International Journal on Emerging Technologies 11(2): 554-559(2020)

ISSN No. (Print): 0975-8364
ISSN No. (Online): 2249-3255

Efficiency Evaluation of Cinnamon Essential Oil Loaded Nanoliposomal Coating for the Post-Harvest Management of Apple (*Malus domestica*)

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(Received 28 December 2019, Revised 25 February 2020, Accepted 27 February 2020)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Apple is a highly demanded fruit because of its nutritional value. However, its insubstantial tissue and sugar composition makes it highly putrescible. The focus of this research was to synthesize and characterize cinnamon essential oil loaded nanoliposomes as an edible coating material and test its feasibility and efficiency in storage life prolongation and sustaining quality characteristics of 'Red Delicious' apples. Preparation of nanoliposomes is complex in comparison to their macro sized counterparts in terms of ratios of individual components, method of preparation and quality. Nanoliposomes were prepared from suitable formulations of sunflower lecithin and different ratios of cinnamon essential oil and tocopherol acetate employing thin film hydration method. Nanoliposomes were characterized for their size, morphology and zeta potential. It was found that nanoliposomes exhibited uni-lamellar and spheroid shaped vesicles with an average size of 935.4 nm. The shrinkage index, physiological loss in weight, pH, total acidity, phenolic content, radical scavenging activity and total plate counts of the fruit samples were examined systematically to analyze fruit condition during 15 days at room temperature of the storage interim. Cinnamon essential oil loaded nanoliposomes were found to be significantly more efficient in sustaining lower change in pH (3.83±0.07), greater firmness (90.14±0.04 N), higher total phenolic content (14.23±0.04 mg GAE/g) and scavenging activity in between (14.38±0.06%) during storage. It was also observed that coated samples showed minimum shrinkage and weight loss in comparison with un-coated samples. Thus, nanoliposomes proved to be functional and beneficial for improving the storage life and sustaining quality characteristics of apples.

Keywords: Lecithin, nanoliposomes, perishable, shelf life, uni-lamellar, zeta potential.

Abbreviations: GRAS, generally regarded as safe; FDA, food and drug administration; CEO, cinnamon essential oil; SI, shrinkage index; PWL, physiological weight loss; TSS, total soluble solids; TA, titratable acidity; TPC, total phenolic content; RSA, radical scavenging activity.

I. INTRODUCTION

Apple is a climacteric fruit belonging to the family of flowering plants called Rosaceae. The climacteric nature of the fruit leads to a decline in quality after harvest due to ethylene production [1]. It has been reported that the estimated postharvest losses of apples range from 25-40% [2]. In the food industry, encapsulation for larger volumes is a low-cost operation when compared to other industries like cosmetics or pharmaceuticals. According to a study there are many types of applications of nano-encapsulation in the food industry due to its advantages of interacting with encapsulated particles [3]. Some of the advantages are increasing encapsulated item's stability by protecting it from chemical or enzymatical breakdown. Nano liposomes are a concentric bleeder structure that encloses an aqueous phase made of lipids. Membranes are generally composed of phospholipids. Conventional liposomes are made of safe and natural materials like egg yolk lecithin, soy, cholesterol etc. Lecithin obtained from natural sources are a combination of phospholipids (insoluble in acetone) and other trivial compounds like carbohydrates, triglycerides etc. Researchers are in search of alternatives to native lecithin as lecithin that are enzymatically hydrolyzed are proving to be profitable and technologically rewarding. Researchers worldwide have used soy lecithin based coatings for many years. Neethirajan and Jayas (2011) have reported that sunflower lecithin could be a prospective and promising alternative to conventional lecithin but it has not been widely used in the food industry [4]. Food coating with alternative, easily obtainable lecithins and their safety assessment when used in nano formulations is under explored. Apples are generally covered with a layer of natural wax, comprising of different ester compounds, which acts as a barrier from drying out and helps to prevent fungal infestation [5]. Other types of

supplement wax that are used, is Carnauba wax from a dessert plant called Candelia and the leaves of the Brazilian palm. Experiments by researchers have shown that plant-based essential oils and coatings can be used to prevent the growth of microorganisms, maintain shelf life, and prevent nutrient loss from foods. Antioxidant, anti-cholesterol and antimicrobial properties of cinnamon essential oil have been reported previously. In addition, cinnamon essential oil is generally regarded as safe (GRAS) as classified by the FDA (FDA 2014). This study focuses on the advances of food nanotechnology and its application in post-harvest management. The aim of this study was to establish a natural edible coating for apples comprising sunflower lecithin and cinnamon essential oil (CEO), using nano-liposome technology for the extended shelf life of apples and to assess the structural and physiochemical properties of the nanoliposome.

