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# DEVELOPMENT OF ZINC FORTIFIED CHITOSAN AND ALGINATE BASED COATINGS FOR APRICOT

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In present investigation, apricots from locally grown 'Sufeda' variety were treated with edible coatings; chitosan and alginate (1 and 2%, respectively) along with zinc salts fortification i.e., zinc sulfate and zinc chloride (30 and 50 ppm, respectively). The zinc fortified chitosan coated apricots showed better control for weight and moisture loss, total soluble solids contents, pH and acidity as compared to alginate based coatings. The edible coated zinc fortified apricots were affected significantly during storage as exhibited by their physico-chemical analyses. Among different treatments, the maximum value of weight loss, pH, titratable acidity, moisture loss was observed in $T_0$ (control) as 49.03±3.51g, 4.76±0.39, 0.27±0.02% malic acid and 21.48±1.88g, respectively, whilst the minimum in $T_{12}$ (apricot containing 2% chitosan coating with 50 ppm $ZnSO_4$) by 55.05±2.53g, 4.18±0.31, 0.27±0.02 % malic acid and 8.27±0.74g, accordingly. It is apparent from results amongst treatments, the minimum value of total soluble solids was recorded in $T_0$ (11.95±0.56$^o$Brix) while it was on the higher side in $T_{12}$ (13.39±0.64$^o$Brix). Overall results revealed that edible coatings could be an effective approach to preserve and improve the physico-chemical qualities of apricot.
**Keywords:** Apricot, zinc fortification, edible coatings, chitosan, alginate, fruit preservation

## INTRODUCTION

Apricot (*Prunus armeniaca*) is a perishable fruit with high sensory and nutritional profile. It may be eaten as fresh, pitted and dried, frozen or canned. In Pakistan, apricot is in abundance with total annual production about 0.325 million tons, mainly cultivated in Chitral, Gilgit and Baltistan (Ali *et al*., 2011). More than 60 varieties of apricot are grown and graded according to their sugar content including sufeda, karfochuli, sharippa, halmanhawalappa, yarqand, marghulam, stachu, badami, karthusa, castle bright and shatrakarfu (Lou *et al.,* 2011).
Edible coating is one of the economical methods of preservation that provides value addition to the apricot. These are biodegradable and environment friendly films as well as coatings innocuous for the health. Accordingly, fruits especially apricots are frequently treated with edible coatings like chitosan, alginate, casinate, soy and whey proteins due to their improved antimicrobial activity (Mitrakas *et al*., 2008). In this perspective, edible coating is one of the promising techniques of preservation with high market potential and acceptability. It involves an intact transparent edible film that acts as a barrier to oxygen absorbency and solute movement, used as host for additives in preserving the properties of product and overall appearance (Falguera *et al.,* 2011). Owing to the consumer's demand for safe and wholesome food, biofilms have received immense attention of the researchers. To improve the overall appearance and retard senescence, edible coatings are applied directly on the food surface by dipping, spraying or brushing to create a modified atmosphere with a range of materials. It has been observed that edible coatings extend the shelf life of fruits through prevention of gas, water and solutes migration using food grade emulsifying and wetting agents. These coatings have attained wide recognition as being environment friendly, non-toxic, biodegradable and relatively safe for food applications (Rojas-Grau *et al*., 2009).
Development of novel coatings with improved functionality and performance for fresh and minimally processed fruits is one of the major challenges being faced by the fruit processing industry. Edible coatings may act good oxygen and lipid barriers at low to intermediate relative humidity as the polymers can effectively make hydrogen bonds. An edible coating must have good sensory profile, acceptable color, flavor, taste and texture with shiny look. Edible coatings are generally biopolymers of proteins and polysaccharides like soy, whey proteins, starch, chitosan and alginate (Valero *et al*., 2013). Biopolymers are usually hydrophilic thereby act as a good barrier against hydrophobic compounds like lipids, oxygen and certain flavors. The commodities with edible coating lose water slowly that have led its application in fruits like apple, mango strawberry, apricot, melon etc. (Dhall, 2013). The objectives of the present study were to develop and optimize biodegradable edible coatings and to assess the storage behavior, stability and retention of zinc fortificants in edible coated apricots.

## MATERIALS AND METHODS

***Procurement of raw materials*****:** Selection of fresh apricots was made on the basis of uniformity in size, shape, color and absence of physical damage.

***Development of fortified edible coatings*****:** Zinc fortified carbohydrate based coatings (chitosan and alginate @ 1 and 2% each) were developed using various levels of zinc sulfate ($ZnSO_4$) and zinc chloride ($ZnCl_2$) as fortificants mentioned in Table 1.

