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Shelf-Life Extension of Spring Roll Wrappers using Acidification Combined with Sodium Benzoate Addition

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Abstract

At ambient temperature, spring roll wrappers used for roti saimai are highly perishable. Adding organic acids such as 0-0.6% citric acid or vinegar (acetic acid) was evaluated for wrapper pH and sensory acceptability. The Addition of 0.4% citric acid or 0.5% vinegar to spring roll wrappers reduced pH below 4.5 and proved acceptable for panelists. Spring roll wrappers treated with 0.4% citric acid or 0.5% vinegar with/without 0.06% sodium benzoate were packed in two bag types (polypropylene; PP and nylon-linear low density polyethylene; nylon-LLDPE) and stored at ambient and refrigerated temperatures to investigate microbial loads. Vinegar had a greater antimicrobial effect than citric acid, while microbial reduction efficacy increased through the synergistic effects of vinegar and sodium benzoate. Spring roll wrappers treated with 0.5% vinegar with/without 0.06% sodium benzoate were selected to assess changes in quality and shelf-life. Results showed no significant differences in thickness and water activity (aw) values among all conditions. Nylon-LLDPE bags maintained spring roll wrapper moisture content better than PP bags but spring roll wrappers packed in nylon-LLDPE cracked more rapidly than those packed in PP bags during storage at refrigerated temperature. Sodium benzoate also decreased spring roll wrapper springiness. Spring roll wrappers treated with 0.5% vinegar and 0.06% sodium benzoate proved an optimal when packed in PP and nylon-LLDPE bags after storage at refrigerated and ambient temperatures, with shelf-lives of 7 and 13 days respectively.

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Shelf-Life;
Sodium Benzoate;
Spring Roll Wrapper.

Introduction

Roti saimai (Ayutthaya's cotton candy) is a popular dessert composed of spring roll wrappers and cotton candy in Phra Nakhon Si Ayutthaya Province, Thailand. However, shelf-life of spring roll wrappers with no preservative treatment is less than

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1 day because of high carbohydrate content, favourable acidity and high water activity (aw) that promote microbial growth. One approach to producing shelf-stable spring roll wrappers is by controlling the growth of spoilage and pathogen microorganisms through the use of hurdle technology. This process ensures the elimination or control of microbial growth as well as nutritional and sensory quality using several preservation factors such as preservatives, pH, aw, packaging and storage temperature. Sodium benzoate is commonly used as a preservative in foods including mushrooms, jams, pickles, purees, fruit yoghurts, salad, sauces, margarines, beers, gelatins, liqueurs, soft drinks, soymilk and spring roll wrappers,[1-4] but chemical substances can adversely impact consumer health and maximum permitted levels in foods are 0.1%.[2,5] Sodium benzoate is most effective in its undissociated form at pH below 4.5. This form can move freely across the plasma membrane into the cytoplasm of microorganisms and retard or inhibit microbial growth through the accumulation of protons and anions inside the microbial cell, disrupting normal metabolism and inhibiting transport system.[6,7] The addition of organic acids to food products promotes acidic conditions and enhances the antimicrobial efficiency of sodium benzoate. Organic acids such as citric acid and vinegar (acetic acid) are generally recognised as safe (GRAS) with no upper limit of daily intake for humans and they also act as antimicrobial agents.[8] Citric acid is an excellent chelating agent that removes some metallic ions required for bacterial growth and disrupts the permeability of the bacterial membrane, thereby limiting the entry of essential nutrients for bacterial growth. Vinegar (acetic acid) performs antibacterial activity by reducing the pH of the substrate and changing bacterial cell permeability by disturbing substrate transport and ionisation of undissociated acid molecules contributing to the depression of intracellular pH.[9]

In addition to these methods, packaging also plays an important role in extending the shelf-life of foods and reducing the use of chemical preservatives. Packaging acts as a protective barrier that protects food from adulteration by moisture, oxygen and microorganisms to prolong shelf-life.[10] Many film types are used for food packaging depending on their characteristics. Nylon exhibits good properties as an oxygen, odour and flavour barrier with mechanical strength and high-temperature performance but has a very poor water vapour barrier.[11] On the other hand, linear low density polyethylene (LLDPE) is a soft, flexible material with a poor barrier to oxygen, odour and flavour but good water vapour barrier properties.[12] Accordingly, the combination as nylon-LLDPE has good oxygen and water vapour barrier properties. Polypropylene (PP) is effective at bearing water vapour with a 5.5 gm^{-2} per 24 h water vapour transmission rate and also has the lowest density of commodity plastics (0.89-0.91 gcm^{-3}). PP has relative values of gas permeability of 1 (N_2), 4.3 (O_2) and 13.6 (CO_2).[13] Research to prolong the shelf-life of food has been conducted using nylon-LLDPE in germinated parboiled brown rice and Chinese pastry (Kha-nom-Pia),[14-15] with PP used in catfish skin crackers, pineapple dodol and smoked dried freshwater garfish.[16-18]

Here, the effects of organic acids (citric acid and vinegar) were investigated on pH and sensory evaluation of spring roll wrappers. A combination of organic acid and sodium benzoate was also assessed for quality change of spring roll wrappers packed in nylon-LLDPE and PP after storage under ambient (28-30 °C) and refrigeration (4 °C) conditions.

Materials and Methods

Preparation of Spring Roll Wrappers

Spring roll wrappers were composed of all-purpose flour 1,000 g and salt 5 g. The mixture was kneaded with 450 ml of water and set aside at room temperature for 15 min. The mixture was then formed into a sheet by smearing over a pan at 40-50 °C for 30 s.

Addition of Organic Acid In Spring Roll Wrappers

Two types of organic acids (citric acid and vinegar) were added to spring roll wrappers at concentrations of 0-0.6%. The pH value and sensory evaluation of spring roll wrappers were further examined.

Determination of pH value

The pH values of the samples were determined with a Docu pH Meter (Sartorius, USA) by blending a 2 g sample aliquot with 2 ml of distilled water.

Sensory Evaluation

Sensory evaluation was performed by 40 panelists in terms of colour, flavour, taste, texture and overall acceptability based on a 9-point hedonic scale from 1 (extremely unacceptable) to 9 (extremely desirable). The panel consisted of 15 men and 25 women aged 18-50.

Addition of Organic Acid and Sodium Benzoate in Spring Roll Wrappers

The spring roll wrapper recipe with a pH value of less than 4.5 was accepted by the panelists and selected. Sodium benzoate was then added to the selected recipe to give a final concentration of 0.06%. The recipe without organic acid and sodium benzoate was used as the control. Wrapper samples were packed as five sheets per bag in PP and nylon-LLDPE bags and then sealed using an impulse heat sealing machine (PSF-300W, China). The bags were kept at ambient and refrigerated temperatures. The effects of organic acid and sodium benzoate were determined on the spring roll wrappers in terms of thickness and microbial load. Triplicate samples were analysed.