II. MATERIALS AND METHODS

The focus of the current research was to assess structural and physiochemical characterization and evaluate the efficacy of CEO loaded nanoliposome for post-harvest storage life prolongation of 'Red delicious' apples. The apple samples in the present investigation were categorized into 10 groups Concentration (C) and Dipping Time (T); C1T2, C1T4, C1T6, C2T2, C2T4, C2T6, C3T2, C3T4, C3T6 and control. (Concentration (C); C1 (1:1), C2 (1:2), C3 (2:1) – CEO: Tocopherol acetate respectively for the development of nanoliposomal solution and (T) the numbers indicate the dipping time in minutes).

***Procurement of Materials*:** Fresh un-coated apples of consistent maturity and size were purchased from a local market in Potheri, Tamil Nadu, India. Apples were washed, disinfected using 0.05% of sodium hypochlorite solution, and rinsed with distilled water and air dried. Food grade sunflower lecithin and tocopherol acetate were purchased from Urban platter, India. Cinnamon essential oil was purchased from Cyrus enterprises, India.

***Preparation and Characterization of CEO Loaded Nanoliposomes*:** Nanoliposomes were synthesized in accordance to the thin film hydration method of Alikhani (2015) employing slight modifications [6]. Nanoliposomes were synthesized from sunflower lecithin along with different ratios of cinnamon essential oil and tocopherol acetate (C1-1:1, C2-1:2 and C3-2:1). Sunflower lecithin (10 g) with different ratios of cinnamon essential oil and tocopherol acetate were dissolved in 50 mL absolute ethanol to form a lipid solution. The organic solvent was subjected to evaporation in a rotary evaporator (IKA, RV 10 Digital V, India), at 55-60℃. The obtained lipid film was dried in a desiccator 60℃ for 24 hours to remove any residual solvent traces. The solution was then rehydrated with 50 mL double distilled water. The nanoliposome dispersions were downsized and homogenized in probe Sonicator (Lark Innovative, India) for 10-15 minutes at 360W. The characterization obtained of the nanoliposomes was done using nano particle analyzer SZ-100, HORIBA scientific to analyze the zeta potential. The surface morphology of nanoliposomes was examined by using SEM (JSM-6360, Jeol).

***Application of Coating Material*:** Dipping technique was employed to coat the apples. Apples were selected into groups; nanoliposomal coating and control. Each treatment replicate had 5 apples. Apples were immersed in the nanoliposome solutions for 2, 4 and 6 minutes. Control samples were washed with distilled water. Samples were analyzed at a regular interval for a period of 15 days at room temperature [7].

***Shrinkage Index (SI)*:** Variations in width of fruit samples was recorded by using digital vernier calipers at constant intervals of storage period [8].

$$\text{Shrinkage Index (SI)} = \frac{(D_0 - D_1)}{D_0} \times 100 \quad (1)$$

where;

D_0 = Initial diameter

D_1 = Diameter at 3, 6, 9, 12 or 15-days interval after storage

***Physiological Weight Loss (PWL)*:** Variation in mass of the fruit samples was noted at constant interims throughout storage using a digital weighing scale. Weight loss was estimated by [9].

$$\text{Physiological Weight Loss (PWL)} = \frac{(P_0 - P_1)}{P_0} \times 100 \quad (2)$$

Where;

P_0 = Initial weight

P_1 = Weight at 3, 6, 9, 12 or 15-days interval after storage.

***Determination of pH*:** The fruit samples (10 g) were processed to obtain the juice. The pH values were noted after placing the pH probe in the sample [10].

***Titratable/Total Acidity (TA)*:** Titrant (0.1N NaOH) was added to the processed fruit juice sample (10 mL) in the presence of phenolphthalein indicator (1%) [11]. The findings were expressed as g/mL malic acid.

***Total Soluble Solids (TSS)*:** The fruit samples (10 g) were processed to obtain the juice. The total soluble solids (TSS) were measured using Fisher Hand Refractometer [12].

***Texture Analysis*:** TA-XT Plus texture analyzer was employed to assess the flesh firmness of the fruit samples. Skin decompression strength was evaluated in order to determine firmness of the fruit upon penetrating the probe (2 mm) at a depth of 5 mm [12].