**Table 1. Study plan for the development of zinc fortified edible coatings**

| Coating Type | Fortificant | Treat. | Coating (%) | Fortificant level (ppm) |
|---|---|---|---|---|
| Control | - | $T_0$ | - | - |
| Alginate | $ZnSO_4$ | $T_1$ | 1 | 30 |
| | | $T_2$ | 1 | 50 |
| | | $T_3$ | 2 | 30 |
| | | $T_4$ | 2 | 50 |
| | $ZnCl_2$ | $T_5$ | 1 | 30 |
| | | $T_6$ | 1 | 50 |
| | | $T_7$ | 2 | 30 |
| | | $T_8$ | 2 | 50 |
| Chitosan | $ZnSO_4$ | $T_9$ | 1 | 30 |
| | | $T_{10}$ | 1 | 50 |
| | | $T_{11}$ | 2 | 30 |
| | | $T_{12}$ | 2 | 50 |
| | $ZnCl_2$ | $T_{13}$ | 1 | 30 |
| | | $T_{14}$ | 1 | 50 |
| | | $T_{15}$ | 2 | 30 |
| | | $T_{16}$ | 2 | 50 |

***Zinc fortified alginate based coatings*****:** Alginate based coatings were prepared by following the protocol of Rojas-Grau*et al.*(2008). The film forming solution was prepared by dissolving alginate powder (2 g) in 100 mL of distilled water and heated at 70 °C with continuous stirring until the clear solution was formed. Citric acid (1 g/100ml) was added followed by continuous stirring for 30 min to prevent enzymatic browning. Glycerol was added as plasticizer (1.5 g/100ml) in alginate solution. Film forming solution was emulsified with sunflower oil (0.025 g/100ml) followed by the addition of N-acetyl L-cysteine (1 g/100ml) and calcium chloride (2 g/100mL water) required for cross linking of carbohydrate polymers. The concentrations of ingredients used in these formulations are shown in Table 2. The fortificants were added as per study plan (Table 1).

***Zinc fortified chitosan based coatings*****:** Chitosan based coatings were prepared according to the procedure of Simoes*et al.* (2009). Coating formulation was prepared by dissolving chitosan (crab shell chitosan, Sigma Chemicals) in distilled water (100 mL) with the addition of glacial acetic acid (1 g) to dissolve chitosan (Table 3). To achieve complete dispersion, solution was heated at 25 °C with continuous stirring for 1 hr. Ascorbic acid (2 g/100ml) and citric acid (1 g/100ml) were added to prevent enzymatic browning followed by continuous stirring for 30 min. Glycerol was added as plasticizer at 1.5 g/100ml to reduce brittleness caused by extensive intermolecular bonding. Film forming solution was emulsified with sunflower oil (0.025 g/100ml) to improve the water vapor barrier properties. For addition of fortificants, Table 1 was followed.

**Table 2. Alginate based coatings formulation**

| Ingredients | Alginate based coating | |
|---|---|---|
| | 1% | 2% |
| Sodium alginate | 1.0 g | 2.0 g |
| N-acetyl L-cysteine | 1.0 g | 1.0 g |
| Calcium chloride | 2.0 g | 2.0 g |
| Glycerol | 1.5 g | 1.5 g |
| Citric acid | 1.0 g | 1.0 g |
| Sunflower oil | 0.025 g | 0.025 g |
| Distilled water | 100 Ml | 100 mL |
| Fortificants | As per study plan | |

**Table 3. Chitosan based coatings formulation**

| Ingredients | Alginate based coating | |
|---|---|---|
| | 1% | 2% |
| Chitosan | 1.0 g | 2.0 g |
| Acetic acid | 1.0 g. | 1.0 g |
| Ascorbic acid | 2.0 g | 2.0 g |
| Citric acid | 1.0 g | 1.0 g |
| Glycerol | 1.5 g | 1.5 g |
| Sunflower oil | 0.025 g | 0.025 g |
| Distilled water | 100 ml | 100 ml |
| Fortificants | As per study plan | |

***Application of edible coatings*****:** After the development of zinc fortified edible coatings *i.e.* alginate and chitosan with their two levels 1 and 2% containing fortificants*i.e.* $ZnSO_4$& $ZnCl_2$ @ 30 & 50 ppm of each were applied on different lots of apricots through dipping. Later, the coated apricots were allowed to dry for 15-20 min.

***Storage of treated apricots*****:** The treated apricots were placed in Controlled Climate Chamber at 4±1 °C temperature and 85±5% relative humidity for eight weeks.

**Physicochemical analyses:**

***Weight loss*****:** Weight loss of all treatments during the entire storage was determined by following the protocol of AOAC (2006).Weight loss was calculated by observing the initial and final weights.