Determination of Thickness

The thickness of spring roll wrappers was measured using a Mitutoyo series 543-390BS thickness gauge with a resolution of 0.001 mm.

Determination of Microbial Loads

The samples (25 g) were homogenised with 225 ml of sterile 0.85% NaCl (W V^{-1}) in a stomacher bag. Total plate counts (TPC) were enumerated by the pour plate method using Plate Count Agar (Hi Media Laboratories Pvt. Ltd., Mumbai, India). Plates were incubated for 24-48 h at 35 °C. Yeasts and moulds were determined after incubation at 25 °C for 3-5 days by the spread plate method. From a microbiological point of view, the end of shelf-life was established when the TPC, yeast and mould exceeded 1×10^4 and 10 CFU·g^{-1} respectively. Only the recipe treated with citric acid or vinegar with a lower microbial load were selected. The selected recipe with/without sodium benzoate was further investigated for changes in aw value, the moisture content, springiness and colour analysis during storage at ambient and refrigerated temperatures.

Determination of aw Value

The samples were minced into small pieces and placed in disposable sample cups. aw value was determined by an Aqualab water activity meter (model series 4TE, Decagon Devices, Pullman, Washington, USA).

Determination of Moisture Content

The samples (3-5 g) were placed in aluminium dishes and measured for pre-dry and dry weights (dried in an air oven at 105 °C until exhibiting constant weight). After drying, the dish was re-weighed to calculate moisture content using equation 1.

$$M_i = W_M - W_D / W_M \qquad \text{... (1)}$$

where W_M is the initial weight of the sample and W_D is the weight after drying.

Determination of Texture

Springiness of the samples was tested using a Tortilla/Pastry burst rig (HDP/TPB) attached to a texture analyzer TA.XT Plus (Stable Micro Systems, UK). TPA settings were test mode compression, pre-test speed 1 mm·s^{-1}, test speed 2 mm·s^{-1}, post-test speed 10 mm·s^{-1}, target mode distance 35 mm, trigger force 5 g and trigger type Auto.

Determination of Colour

CIELAB parameters were calculated for CIE illuminant D_{65} and 10° standard observer conditions using an Ultra Scan Vis (Hunter Lab, USA). All experiments were carried out in triplicate.

Statistical Analysis

Three independent replicates were conducted and mean values were reported. Statistical analysis of all data was performed using SPSS Ver. 16.0 (SPSS Inc., USA). One-way ANOVA (one-way analysis of variance) and Duncan's multiple range comparison were used to determine the level of significant differences ($P<0.05$).

Results and Discussion

Effect of Organic Acid on pH Value of Spring Roll Wrappers

Effectiveness of the preservative depends on the pH value of the food product; pH is also one of the factors that determines growth and survival of microorganisms during food processing and storage.[19] Sodium benzoate exhibited the highest antimicrobial potential when pH fell below 4.5. Therefore, the effect of organic acid (citric acid and vinegar) concentration on the pH value of spring roll wrappers was investigated. Spring roll wrappers without organic acid (control recipe; C) had a pH value of 6.07 which is slightly acidic. As the acid concentration increased, the pH of spring roll wrappers treated with citric acid or vinegar decreased significantly (Table 1). The use of 0.4% citric acid and 0.5% vinegar led to pH below 4.5.

Table 1: pH values of spring roll wrappers

Organic acid	Concentration (%)	pH values
Control	0.0	6.07 ± 0.00^{a}
Citric acid	0.1	5.29 ± 0.01^{b}
	0.2	4.96 ± 0.01^{c}
	0.3	4.75 ± 0.03^{d}
	0.4	4.49 ± 0.01^{e}
	0.5	4.38 ± 0.01^{f}
	0.6	4.25 ± 0.02^{g}
Vinegar	0.1	5.23 ± 0.00^{b}
	0.2	4.91 ± 0.00^{c}
	0.3	4.74 ± 0.00^{d}
	0.4	4.58 ± 0.00^{e}
	0.5	4.45 ± 0.01^{f}
	0.6	4.31 ± 0.00^{g}

The lowercase letters indicate significant differences in pH values of spring roll wrappers (P<0.05).

Sensory Analysis

Results revealed no significant differences in colour scores. There were also no obvious differences in texture scores among spring roll wrappers treated with 0-0.6% citric acid and vinegar. Spring roll wrappers treated with 0.5% and 0.6% citric acid had significantly lower taste and overall acceptability scores compared with the C recipe (Figure 1a). The panelists awarded significantly lower scores for flavour, taste and overall acceptability for spring roll wrappers treated with high concentration of vinegar (0.6%) because of sour tongue and off-odour[20] (Figure 1b). According to the results of pH values and sensory evaluation, spring roll wrappers treated with 0.4% citric acid (CI) and 0.5% vinegar (V) were selected for further investigation combined with 0.06% sodium benzoate based on quality changes during storage at ambient and refrigerated temperatures.

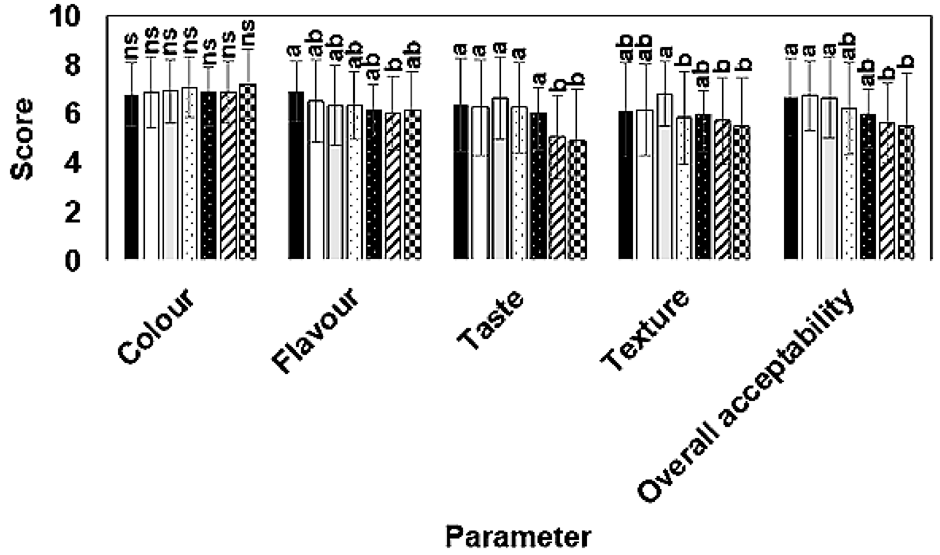
Effect of Organic Acid and Sodium Benzoate on pH Value of Spring Roll Wrappers