***Total Phenolic Content*:** Gallic acid equivalence (GAE) method was followed to estimate phenolic content [13]. Sample (1 mL) was incubated for 30 minutes after adding equal amount (5 mL) of Folin's phenol solution and sodium carbonate. The spectrophotometer reading at 760 nm was recorded. The data was presented as mg GAE/ g (fruit sample).

***Antioxidant Activity*:** The degree of antioxidant activity retention of the fruit samples was analyzed by DPPH radical scavenging activity (RSA) assay [14]. DPPH was added to sample solution and incubated (30 minutes). The spectrophotometer reading at 517 nm was noted and findings were presented as percent RSA.

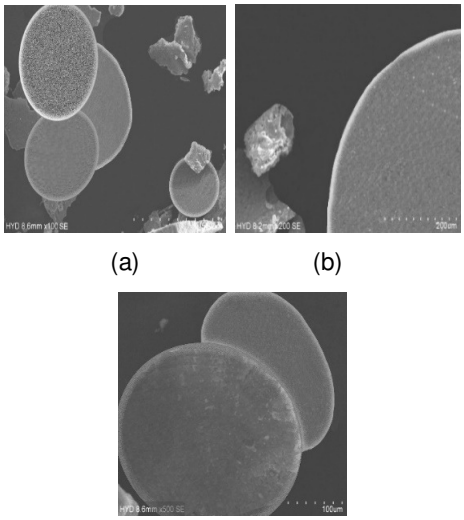
***Microbial Analysis*:** Fruit sample (10 mL) was used to make serial dilutions. The enumeration of different microbial groups was carried out using total plate count methodology and findings were denoted as log CFU/g [15].

***Statistical Analysis*:** Data acquired was analyzed by SPSS (19.0). The data was subjected to one-way ANOVA by Duncan's multiple range tests ($p \leq 0.05$) and

findings were depicted as mean ± standard deviation (SD).

III. RESULTS AND DISCUSSION

The SEM images of the nanoliposomes obtained from sunflower lecithin, CEO and tocopherol acetate are presented in the Fig. 1 (a-c) with different scale of magnification. The surface morphology of the synthesized nanoliposomes was found to be in spherical shapes and exhibited uni-lamellar structure [16]. There were also few traces of liposomal clusters observed, which might have been formed due to the aggregation of nanoliposomes, which might have been induced inadvertently by solvent evaporation during sample preparation [17].



(a) (b)

(c)

Fig. 1. SEM analysis of CEO loaded nanoliposomes in micro-graph scale (a) 500µm; (b) 200µm; (c) 100µm.

The size distribution analysis is one of the crucial criteria to examine the stability of the nanoliposomes. The average size was detected to be 935.4 nm and the corresponding zeta potential was -10mV, which corresponds to the incipient stability of the solutions [18].

***Shrinkage index (SI)*:** The findings related to percentage of shrinkage of fruit samples throughout storage are depicted in Table 1. All the coated samples had significantly lower SI as compared to control (17.88±0.2) on all the days of observation. It was observed that C3T6 (9.04±0.8) showed minimum shrinkage followed by C1T6 (9.89±0.6) and C3T4 (10.81±0.4).

***Physiological Weight Loss (PWL)*:** The variations in weight loss of coated and uncoated samples are denoted in Table 1. On comparison of the extent of PWL in fruit samples coated with nanoliposomal solution it was found that C3T6 (12.49±0.9) had lowest percentage of weight loss followed by C1T6 (13.05±0.2) and C2T6 (13.35±0.5). The restrained decrease in PWL can be traced to the efficacy of nanoliposomal coating acting as a semi-permeable barrier reducing respiration and water loss [19].

***pH Variation*:** A gradual rise in pH was recorded during storage interim (Table 2). Similar trend has been observed in mango fruit ripening [20].

Uncoated apples had greater pH (3.89±0.08) during storage due to the greater usage of organic acids. Amongst coated samples it was found that C3T6 (3.83±0.07) sustained lower pH change followed by C1T6 (3.84±0.04), and C3T4 (3.86±0.01). pH has been shown to have a controlled increase due to the nano-liposomal barrier reducing respiration, thereby slowing the maturing process.

