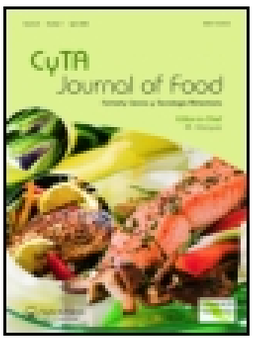

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Use of ginger essential oil-fortified edible coatings in Kashar cheese and its effects on *Escherichia coli* O157:H7 and *Staphylococcus aureus*

El uso de recubrimientos comestibles enriquecidos con aceite esencial de jengibre en el queso Kashar y sus efectos en *Escherichia coli* O157:H7 y *Staphylococcus aureus*

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In this study, edible coating (WPIG) was produced by using 1.5% (w/v) sorbitol + 5% (w/v) whey protein isolate (WPI) + 0.5% (w/v) alginate and 1.5% (v/v) ginger essential oil. Kashar cheese samples were artificially contaminated with *Escherichia coli* O157:H7 and *Staphylococcus aureus* at a level of 10^6 cfu/mL. After coating some of the Kashar samples with edible coating, all samples were stored at 4 °C for 30 days. Antimicrobial activities and selected physical-chemical parameters were assessed on the 1st, 7th, 15th and 30th days of storage. WPI was found to have good water barrier properties, which improved with the addition of 1.5% (v/v) ginger essential oil to the coating, and WPIG was determined to have antimicrobial effects. During storage, *Escherichia coli* O157:H7 and *Staphylococcus aureus* levels increased in the control samples, while they decreased in the coated samples.

Keywords: edible coating; Kashar cheese; ginger essential oil; antimicrobial effect

En este estudio, se elaboró recubrimiento comestible (WPIG) utilizando 1,5% (w/v) de sorbitol + 5% (w/v) de aislado proteínico de suero lácteo (WPI) + 0,5% (w/v) de alginato y 1,5% (v/v) de aceite esencial de jengibre. Las muestras de queso Kashar fueron contaminadas artificialmente con *Escherichia coli* O157:H7 y *Staphylococcus aureus* a un nivel de 10^6 cfu/mL. Después de recubrir algunas de las muestras de Kashar con recubrimiento comestible, todas las muestras se almacenaron a 4 °C durante 30 días. Se estudiaron las actividades antimicrobiales y los parámetros fisicoquímicos seleccionados en el día 1, 7, 15 y 30 de almacenamiento. Se encontró que WPI tenía unas propiedades de barrera de agua favorables, las cuales mejoraron cuando se añadió un 1,5% (v/v) de aceite esencial de jengibre al recubrimiento, además se determinó que WPIG tenía efectos antimicrobiales. Durante el almacenamiento, los niveles de *Escherichia coli* O157:H7 y *Staphylococcus aureus* aumentaron en las muestras control, mientras que disminuyeron en las muestras con recubrimiento.

Palabras clave: recubrimiento comestible; queso Kashar; aceite esencial de jengibre; efecto antimicrobiano

Introduction

Kashar cheese is a semi-hard cheese type, whose production is not governed by one standard technique. Referred to by different names, such as Kackavaly, Pirdop, Epiri, Dobrogean and Sarplaninski, in different regions, Kashar cheese is the most commonly consumed cheese type in Turkey (Cetinkaya & Soyutemiz, 2004). This cheese, traditionally produced from sheep milk, contains 24.2% protein, 25.1% fat, 4.2% ash, 41.9% water and 4.6% salt (Cetinkaya & Soyutemiz, 2004). Today, however, it is mostly produced from cow's milk (Durlu-Özkaya & Gün, 2014).

