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Sensory Evaluation of Baked Chicken Wrapped with Antimicrobial Apple and Tomato Edible Films Formulated with Cinnamaldehyde and Carvacrol

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ABSTRACT: The addition of plant essential oils to edible films and coatings has been shown to protect against bacterial pathogens and spoilage while also enhancing sensory properties of foods. This study evaluated the effect of adding 0.5 and 0.75% carvacrol (active ingredient of oregano oil) to apple- and tomato-based film-forming solutions and 0.5 and 0.75% cinnamaldehyde (active ingredient of cinnamon oil) to apple-based film-forming solutions on sensory properties of cooked chicken wrapped with these films. Paired preference tests indicated no difference between baked chicken wrapped with tomato and apple films containing 0.5% carvacrol and cinnamaldehyde compared to chicken wrapped with tomato or apple films without the plant antimicrobials. The taste panel indicated a higher preference for carvacrol-containing tomato-coated chicken over the corresponding apple coating. There was also a higher preference for cinnamaldehyde-containing apple films over corresponding carvacrol-containing wrapping. Films containing antibacterial active compounds derived from essential oils can be used to protect raw chicken pieces against bacterial contamination without adversely affecting preferences of wrapped chicken pieces after baking.

KEYWORDS: *Antibacterial films and coatings, essential oils, cooked chicken, hedonic evaluation, sensory preferences*

INTRODUCTION

The use of edible films and coatings to protect and preserve foods is increasing because they offer several advantages over synthetic materials, such as being biodegradable and environmentally friendly.[1] The ability of edible films to retard moisture, oxygen, aroma, and solute transport may also be further enhanced by including additives, such as antioxidants, antimicrobials, colorants, flavors, fortifying nutrients, and spices in film formulation.[2] The addition of natural antioxidants derived from fruit and vegetable extracts to increase the shelf life of food products has become a popular strategy. Edible films and coatings can be used as carriers of plant essential oils, whereby the active antibacterial components present in the oils may protect food against bacterial pathogens and spoilage organisms while potentially enhancing sensory properties of coated foods.

McHugh and others[3] developed the first edible films made from fruit purees. They found that apple-based edible films are excellent oxygen barriers but not very good moisture barriers. Apple wraps used on fresh-cut apple slices proved more effective than coatings to increase their shelf life, reduce moisture loss, and cause brown.[4] A diet rich in apple fruit is considered beneficial for human health. Apple fruit contains several health- and sensory-related constituents, including dietary fiber, sugars, vitamins, and phenolic compounds. There is strong evidence that phenolic compounds may help prevent cardiovascular disease and cancer.[5]

In addition to its flavor properties, tomatoes are also reported to possess numerous beneficial nutritional and bioactive components that may promote human health. These include the nutrients vitamin A, vitamin C, iron, and potassium; nonnutritive digestible and indigestible dietary fiber; the antioxidative compounds lycopene, β-carotene, and lutein;[6,7] cholesterol-lowering properties;[8,9] and glycoalkaloids tomatine and dehydrotomatine; and immune-system-enhancing properties.[10] Consumption of tomatoes, tomato products, and isolated bioactive tomato ingredients is reported to be associated with a lowered risk of cancer,[11] heart disease,[12] diabetes,[13] and hypertension.[14]

These considerations suggest that edible tomato films containing antimicrobials may have multiple benefits. These include protection of food against contamination by pathogenic microorganisms as well as nutritional and health benefits associated with the consumption of the above-mentioned tomato ingredients that may be present in the films.

Oregano essential oil is compatible with the sensory characteristics of tomato-based films. In addition to desirable antimicrobial and barrier properties in these films, oregano oil exhibits antioxidative and other beneficial effects that are reported to be associated with tomatoes.[15,16] We previously demonstrated the antimicrobial effectiveness against foodborne pathogens of oregano oil in phosphate buffers[17,18] and in films prepared from fruits and vegetables.[19−25]

Antimicrobial assays of tomato films indicated that optimum antimicrobial effects occurred when 0.75% carvacrol (main active compound of oregano oil) was added to tomato purees before film preparation. High-performance liquid chromatog-

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Set: _____

Sensory Testing

Name:____ Date:_________

INSTRUCTIONS:

1.- Taste the product on the left first, and the product on the right second. Take a cracker and water as needed between samplings. Now that you've tasted both products, which one do you prefer? Please **choose one** by circling the corresponding numerical code:

____116_____ _____968_____

2.- Please comment on the reason for your choice:

Figure 1. Questionnaire used for the sensory evaluation of baked chicken wrapped with antimicrobial apple and tomato edible films formulated with cinnamaldehyde and carvacrol.