The pH values of spring roll wrappers treated with 0.4% citric acid or 0.5% vinegar combined with 0.06% sodium benzoate after storage at ambient and refrigerated temperatures were determined. At ambient and refrigerated temperatures, highest pH values of 6.27-6.32 and 6.28-6.32 were obtained for the control-based (C-based) recipes. Addition of citric acid or vinegar led to a decline in pH values of spring roll wrappers. The temperature and 0.06% sodium benzoate addition did not significantly affect the pH of spring roll wrappers when combined with 0.4% citric acid (CIB) or 0.5% vinegar (VB) (Table 2). These results concurred with a study in soymilk where the pH value of soymilk treated with sodium benzoate and citric acid did not reduce

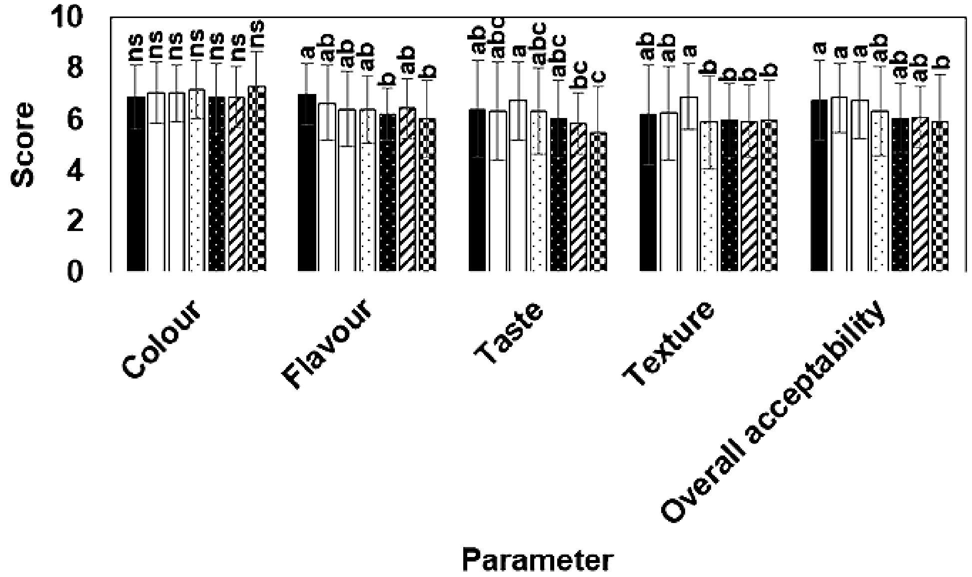
Table 2: pH values of spring roll wrappers after 1 day of storage at ambient and refrigerated temperatures

Temperature	Code	pH value
Ambient	C	6.27 ± 0.05^{a}
	CB	6.32 ± 0.02^{a}
	CI	4.49 ± 0.03^{b}
	CIB	4.50 ± 0.04^{b}
	V	4.49 ± 0.03^{b}
	VB	4.51 ± 0.01^{b}
Refrigerated	C	6.28 ± 0.03^{a}
	CB	6.32 ± 0.03^{a}
	CI	4.50 ± 0.05^{b}
	CIB	4.50 ± 0.01^{b}
	V	4.48 ± 0.02^{b}
	VB	4.51 ± 0.08^{b}

Control recipe (C) treated with sodium benzoate (CB). C recipe treated with 0.4% citric acid (CI) combined with 0.06% sodium benzoate (CIB). C recipe treated with 0.5% vinegar (V) combined with 0.06% sodium benzoate (VB).
The lowercase letters indicate significant differences in pH values of spring roll wrappers (P<0.05).



1a



1b

Fig. 1: Sensory qualities of spring roll wrappers.
(a) Concentration of citric acid 0% (■); 0.1% (□); 0.2% (▒); 0.3% (⁚); 0.4% (■), 0.5% (▨) and 0.6% (▩).

(b) Concentration of vinegar 0% (■); 0.1% (□); 0.2% (▒); 0.3% (⁚); 0.4% (■), 0.5% (▨) and 0.6% (▩).

The lowercase letters indicate significant differences in sensory scores of spring roll wrappers (P<0.05). ns indicates there is no significant difference in sensory scores of spring roll wrapper (P>0.05).

when compared to soymilk treated with citric acid alone.[21] However, these results were different from the study in puree which found that the addition of combinations of sodium benzoate, potassium sorbate and citric acid led to a decline in pH of puree kept at ambient (15-25 °C) and refrigeration (4 °C) conditions.[19]

Table 3: Changes in thickness values of spring roll wrappers after 1 day of storage at ambient and refrigerated temperatures

Temperature	Code	Thickness value (mm)
Ambient	CP	0.917±0.002^{ns}
	CBP	0.896±0.004^{ns}
	CIP	0.895±0.004^{ns}
	CIBP	0.986±0.004^{ns}
	VP	0.966±0.003^{ns}
	VBP	0.995±0.002^{ns}
	CN	1.047±0.002^{ns}
	CBN	0.896±0.002^{ns}
	CIN	0.876±0.019^{ns}
	CIBN	1.066±0.003^{ns}
	VN	0.954±0.003^{ns}
	VBN	0.994±0.003^{ns}
Refrigerated	CP	0.977±0.001^{ns}
	CBP	0.995±0.003^{ns}
	CIP	0.995±0.003^{ns}
	CIBP	0.985±0.003^{ns}
	VP	0.975±0.004^{ns}
	VBP	0.956±0.003^{ns}
	CN	0.993±0.059^{ns}
	CBN	0.954±0.065^{ns}
	CIN	0.954±0.065^{ns}
	CIBN	0.990±0.007^{ns}
	VN	0.979±0.014^{ns}
	VBN	0.953±0.064^{ns}

CP and CBP indicate that C and CB recipes were packed in PP bag. CN and CBN indicate that C and CB recipes were packed in nylon-LLDPE bag. CIP and CIBP indicate that CI and CIB recipes were packed in PP bag. CIN and CIBN indicate that CI and CIB recipes were packed in nylon-LLDPE bag. VP and VBP indicate that V and VB recipes were packed in PP bag. VN and VBN indicate that V and VB recipes were packed in nylon-LLDPE bag.

ns indicates there is no significant difference in thickness values of each recipe after 1 day of storage (P>0.05).

Thickness

Thicknesses of spring roll wrappers packed in PP and nylon-LLDPE bags were investigated for six recipes after 1 day of storage at ambient and refrigerated temperatures. There were no significant differences in thickness among all recipes, with a range of 0.876-1.066 mm and 0.953-0.995 mm after storage at ambient and refrigerated temperatures respectively (Table 3). This indicated that organic acid, sodium benzoate, packaging film and temperature did not affect spring roll wrapper thickness.