Edible films and edible coatings are thin, edible membrane layers that can facilitate humidity, oxygen and liquid transmissions (Guilbert, 1986), and they are classified, according to their source of raw materials, into three main groups – polysaccharide, oil and protein-based films (Kester & Fennema, 1986). Milk protein and whey protein (WP) form important parts of protein-based edible coatings, with the latter comprising 20% of these coatings (Brunner, 1977). In addition to having high nutritional value and functional properties, whey protein isolate (WPI) coatings are used in edible coatings due to their advantageous features such as low oxygen permeability, gelation, thermal stability, foaming and their ability to create polymers through covalent binding to carbohydrates (Kavas & Kavas, 2014). Sorbitol, prominent among the plasticizers because of its lower moisture absorption and high dissolution capabilities, has been preferred in many of the studies conducted on WPI-based films and coatings (Kavas & Kavas, 2014; Krochta & De Mulder-Johnson, 1997; Ressouany, Vachon, & Lacroix, 1998; Torlak & Nizamoğlu, 2011). Research shows that antioxidant and antimicrobial active compounds can be added to edible films and coatings. In this respect, essential oils, which have gained attention in recent years owing to their antimicrobial activities, are frequently used for controlling the growth of pathogenic bacteria and thereby diminishing the occurrence of degradation in foods (Burt, 2004; Joerger, 2007; Padgett, Han, & Dawson, 1998; Ouattara, Sabato & Lacroix, 2001; Zivanovic, Chi, & Draughon, 2005). In edible film systems and edible coating systems, it has been reported that the antimicrobial agent slowly passes from the film layer to the food, leaving a high concentration of the antimicrobial agent remaining in the coating and at the surface of the food and thereby providing a long-term effect against microorganisms (Coma et al., 2002).

Ginger has been long used in traditional medicine, beverages and perfumes, and as a spice in cooking (El-Ghorab, Nauman, Anjum, Hussain, & Nadeem, 2010). Ginger-flavored compounds, which have anti-inflammatory, antiseptic, anti-parasitic and immunomodulatory properties when consumed in natural ways (Onu,

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2010), are bound to oleoresin at 1–4% levels in their essential oil (Govindarajan & Connell, 1983). The composition of the essential oil varies according to growing conditions (Stoyanova, Konakchiev, Damyanova, Stoilova, & Suu, 2006) and is mainly formed of sesquiterpene hydrocarbons (especially zingiberene, ar-curcumene, β-bisabolene and β-sesquiphellandrene) (Norajit, Laohakunjit, & Kerdchoechuen, 2007). According to some researchers, ginger's essential oil has antioxidant, antifungal (Sharma & Sharma, 2011; Shetty, 1997) and antimicrobial properties against both Gram(+) and Gram(-) bacteria (Alzoreky & Nakahara, 2003; Bonjar, Aghighi, & Nik, 2004; Chao, Young, & Oberg, 2000; Martins et al., 2001; Stoyanova et al., 2006; Wei & Shibamoto, 2010). The antimicrobial properties vary depending on the concentration (Toroglu, Dıgrak, & Cenet, 2006). However, in other studies, ginger essential oil has been reported to have weak or no antimicrobial properties (Onyeagba, Ugbogu, Okeke, & Iroakasi, 2004; Wannissorn, Jarikasem, Siriwangchai, & Thubthimthed, 2005; Zaika, 1988).

In this study, edible coating (WPI) was produced by adding 1.5% sorbitol (S) and 0.5% (w/v) alginate (Alg) to WPI. This filmogenic solution was separated into two parts, one of which was fortified with WPIG [1.5% (v/v) ginger essential oil (G) (*Zingiber officinale* Roscoe)], to yield a WPIG-based coating. One group of Kashar cheese samples was coated with this coating, a second group was coated only with WPI, and a third group of cheese samples was left uncoated (control (K) sample). All of the cheese samples were artificially contaminated with *Escherichia coli* O157:H7 (*E. coli* O157:H7) and *Staphylococcus aureus* (*S. aureus*) at 10^6 Log10 cfu/g and stored at 4°C. The samples were analyzed in terms of microbiological and physicochemical properties on the 1st, 7th, 15th and 30th days of storage.

