Soft	3

		Flavor	Characteristic	NC	NC	Increased	Ripen	3
30%	DM	Color	Light Green	NC	Slightly Changed	Brownish Green	Brown	3
		Texture	Characteristic	NC	NC	Slightly Soft	Soft	3
		Flavor	Characteristic	NC	NC	Not Changed	Ripen	3
	SM	Color	Light Green	NC	Slightly Changed	Brown	Brown	3
		Texture	Characteristic	NC	NC	Slightly Soft	Soft	3
		Flavor	Characteristic	NC	NC	Increased	Ripen	3

Note: DM = Dipping Method, SM = Spraying Method, NC = Not Changed

Table 5: Changes in physical parameters of formalin-treated carrot

Formalin Solution Strength	**Formalin Treatment Method**	**Observation Parameters**	**Observation Period (Days)**					**Acceptance Period (Days)**
			0	**1**	**3**	**5**	**7**	
Control (0%)	-	Color	Reddish Orange	NC	NC	Pale	Pale	4
		Texture	Characteristic	NC	NC	Soft	Soft	4
		Flavor	Fresh and Strong	NC	Slightly offensive	Offensive	Offensive	4
1%	DM	Color	Reddish Orange	NC	Pale	Pale	Pale	3
		Texture	Characteristic	NC	Soft	Soft	Soft	3
		Flavor	Fresh and Strong	NC	Offensive	Offensive	Offensive	3
	SM	Color	Reddish Orange	NC	Pale	Pale	Pale	2
		Texture	Characteristic	NC	Slightly Soft	Soft	Soft	2
		Flavor	Fresh and Strong	NC	NC	Offensive	Offensive	2
10%	DM	Color	Reddish Orange	NC	Pale	Pale	Pale	3
		Texture	Characteristic	NC	NC	Soft	Soft	3
		Flavor	Fresh and Strong	NC	Offensive	Offensive	Offensive	3
	SM	Color	Reddish Orange	NC	Pale	Pale	Pale	3
		Texture	Characteristic	NC	Slightly Soft	Soft	Soft	3
		Flavor	Fresh and Strong	NC	NC	Offensive	Offensive	3
20%	DM	Color	Reddish Orange	NC	Pale	Pale	Pale	3
		Texture	Characteristic	NC	NC	Soft	Soft	3
		Flavor	Fresh and Strong	NC	Offensive	Offensive	Offensive	3
	SM	Color	Reddish Orange	NC	Pale	Pale	Pale	3
		Texture	Characteristic	NC	Slightly Soft	Soft	Soft	3
		Flavor	Fresh and Strong	NC	NC	Offensive	Offensive	3
30%	DM	Color	Reddish Orange	NC	Pale	Pale	Pale	3
		Texture	Characteristic	NC	NC	Soft	Soft	3

		Flavor	Fresh and Strong	NC	Offensive	Offensive	Offensive	3
	SM	Color	Reddish Orange	NC	Pale	Pale	Pale	3
		Texture	Characteristic	NC	Slightly Soft	Soft	Soft	3
		Flavor	Fresh and Strong	NC	NC	Offensive	Offensive	3