Weigh loss = Initial weight – Final weight

***Moisture loss*****:** Moisture loss of varyingly treated apricots was recorded by adopting the method of AOAC (2006).

***Extraction of juice***: For juice extraction, 100 g fruit was blended in 200 mL distilled water followed by filtration to remove insoluble contents. The extracted juice was subjected to various tests like pH, titratable acidity and total soluble solids.

***pH***: The pH of all samples was determined using digital pH meter following the guidelines of AOAC (2006).

***Total soluble solids***: Total soluble solids were recorded by Refractometer (ABBE'S Refractometer, Bellingham Stanley, BS eclipse, UK, 45-03) according to standard procedure of AOAC (2006) on fortnightly basis up to two months. Purposely, a drop of juice was placed on refractometer and reading was noted. The results were expressed as °Brix.

***Titratable acidity***: The acidity of each sample was determined using digital Acidity Meter (QA supplies LLC, USA). Accordingly, 300 µLof juice was taken followed by the addition of 30 ml distilled water. The resultant solution was poured on electronic detector of the digital acidity meter and expressed as % acidity on citric acid basis.

***Statistical analysis***: The collected data were analyzed statistically through completely randomized design (CRD) using Cohort version 6.1 (Costat-2003). The level of significance (5%) was also determined (ANOVA) according to the guideline of Steel *et al*. (1997).

## RESULTS

### Physico-chemical analyses of zinc fortified edible coated apricots

Mean squares regarding weight loss, pH, titratable acidity and total soluble solids of zinc fortified edible coated apricots showed significant differences between treatments and storage duration. However their interaction was non-significant.Among different treatments means, maximum weight loss was reported in $T_0$ (control) 49.03±3.51g however, it was minimum in $T_{12}$ (apricot containing 2% chitosan coating with 50 ppm $ZnSO_4$) 55.05±2.53g. Similarly, $T_{16}$ (apricot containing 2% chitosan coating with 50 ppm $ZnCl_2$), $T_4$ (apricot containing 2% alginate coating with 50 ppm $ZnSO_4$) and $T_8$ (apricot containing 2% alginate coating with 50 ppm $ZnCl_2$) behaved statistically alike in this regards with 8.83%, 8.81% and 8.81% weight loss respectively (Table 4). As far as the effect of different storage duration is concerned, consistent decrease was observed in weight and it was 17.41% after day-60.

Likewise, the maximum value for pH was observed in $T_0$ as 4.76±0.39 though, the minimum in $T_{12}$, $T_{16}$, $T_4$ and $T_8$ as 4.18±0.31, 4.22±0.34, 4.25±0.32 and 4.27±0.24, respectively (Table 5). The pH significantly increased during storage that varied from 4.18±0.13 at beginning to 4.58±0.37 in the end of storage. Similarly amongst treatments, the maximum recorded titratable acidity was in $T_0$ (0.18±0.02) whilst the