***Titratable/Total Acidity (TA)*:** The total acidity of the fruit samples displayed a depleting trend during the course of storage period (Table 2). The highest TA was observed in C3T6 (0.16±0.04 g/mL) followed by C1T6 (0.15±0.07 g/mL), C3T4 (0.15±0.04 g/mL) and C2T6 (0.15±0.07 g/mL). Control showed minimum TA (0.13±0.02 g/mL). A parallel trend in TA has been studied in guava throughout maturation [21]. Nanoliposomal coating applied on apples may have led to restricted use of organic acids due to reduced respiration resulting in lowered acid depletion rates.

***Total Soluble Solids (TSS)*:** Significant increase was observed in TSS throughout the storage (Table 3). Highest TSS was found in control sample (12.76±0.04 °B). The lowest TSS was recorded on C3T6 (12.24±0.08°B) followed by C1T6 (12.32±0.04 °B) and C3T4 (12.38±0.09 °B). According to the study elevated TSS during fruit maturation is due an increase in starch hydrolysis. Nanoliposomal coating was found to have delayed this process by reducing internal respiration and metabolism [22].

***Texture Analysis*:** The flesh puncture strength of the fruit samples significantly reduced with storage (Table 3). The data indicated that the CEO loaded nanoliposomal coating significantly aided in keeping fruits firm, acting as a barrier to nutrient loss. The nanoliposomal coating maintained the maximum firmness of coated fruits until last day of storage. Highest firmness at end of storage was obtained in C3T6 (90.14±0.4 N) followed by C1T6 (89.26±0.4 N) and C2T6 (86.58±0.7 N). Control samples showed the minimum firmness (78.5±0.6 N).

***Total Phenolic Content (TPC)*:** A significant depletion in the phenolic content was noted during the course of storage (Table 4). The highest value was observed in C3T6 (14.23±0.04 mg GAE/g) succeeded by C3T4 (13.43±0.02 mg GAE/g), C1T6 (13.25±0.06 mg GAE/g) and C3T2 (13.07±0.05 mg GAE/g). Control samples showed relatively greater rate of reduction in phenolic content owing to higher metabolic activity [23].

Antioxidant Activity: There was significant reduction observed in antioxidant activity throughout storage (Table 4). C3T6 exhibited the maximum scavenging activity (14.38±0.6) followed by C1T6 (14.07±0.3), C3T4 (13.71±0.4) and C2T6 (13.69±0.7) at the end of storage interim. Control samples displayed minimum antioxidant activity (7.43±0.4). The nanoliposomal coating on fruit samples therefore scavenged the DPPH radicals by a greater degree in comparison to the control samples. The scavenging activity can also be attributed to the malic acid content in both coated and non-coated fruit samples, which shows gradual decline during storage [24].

***Microbial Analysis*:** Total microbial count showed a significant increase with storage (Table 5).

The highest number of colonies was observed in control (7.27±0.01 log CFU/g). The least microbial count was displayed by C3T6 (6.96±0.03 log CFU/g), C1T6 (7.00±0.02 log CFU/g), C3T4 (7.01±0.05 log CFU/g) and C3T2 (7.05±0.02 log CFU/g). The shielding effect of nanoliposomal barrier exploiting the antimicrobial effect of CEO has shown to decrease the proliferation of microbes [25].

Table 1: Effect of varying coating compositions on Shrinkage Index (SI) [%] and Physiological Weight Loss (PWL) [%].