Materials and methods

WPI, alginate and sorbitol

For the preparation of the edible coating the WPI was obtained from Bipro, Davisco Foods International, Le Sueur, MN, USA, and the D-sorbitol (S1876 Sigma-Aldrich) and alginate were obtained from Fluka-Norway.

Essential oils

The ginger essential oils purchased for this study were extracted from the flora of Izmir, Turkey. Depending on the amount of the plant material available, essential oil was obtained via hydro-distillation for 3 h using a Clevenger-type apparatus (Bounatirou et al., 2007).

Analysis of essential oils and volatile compounds by GC

The oils used were derived from ginger, and the active components, zingiberene, geranial, camphene, *β*-ses-quiphellandrene and neral, were obtained from Sigma-Aldrich (Steinheim, Germany). Determination of the active substances of the essential oils was made using a Shimadzu GC-9A Model gas chromatograph, equipped with Thermon-600 T (30 m × 0.25 mm × 0.25 µm film thickness). The oven was set at a temperature range of 15–200°C/min for a total of 15 min. Other operating conditions included a carrier gas of nitrogen with a flow rate of 10.0 ml/min; injector and detector temperatures of 250°C and 300°C, respectively; split ratio of 1:20; and column pressure of 56.8 hPa.

Kashar cheese

The whole-fat, semi-hard Kashar cheese samples were produced with cow's milk (protein: 3.5%, carbohydrates: 2.4%). Milk was heated to 34°C and a commercial rennet was used. The milk was coagulated with animal rennet for 40 min. The draining of the whey was achieved by cutting the curds into small pieces and then using a cheese cloth to press them. The curd was then left to sit for two hours to recover, after which the acidity was checked and found to have a pH of 5.2–5.4 (Yetismeyen, 1997). Next, the pressed curd was broken into small pieces and added to 75°C water in a mixer to make dough. Lastly, the doughy substance was divided into four 100 g ball-shaped pieces of cheese. These cheese pieces were kept in a 6–8% salt solution for an hour before being hung at room temperature on a metal bar to drain excessive salt solution, and then they were stored at 4°C for 30 days.

Preparation of edible coating solution

Edible coatings were prepared according to the protocols established by Pintado, Ferreira Maria & Sousa (2010) and McHugh and Krochta (1994), with some modifications. Accordingly, 5% w/v WPI was prepared, and after the addition of 1.5% w/v sorbitol and 0.5% w/v alginate (in order to increase the mechanical properties of the coating solution) to the solution, a homogenizer was used to perform the homogenization process (20,000 rpm for 1 min (3–16 K Type-Model, Sigma, Germany)). The mixture's pH was adjusted to 8 and kept in a water bath at 90 ± 2 °C for 30 min in order to improve the mechanical properties of the coating. In the standby stage, 0.5% alginate was added. After the solution was cooled to room temperature, alginate-sorbitol-amended WPI was obtained. The cooled coating solution was filtered and divided into two equal parts; the first part was coated edible coating with only WPI; the second part was coated edible coating with 1.5% (v/v) WPIG. Ginger ratio was determined based on the results of preliminary trials, where 0.5% (v/v), 1% (v/v) and 1.5% (v/v) ginger were added. The best results were achieved with the 1.5% (v/v) treatment. Following the ginger essential oil addition, in order to maintain the homogeneous distribution of oil in the solution, Tween 20 (0.5% (v/v)) was added (Zivanovic et al., 2005), and the solution was centrifuged again at 20,000 rpm for 1 min (3–16 K Type-Model, Sigma, Germany) (Torlak and Nizamoglu, 2011) and then cooled to room temperature. As a result of this procedure, the coating forming solutions, WPIG and WPI, were obtained.