**Table 4. Effect of treatments and storage on weight loss of zinc fortified edible coated apricots (g)**

| Days | Treatments | | | | | | | | | | | | | | | | | Means |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $T_0$ | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_7$ | $T_8$ | $T_9$ | $T_{10}$ | $T_{11}$ | $T_{12}$ | $T_{13}$ | $T_{14}$ | $T_{15}$ | $T_{16}$ | |
| **0** | 59.20 ±3.79 | 58.00 ±2.92 | 58.40 ±3.67 | 56.24 ±3.39 | 57.43 ±2.94 | 57.65 ±3.10 | 56.94 ±2.85 | 56.13 ±2.54 | 57.16 ±2.62 | 56.92 ±3.02 | 58.43 ±3.66 | 57.63 ±3.07 | 58.96 ±2.77 | 59.13 ±2.41 | 57.49 ±3.97 | 55.42 ±2.57 | 57.33 ±2.44 | 57.56± 3.42a |
| **15** | 52.40 ±3.46 | 54.44 ±3.23 | 55.09 ±3.19 | 54.55 ±2.69 | 55.23 ±3.13 | 54.95 ±2.78 | 53.66 ±3.21 | 54.36 ±2.41 | 55.17 ±2.52 | 54.15 ±2.65 | 55.20 ±3.56 | 54.65 ±3.21 | 57.06 ±2.91 | 55.63 ±3.35 | 54.35 ±3.00 | 52.62 ±2.37 | 55.27 ±3.61 | 54.63± 3.54b |
| **30** | 46.36 ±3.38 | 51.52 ±2.34 | 52.44 ±2.56 | 51.82 ±2.94 | 53.65 ±3.24 | 52.50 ±3.21 | 51.41 ±2.43 | 51.59 ±2.58 | 53.33 ±3.65 | 52.52 ±2.21 | 52.86 ±3.25 | 52.22 ±3.32 | 55.30 ±2.63 | 53.09 ±2.81 | 51.92 ±3.36 | 50.11 ±3.10 | 53.39 ±3.18 | 52.12± 3.45b |
| **45** | 44.03 ±2.75 | 49.25 ±2.61 | 49.92 ±3.08 | 47.78 ±3.09 | 51.16 ±3.13 | 49.22 ±2.64 | 48.61 ±2.95 | 48.94 ±2.99 | 51.78 ±3.79 | 49.37 ±2.74 | 49.18 ±2.95 | 49.55 ±2.88 | 53.14 ±2.46 | 50.84 ±3.06 | 49.27 ±2.99 | 47.14 ±3.46 | 51.55 ±3.40 | 49.45± 3.52c |
| **60** | 43.15 ±3.69 | 47.31 ±2.66 | 48.53 ±2.82 | 46.38 ±3.62 | 49.30 ±2.86 | 47.41 ±3.30 | 46.81 ±3.58 | 45.98 ±3.44 | 49.30 ±3.30 | 46.99 ±3.11 | 47.68 ±2.83 | 47.32 ±2.82 | 50.81 ±2.65 | 49.07 ±3.37 | 47.58 ±3.02 | 45.35 ±2.37 | 49.24 ±3.54 | 47.54± 3.39d |
| **Means** | 49.03 ±3.51 d | 52.10 ±2.78 bc | 52.88 ±3.32 bc | 51.35 ±3.37 c | 53.35 ±3.41 b | 52.35 ±3.29 bc | 51.49 ±3.0 c | 51.40 ±2.8 c | 53.35 ±3.18 b | 51.99 ±2.82 c | 52.67 ±3.27 bc | 52.28 ±3.21 bc | 55.05 ±2.53 a | 53.55 ±3.44 b | 52.12 ±3.16 bc | 50.13 ±3.18 cd | 53.36 ±3.16 b | |

Means sharing the same letter in a row are not significantly different
$T_0$: Control (without fortificant)
$T_1$: Apricot containing 1% alginate coating having 30 ppm $ZnSO_4$; $T_9$: Apricot containing 1% chitosan coating having 30 ppm $ZnSO_4$
$T_2$: Apricot containing 1% alginate coating having 50 ppm $ZnSO_4$; $T_{10}$: Apricot containing 1% chitosan coating having 50 ppm $ZnSO_4$
$T_3$: Apricot containing 2% alginate coating having 30 ppm $ZnSO_4$; $T_{11}$: Apricot containing 2% chitosan coating having 30 ppm $ZnSO_4$
$T_4$: Apricot containing 2% alginate coating having 50 ppm $ZnSO_4$; $T_{12}$: Apricot containing 2% chitosan coating having 50 ppm $ZnSO_4$
$T_5$: Apricot containing 1% alginate coating having 30 ppm $ZnCl_2$; $T_{13}$: Apricot containing 1% chitosan coating having 30 ppm $ZnCl_2$
$T_6$: Apricot containing 1% alginate coating having 50 ppm $ZnCl_2$; $T_{14}$: Apricot containing 1% chitosan coating having 50 ppm $ZnCl_2$
$T_7$: Apricot containing 2% alginate coating having 30 ppm $ZnCl_2$; $T_{15}$: Apricot containing 2% chitosan coating having 30 ppm $ZnCl_2$
$T_8$: Apricot containing 2% alginate coating having 50 ppm $ZnCl_2$; $T_{16}$: Apricot containing 2% chitosan coating having 50 ppm $ZnCl_2$