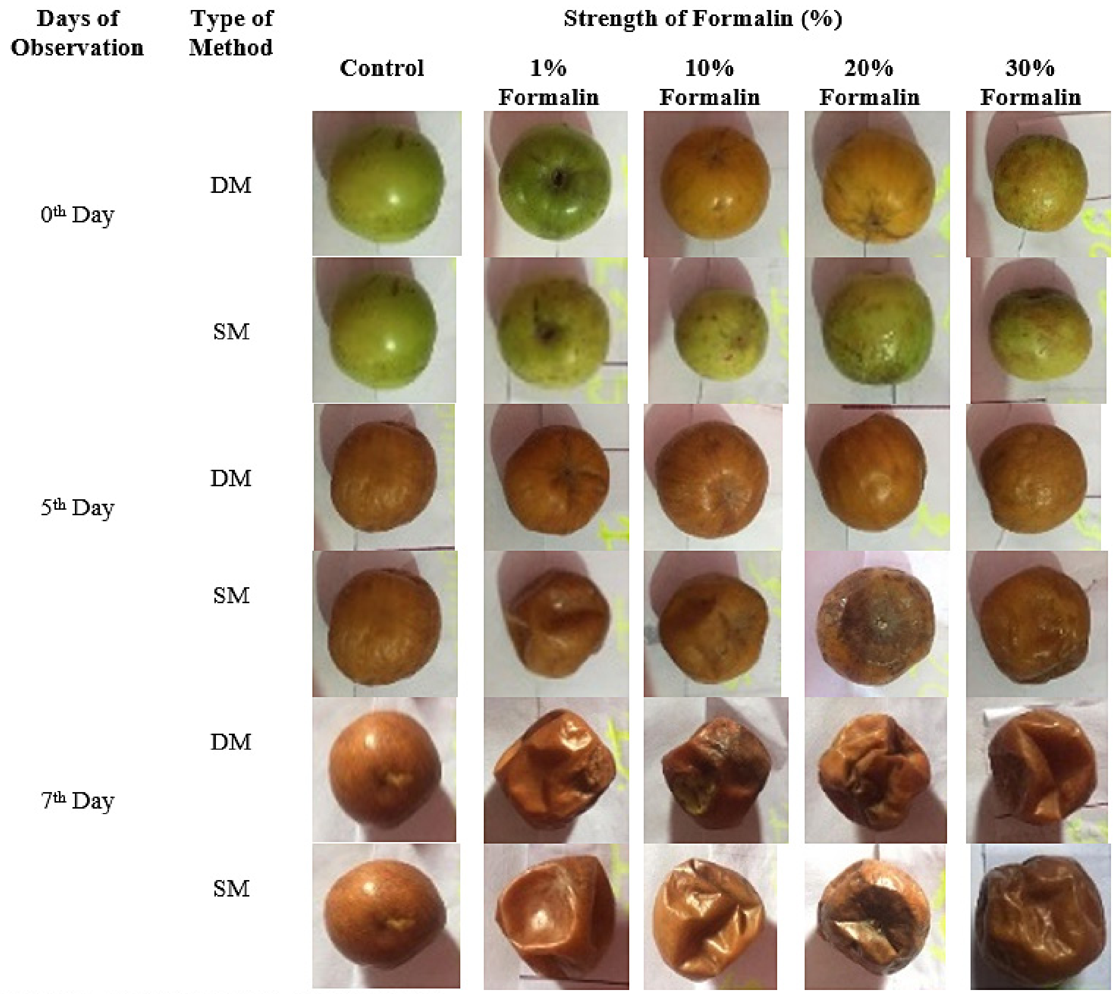
Note: DM = Dipping Method, SM = Spraying Method, NC = Not Changed

Table 6: Changes in physical parameters of formalin-treated green papaya

Formalin Solution Strength	Formalin Treatment Method	Observation Parameters	Observation Period (Days)					Acceptance Period (Days)
			0	1	3	5	7	
Control (0%)	-	Color	Dark Green	NC	Green	Green	Blackish Green	4
		Texture	Hard	NC	Slightly Soft	Soft	Very Soft	4
		Flavor	Fresh and Strong	NC	Strong	Offenssive	Offensive	4
1%	DM	Color	Dark Green	NC	Green	Green	Blackish Green	3
		Texture	Hard	NC	Slightly Soft	Slightly Soft	Soft	3
		Flavor	Fresh and Strong	NC	Not Offensive	Offensive	Offensive	3
	SM	Color	Dark Green	NC	NC	Green	Blackish Green	3
		Texture	Hard	NC	NC	Slightly Soft	Soft	3
		Flavor	Fresh and Strong	NC	Not Offensive	Offensive	Offensive	3
10%	DM	Color	Dark Green	NC	Green	Blackish Green	Blackish Green	2
		Texture	Hard	NC	Slightly Soft	Slightly Soft	Soft	2
		Flavor	Fresh and Strong	NC	Offensive	Offensive	Offensive	2
	SM	Color	Green	NC	Blackish Green	Blackish Green	Blackish Green	2
		Texture	Hard	NC	NC	Slightly Soft	Slightly Soft	2
		Flavor	Fresh and Strong	NC	Offensive	Offensive	Offensive	2
20%	DM	Color	Dark Green	NC	NC	Blackish Green	Blackish Green	2
		Texture	Hard	NC	Slightly Soft	Slightly Soft	Soft	2
		Flavor	Fresh and Strong	NC	Offensive	Offensive	Offensive	2