Microbial loads

Samples analyses were terminated when microbial loads were exceeded or the spring roll wrappers cracked. According to food safety guidance of the Thai Industrial Standards Institute (TISI), TPC for spring roll wrappers must not exceed 10^4 CFU·g^{-1} while yeast and mould counts must not exceed 10 CFU·g^{-1}. TPC, yeast and mould were highest in C recipes (Tables 4 and 5). The C recipes treated with/without sodium benzoate and CI recipes without sodium benzoate packaged in both bag types (PP and nylon-LLDPE bags) were kept for less than 1 day at ambient and refrigerated temperatures. After storage at ambient temperature, CIB recipes packed in both bag types had a longer shelf-life (1 day), while all recipes packed in nylon-LLDPE bags had lower TPC, yeast and mould levels than those packed in PP bags. This result suggested that sodium benzoate and nylon-LLDPE packaging material had a major influence on microbial reduction. Nylon-LLDPE showed excellent oxygen and water vapour barrier properties that retard microbial growth. Similarly, Pla-duk-ra packed in nylon-LLDPE bags had longer shelf-life (60 days) than when packaged in PP bags.[22] Furthermore, packages with a high oxygen barrier defeated microorganisms that required oxygen to survive in preservative-free white bread and fresh rice noodles.[10,23] Oxygen permeability depends on both packaging material and thickness of the bag. The nylon-LLDPE bag (100 μm) was thicker than the PP bag (40 μm) leading to superior oxygen barrier property.[24] Moreover, addition of organic acid (citric acid or vinegar) combined with sodium benzoate showed stronger antibacterial activity than sodium benzoate alone. This result concurred with a study on orange-fleshed sweet potato.

Table 4: Changes in TPC of spring roll wrappers during storage at ambient and refrigerated temperatures

Storage time (days)	Recipes												
	Temperature	CP	CBP	CIP	CIBP	VP	VBP	CN	CBN	CIN	CIBN	VN	VBN
	Total plate count (CFU · g^{-1})												
1		2.5×10^{5}	2.1×10^{5}	1.1×10^{5}	4.0×10^{3}	$<2.5\times10^{2}$	<25	2.5×10^{4}	1.2×10^{4}	2.5×10^{4}	3.5×10^{3}	$<2.5\times10^{2}$	<25
2					9.6×10^{4}	2.1×10^{3}	<25				5.6×10^{4}	1.8×10^{2}	<25
3						5.6×10^{4}	$<2.5\times10^{2}$					6.3×10^{3}	<25
4							<25					9.0×10^{4}	<25
5							*						$<2.5\times10^{2}$
7	Ambient												<25
9													<25
11													<25
13													<25
15													*
1		2.2×10^{5}	1.1×10^{4}	1.9×10^{4}	<25	<25	<25	1.9×10^{4}	1.1×10^{4}	2.3×10^{4}	$<2.5\times10^{2}$	$<2.5\times10^{2}$	$<2.5\times10^{2}$
2					<25	<25	<25				<25	<25	<25
3					$<2.5\times10^{2}$	$<2.5\times10^{2}$	$<2.5\times10^{2}$				*	*	*
4	Refrigerated				<25	<25	<25						
5					<25	<25	<25						
7					*		<25						
9							*						

[a]Abbreviations are the same as Table 3.
* indicate that the cracking in spring roll wrappers.

Table 5: Changes in yeast and mould of spring roll wrappers during storage at ambient and refrigerated temperatures

Storage time (days)	Temperature	CP	CBP	CIP	CIBP	VP	VBP	CN	CBN	CIN	CIBN	VN	VBN
		Recipes[a]											
		Yeast and mould (CFU · g^{-1})											
1	Ambient	4.0×10^3	33×10^3	15×10^3	<10	<10	<10	36×10^3	21×10^3	10×10^3	<10	<10	<10
2					12×10^3	<10	<10				<10	<10	<10
3						<10	<10					<10	<10
4							<10					<10	<10
5							*						<10
7													<10
9													<10
11													<10
13													<10
15													*
1	Refrigerated	15×10^3	11×10^3	<10	<10	<10	<10	13×10^3	<10	<10	<10	<10	<10
2					<10	<10	<10				<10	<10	<10
3					<10	<10	<10				*	*	*
4					<10	<10	<10						
5					<10	13×10^3	<10						
7					*		<10						
9							*						

[a]Abbreviations are the same as Table 3.
* indicate that the cracking in spring roll wrappers.

Results showed that combinations of chemical preservatives (potassium sorbate and sodium benzoate) together with organic acid (1% citric acid) gave significant reductions in TPC for products stored at ambient and refrigerated temperatures.[19] The CI-based recipes had a shorter shelf-life than V-based recipes. The longest shelf-life was found in the VBN recipe (13 days) that was spoiled by physical (cracking), not by microbial contamination (TPC < 25 $\times10^2$ CFU·g^{-1}). This result implied that vinegar was more effective than citric acid in extending the shelf-life of spring roll wrappers. Citric acid had higher molecular size and, therefore, a lower capacity to enter the bacteria cell.[25] Other studies also reported that acetic acid reduced populations of *Listeria monocytogenes* on meat,[26] whereas citric acid was partially inhibitory against *B. subtilis* and *Staphylococcus aureus*.[27] Many reports have investigated the antibacterial activity of vinegar (acetic acid), either alone in Irish brown crab meat, guinea pig meat, fresh meat and fresh silver carp fish,[28-31] in combination with acetic acid and sodium benzoate in Tybo drink[9] or with citric acid in fresh cut cabbage, sweet potato, peach fruit, carrot and orange juices, ready-to-eat fish patties and canned litchi.[32-38] After refrigerated storage, all recipes had lower microbial loads (TPC, yeast and mould). This finding concurred with a previous report demonstrating that fresh rice noodles stored at 4 °C had a longer shelf-life than those stored at 25 °C because the lower temperature retarded growth of spoilage microorganisms.[23] At low temperature, the fluidity of the cytoplasmic membrane of microorganisms is reduced, therefore disrupting the transport mechanism.[39] TPC values of CIB and V-based recipes packaged in both bag types were lower than 25 $\times10^2$ CFU·g^{-1}, while the slowest cracking of spring roll wrappers was observed in the VBP recipe. The combination of a number of hurdles (chemical preservative, organic acid, packaging and temperature) resulted in higher or multiple inhibitory effects against microorganisms compared with a single hurdle. The VB recipe treated with 0.5% vinegar combined with 0.06% sodium benzoate was optimal for extending the shelf-life of spring roll wrappers. The product packed in PP and nylon-LLDPE bags stored at refrigerated and ambient temperatures had a shelf-life of 7 and 13 days respectively. Therefore, only C-based recipes and V-based recipes packed in PP and nylon-LLDPE bags were selected for further investigation in terms of aw, moisture content, springiness and colour analysis during storage at ambient and refrigerated temperatures.