**Table 5. Effect of treatments and storage on pH of zinc fortified edible coated apricots**

| Days | $T_0$ | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_7$ | $T_8$ | $T_9$ | $T_{10}$ | $T_{11}$ | $T_{12}$ | $T_{13}$ | $T_{14}$ | $T_{15}$ | $T_{16}$ | Means |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 4.26±0.13 | 4.24±0.15 | 4.14±0.11 | 4.15±0.10 | 4.10±0.14 | 4.15±0.09 | 4.26±0.16 | 4.25±0.15 | 4.17±0.12 | 4.12±0.08 | 4.18±0.07 | 4.17±0.09 | 4.18±0.06 | 4.20±0.14 | 4.22±0.17 | 4.10±0.10 | 4.17±0.08 | 4.18±0.13c |
| 15 | 4.56±0.18 | 4.35±0.16 | 4.35±0.21 | 4.31±0.22 | 4.22±0.23 | 4.26±0.16 | 4.35±0.18 | 4.35±0.21 | 4.28±0.24 | 4.25±0.20 | 4.34±0.19 | 4.29±0.15 | 4.26±0.22 | 4.31±0.25 | 4.33±0.27 | 5.29±0.24 | 4.28±0.28 | 4.37±0.26b |
| 30 | 4.71±0.31 | 4.40±0.26 | 4.35±0.18 | 4.33±0.27 | 4.29±0.21 | 4.31±0.16 | 4.40±0.31 | 4.38±0.24 | 4.34±0.28 | 4.30±0.19 | 4.39±0.11 | 4.43±0.28 | 4.22±0.22 | 4.44±0.36 | 3.53±0.29 | 4.53±0.24 | 4.29±0.27 | 4.39±0.35b |
| 45 | 5.05±0.42 | 4.34±0.39 | 4.26±0.26 | 4.22±0.37 | 4.24±0.29 | 4.35±0.21 | 4.34±0.28 | 4.46±0.31 | 4.20±0.24 | 4.51±0.28 | 4.70±0.41 | 4.63±0.43 | 4.06±0.44 | 4.94±0.46 | 4.60±0.41 | 4.34±0.42 | 4.12±0.21 | 4.43±0.41a |
| 60 | 5.20±0.41 | 4.49±0.34 | 4.41±0.21 | 4.37±0.38 | 4.39±0.27 | 4.50±0.24 | 4.49±0.21 | 4.61±0.23 | 4.35±0.37 | 4.66±0.19 | 4.85±0.21 | 4.78±0.36 | 4.21±0.32 | 5.09±0.20 | 4.75±0.18 | 4.49±0.15 | 4.27±0.33 | 4.58±0.37a |
| Means | 4.76±0.39 a | 4.36±0.21 ab | 4.30±0.33 b | 4.28±0.21 b | 4.25±0.32 b | 4.31±0.36 ab | 4.37±0.24 ab | 4.41±0.23 ab | 4.27±0.24 b | 4.37±0.35 ab | 4.49±0.28 ab | 4.46±0.27 ab | 4.18±0.31 b | 4.59±0.37 ab | 4.48±0.22 ab | 4.55±0.21 ab | 4.22±0.34 b | |

Means sharing the same letter in a row are not significantly different

**Table 6. Effect of treatments and storage on acidity of zinc fortified edible coated apricots (% Malic acid)**

| Days | $T_0$ | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_7$ | $T_8$ | $T_9$ | $T_{10}$ | $T_{11}$ | $T_{12}$ | $T_{13}$ | $T_{14}$ | $T_{15}$ | $T_{16}$ | Means |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.24±0.03 | 0.26±0.02 | 0.29±0.03 | 0.28±0.01 | 0.29±0.03 | 0.26±0.02 | 0.22±0.01 | 0.27±0.02 | 0.29±0.03 | 0.23±0.01 | 0.29±0.03 | 0.28±0.02 | 0.32±0.03 | 0.27±0.01 | 0.26±0.01 | 0.27±0.02 | 0.34±0.03 | 0.27±0.02a |
| 15 | 0.21±0.02 | 0.23±0.01 | 0.26±0.02 | 0.25±0.01 | 0.26±0.02 | 0.23±0.02 | 0.19±0.01 | 0.24±0.02 | 0.26±0.03 | 0.20±0.01 | 0.26±0.03 | 0.25±0.02 | 0.28±0.03 | 0.24±0.02 | 0.23±0.01 | 0.24±0.01 | 0.31±0.02 | 0.24±0.01ab |
| 30 | 0.19±0.02 | 0.22±0.02 | 0.24±0.01 | 0.24±0.01 | 0.25±0.02 | 0.23±0.02 | 0.20±0.02 | 0.24±0.01 | 0.24±0.02 | 0.20±0.01 | 0.25±0.02 | 0.24±0.01 | 0.27±0.02 | 0.23±0.02 | 0.22±0.02 | 0.23±0.01 | 0.24±0.01 | 0.23±0.02ab |
| 45 | 0.15±0.01 | 0.19±0.02 | 0.21±0.02 | 0.21±0.02 | 0.22±0.01 | 0.20±0.01 | 0.17±0.02 | 0.21±0.02 | 0.21±0.02 | 0.17±0.01 | 0.22±0.02 | 0.21±0.01 | 0.24±0.02 | 0.20±0.01 | 0.19±0.02 | 0.20±0.01 | 0.21±0.01 | 0.20±0.02b |
| 60 | 0.12±0.01 | 0.18±0.02 | 0.18±0.01 | 0.17±0.02 | 0.23±0.02 | 0.19±0.01 | 0.19±0.01 | 0.18±0.02 | 0.19±0.01 | 0.17±0.02 | 0.23±0.01 | 0.16±0.02 | 0.22±0.01 | 0.20±0.02 | 0.21±0.01 | 0.19±0.02 | 0.18±0.02 | 0.19±0.01b |
| Means | 0.18±0.02 b | 0.22±0.02 ab | 0.23±0.02 ab | 0.23±0.01 ab | 0.25±0.02 a | 0.22±0.01 ab | 0.19±0.01 b | 0.23±0.02 ab | 0.24±0.02 ab | 0.19±0.02 b | 0.25±0.01 ab | 0.23±0.01 b | 0.27±0.02 a | 0.23±0.02 a | 0.22±0.01 ab | 0.23±0.01 ab | 0.26±0.02 a | |