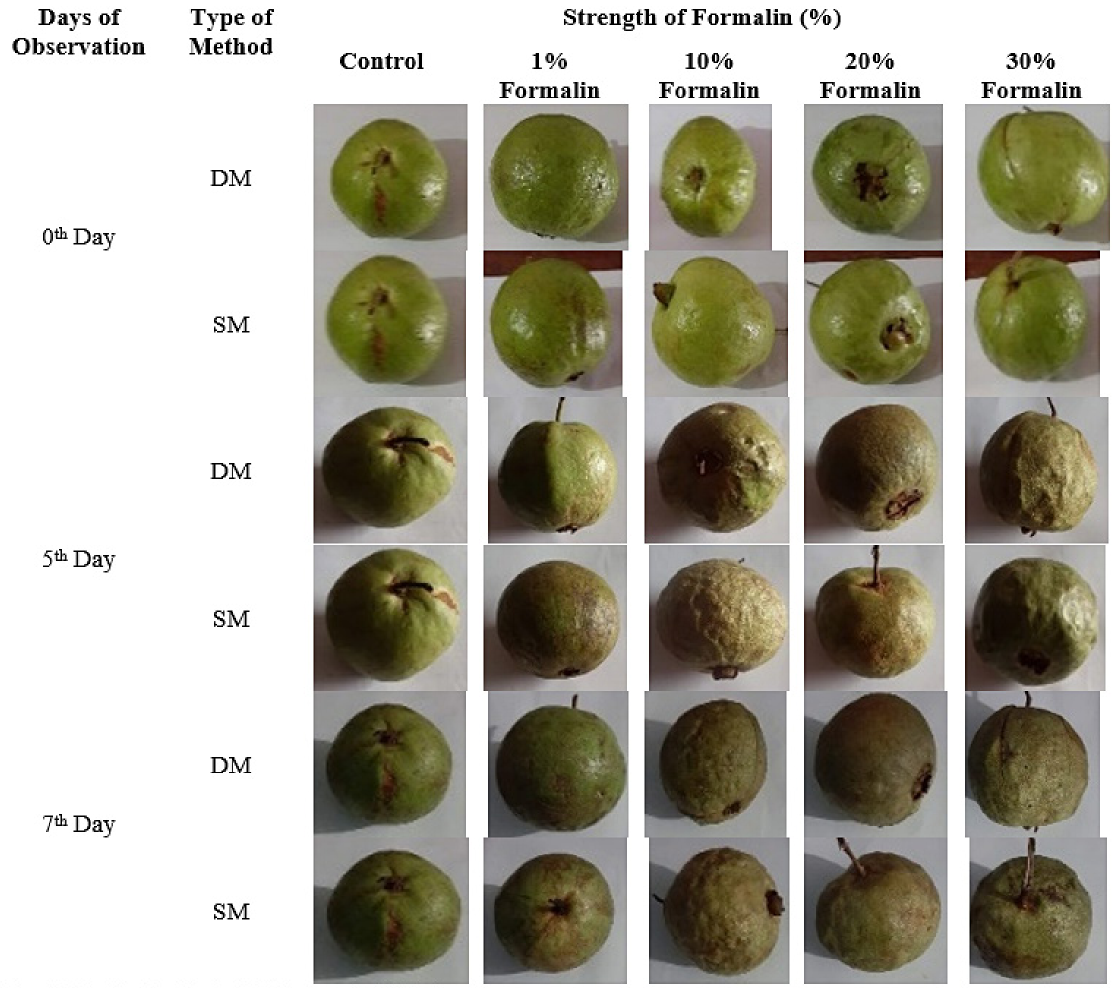
	SM	Color	Dark Green	NC	Green	Blackish Green	Blackish Green	2
		Texture	Hard	NC	NC	Slightly Soft	Soft	2
		Flavor	Fresh and Strong	NC	Offensive	Offensive	Offensive	2
30%	DM	Color	Green	NC	Blackish Green	Blackish Green	Blackish Green	2
		Texture	Hard	NC	NC	Slightly Soft	Soft	2
		Flavor	Fresh and Strong	NC	Offensive	Offensive	Offensive	2
	SM	Color	Dark Green	NC	Green	Blackish Green	Blackish Green	2
		Texture	Hard	NC	Slightly Soft	Soft	Soft	2
		Flavor	Fresh and Strong	NC	Offensive	Offensive	Offensive	2