Preparation and storage of samples

The *E. coli* O157:H7 (ATCC 43895) and *S. aureus* (ATCC 6538) strains used for the artificial contamination of Kashar cheese samples were obtained from Hemakim Corporation (Turkey). For the artificial contamination, 10^6 cfu/g inocula were used. The 100 g Kashar cheese samples that had been placed in sterile containers were contaminated by spreading 0.1 mL of inoculum across the surface of the samples using a Drigalski spatula. Contaminated samples were kept in a sterile cabinet at +4°C for 15 min for adhesion and absorption of inocula. The artificially contaminated cheese samples were

then dipped into the coating forming solutions, WPIG and WPI. The samples were dried in a refrigerated oven for approximately 4–5 h before being vacuum packaged. The prepared samples were stored at 4 ± 1°C for 30 days, during which *E. coli* O157: H7 and *S. aureus* counts (Food and Drug Administration, 2001) were calculated in terms of Log_{10} cfu/g on the 1st, 7th, 15th and 30th days of storage.

Microbiological analysis

E. coli O157:H7 was enriched in selective modified EC Broth at 35–37°C for 24–48 h. For enumeration of *E. coli* O157:H7, Sorbitol MacConkey Agar containing Cefixime-Tellurite Supplement was used, and the *E. coli* was incubated at 35–37° C for 24–48 h. For enumeration of *S. aureus*, 5% Egg Yolk Tellurite emulsion was added to Baird Parker Agar, and *S. aureus* was incubated under aerobic conditions at 35–37°C for 24–48 h (Food And Drug Adminıstratıon, 2001).

Physical–chemical analysis

Weight loss percentages of Kashar cheese samples during storage were determined gravimetrically. Using a penetrometer (4500 CT3 texture analyzer Brookfield, USA), the inner–outer hardness of the cheese samples was found to be 3 ± 1ºC. The pH values were examined with a SS-3 Zeromatic pH meter (Beckman Instruments Inc., California, USA). Analyses of acidity (° SH) and fat content (%) were performed according to AOAC (1990). Coating thicknesses were measured using a micrometer at 0.005 mm precision (Digimatic Micrometer, Japan). Water vapor permeability (WVP) of coatings was determined gravimetrically at 25^0C using a modified ASTM E96-80 (ASTM, 1983) procedure. The test edible coating was sealed in a glass dish containing anhydrous calcium chloride (Merck, Darmstadt, Germany), 0% RH. This dish was then placed in a desiccator maintained at 52 ± 2% RH with saturated magnesium nitrate (Merck, Darmstadt, Germany). The water vapor transferred through the coating and absorbed by the desiccant was determined by measuring the weight gain. WVP was calculated using the following equation:

$$WVP = c\frac{x}{A \times \Delta p}$$

A: Surface area (m^2)
WVP: Water vapor permeability (g mm m^{-2} h^{-1} kPa^{-1})
Δp: Partial pressure difference of the gases (kPa)
x: Coating thickness (mm)

Statistical evaluation

Five different cheese samples were examined with three parallels and two repetitions. Statistical analyses were performed using the SPPS version 15 statistical analysis package software. Data significance derived from analysis of variance (ANOVA) was tested according to the Duncan multiple comparison test at the $p < 0.05$ level.

Results and discussion

Ginger essential oil, containing zingiberene (39.12%), geranial (13.44%), camphene (11.15%), *β*-ses-quiphellandrene (10.64%) and neral (6.61%), was obtained from the *Zingiber officinale* Roscoe species.

The decrease in pH values detected in K samples during storage was higher than that in WPIG and WPI samples (Table 1). Fat levels in Kashar cheese fortified with essential oil increased during storage (Table 1); the relationship between the two parameters was found to be significant ($p < 0.05$). Additionally, coating the cheese samples with WPIG-based coating had a significant effect on the fat levels of the samples ($p < 0.05$). The higher fat values in samples coated with WPIG-based coating compared with the K sample are associated with the former's higher dissolution of the essential oil in the lipid fraction of the cheese, which can be attributed to the WPIG-based coating's hydrophobic properties (Holley & Patel, 2005) and it being a good barrier against fat (Koyuncu & Savran, 2002). Weight losses in coated Kashar cheese samples were lower than those in K samples (Figure 1). As seen in Figure 1, the inner and outer hardness values during the storage of the samples coated with WPIG were lower than the uncoated K samples. The differences observed between coated and

Table 1. The average pH, °SH and fat values in WPIG, WPI samples and control samples during storage time.