Interval	3rd Day		6th Day		9th Day		12th Day		15th Day	
Coating	SI	PWL	SI	PWL	SI	PWL	SI	PWL	SI	PWL
Control	2.52±0.8^{e}	3.44±0.5^{g}	7.64±0.8^{h}	6.45±0.4^{f}	10.48±0.7^{f}	11.04±0.8^{g}	14.18±0.3^{h}	12.62±0.5^{e}	17.88±0.2^{i}	14.91±0.4^{g}
C1T2	1.13±0.8^{a}	3.14±0.3^{f}	4.26±0.7^{e}	6.15±0.3^{e}	5.41±0.2^{e}	10.72±0.3^{f}	9.12±0.8^{g}	12.58±0.3^{e}	15.12±0.7^{h}	14.30±0.4^{f}
C1T4	1.40±0.8^{b}	2.43±0.3^{c}	4.78±0.5^{f}	5.15±0.5^{c}	4.51±0.6^{c}	10.31±0.3^{e}	8.76±0.9^{f}	12.31±0.5^{d}	14.42±0.6^{g}	14.03±0.5^{e}
C1T6	1.39±0.5^{b}	2.00±0.5^{a}	3.08±0.5^{b}	4.30±0.4^{a}	4.23±0.4^{b}	9.32±0.4^{b}	5.93±0.6^{a}	11.33±0.7^{b}	9.89±0.6^{b}	13.05±0.2^{b}
C2T2	1.41±0.8^{b}	3.01±0.8^{e}	4.82±0.1^{f}	6.03±0.3^{e}	7.36±0.5^{h}	10.77±0.5^{f}	7.93±0.5^{e}	12.49±0.5^{e}	14.19±0.7^{f}	14.36±0.7^{f}
C2T4	1.69±0.5^{c}	2.58±0.5^{d}	5.07±0.3^{g}	5.17±0.8^{c}	6.20±0.3^{f}	10.06±0.5^{d}	7.89±0.3^{e}	12.22±0.7^{d}	13.26±0.3^{e}	13.80±0.8^{d}
C2T6	1.96±0.1^{d}	2.15±0.9^{b}	3.92±0.8^{d}	4.73±0.9^{b}	5.06±0.3^{d}	9.76±0.8^{c}	6.47±0.8^{c}	11.63±0.7^{c}	10.98±0.8^{c}	13.35±0.5^{c}
C3T2	1.70±0.5^{c}	2.58±0.5^{d}	4.51±0.8^{e}	5.89±0.5^{d}	7.07±0.7^{g}	10.63±0.5	9.05±0.1^{g}	12.21±0.6^{d}	11.91±0.5^{d}	14.22±0.4^{f}
C3T4	1.42±0.1^{b}	2.30±0.5^{c}	3.40±0.1^{c}	5.02±0.4^{c}	4.55±0.2^{c}	10.19±0.5^{d}	7.68±0.6^{d}	11.77±0.9^{c}	10.81±0.4^{c}	13.78±0.5^{d}
C3T6	1.13±0.5^{a}	2.15±0.9^{b}	2.82±0.8^{a}	4.30±0.9^{a}	3.95±0.3^{a}	9.04±0.2^{a}	6.21±0.8^{b}	11.05±0.2^{a}	9.04±0.8^{a}	12.49±0.9^{a}

The data is denoted as Mean ± S.D; $p \leq 0.05$, (n=5). Disparate superscripts represent significant difference among different groups in the column.

Table 2: Effect of varying coating compositions on pH and Titratable Acidity (TA) [g/mL].

Interval	3rd Day		6th Day		9th Day		12th Day		15th Day	
Coating	pH	TA	pH	TA	pH	TA	pH	TA	pH	TA
Control	3.67±0.04^{c}	0.24±0.07^{a}	3.73±0.04^{b}	0.22±0.04^{a}	3.80±0.04^{a}	0.19±0.04^{a}	3.85±0.04^{a}	0.17±0.01^{b}	3.89±0.08^{b}	0.13±0.02^{a}
C1T2	3.67±0.04^{c}	0.24±0.07^{a}	3.74±0.01^{d}	0.22±0.04^{a}	3.80±0.07^{a}	0.19±0.07^{a}	3.85±0.04^{a}	0.16±0.04^{a}	3.87±0.04^{b}	0.14±0.07^{b}
C1T4	3.67±0.04^{c}	0.25±0.01^{b}	3.73±0.04^{b}	0.22±0.04^{a}	3.79±0.04^{a}	0.19±0.04^{a}	3.84±0.04^{a}	0.16±0.04^{a}	3.86±0.04^{b}	0.14±0.04^{b}
C1T6	3.66±0.04^{b}	0.25±0.08^{b}	3.72±0.04^{a}	0.23±0.01^{b}	3.76±0.04^{a}	0.21±0.01^{c}	3.83±0.04^{a}	0.17±0.01^{b}	3.84±0.04^{a}	0.15±0.07^{c}
C2T2	3.67±0.04^{c}	0.25±0.01^{b}	3.73±0.04^{b}	0.22±0.04^{a}	3.78±0.04^{a}	0.19±0.01^{a}	3.85±0.04^{a}	0.16±0.04^{a}	3.87±0.01^{b}	0.14±0.09^{b}
C2T4	3.66±0.04^{b}	0.25±0.04^{b}	3.73±0.04^{b}	0.23±0.01^{b}	3.79±0.04^{a}	0.19±0.04^{a}	3.85±0.04^{a}	0.16±0.07^{a}	3.86±0.04^{b}	0.14±0.04^{b}
C2T6	3.66±0.04^{b}	0.25±0.01^{b}	3.72±0.04^{a}	0.22±0.04^{a}	3.77±0.04^{a}	0.20±0.04^{b}	3.84±0.04^{a}	0.17±0.00^{b}	3.88±0.04^{b}	0.15±0.07^{c}
C3T2	3.67±0.04^{c}	0.24±0.04^{a}	3.73±0.04^{a}	0.22±0.04^{a}	3.78±0.04^{a}	0.19±0.04^{a}	3.85±0.06^{a}	0.16±0.04^{a}	3.87±0.01^{b}	0.14±0.04^{b}
C3T4	3.66±0.04^{b}	0.25±0.04^{b}	3.72±0.04^{a}	0.23±0.01^{b}	3.77±0.02^{a}	0.21±0.00^{c}	3.83±0.04^{a}	0.17±0.04^{b}	3.86±0.01^{b}	0.15±0.04^{c}
C3T6	3.65±0.04^{a}	0.25±0.04^{b}	3.72±0.07^{a}	0.23±0.01^{b}	3.75±0.03^{a}	0.21±0.04^{c}	3.82±0.08^{a}	0.17±0.08^{b}	3.83±0.07^{a}	0.16±0.04^{d}