Note: DM = Dipping Method, SM = Spraying Method, NC = Not Changed



Note: DM = Dipping Method, SM = Spraying Method

Fig. 1: Effect of Formalin on Postharvest Quality of Plum



Note: DM = Dipping Method, SM = Spraying Method

Fig. 2: Effect of Formalin on Postharvest Quality of Guava

Effect of Formalin on Weight Loss of the Treated Fruits and Vegetables

The total weight loss of treated (both dipping and spraying method) fruits and vegetables during the storage period at 25 ± 2°C (room temperature) is shown in Figure 3. Formalin-treated fruits and vegetables lost their weight irregularly during the storage period, and no trend was observed in weight loss among the samples. Throughout the storage period, variations in weight loss in the application of different concentrations among samples were seen for both methods of treatment (dipping and spraying). In the case of formalin-treated samples, the weight loss trend was the same in different concentrations. But the weight loss was highest for 20% formalin-treated plum and lowest at 1% concentration in dipping mode. The minimum weight loss was found for control guava. The untreated samples' weight loss was stable, indicating their freshness, while the treated samples' weight loss fluctuated as a result of internal chemical reactions and the end of respiration. However, fruits and vegetables lost weight as a result of water loss, microbial degradation, and storage room conditions like humidity and temperature.[17] However, several researches revealed the reverse consequence when growth hormone or chemical coatings were used to extend shelf life.[18] Previous studies found that the weight loss of formalin-treated mangoes was static up to the third day and the trends of weight loss dropped to a certain level on the fifth day and suddenly raised on the eighth day. The rate of weight loss in samples dipped in formalin was decreased with increasing the concentration of formalin.[9] This finding is consistence with the present study.