Tabla 1. El promedio de pH, °SH y valores de grasa en las muestras WPIG,WPI y las muestras control durante el tiempo de almacenamiento.

	Storage time (Day)	K	WPIG	WPI
pH	**1**	5.40 ± 0.60^{aA}	5,31 ± 0.32^{aB}	5,31 ± 0.25^{aB}
	7	5,30 ± 0.50^{aA}	5,25 ± 0.49 ^{aB}	5,28 ± 0.50^{aB}
	15	5,29 ± 0.62^{aA}	5,24 ± 0.55 ^{aB}	5,25 ± 0.65 ^{aB}
	30	5,02 ± 0.81^{bA}	5,24 ± 0.59 ^{aB}	5,18 ± 0.69 ^{aB}
Titratable acidity (°SH)	**1**	104,00 ± 5.12^{aA}	105,00 ± 3.21 ^{aB}	105,00 ± 3.31 ^{aB}
	7	128,75 ± 6.25 ^{bA}	115,25 ± 5.35 ^{aB}	118,35 ± 6.30 ^{aB}
	15	131,00 ± 7.33 ^{bA}	120,00 ± 6.13 ^{aB}	122,00 ± 7.10 ^{aB}
	30	132,25 ± 7.54 ^{bA}	128,00 ± 6.25 ^{aB}	129,00 ± 8.25 ^{aB}
% Fat	**1**	28,48 ± 1.78^{aA}	30,25 ± 2.74 ^{aB}	29,25 ± 3.75 ^{aC}
	7	28,23 ± 3.10^{aA}	30,44 ± 2.43 ^{aB}	29,40 ± 3.43 ^{aC}
	15	28,12 ± 3.10^{aA}	31,08 ± 2.24 ^{bB}	30,00 ± 3.70 ^{bC}
	30	28,96 ± 3.05^{aA}	31,60 ± 2.12 ^{bB}	30,50 ± 3.65 ^{bC}

Notes: Mean ± standard deviation ($n = 3$)
a, b, c, d: The differences between the values in the same column are statistically significant ($p < 0.05$).
$^{A, B:}$ The differences between the values in the same line are statistically significant ($p < 0.05$).

Notas: Promedio ± desviación estándar (n = 3)
a, b, c, d: Las diferencias entre los valores en la misma columna son estadísticamente significativas (p < 0,05).
$^{A, B:}$ Las diferencias entre los valores en la misma línea son estadísticamente significativas (p < 0,05).