aw Value

There were no significant differences in aw values between all recipes after 1 day of storage with values ranging from 0.99-1.00 (Table 6). This result was similar to roll pastry that had aw values of 0.75-0.90.[40] No significant difference was found between the aw values of C-based and V-based recipes packaged in PP and nylon-LLDPE bags during storage at ambient and refrigerated temperatures. This result demonstrated that vinegar, sodium benzoate, packaging and storage temperature did not affect aw values. Our results differed from observations on Frankfurter sausages where weak organic acid caused lower aw values.[41]

Table 6: Changes in aw values of spring roll wrappers during storage at ambient and refrigerated temperatures

Storage time (days)	Recipes[a]								
	Temperature	CP	CBP	CN	CBN	VP	VBP	VN	VBN
1	Ambient	0.99 ± 0.01^{NS}	1.00± 0.01^{NS}	0.99 ± 0.01^{NS}	1.00±0.01^{NS}	1.00±0.01^{NSns}	1.00±0.01^{NSns}	1.00±0.01^{NSns}	1.00± 0.01^{NSns}
3						0.98±0.02^{ns}	0.99±0.01^{ns}	0.99±0.01^{ns}	0.99± 0.01^{ns}
5							0.98±0.02^{ns}		1.00±0.01^{ns}
7									0.98±0.02^{ns}
9									0.99±0.01^{ns}
11									1.00±0.01^{ns}
13									0.99±0.01^{ns}
1	Refrigerated	0.99 ± 0.01^{NS}	0.99 ± 0.01^{NS}	0.99 ± 0.01^{NS}	0.99 ± 0.01^{NS}	1.00±0.01^{NSns}	1.00±0.01^{NSns}	0.99 ± 0.0^{1NS}	1.00±0.01^{NS}
3						0.99±0.01^{ns}	0.99± 0.01^{ns}		
5						1.00±0.01^{ns}	1.00± 0.01^{ns}		
7							0.98±0.02^{ns}		

[a]Abbreviations are the same as Table 3.

NS and ns indicate there is no significant difference in aw values of spring roll wrappers after 1 day of storage and in aw values of each recipe throughout the storage days respectively (P>0.05).

Table 7: Changes in moisture contents (%) of spring roll wrappers during storage at ambient and refrigerated temperatures

Storage time (days)		Recipes[a]							
	Temperature	CP	CBP	CN	CBN	VP	VBP	VN	VBN
1		46.72± 0.22^{A}	42.33± 0.96^{D}	45.11± 0.35^{B}	42.87± 0.35^{CD}	44.15± 0.31^{BCb}	39.40± 0.15^{Ec}	44.35± 0.53^{Bns}	44.05± 1.99^{BCns}
3						46.29± 0.03^{a}	45.00± 0.26^{b}	45.18± 0.19^{ns}	44.89± 2.02^{ns}
5							45.18± 0.19^{ab}		45.99± 0.28^{ns}
7	Ambient								46.12± 0.63^{ns}
9									45.71± 0.49^{ns}
11									46.67± 0.55^{ns}
13									45.89± 0.15^{ns}
1		45.73± 0.35^{A}	42.79± 0.2^{C}	42.81± 0.20^{C}	40.53± 0.24^{D}	44.48± 0.54^{Bc}	40.47± 1.56^{Db}	39.28± 0.07^{E}	44.05± 0.33^{B}
3						44.66± 0.39^{bc}	45.14± 0.34^{a}		
5	Refrigerated					45.65± 0.63^{ab}	45.29± 0.84^{a}		
7							45.78± 0.88^{a}		

[a]Abbreviations are the same as Table 3.
The capital letters indicate significant differences in moisture contents of spring roll wrappers after 1 day of storage (P<0.05).
The lowercase letters indicate significant differences in moisture contents of each recipe throughout the storage days (P<0.05).
ns indicates there is no significant difference in moisture contents of each recipe throughout the storage days (P>0.05).

Moisture Contents

After 1 day of storage at ambient temperature, C-based recipes treated with sodium benzoate decreased significantly in moisture contents compared with untreated recipes. The Moisture contents of VBP recipes were lower than VP recipes (Table 7). Sodium benzoate reduced the moisture content of green onions.[42] In addition, no significant difference was recorded in the moisture contents between VN and VBN recipes. This result concurred with a study on dried prunes which found that sodium benzoate preserved low moisture content.[43] Spring roll wrappers packed in PP and nylon-LLDPE bags showed differences in the trend of moisture content. The moisture contents of CN recipes were significantly less than for CP recipes, while no significant differences were recorded in moisture contents between CBP and CBN, and VP and VN recipes. However, VBN recipes had higher moisture content than VBP recipes. After 13 days of storage, spring roll wrappers at ambient temperature showed no significant difference in moisture content for V-based recipes packed in nylon-LLDPE bags, whereas the moisture contents of V-based recipes packed in PP bags increased. PP bags generally have good water vapour barrier properties. However, one study found that PP woven sacks had high water vapour transmission rate with increased moisture content,[44] while nylon-LLDPE bags had good water vapour barrier properties which delayed moisture absorption, concurring with a previous result.[45] The thickness of nylon-LLDPE bags (100 μm) was greater than PP bags (40 μm) and this gave higher water vapour barrier efficiency. Bag thickness can affect moisture content differently. Minimally processed onions packed in PP bags of 50 μm thickness showed reduced dryness compared with those packed in PP bags of 25 μm thickness,[46] while lychees wrapped in 75 μm thickness PP bags showed higher moisture (83.85%) than those wrapped in 100 μm thickness.[47] After storage at a refrigerated temperature, similar moisture content trends were observed, except in the VBN recipe where moisture content was higher than the VN recipe after 1 day of storage.

Table 8: Changes in springiness (cm) of spring roll wrappers during storage at ambient and refrigerated temperatures

Storage time (days)	Temperature	Recipes[a] CP	CBP	CN	CBN	VP	VBP	VN	VBN
1	Ambient	2,251.50± 70.43[CD]	2,401.05 ±44.62[CD]	2,176.95 ±112.08[D]	2,395.15 ±166.81[CD]	2,461.55 ±93.97[Cns]	2,288.20 ±99.14[CDa]	3,169.10 ±85.84[Ans]	2,764.80 ±154.43[Ba]
3						2,426.20 ±47.09[ns]	2,017.85 ±101.19[b]	3,132.70 ±86.69[ns]	2,707.50 ±220.05[a]
5							1,612.95 ±113.35[c]		2,688.85 ±129.33[a]
7									2,617.70 ±215.53[ab]
9									2,271.00 ± 84.85[bc]
11									2,047.50 ±85.56[cd]
13									1,697.00 ±130.11[d]
1	Refrigerated	2,488.00 ±20.65[AB]	2,510.80 ±279.17[AB]	2,739.70 ±186.68[A]	2,807.50 ±56.29[A]	2,172.05 ±14.35[BCa]	2,361.90 ±75.09[ABCa]	1,925.15 ±17.32[C]	2,014.45 ±393.08[C]
3						2,147.75 ±29.63[a]	1,820.45 ±91.71[b]		
5						1,939± 88.81[b]	1,493.90 ±22.20[c]		
7							1,395 ±55.4[c]		

[a]Abbreviations are the same as Table 3.
The capital letters indicate significant differences in springiness of spring roll wrappers after 1 day of storage (P<0.05).
The lowercase letters indicate significant differences in springiness of each recipe throughout the storage days (P<0.05).
ns indicates there is no significant difference in springiness of each recipe throughout the storage days (P>0.05).