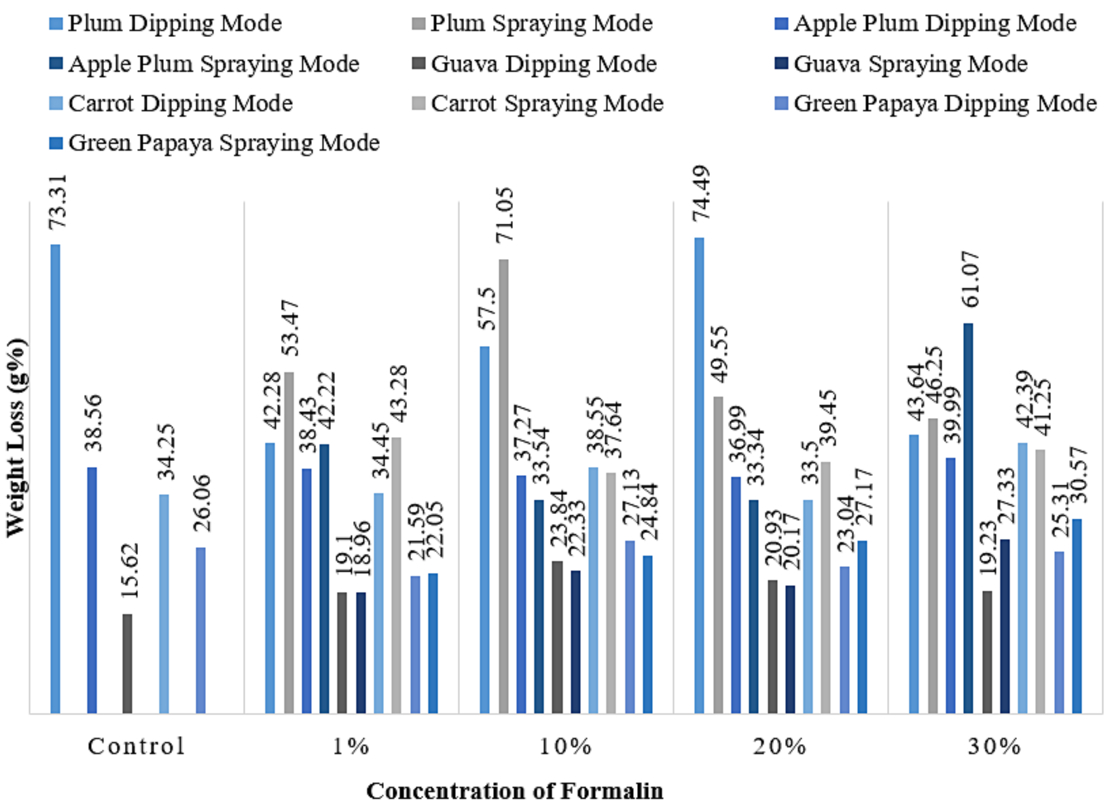


Fig. 3: Effect of formalin on the weight of the treated fruits and vegetables on different days

Shelf Life of Formalin Treated Fruits and Vegetables

In the cases of plum, guava, and carrot, the combined impact of formalin treatments (dipping and spraying) with various concentrations on the shelf life of fruits and vegetables was highly prominent (Figure 4 and Figure 5). Guava in the control treatment was shown to have the highest shelf life (5 days). Additionally, after being treated with 10%, 20%, and 30% formalin solution apple plum and green papaya showed the lowest shelf life (2 days) in both methods. The formalin treatments accelerated the fruits and vegetables softening by increasing the rate of starch and pectin degradation. Formalin only works on protein to increase shelf life, but on fruits that mostly contain carbohydrates formalin does not influence increasing their shelf life. Rather, it has a negative impact on their shelf life.[16] Mangoes, mushrooms, and litchis were dipped in 0%, 1%, 5%, and 10% formalin solution and stored for 7 days in a previous study. The results showed that no significant increase in shelf life was observed for mangoes and litchis. Though, formalin-treated mushrooms showed extended shelf life than control mushrooms.[16]

Proximate Analysis

After comparing the physical characteristics of control samples with formalin-treated samples, we found that 30% of formalin-treated samples had undergone severe damage and can not use for further examination. Then we choose to use the 20% formalin-treated samples from both treatment methods. Because these samples might be more capable to indicate any nutritional losses in comparison to controls, whereas two other samples that were treated with 1% and 10% concentrations would not more capable.

Moisture Content

Proximate analysis results revealed that significant changes in moisture content were observed in the formalin-treated apple plum and carrot samples compared to the control sample (Table 7). Observation of the present study showed a downward trend in moisture content. The lowest moisture content reduction was found in green papaya (7.72% in the control and 7.62% in the treated sample) and the highest reduction in carrots (15.46% in the control and 10.76% in the treated sample). The difference in composition especially moisture content was observed in a previous study in formalin-added fruits and vegetables samples compared to non-added samples.[19]