Means sharing the same letter in a row are not significantly different

minimum 0.27±0.02, 0.26±0.02, 0.25±0.02 and 0.24±0.02 (% malic acid) in $T_{12}$, $T_{16}$, $T_4$ and $T_8$, respectively (Table 6). During storage, there was a momentous decline in titratable acidity that differed from 0.27±0.02 at start to 0.19±0.01 (% malic acid) at 60$^{th}$ day.

The results showed amongst treatments, the minimum value of total soluble solids was recorded in T0 (11.95±0.56) whilst, the maximum in T12 (13.39±0.64), T16 (12.98±0.46), T4 (13.94±0.32) and T8 (12.89±0.26 °Brix), respectively (Table 7). It is obvious from the means that there was a gradual increase in total soluble solids of edible coated fortified apricots; 12.24±0.41, 12.55±0.26, 12.72±0.46, 12.83±0.59 and 13.02±0.66 °Brix at 0, 15, 30, 45 and 60 day of storage.

Mean squares for moisture loss in edible coated zinc fortified apricots delineated significant variations with respect to treatments and storage. Furthermore, interaction between them was found non-significant. Moisture loss was directly affected by the applications of edible coatings/film. It is apparent from results the highest value of moisture loss was noticed in $T_0$ (control) 21.48±1.88g whilst, the lowest in $T_{12}$ (apricot containing 2% chitosan coating with 50 ppm $ZnSO_4$) trailed by $T_{16}$ (apricot containing 2% chitosan coating with 50 ppm $ZnCl_2$), $T_4$ (apricot containing 2% alginate coating with 50 ppm $ZnSO_4$) and $T_8$ (apricot containing 2% alginate coating with 50 ppm $ZnCl_2$) by 8.27±0.74, 8.67±0.62, 8.87±0.57 and 8.34±0.39g, respectively (Table 8). There was a gradual increase in moisture loss of edible coated apricots as the storage proceed that differed from 5.05±0.47 to 9.40±0.83, 14.05±0.78 and 17.39±1.57g at 15$^{th}$, 30$^{th}$, 45$^{th}$ and 60$^{th}$ day, respectively.

## DISCUSSION

The weight loss is primarily coupled with moisture evaporation and respiration through the outer covering of fruit. The rate at which water is evaporated depends on the water pressure gradient between the fruit tissue and surrounding environment. Chitosan coatings function as a barrier thereby restricting water transfer and protecting fruit