Springiness

After 1 day of storage, no significant difference was recorded in springiness between recipes untreated and treated with sodium benzoate at both temperatures, except in the VN recipe that gave higher springiness than the VBN recipe (Table 8). There was also no significant difference in springiness between C-based recipes packaged in PP and nylon-LLDPE bags, while V-based recipes packaged in nylon-LLDPE bags had higher springiness than those packed in PP bags at ambient temperature. Spring roll wrappers cracked due to a decrease in springiness with increasing storage time. The V-based recipes without sodium benzoate had slightly less springiness than those with sodium benzoate at both temperatures, while V-based recipes packed in nylon-LLDPE bags stored at refrigerated temperature had lower springiness and cracked more easily than those stored at ambient temperature. Although the nylon-LLDPE bag had a good water vapour barrier, at a refrigerated temperature, spring roll wrappers packed in nylon-LLDPE cracked more easily than those in PP bags. These results suggested that spring roll cracking depended on a combination of sodium benzoate, package type and temperature. Sodium benzoate and low temperatures led to a decrease in the springiness of spring roll wrappers during storage. Refrigerated temperatures retarded the growth of total microbes but spring roll wrappers easily cracked. This could be caused by the development of the gluten network at refrigerated temperature that was more restricted at ambient temperature.[48] This result concurred with an earlier finding which determined that the springiness of noodles kept at refrigerated temperature was lower than those kept at ambient temperature.[48] In this study, shelf-lives of spring roll wrappers stored at refrigerated and ambient temperatures were 7 and 13 days respectively.

Colour Analysis

Spring roll wrappers treated with 0.5% vinegar combined with/without 0.06% sodium benzoate are depicted in Figure 2. There were no clear significant differences in L* and a* values among all recipes after storage for 1 day at ambient temperature. The CP recipe had a lower b* value than the CBP recipe, whereas there were no significant differences in b* values in the other recipes. In addition, the b* values of all recipes packaged in nylon-LLDPE bags were higher than those packaged in PP bags (Table 9). Results demonstrated that vinegar, sodium benzoate and packaging did not affect the L* and a* values of spring roll wrappers, whereas PP bags showed decreased b* values of spring roll wrappers. The L* values of V-based recipes treated with sodium benzoate tended to increase, whereas V-based recipes not treated with sodium benzoate showed no clear increase in L* values during storage at ambient temperature. This indicated that sodium benzoate played a major role in increasing the L* value of spring roll wrappers. The a* and b* values of spring roll wrappers treated with vinegar tended to increase throughout storage at both temperatures. This result was similar to observations in Chom Phu Longan which found that the a* and b* values of Chom Phu Longan treated with organic acid (3% and 4% citric acid) combined with chitosan were higher than for 0% citric acid.[49] At refrigerated temperature, the V-based recipes packed in nylon-LLDPE bags had L*, a* and b* values higher than those packed in PP bags. This result was similar to the L* value in Namkneaw chilli paste, which increased with storage time.[50] The nylon-LLDPE bag protected the reduction of L*, a* and b* values. No significant differences in L* values were recorded among the C-based recipes. The a* and b* values of C recipes treated with sodium benzoate and packed in nylon-LLDPE bags were higher than the C recipes not treated with sodium benzoate and packed in PP bags respectively.

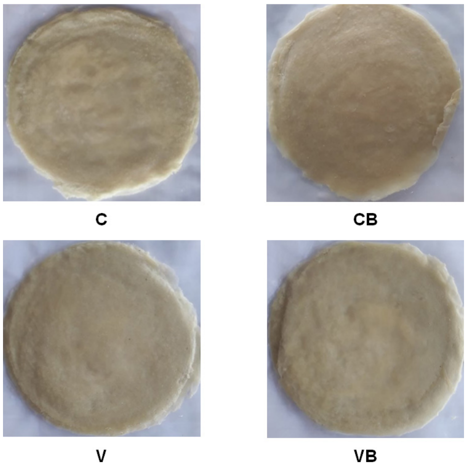


Fig. 2: The visual appearance of spring roll wrappers

Table 9: Changes in colours of spring roll wrappers during storage at ambient and refrigerated temperatures

Storage time (days)	Recipes[a]								
	Temperature	CP	CBP	CN	CBN	VP	VBP	VN	VBN
					L* value				
1	Ambient	45.34±7.17^{AB}	47.28±3.86^{AB}	48.56±8.91^{AB}	52.46±3.23^{A}	49.66±2.76^{ABns}	42.85±2.47^{Bb}	51.31±2.83^{Ab}	48.01±4.15^{ABd}
3						50.96±2.20^{ns}	52.31±1.50^{a}	52.92±2.54^{ab}	48.97±2.16^{d}
5							54.29±1.10^{a}		52.28±2.84^{c}
7									53.35±0.78^{bc}
9									55.68±0.90^{ab}
11									56.00±1.21^{ab}
13									57.00±0.98^{a}
1	Refrigerated	42.99±8.75^{C}	44.07±3.43^{BC}	52.35±4.68^{ABC}	50.49±3.19^{ABC}	42.78±10.99^{Cb}	42.91±8.03^{Cb}	50.07±6.61^{AB}	56.06±3.46^{A}
3						55.55±3.59^{a}	53.19±6.63^{a}		
5						57.57±1.56^{a}	55.37±3.01^{a}		
7							60.25±2.04^{a}		
					a* value				
1	Ambient	-1.00±0.09^{B}	-0.68±0.39^{AB}	-0.28±0.43^{A}	-0.40±0.37^{A}	-0.32±0.22^{Ab}	-0.49±0.19^{Ac}	-0.62±0.32^{ABb}	-0.55±0.25^{Ad}
3						0.57±0.12^{a}	0.49±0.26^{b}	-0.28±0.22^{a}	-0.24±0.33^{d}
5							1.00±0.15^{a}		0.73±0.41^{c}
7									0.97±0.18^{bc}
9									1.25±0.45^{b}
11									1.75±0.56^{a}
13									1.98±0.13^{a}
1	Refrigerated	-1.25±0.19^{E}	-0.91±0.13^{D}	-0.39±0.22^{C}	-0.07±0.15^{B}	-0.34±0.08^{Cb}	-0.57±0.17^{CDc}	0.62±0.35^{A}	0.76±0.45^{A}
3						0.34±0.13^{ab}	0.62±0.25^{b}		
5						0.44±0.10^{a}	0.98±0.18^{a}		
7							1.22±0.35^{a}		