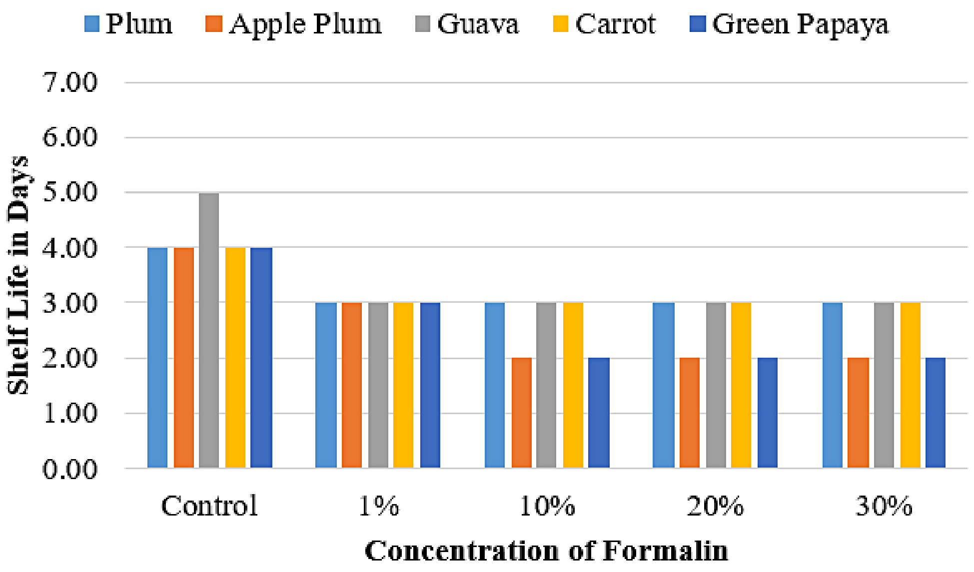


Fig. 4: Shelf life of formalin-treated fruits and vegetables by dipping in different concentrations of formalin solution.

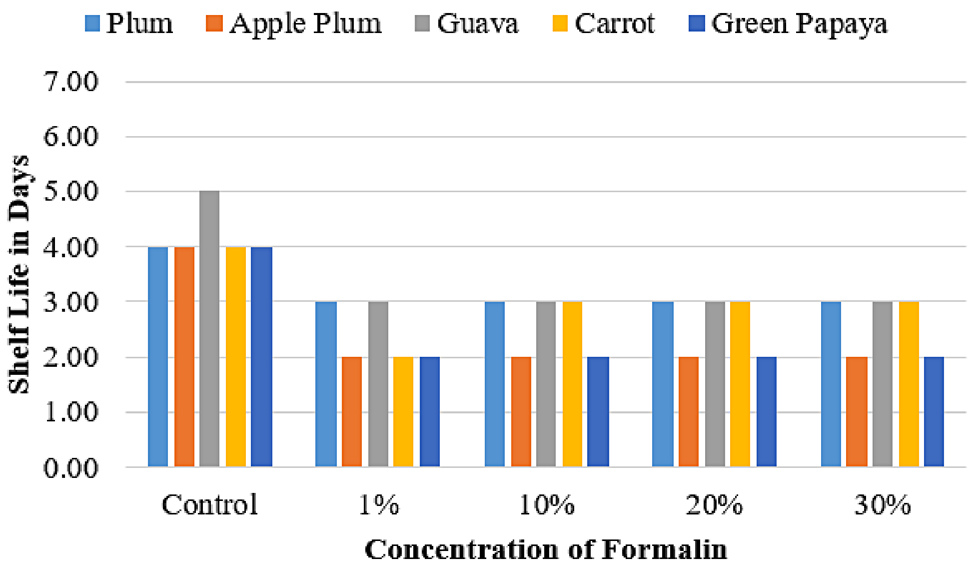


Fig. 5: Shelf life of formalin-treated fruits and vegetables by spraying with different concentrations of formalin solution

Table 7: Nutritive properties of control and formalin-treated fruits and vegetables

Nutritive properties	Fruits and Vegetables Samples	Control (%)	20% Formalin Treated samples (%)
Moisture content	Plum	14.01 ± 0.54[a]	11.51 ± 0.30[a]
	Apple Plum	14.79 ± 0.88[a]	11.37 ± 0.13[b]
	Guava	15.79 ± 0.58[a]	14.33 ± 0.88[a]
	Carrot	15.46 ± 0.59[a]	10.76 ± 0.71[b]
	Green Papaya	7.72 ± 0.04[a]	7.62 ± 0.08[a]
Ash Content	Plum	0.56 ± 0.07[a]	0.35 ± 0.01[a]
	Apple Plum	0.65 ± 0.03[a]	0.37 ± 0.0007[a]
	Guava	0.45 ± 0.03[a]	0.33 ± 0.035[a]
	Carrot	0.56 ± 0.08[a]	0.35 ± 0.02[a]
	Green Papaya	0.8 ± 0.007[a]	0.56 ± 0.14[b]
Carbohydrate Content	Plum	11.00 ± 0.707[a]	2.81 ± 0.265[a]
	Apple Plum	18.00 ± 0.707[a]	3.25 ± 0.707[b]
	Guava	16.00 ± 0.707[a]	2.75 ± 0.177[b]
	Carrot	15.00 ± 0.707[a]	1.44 ± 0.08[b]
	Green Papaya	10.00 ± 0.707[a]	1.44 ± 0.08[b]
Protein Content	Plum	0.75 ± 0.009[a]	0.62 ± 0.047[a]
	Apple Plum	0.75 ± 0.002[a]	0.45 ± 0.001[b]
	Guava	7.06 ± 0.16[a]	3.79 ± 0.218[b]
	Carrot	0.70 ± 0.073[a]	0.61 ± 0.052[a]
	Green Papaya	0.77 ± 0.06[a]	0.67 ± 0.019[a]
Fat Content	Plum	0.79 ± 0.007[a]	0.55 ± 0.138[a]
	Apple Plum	0.75 ± 0.047[a]	0.59 ± 0.01[a]
	Guava	0.99 ± 0.055[a]	0.65 ± 0.139[b]
	Carrot	0.39 ± 0.022[a]	0.32 ± 0.016[a]
	Green Papaya	0.42 ± 0,094[a]	0.37 ± 0.07[a]