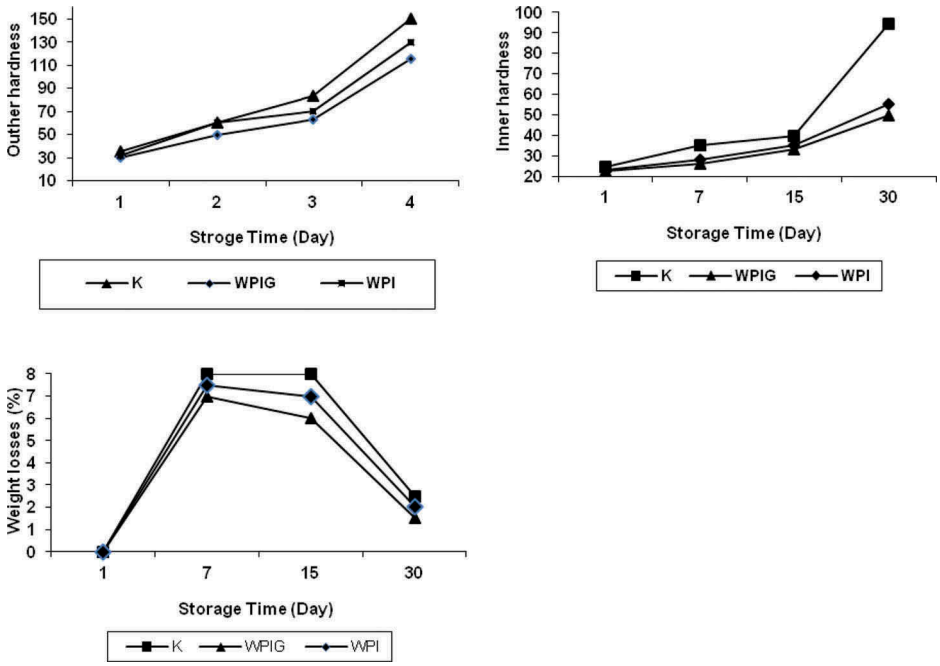

Figure 1. The average weight loss (%) and inner–outer hardness values of WPIG samples, WPI samples and non-coated K samples during storage time.

Figura 1:El promedio de pérdida de peso (%) y los valores de dureza interior y exterior de las muestras WPIG, las muestras WPI y las muestras K sin recubrimiento durante el tiempo de almacenamiento.

Table 2. Thicknesses and water vapor permeability of WPI and WPIG-based films.

Tabla 2 Grosor y permeabilidad del vapor de agua de los plásticos film de WPI y WPIG.

Samples	Thickness /mm ± б	Water vapor permeability (g mm m^{-2} h^{-1} kPa^{-1})
WPI	0.180 ± 0.005	8.58 g mm m^{-2} h^{-1} kPa^{-1a}
WPIG	0.181 ± 0.004	8.40 g mm m^{-2} h^{-1} kPa^{-1b}

Notes: Mean ± standard deviation (n = 3)
a, b, c,: The differences between the values in the same column are statistically significant ($p < 0.05$).

Notas: Promedio ± desviación estándar (n = 3)
a, b, c,: Las diferencias entre los valores en la misma columna son estadísticamente significativas (p < 0,05).

uncoated (K) cheese samples during storage were statistically significant in terms of inner and outer hardness values ($p < 0.05$). The effect of edible coating on weight loss was significant ($p < 0.05$), and WPIG-based coating formed a good water barrier.

The WVP of WPIG-based coating was 8.40 g mm m^{-2} h^{-1} kPa^{-1}, while for the WPI coating, it was 8.58 g mm m^{-2} h^{-1} kPa^{-1} (Table 2). A significant relationship was detected between WPIG addition (1.5% v/v) and the increase in the water barrier property of the WPI-based coating ($p < 0.05$). Studies have reported that coating prevents water vapor transmission and thereby reduces economic losses (Krochta & De Mulder-Johnston, 1997; Sarıoglu & Oner, 2006). The results related to WPIG-based coatings in this study were consistent with those in the literature. The thicknesses of the WPIG-based coating and the WPI coating were 0.181 ± 0.004 mm and 0.180 ± 0.005, respectively. The difference between the coating thicknesses was not found to be significant ($p > 0.05$).

In our study, cheese samples were artificially contaminated with pathogenic microorganisms at 10^6 $\log_{10}$ cfu/g (6 $\log_{10}$ cfu/g). After adding a concentration of 1.5% (v/v) of ginger essential oil to WPIG-based coating, the coating's bacteriostatic and bactericidal effects were determined (Table 3). Antimicrobial activity observed in the WPI-coated samples was found to increase significantly with the addition of 1.5% (v/v) of ginger oil (Table 3). Significant relationships were therefore determined between the cheeses coated with WPI-based coating and antimicrobial activity and also between the increase in antimicrobial activity and the

Table 3. The average microorganism counts and standard deviation values in WPI, WPIG and K samples (n = 3); ($p < 0.05$).