The data is denoted as Mean ± S.D; $p \leq 0.05$, (n=5). Disparate superscripts represent significant difference among different groups in the column.

Table 3: Effect of varying coating compositions on Total Soluble Solids (TSS) [ºB] and Texture (Firmness).

Interval	3rd Day		6th Day		9th Day		12th Day		15th Day	
Coating	TSS	Texture	TSS	Texture	TSS	Texture	TSS	Texture	TSS	Texture
Control	11.26±0.04^{b}	102.28±0.7^{a}	11.46±0.04^{b}	96.84±0.4^{b}	11.82±0.04^{c}	92.72±0.7^{b}	12.26±0.04^{b}	84.58±0.4^{a}	12.76±0.04^{d}	78.5±0.6^{a}
C1T2	11.22±0.04^{b}	102.26±0.4^{a}	11.42±0.04^{b}	96.32±0.3^{a}	11.82±0.04^{c}	92.3±0.6^{a}	12.16±0.04^{a}	84.7±0.6^{b}	12.48±0.04^{b}	79.78±0.7^{b}
C1T4	11.18±0.04^{a}	102.88±0.4^{c}	11.40±0.06^{b}	97.16±0.4^{c}	11.76±0.04^{b}	92.82±0.7^{c}	12.14±0.04^{a}	85.26±0.4^{c}	12.46±0.04^{b}	81.42±0.7^{d}
C1T6	11.12±0.04^{a}	105.24±0.4	11.34±0.04^{a}	100.04±0.4^{g}	11.66±0.04^{a}	95.04±0.3^{f}	12.02±0.04^{a}	91.42±0.4^{g}	12.32±0.04^{b}	89.26±0.4^{f}
C2T2	11.24±0.04^{b}	102.26±0.2^{a}	11.42±0.07^{b}	97.16±0.1^{c}	11.78±0.04^{b}	92.34±0.4^{a}	12.18±0.07^{a}	85.44±0.8^{d}	12.58±0.04^{c}	81.82±0.7^{e}
C2T4	11.18±0.04^{a}	103.02±0.1^{d}	11.40±0.06^{b}	98.02±0.1^{d}	11.76±0.04^{b}	92.88±0.7^{c}	12.14±0.04^{a}	86.68±0.7^{d}	12.54±0.04^{c}	83.2±0.6^{f}
C2T6	11.16±0.04^{a}	103.26±0.1^{e}	11.38±0.08^{a}	98.8±0.6^{f}	11.70±0.06^{b}	94.52±0.7^{e}	12.10±0.04^{a}	89.42±0.4^{e}	12.46±0.04^{b}	86.58±0.7^{h}
C3T2	11.22±0.04^{b}	102.24±0.4^{a}	11.40±0.04^{b}	97.2±0.4^{c}	11.84±0.04^{c}	92.84±0.4^{c}	12.14±0.04^{a}	85.2±0.6^{c}	12.42±0.09^{b}	80.86±0.8^{c}
C3T4	11.18±0.07^{a}	102.6±0.8^{b}	11.38±0.04^{a}	98.68±0.4^{e}	11.76±0.08^{b}	93.84±0.4^{d}	12.12±0.04^{a}	89.64±0.4^{f}	12.38±0.09^{b}	83.46±0.4^{g}
C3T6	11.14±0.04^{a}	105.66±0.8^{f}	11.32±0.07^{a}	102.12±0.4^{h}	11.64±0.04^{a}	97.22±0.4^{g}	12.04±0.04^{a}	84.58±0.4^{a}	12.24±0.08^{a}	90.14±0.4^{h}

The data is denoted as Mean ± S.D; $p \leq 0.05$, (n=5).Disparate superscripts represent a significant difference among different groups in the column.