**Table 7. Effect of treatments and storage on total soluble solids of zinc fortified edible coated apricots (°Brix)**

| Days | Treatments | | | | | | | | | | | | | | | | | Means |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $T_0$ | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_7$ | $T_8$ | $T_9$ | $T_{10}$ | $T_{11}$ | $T_{12}$ | $T_{13}$ | $T_{14}$ | $T_{15}$ | $T_{16}$ | |
| 0 | 12.13 ±0.13 | 12.22 ±0.16 | 12.18 ±0.18 | 12.14 ±0.11 | 12.25 ±0.26 | 12.21 ±0.27 | 12.21 ±0.15 | 12.34 ±0.24 | 12.25 ±0.29 | 12.24 ±0.24 | 12.16 ±0.14 | 12.30 ±0.31 | 12.30 ±0.35 | 12.28 ±0.26 | 12.30 ±0.34 | 12.29 ±0.42 | 12.31 ±0.33 | 12.24± 0.41c |
| 15 | 12.15 ±0.23 | 12.35 ±0.35 | 12.31 ±0.38 | 12.57 ±0.27 | 12.49 ±0.38 | 12.47 ±0.29 | 12.66 ±0.29 | 12.41 ±0.28 | 12.74 ±0.32 | 12.56 ±0.27 | 12.61 ±0.22 | 12.47 ±0.17 | 12.87 ±0.36 | 12.49 ±0.23 | 12.56 ±0.25 | 12.66 ±0.13 | 12.90 ±0.38 | 12.55± 0.26b |
| 30 | 12.19 ±0.11 | 12.67 ±0.29 | 12.69 ±0.35 | 12.77 ±0.34 | 12.91 ±0.39 | 12.66 ±0.26 | 12.72 ±0.21 | 12.75 ±0.37 | 12.87 ±0.24 | 12.68 ±0.30 | 12.64 ±0.19 | 12.74 ±0.22 | 12.92 ±0.31 | 12.69 ±0.35 | 12.69 ±0.28 | 12.74 ±0.37 | 12.91 ±0.27 | 12.72± 0.46ab |
| 45 | 11.61 ±0.29 | 12.70 ±0.18 | 12.79 ±0.36 | 12.70 ±0.27 | 13.45 ±0.46 | 12.69 ±0.24 | 12.73 ±0.48 | 12.74 ±0.47 | 13.06 ±0.50 | 12.64 ±0.41 | 12.75 ±0.35 | 12.74 ±0.27 | 14.21 ±0.24 | 12.70 ±0.43 | 12.79 ±0.53 | 12.66 ±0.34 | 13.18 ±0.51 | 12.83± 0.59a |
| 60 | 11.68 ±0.45 | 12.64 ±0.37 | 12.62 ±0.53 | 12.70 ±0.50 | 13.59 ±0.29 | 12.65 ±0.31 | 12.87 ±0.47 | 13.22 ±0.39 | 13.55 ±0.47 | 13.80 ±0.45 | 12.37 ±0.31 | 13.04 ±0.58 | 14.66 ±0.84 | 12.60 ±0.26 | 12.68 ±0.55 | 13.10 ±0.58 | 13.60 ±0.40 | 13.02± 0.66a |
| Means | 11.95 ±0.56 c | 12.51 ±0.45 bc | 12.52 ±0.36 bc | 12.58 ±0.58 bc | 13.94 ±0.32 ab | 12.54 ±0.52 bc | 12.64 ±0.36 bc | 12.69 ±0.54 bc | 12.89 ±0.26 ab | 12.78 ±0.58 b | 12.51 ±0.43 bc | 12.66 ±0.55 bc | 13.39 ±0.64 a | 12.55 ±0.59 bc | 12.60 ±0.47 bc | 12.69 ±0.58 bc | 12.98 ±0.46 ab | |

Means sharing the same letter in a row are not significantly different

**Table 8. Effect of treatments and storage on moisture loss of zinc fortified edible coated apricots (%)**

| Days | Treatments | | | | | | | | | | | | | | | | | Means |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $T_0$ | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_7$ | $T_8$ | $T_9$ | $T_{10}$ | $T_{11}$ | $T_{12}$ | $T_{13}$ | $T_{14}$ | $T_{15}$ | $T_{16}$ | |
| 15 | 11.48 ±0.62 | 6.12 ±0.46 | 5.66 ±0.17 | 2.97 ±0.19 | 3.82 ±0.14 | 4.64 ±0.28 | 5.68 ±0.24 | 3.16 ±0.21 | 3.47 ±0.12 | 4.85 ±0.30 | 5.51 ±0.40 | 5.18 ±0.43 | 3.22 ±0.22 | 5.92 ±0.45 | 5.47 ±0.13 | 5.05 ±0.33 | 3.59 ±0.33 | 5.05 ±0.47d |
| 30 | 21.70 ±1.61 | 11.15 ±0.87 | 10.20 ±0.28 | 7.83 ±0.34 | 6.57 ±0.35 | 8.89 ±0.52 | 9.63 ±0.60 | 8.06 ±0.48 | 6.70 ±0.27 | 7.69 ±0.29 | 9.51 ±0.73 | 9.39 ±0.61 | 6.20 ±0.55 | 10.21 ±0.82 | 9.69 ±0.79 | 9.56 ±0.64 | 6.87 ±0.67 | 9.40 ±0.83c |
| 45 | 25.61 ±2.14 | 15.08 ±0.92 | 14.51 ±0.94 | 15.03 ±0.82 | 10.92 ±0.25 | 14.62 ±0.61 | 14.57 ±0.71 | 12.80 ±0.29 | 9.42 ±0.98 | 13.22 ±0.81 | 15.83 ±0.73 | 14.02 ±0.78 | 9.86 ±0.43 | 14.05 ±0.68 | 14.31 ±0.30 | 14.95 ±0.26 | 10.08 ±0.45 | 14.05 ±0.78b |
| 60 | 27.12 ±2.56 | 18.43 ±0.77 | 16.89 ±1.23 | 17.55 ±0.91 | 14.17 ±0.66 | 17.76 ±0.83 | 17.79 ±1.06 | 18.09 ±1.32 | 13.75 ±1.01 | 17.46 ±0.82 | 18.39 ±0.63 | 17.89 ±1.14 | 13.82 ±1.17 | 17.02 ±1.42 | 17.25 ±1.37 | 18.17 ±1.20 | 14.12 ±0.57 | 17.39 ±1.57a |
| Means | 21.48 ±1.88 a | 12.70 ±0.88 b | 11.82 ±0.75 bc | 10.85 ±0.90 c | 8.87 ±0.57 d | 11.48 ±0.92 bc | 11.92 ±0.47 bc | 10.53 ±0.52 c | 8.34 ±0.39 d | 10.81 ±0.58 c | 12.31 ±0.80 b | 11.62 ±0.98 bc | 8.27 ±0.74 d | 11.80 ±0.78 bc | 11.68 ±0.51 bc | 11.93 ±0.99 bc | 8.67 ±0.62 d | |