Tabla 3. El promedio de recuentos de microorganismos y los valores de desviación estándar en las muestras WPI, WPIG y K (n = 3); (p < 0,05).

		Microorganisms count ($\log_{10}$ cfu/g)		
Microorganisms	Day	K	WPI	WPIG
***E.coli* O157:H7**	1	6.02 ± 0.11^{aA}	6.00 ± 0.87^{aB}	5.82 ± 0.05^{aC}
	7	6.88 ± 0.23^{bA}	$5,92 \pm 0.81^{bB}$	5.63 ± 1.12^{bC}
	15	6.91 ± 0.09^{bA}	5.81 ± 0.91^{cB}	5.17 ± 2.47^{cC}
	30	7.11 ± 0.05^{cA}	$5,10 \pm 0.93^{dB}$	2.93 ± 0.54^{dC}
S.aureus	1	6.29 ± 2.36^{aA}	6.20 ± 0.87^{aB}	6.12 ± 2.87^{aC}
	7	6.42 ± 1.12^{bA}	$6,00 \pm 0.81^{bB}$	5.44 ± 1.47^{bC}
	15	6.76 ± 1.08^{bA}	$5,95 \pm 0.91^{bB}$	2.48 ± 2.10^{cC}
	30	7.27 ± 2.05^{cA}	$5,02 \pm 0.93^{cB}$	10 >

Notes: a, b, c, d: The differences between the values in the same column are statistically significant ($p < 0.05$).
A, B: The differences between the values in the same line are statistically significant ($p < 0.05$).

Notas: a, b, c, d: Las diferencias entre los valores en la misma columna son estadísticamente significativas (p < 0,05).
A, B: Las diferencias entre los valores en la misma línea son estadísticamente significativas (p < 0,05).

addition of ginger oil to the coating ($p < 0.05$). Moreover, a significant relationship was detected between essential oil fortification and antimicrobial effect in terms of storage days ($p < 0.05$), where it was found that the antimicrobial effect of essential oil increased in the later days of the storage period. This result was associated with the slower transmission of antimicrobial agent from the coating layer to food in the edible coating systems, whereby a high concentration of antimicrobial agent was left in the coating and at the surface of the food, which in effect provides a long-lasting defense against microorganisms (Cagri, Ustunol, & Ryser, 2002; Coma et al., 2002). Additionally, depending on the acidity increase in cheese samples, the hydrophobic properties of essential oil also increases, indicating that the essential oil is easily dissolved in the lipid phase of the food and the bacteria, thereby providing an increase in the antimicrobial activity (Holley & Patel, 2005).

In our study, WPIG-based coating was detected to have a bacteriostatic effect against both microorganisms (Table 3), whereas a bactericidal effect was only detected for the *S. aureus* microorganism on the 30th day, with no equivalent effect found for *E. coli* O157:H7 during the same time period. The bacteriostatic effect against *S. aureus* was observed on the 7th day of storage (5.44 Log_{10} cfu/g), when the microorganism count was reduced to the level of 2.48 Log_{10} cfu/g. A bactericidal effect of the essential oil against *S. aureus* was found to occur on the 30th day. The resistance of *S. aureus* to essential oil was higher than that of *E. coli* O157:H7 on the 1st day of storage. However, the inactivation level observed in *S. aureus* between the 1st and 7th days of storage was 3.5 times greater than that of *E. coli* O157:H7. The bacteriostatic effect of WPIG-based coating on *E. coli* O157:H7 started from the 1st day of storage and reached its highest level on the 30th day of storage. On the 30th day, *E. coli* O157:H7 decreased to 3.93 Log_{10} cfu/g. Microbial growth was found to be the highest in the K sample throughout the period of storage. Accordingly, the highest increases in the average of the 1st and 30th days in the K sample were found to be *E. coli* O157:H7 (7.11 Log_{10} cfu/g increased by 1.09 Log_{10} cfu/g) and *S. aureus* (7.27 Log_{10} cfu/g 0.98 Log_{10} cfu/g increased by 7.27 Log_{10} cfu/g). The increase of *E. coli* O157:H7 levels in the K sample throughout the storage period was higher than that of *S. aureus*. Moreover, *E. coli* O157:H7 levels in the K sample were higher compared to *S. aureus* levels in the same sample on the 7th and 15th days of storage, although the case was the opposite on the 30th day of storage. This was associated with an increase in acidity on the 30th day. In our study, the increase in acidity determined in the K sample throughout the storage period was higher than that in coated samples. *S. aureus* was less affected by the increase in acidity detected on the 30th day of storage in the K sample. The more resistant microorganism to ginger essential oil added to WPIG-based coating at the level of 1.5% (v/v) was found to be *E. coli* O157:H7.