Table 4: Effect of varying coating compositions on Total Phenolic Content (TPC) [mg GAE/g] and Radical Scavenging Activity (RSA) [%].

Interval	3rd Day		6th Day		9th Day		12th Day		15th Day	
Coating	TPC	RSA	TPC	RSA	TPC	RSA	TPC	RSA	TPC	RSA
Control	25.21±0.01^{f}	20.10±0.3^{a}	25.58±0.02^{g}	17.82±0.1^{a}	19.40±0.01^{a}	15.07±0.3^{a}	16.02±0.06^{a}	12.08±0.1^{a}	9.88±0.06^{a}	7.43±0.4^{a}
C1T2	23.78±0.07^{b}	22.04±0.1^{b}	24.48±0.03^{b}	20.30±0.4^{c}	20.20±0.01^{b}	18.16±0.3^{b}	17.30±0.07^{b}	16.29±0.2^{d}	11.54±0.04^{c}	11.44±0.3^{b}
C1T4	23.67±0.07^{b}	22.24±0.5^{c}	24.68±0.04^{c}	21.66±0.4^{f}	20.58±0.01^{d}	20.30±0.4^{e}	17.66±0.07^{d}	17.75±0.4^{f}	12.54±0.08^{d}	12.33±0.2^{d}
C1T6	24.34±0.04^{d}	22.52±0.1^{d}	24.91±0.03^{e}	22.63±0.1^{g}	21.59±0.01^{d}	20.66±0.1^{f}	18.36±0.01^{g}	18.87±0.2^{g}	13.25±0.06^{f}	14.07±0.3^{f}
C2T2	23.68±0.06^{b}	22.17±0.1^{c}	24.34±0.01^{a}	19.89±0.1^{b}	20.34±0.04^{c}	18.51±0.3^{c}	17.46±0.06^{c}	15.07±0.6^{b}	11.19±0.01^{b}	12.41±0.2^{d}
C2T4	23.53±0.06^{a}	22.22±0.1^{c}	24.54±0.08^{b}	21.25±0.2^{d}	20.81±0.01^{d}	18.87±0.2^{d}	17.61±0.03^{d}	15.35±0.9^{c}	12.44±0.03^{d}	12.46±0.4^{d}
C2T6	24.32±0.04^{d}	22.32±0.1^{b}	24.86±0.01^{d}	21.43±0.1^{e}	21.42±0.08^{c}	20.66±0.1^{f}	18.09±0.03^{e}	16.24±0.4^{d}	12.49±0.02^{d}	13.69±0.7^{e}
C3T2	24.03±0.07^{c}	22.14±0.2^{c}	24.79±0.03^{d}	20.35±0.5^{c}	20.23±0.04^{c}	18.54±0.4^{c}	17.75±0.07^{d}	17.34±0.3^{e}	13.07±0.05^{e}	12.15±0.5^{c}
C3T4	24.12±0.07^{c}	22.88±0.1^{e}	24.79±0.03^{d}	21.76±0.2^{f}	20.73±0.03^{d}	20.43±0.1^{e}	17.78±0.07^{d}	19.56±0.9^{h}	13.43±0.02^{f}	13.71±0.4^{e}
C3T6	24.51±0.05^{e}	23.03±0.5^{f}	25.11±0.03^{f}	22.47±0.2^{f}	21.23±0.01^{e}	21.17±0.4^{g}	18.28±0.06^{f}	20.38±0.1^{f}	14.23±0.04^{g}	14.38±0.6^{g}

The data is denoted as Mean ± S.D; $p \leq 0.05$, (n=5). Disparate superscripts represent a significant difference among different groups in the column.

Table 5: Effect of varying coating compositions on Total Plate Count [Log CFU.g^{-1}].