				b* value					
1	Ambient	5.52±0.60^{D}	7.00±1.21^{BC}	7.76±0.99^{AB}	8.51±0.71^{A}	5.97±0.41C^{Db}	4.85±0.95^{Db}	6.86±0.46B^{Cb}	7.21±1.26^{BCd}
3						6.25±0.52^{a}	5.64±0.34^{b}	7.60±1.50^{a}	9.93±1.54^{c}
5							6.15±0.31^{a}		10.69±1.43^{bc}
7							6.31±0.67^{a}		11.94±0.89^{ab}
9									12.45±0.72^{ab}
11									12.24±0.95^{a}
13									12.75±0.80^{a}
1	Refrigerated	6.35±0.87^{CD}	5.78±0.55^{CD}	6.87±0.72^{BC}	8.38±1.56^{A}	5.73±0.50^{CDb}	5.12±0.60^{Dc}	7.95±0.31A^{Bab}	8.27±1.07^{Aab}
3						7.37±1.30^{a}	7.19±0.55^{b}		
5						8.51±0.53^{a}	8.48±0.84^{a}		
7							9.03±1.10^{a}		

[a]Abbreviations are the same as Table 3.
The capital letters indicate significant differences in colours of spring roll wrappers after 1 day of storage ($P<0.05$).
The lowercase letters indicate significant differences in colours of each recipe throughout the storage days ($P<0.05$).
ns indicates there is no significant difference in colours of each recipe throughout the storage days ($P>0.05$).

Conclusions

There is increasing awareness and concern by consumers about the effects of chemical preservatives on health which requires the use of these substances to be kept to a minimum. A combination of sodium benzoate 0.06% and vinegar 0.5%, packed in nylon-LLDPE or PP bags and stored at ambient or refrigerated temperature, represents the best alternative method to extend the shelf-life of spring roll wrappers.

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Conflict of Interest

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References

1. Olotu I. O., Obadina A. O., Sobukola O. P., Adegunwa M., Adebowale A. A., Kajihausa E., Sanni L. O., Asagbra Y., Ashiru B., Keith T. Effect of chemical preservatives on shelf-life of mushroom (*Pleurotus ostreatus*) cultivated on cassava peels. *Int J Food Sci*. 2015; 50(6): 1477-1483.
2. Shahmohammadi M., Javadi M., Nassiri-Asl M. An overview on the effects of sodium benzoate as a preservative in food products. *Biotech Health Sci*. 2016; 3(3): 35-84.
3. Linke B. G. O., Casagrande T. A. C., Cardoso L. A. C. Food additives and their health effects: A review on preservative sodium benzoate. *Afr J Biotechnol.* 2018; 17(10): 306-310.

4. Arekemase M. O., Babashola D. R. Assessment of the effectiveness of ginger (*Zingiber officinale*), clove (*Syzygium aromatium*) and sodium benzoate on the shelf-life of soymilk. *Not Sci Biol*. 2019; 11(4): 400-409.
5. Gören A. C., Bilsel G., Şimşek A., Bilsel M., Akçadağ F., Topal K., Ozgen H. HPLC and LC-MS/MS methods for determination of sodium benzoate and potassium sorbate in food and beverages: performances of local accredited laboratories via proficiency tests in Turkey. *Food Chem*. 2015; 175(15): 273-279.
6. López-Malo A., Barreto-Valdivieso J., Palou E., MartÍn F. S. *Aspergillus flavus* growth response to cinnamon extract and sodium benzoate mixture. *Food control*. 2007; 18(11): 1358-1362.
7. Mani-López E., GarcÍa H. S., López-Malo A. Organic acids as antimicrobials to control *Salmonella* in meat and poultry products. *Food Res Int.* 2012; 45(2): 713-721.
8. Lewis R. J. Food Additives Handbook. New York: Van Nostrand Reinhold; 1989.
9. Ahaotu I., Uchendu C. G., Maduka N., Odu N. N. Physicochemical properties and shelf-life stability of Tybo drink preserved with acetic acid and sodium benzoate. *Niger J Microbiol*. 2019; 33(2): 4713-4731.
10. Upasen S., Wattanachai P. Packaging to prolong shelf-life of preservative-free white bread. *Heliyon.* 2018; E00802.
11. Wu F., Misra M., Mohanty A. K. Challenges and new opportunities on barrier performance of biodegradable polymers for sustainable packaging. *Prog Polym Sci.* 2021; 117: 101395.
12. Mangaraj S, Goswami T. K., Mahajan P. V. Applications of plastic films for modified atmosphere packaging of fruits and vegetables: a review. *Food Eng Rev.* 2009; 1(2): 133-158.
13. Siracusa V. Food packaging permeability behaviour: a report. *Int J Poly Sci*. 2012; 2012: 1-12.
14. Ranmeechai N., Photchanachai S. Effect of modified atmosphere packaging on the quality of germinated parboiled brown rice. *Food Sci Biotechnol.* 2017; 26(2): 303-310.
15. Chuaythong C., Rachtanapun C. Effect of packaging film and oxygen absorber on shelf-life extension of Chinese pastry (Kha-nom Pia). *Ital J Food Sci.* 2018; 30(5): 51-56.
16. Umam A. K., Rostini I., Subiyanto, Intan R. Estimations of shelf life of catfish skin crackers in polypropylene plastic packaging using the ASLT (Accelerated Shelf-Life Testing) method. *World Sci News.* 2019; 133: 248-262.
17. Afifah N., Ratnawati L. Shelf-life prediction of pineapple dodol packed with edible film using accelerated shelf-life tests. In IOP Conf. Series: Earth and Environmental Science, 2021; PP. 012119. Malang: Indonesia.
18. Tepmuangkhun J., Gawborisut S. Using polypropylene bags for long-term storage of smoked dried freshwater garfish *Xenentodon cancila* (Hamilton, 1822). *J Fish Environ*. 2021; 45(3): 28-41.
19. Musyoka J. N., Abong G. O., Mbogo D. M., Fuchs R., Low J., Heck S., Muzhingi T. Effects of acidification and preservatives on microbial growth during storage of orange fleshed sweet potato puree. *Int J Food Sci.* 2018; 2018: 1-11.
20. Nielsen G.D. Sensory irritation of vapours of formic, acetic, propionic and butyric acid. *Regul Toxicol Pharmacol*. 2018; 99: 89-97.
21. Agbaka J. I., Ishiwu C. N., Ibrahim A. N. Effect of addition of citric acid and sodium benzoate on pH and microbial profile of soymilk. *Asian J Agric Food Sci.* 2020; 15(4): 21-31.
22. Pongsetkul J, Benjakul S. Development of modified atmosphere packaging (MAP) on shelf-life extension of pla-duk-ra (dried fermented catfish) stored at room temperature. *Food control.* 2021; 124: 107882.
23. Rachtanapun P., Tangnonthaphat T. Effects of packaging types and storage temperatures on the shelf-life of fresh rice noodles under vacuum conditions. *Chiang Mai J Sci.* 2011; 38(4): 579-589.
24. Preetha P., Varadharaju N., Vennila, P. Enhancing the shelf-life of fresh-cut bitter gourd using modified atmospheric packaging. *Afr J Agric Res.* 2015; 10(10): 1943-1951.
25. Ouattara B., Simard R. E., Holley R. A., Piette G. J. P., Begin A. Inhibitory effect of organic acids upon meat spoilage bacteria. *J. Food Prot.* 1997; 60(3): 246-253.
26. Gonzalez-Fandos E., Herrera B. Efficacy of acetic acid against *Listeria monocytogenes*