The results obtained regarding *E. coli* O157:H7 and *S. aureus* in our study were consistent with those of other studies on the antimicrobial effects of different essential oils (Celikel & Kavas, 2008; Lee & Krochta, 2002; Raybaudi-Massilia, Mosqueda-Melgar & Martín-Belloso, 2008; Seydim & Sarikus, 2006; Rojas-Graü et al., 2007). The antimicrobial and antifungal effects of ginger essential oil were found to be high in some studies (Alzoreky & Nakahara, 2003; Bonjar et al., 2004; Chao et al., 2000; Martins et al., 2001; Sharma & Sharma, 2011; Shetty, 1997; Stoyanova et al., 2006; Wei & Shibamoto, 2010) but weak or absent in others (Onyeagba Ugbogu, Okeke & Iroakasi, 2004; Wannissorn et al., 2005; Zaika, 1988). Additionally, the antimicrobial effect of ginger was found to vary depending on certain factors, such as plant species, harvesting time, geographical conditions and the ratio of active ingredient (Cagri et al., 2002; Cha & Chinnan, 2004; Joerger, 2007; Sağdıç, Kuşçu, Özcan, & Özçelik 2002; Torlak & Nizamoglu, 2011). In our study, it was found that the addition of 1.5% (v/v) of ginger essential oil to WPI+S+Alg-based coating had a bacteriostatic effect on *E. coli* O157:H7 and a bactericidal effect on *S. aureus* during 30 days of storage. Our results were therefore found to be consistent with some of the research found in the literature, while there were others that our results were found to be in disagreement with. Furthermore, in our study, it was concluded that the essential oil could potentially have a bactericidal effect on *E. coli* O157:H7 by increasing the concentration of the essential oil or by extending the shelf life.

Conclusion

The effect of coating on the increase in acidity (decrease in pH) was significant ($p < 0.05$). The lower titration acidity in coated samples compared to the K sample was associated with the structure of the coating. The coating of cheese samples with WPIG-based coating reduced the weight loss of the cheese. The effect of WPIG-based coating on weight loss and fat levels was significant ($p < 0.05$). It was found that fortification of WPI+S+Alg-based coating with 1.5% ginger essential oil (v/v) had an antimicrobial effect, significantly decreasing the levels of microorganisms in coated samples. The antimicrobial effect provided by ginger essential oil during storage was observed to be in the form of a bacteriostatic effect on *E. coli* O157:H7 and a bactericidal effect on *S. aureus*. The microorganism counts increased in the non-coated K sample during storage. WPI-based coating was determined to be a good water and fat barrier, and with the addition of 1.5% (v/v) ginger essential oil to WPI-based coating (WPIG), the above-mentioned properties improved and there was an increase in antimicrobial activity. At the end, WPIG was found to be more effective in the extension of the storage period compared to WPI WPIG-based coating and was shown to have good water and fat barrier properties.

Disclosure statement

No potential conflict of interest was reported by the authors.

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