Note: Means in the same row with the same superscript are not significantly different at P<0.05. Moisture, Ash, and Carbohydrate percentage are presented in wet basis. Protein and Fat percentages presented in dry basis.

Ash Content

Results indicated that ash content was reduced in formalin-treated fruits and vegetables compared to the respective control (Table 7). In the case of green papaya significant changes (P<0.05) in ash content were observed in the formalin-treated samples. The highest reduction in ash content was found in green papaya (0.8% in the control and 0.56% in the treated sample) and the lowest was observed in guava (0.45% in the control and 0.33% in the treated sample). Most of the inorganic compounds or minerals are present in ash, which may decrease in storage conditions. The mushroom was treated at 5% formaldehyde concentration and found a 0.29% decrease in ash content.[20]

Carbohydrate Content

Carbohydrate content was reduced in almost all treated fruits and vegetables samples (Table 7). A significant reduction (P<0.05) trend was observed in carbohydrate content after being treated with formalin. The highest reduction in carbohydrate content was found in apple plum (18.00% in control and 3.25% in the treated sample) while plum showed the lowest decrease in the amount of carbohydrate content (11.00% in control and 2.81% in the treated sample). Fruits and vegetables contained carbohydrates which were stored as starch in fruits and vegetables pulps. After maturation, different enzymes are responsible for ripening such as amylase, cellulose, and invertasedegraded starch such as glucose, maltose, and sucrose. After treatment with formalin selected enzymes activity was decreased, and may reduce the carbohydrate content of fruits and vegetables.[21] Besides, formaldehyde is a well-known cross-linking agent that affects the starch degradation enzyme of fruits and vegetables which reduces carbohydrate content.[22]

Crude Protein Content

Guava showed the highest protein content loss (7.06% in the control and 3.79% in the treated sample), while carrots showed the lowest amount of protein content loss (0.70% in the control and 0.61% in the treated sample). In the case of apple plum and guava, there were significant (P<0.05) reductive changes in protein content were observed in the formalin-treated samples than in the control (Table 7). Formaldehyde is a well-known cross-linking agent that can inactivate, stabilize, or immobilize proteins, make methyl-bridge, and reduce the active surface of the amino acid linkage.[21] Though fruits and vegetables have a naturally lower amount of protein but formalin has effects on their protein.[23] Mango contains some amount of protein and normal mango flesh contains 6.26% of protein and after treatment with formalin, the flesh retains 5.28% of protein.[24]

Fat Content

Similar decreased trends were also seen in the fat content after being treated with formalin. Guava showed the highest fat content loss (0.99% in the control and 0.65% in the treated sample), while green papaya showed the lowest amount of fat content (0.42% in the control and 0.37% in the treated sample) loss (Table 7). Significant change (P<0.05) in fat content was observed in the guava sample after formalin treatment.

pH Content

At 25°C, the difference in pulp pH between the control plum (3.69) and the formalin-treated plum (3.27) was the highest, and the difference between the control green papaya (5.83) and the formalin-treated green papaya (5.80) was lowest. No significant differences in the pulp pH content were seen as a result of formalin treatment (Table 8). The pH has an impact on microbial attacks and shelf life.[25]