attached to poultry skin during refrigerated storage. *Foods*. 2014; 3(3): 527-540.
27. Pundir R. K., Jain P. Evaluation of five chemical food preservatives for their antibacterial activity against bacterial isolates from bakery products and mango pickles. *J Chem Pharm Res*. 2011; 3(1): 24-31.
28. McDermott A., Whyte P., Brunton N., Lyng J., Fagan J., Bolton D. J. The effect of organic acid and sodium chloride dips on the shelf-life of refrigerated Irish brown crab (*Cancer pagurus*) meat. *LWT-Food Sci Technol.* 2018; 98: 141-147.
29. Guevara J., Reyna L., Pedemonte A., Vergaray R., Pachas J. Combined effect of ultraviolet radiation and application of acetic acid on the quality of guinea pig meat and increased of its shelf-life. *Pharm Pharmacol Int.* 2018; 6(1): 71-75.
30. Shewail A., Shaltout F. A., Gerges T. M. Impact of some organic acids and their salts on microbial quality and shelf life of beef. *Assiut Vet Med J.* 2018; 64(159): 164-177.
31. Monirul i., Yang F., Niaz M., Qixing J., Wenshui X. Effectiveness of combined acetic acid and ascorbic acid spray on fresh silver carp (*Hypophthamichthys molitrix*) fish to increase shelf-life at refrigerated temperature. *Curr Res Nutr Food Sci.* 2019; 7(2): 415-426.
32. Sgroppo S. C., Vergara L. E., Tenev M. D. Effects of sodium metabisulphite and citric acid on the shelf-life of fresh cut sweet potatoes. *Span J Agric Res*. 2010; 8(3): 686-693.
33. Manolopoulou E., Varzakas T. Effect of storage conditions on the sensory quality, colour and texture of fresh-cut minimally processed cabbage with the addition of ascorbic acid, citric acid and calcium chloride. *Food Sci Nutr.* 2011; 2: 956-963.
34. Yang C., Chen T., Chen B., Sun S., Song H., Chen D., Xi W. Citric acid treatment reduces decay and maintains the postharvest quality of peach (*Prunus persica* L.) fruit. *Food Sci Nutr.* 2019; 7: 3635–3643.
35. Saha P., Singh J. P., Sourav S., Humayun A., Ramalingam C. Optimization of citric acid and malic acid to enhance flavour and shelf-life of mango juice. *J Chem Pharm.* 2013; 5(9): 90-95.
36. Humayun A., Gautam C. K., Madhav M., Sourav S., Ramalingam C. Effect of citric and malic acid on shelf-life and sensory characteristics of orange juice. *Int J Pharm Pharm Sci*. 2014; 6(2): 117-119.
37. Bou R., Claret A., Stamatakis A., MartÍnez B., Guerrero L. Quality changes and shelf-life extension of ready-to-eat fish patties by adding encapsulated citric acid. *J Sci Food Agric.* 2017; 97(15): 5352-5360.
38. Win N. N. C., Soe T. T., Kar A., Soe Y. Y., Lin M. Effects of syrup solution with different concentrations of citric acid on quality and storage life of canned litchi. *OALib Journal*. 2021; 8(10): e8033.
39. ValÍk L., Medved'ová A., Bajúsová B., Liptáková D. Variability of growth parameters of *Staphylococcus aureus* in milk. *J Food Nutr Res.* 2008; 47(1): 18-22.
40. Nagy K. S., Sheikh M. El, Aly S. S. H. Prolonging of shelf-life of spring roll pastry by ozone treatment and modified atmosphere packaging. *Curr Sci Int.* 2017; 6(1): 50-57.
41. Stekelenburg F. K. Enhanced inhibition of *Listeria monocytogenes* in Frankfurter sausage by the addition of potassium lactate and sodium acetate mixtures. *Food Microbiol.* 2003; 20(1): 133-137.
42. Memon N., Gat Y., Arya S., Waghmare R. Combined effect of chemical preservative and different doses of irradiation on green onions to enhance shelf-life. *J Saudi Soc Agric Sci.* 2020; 19(3): 207-215.
43. Schade J. E., Stafford A. E., King A. D. Preservation of high-moisture dried prunes with sodium benzoate instead of potassium sorbate. *J Sci Food Agric.* 1973; 24(8): 905-911.
44. Awoyale W., Maziya-Dixon B., Menkir A. Effect of packaging materials and storage conditions on the physicochemical and chemical properties of ogi powder. *J Food Agric Environ.* 2013; 11(3&4): 242-248.
45. Shakerardekani A., Karim R. Effect of different types of plastic packaging films on the moisture and aflatoxin contents of pistachio nuts during storage. *J Food Sci Technol.* 2013; 50: 409-411.
46. Bhuvaneswari S., Narayana C. K., Udhayakumar R., Veere G. R. Effect of

packaging and storage temperature on shelf-life of minimally processed onion (*Allium cepa* L.). *J Hortic Sci.* 2015; 10(2): 216-219.

47. Talukder F. U., Rahman Md. S., Hassan Md. K. Effects of packaging and low temperature on shelf-life and quality of litchis. *Int J Hortic Sci Technol*. 2020; 7(2): 103-118.
48. Li L., Wang N., Ma S., Yang S., Chen X., Ke Y., Weng X. Relationship of moisture status and quality characteristics of fresh wet noodles prepared from different grade wheat flours from flour milling streams. *J Chem.* 2018; 2018: 1-8.
49. Adisak J., Quyen D. T. M., Thinh D. C., Jintana J. Effect of chitosan combined with citric acid and temperature on shelf life of Chom Phu Longan. Proc. 7th International Postharvest Symposium. *Acta Horticulturae.* 2013; 1012, ISHS2013.
50. Lapchutiporn J., Tuitemwong P., Tuitemwong K., Kunkriangvong J. Accelerated shelf-life testing of a “Namkneaw” chilli paste. In Proceedings of 46th Kasetsart University Annual Conference: Science, 2008; pp. 301-309. Bangkok: Thailand.