Interval	Total Plate Count [Log CFU.g^{-1}]					
Coating	0th Day	3rd Day	6th Day	9th Day	12th Day	15th Day
Control	5.38±0.08^{c}	6.02±0.02^{d}	6.57±0.01^{d}	6.84±0.04^{d}	7.04±0.02^{d}	7.27±0.01^{d}
C1T2	5.38±0.08^{c}	5.92±0.02^{c}	6.37±0.09^{c}	6.62±0.05^{b}	6.82±0.03^{b}	7.09±0.05^{b}
C1T4	5.37±0.08^{b}	5.87±0.02^{b}	6.38±0.08^{c}	6.63±0.03^{b}	6.82±0.03^{b}	7.09±0.01^{b}
C1T6	5.36±0.08^{a}	5.81±0.03^{b}	6.36±0.03^{c}	6.59±0.01^{b}	6.80±0.06^{b}	7.00±0.02^{b}
C2T2	5.38±0.02^{c}	5.92±0.02^{c}	6.41±0.03^{c}	6.62±0.01^{b}	6.83±0.03^{b}	7.10±0.05^{b}
C2T4	5.38±0.08^{c}	5.92±0.02^{c}	6.36±0.01^{c}	6.62±0.01^{b}	6.80±0.01^{b}	7.08±0.01^{b}
C2T6	5.38±0.04^{c}	5.90±0.02^{c}	6.41±0.05^{c}	6.70±0.05^{c}	6.90±0.03^{c}	7.11±0.09^{b}
C3T2	5.38±0.08^{c}	5.92±0.01^{c}	6.37±0.03^{c}	6.60±0.03^{b}	6.82±0.02^{b}	7.05±0.02^{b}
C3T4	5.37±0.06^{b}	5.92±0.03^{c}	6.28±0.05^{b}	6.59±0.01^{b}	6.80±0.02^{b}	7.01±0.05^{b}
C3T6	5.37±0.04^{b}	5.73±0.05^{a}	6.14±0.03^{a}	6.44±0.03^{a}	6.73±0.01^{a}	6.96±0.03^{a}

The data is denoted as Mean ± S.D; $p \leq 0.05$, (n=5). Disparate superscripts represent a significant difference among different groups in the column.

IV. CONCLUSION

The aim of this study was to establish a natural coating comprising sunflower lecithin and cinnamon essential oil (CEO), using nano-liposome technology for the extended storage life of apples and to assess the structural and physiochemical properties of the nanoliposome.

The nanoliposomal solution was prepared and coated on the surface of the fruit samples and storage studies of all coated and un-coated fruit samples were performed by comparing physio-chemical, textural and microbiological parameters at regular interval of the 15-day keeping period at room temperature. The investigation has shown the feasibility and effective utilization of CEO exploiting the nano-liposomal encapsulation technology. Nanoliposomal coated apples showed better results for all quality characteristics in contrast to uncoated apples. The nanoliposomal coating was effective in minimizing physiological loss in weight along with total acidity, total soluble solids and microbial proliferation and it also aided in maximum retention of firmness, phenolic content and antioxidant activity.

Among the three dipping time employed T6 (6 minutes) proved to be efficient in sustaining quality characteristics as it allowed maximum time for adherence of nanoliposomal vesicles on the surface of the fruits. Among the different treatment concentration C3 comprising of 2:1 ratio of CEO and tocopherol acetate showed better outcome in quality parameter analysis followed by C1 (1:1) and concentrations C2 (1:2). Thus, C3T6 has showed preferable results in all the parameters examined in this study.

V. FUTURE SCOPE

The CEO loaded nanoliposomal solution as a coating material is biodegrad able and relatively less costly. Experiments on exploiting nanoliposomes as an effective coating material have been limited to laboratory scale. Extensive research is therefore required to utilize sunflower lecithin's potential as a primary lipid component to synthesize nanoliposomal coatings for the preservation of various seasonal fruits and vegetables.

ACKNOWLEDGEMENTS

The authors acknowledge and extend their gratitude to Director (E&T) and Dean (Bio-Engineering) SRM Institute of Science and Technology. Authors also express their acknowledgement to Department of Biotechnology and Food Process Engineering for providing the facilities to support the research.

Conflict of Interest. Conflict of interest declared none.

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How to cite this article: Mitra, A., Selvam, S. P., Shehabudheen, S., Anitha, P. M. and Kumar, M. M. (2020). Efficiency Evaluation of Cinnamon Essential Oil Loaded Nanoliposomal Coating for the Post-Harvest Management of Apple (*Malus domestica*). *International Journal on Emerging Technologies*, *11*(2): 554–559.