Table 8: pH and Vitamin C content of control and formalin-treated fruits and vegetables

	Fruits and Vegetables Samples	Control	20% Formalin Treated Samples
pH Content	Plum	3.69 ± 0.064^{a}	3.27 ± 0.08^{a}
	Apple Plum	4.44 ± 0.11^{a}	4.34 ± 0.06^{a}
	Guava	4.34 ± 0.035^{a}	4.17 ± 0.01^{a}
	Carrot	6.68 ± 0.035^{a}	6.46 ± 0.13^{a}
	Green Papaya	5.83 ± 0.081^{a}	5.8 ± 0.035^{a}
Vitamin C content (mg/100g)	Plum	5.61 ± 0.28^{a}	4.23 ± 0.601^{a}
	Apple Plum	6.56 ± 0.0007^{a}	2.73 ± 0.025^{b}
	Guava	63.97 ± 0.198^{a}	22.32 ± 0.86^{b}
	Carrot	5.51 ± 0.25^{a}	1.98 ± 0.035^{b}
	Green Papaya	6.44 ± 0.25^{a}	4.52 ± 0.25^{a}

Note: Means in the same row with the same superscript are not significantly different at P<0.05.

Vitamin C Content

Results showed that Vitamin C content was dramatically affected by the formalin treatments (Table 8). In the case of apple plum, guava, and carrot, significant (P<0.05) loss in vitamin C content was observed in the formalin-treated samples compared to the control. The highest loss of vitamin C content occurred in guava while plum showed the lowest amount of vitamin C content loss. Adulterants had a significant effect on ascorbic acid and vitamin

C content decreased gradually during storage and the addition of different chemical adulterants.[26] The decrease in vitamin C content with storage duration was attributed to the oxidation of ascorbic acid into dehydro-ascorbic acid by the enzyme ascorbic acid oxidase.[27]

Conclusion

The study results revealed that no noticeable benefits were observed in different concentrations (1%, 10%, 20%, and 30%) and methods of application (dipping and spraying) of formalin treatment on samples of plum, apple plum, guava, carrot, and green papaya over control in terms of physical characteristics and shelf life during storage. Moreover, treated fruits and vegetables samples with higher concentrations of formalin went to faster deterioration in physical changes (color, texture, flavor, etc.), compared to treat with lower concentrations, and the almost same pattern of physical changes was observed in dipped and sprayed samples. The alterations in skin color clearly showed the sign of deterioration of treated samples during the period of storage. The color of fruits and vegetables deteriorated more quickly with the higher formalin concentration in the solution compared to the lower concentration. There was no significant change in weight loss between the treated and untreated fruits and vegetables. Formalin-treated fruits and vegetables lost their weight irregularly during the storage period, and no trend was observed in weight loss among the samples. Therefore, it is determined that formalin has no impact on weight loss. Apple plum and green papaya showed the lowest shelf life in both treatment methods whereas plum and guava showed their shelf life at 3 days. Generally, formalin works on protein content, so for fruits and vegetables rich in carbohydrates, formaldehyde has very negligible influence in extending their shelf life whereas it works negatively on their shelf life. Nutritional composition analyses revealed that a significant reduction ($P<0.05$) trend on some nutritional parameters (carbohydrate, protein, fat, vitamin C) was observed in formalin-treated apple plum and guava when compared with the control. No significant differences in the pulp pH content were seen as a result of formalin treatment in fruits and vegetables.

From the overall results of the present experiment, it is summarized that formalin had no positive effect on enhancing the postharvest quality of selected fruits and vegetables at any concentration and in the method of application. These results run counter to the general belief of people that formalin is used to enhance the shelf life of fruits and vegetables. In conclusion, it is anticipated that the findings of this study will increase the trust of growers, traders, and finally consumers of fruits and vegetables against unfounded rumors of adulterating plum, apple plum, guava, carrot, and green papaya with formalin to increase shelf life and other quality.

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Conflict of Interest

The authors do not have any conflict of interest.

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