Means sharing the same letter in a row are not significantly different

from mechanical injuries, thus delaying dehydration (Ribeiro *et al.,* 2007).

The current results are in agreement with the earlier investigations of Han *et al.* (2004) who reported a significant decline in weight loss of strawberries treated with various coatings. They concluded that chitosan coatings are effective to preserve the nutrition and shelf life of strawberry especially in the form of chitosan+calcium & chitosan+vitamin E, as carriers of calcium (78.9-180%) and vitamin E (85%). They were of the view that coatings provide resistance to increase in pH during storage of apricots. Accordingly, chitosan coatings increase the shelf life up to 3 weeks & 6 months at 2 & -23°C by reducing weight loss, discoloration, alteration in pH & acidity and drip loss after thawing. Likewise, Ghasemnezhad *et al.* (2010) reported that coatings have a significant role in the oxygen permeability, moisture, pH and acidity retention over the storage and observed variability in pH from 3.2 to 3.5 whilst, titratable acidity form 2.5 to 2.7%. They also demonstrated that edible coatings are important for consistent behavior in TSS and their values were in the range of 8.5-10.5 °Brix. The instant results are also in harmony with Akin *et al.* (2008) that pH of apricot was in the range of 3.61-3.83 whereas, acidity 0.17-0.79 (% malic acid) and 0.62-2.5 (% citric) on dry weight basis.

Afterwards, Hussain *et al.* (2010) documented apricot total acidity as 1.44±0.11-2.83±0.11 g/100g on dry weight basis while Aubert *et al.* (2010) recorded the total titratable acidity of apricot 28.8-29.5 mEq/100g and TSS 9.7-10.6 °Brix. The results of instant investigations are in accordance with the findings of Ambrosio *et al.* (2013), explicated that edible coatings are promising tool for retaining the acidity of fruit and noted the value for this trait 15.12-18.66g malic acid/L. They also revealed that coatings have a positive role in maintaining TSS during storage and observed total soluble solids contents in the range of 13.57.15.98 °Brix. The titratable acidity is principally correlated to the concentration of organic acids found in the fruits. The decline in acidity during storage is probably due to the occurrence of metabolic changes in fruits or also because of the consumption of organic acid in respiratory process that is synchronized with the observation of Echeverria and Valich (1989).

The increase in pH of apricot during storage might be due to the semi-permeable chitosan film formed on the surface of the fruit that has customized the internal atmosphere, endogenous $O_2$ and $CO_2$ concentration of the fruit thus retarding ripening (Bai *et al.,* 1988).
One of the researchers groups, Ayranci and Tunc (1997) conducted trial on coated apricots with composition containing stearic acid and noticed lower water lossesmight be due to the hydrophobicity provided by the stearic acid.

***Conclusion***: Current study depicted that chitosan based coatings ($T_4$, $T_8$, $T_{12}$ and $T_{16}$) performed better than that of alginate types to good suspending, stabilizing, gel producing and film forming properties with minimum drop-off. Coatings developed from alginate exhibit poor water resistance because of their hydrophilic nature. Additionally, chitosan forms transparent film which enhances keeping quality and extends the storage life of apricots. Chitosan films are normally cohesive, compact and the coated surface has a smooth texture without pores. The chemical composition of chitosan and structure of their polymer affects film permeability. Another justification regarding better performance of chitosan based coatings is that their polymers bonded through hydrogen and other forces eventually develop strong crumb like structure which restrict moisture to evaporate from the surface of fruit. The ionic functional groups generate strong polymer chain interactions which limit chain motion. Cross-linking of polymers chain with ions lowers the permeability as well as transforms the pH and resultantly protects the fruit from dehydration. Conclusively, Chitosan and Alginate based edible coating can be a handy tool for zinc fortification of fruits like apricots as these are good carriers of zinc salts. Furthermore, zinc fortified chitosan and alginate based coatings also play an imperative role in enhancing the shelf life and keeping quality of fruits.

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