raphy (HPLC) analysis of the films indicated that the carvacrol concentrations and bactericidal effects of the films remained unchanged over a storage period of up to 98 days at 5 or 25 °C. In a related study, Du and others[23] demonstrated that carvacrol in apple films also inhibited the growth of *Escherichia coli* O157:H7, even after storage at 5 or 25 °C for 7 weeks. In related studies, we found that carvacrol and cinnamaldehyde (main component of cinnamon oil) incorporated into tomato- and apple-based edible films were also effective against foodborne pathogens.[19,22−25]

According to a report from the Center of Disease Control, contaminated poultry was the most commonly identified source of food poisoning in the United States in 2006.[26] In continuing studies on the effectiveness of fruit- and vegetable-based antimicrobial films, we found that wrapping chicken breast pieces with apple films containing 0.5% carvacrol or cinnamaldehyde reduced the growth of *E. coli* O157:H7, *Salmonella enterica*, and *Listeria monocytogenes* after storage at 4 °C for 72 h.[27] This study showed that the bactericidal activity of apple film wraps on poultry products was greater with carvacrol than with cinnamaldehyde and that *E. coli* O157:H7 was more resistant than *S. enterica* and *L. monocytogenes*. The data also showed that carvacrol added to tomato-based film-forming solution was effective against *E. coli* O157:H7 at a concentration of 0.75% but not at 0.5%.

An unresolved issue in all studies with antimicrobial films is how they would influence sensory properties of food. Preference testing is very sensitive even for untrained taste judges to compare the effect of food formulation changes, although it does not determine the degree of liking or overall acceptability (references). The main objective of this study was to evaluate the human preferences of cooked chicken breast pieces wrapped with tomato- and apple-based films containing 0.5−0.75% carvacrol or cinnamaldehyde.

MATERIALS AND METHODS

Preparation of Antibacterial Apple and Tomato Films. The films were made by batch casting according to the procedures used in previous studies for tomato-based films[22] and apple-based films with carvacrol at 0.5 and 0.75% (w/w) in the film-forming solutions.[23,27] Apple-based control films without antimicrobials and with 0.5 and 0.75% (w/w) cinnamaldehyde in the film-forming solution were prepared by the method described by Ravishankar and others.[27]

Measurement of Carvacrol and Cinnamaldehyde in Films by HPLC. The method used is described by Du and others.[22,23] Briefly, for HPLC studies, three 50 mm diameter film discs were covered in folded aluminum foil, sealed in plastic bags, and stored under refrigeration until testing. Each film was weighed (ca. 230 mg) and homogenized in an Omni International homogenizer (Gainesville, VA) in 10 mL of 50% ethanol (prepared from 95% ethanol, ACS/USP grade) for 5 min on low speed with a blade attachment and then for 5 min on high speed with a generator probe. The extract was filtered through a 0.45 μm nylon membrane (Sigma, St. Louis, MO) and injected directly into the HPLC column. The HPLC system consisted of a Beckman 110B pump, a Thermo Separation Products AS3500 autosampler (loop size of 100 μL), and an UV 3000HR scanning detector with both deuterium and tungsten lamps. Thermo Separation Products PC1000 System Software controlled the system. The following conditions were used: a Supelco LC-ABZ column was used (250 × 4.6 mm plus a 2 cm precolumn); the particle size of the column packing was 5 μm; and the eluent consisted of 50% acetonitrile, 50 mM ammonium phosphate, and 0.05% phosphoric acid at pH 3.1. The eluent was degassed once before use. The flow rate of the pump was 1 mL/min, and the sample volume injected was 20 μL. Absorbance was monitored at 200 and 280 nm, at 12 and 6.4 min retention time for carvacrol and cinnamaldehyde, respectively. The concentration of both antibacterial compounds in the dried films was reported as a percentage (w/w).

Preparation of Film-Wrapped Baked Chicken Pieces. Boneless, skinless chicken breasts (Empire Kosher Poultry, Inc., Mifflintown, PA) were defrosted overnight under refrigeration. The average weight of the pieces was 189 g. The amount of weighed edible film needed to completely encase a whole chicken breast was estimated visually. The average weight of one chicken breast was divided by the weight of the film needed to encase the chicken breast to obtain a chicken/film ratio. This was done for both the apple and tomato films with antibacterial compounds, as well as the control films. The actual weight of film needed to encase one chicken breast was found to be ca. 6 g, and the chicken/film ratio was 31.5. For 2 samples/judge and 60 judges in the sensory panel, the chicken breast was cut into cubes of 12 ± 2 g each to obtain approximately 1440 g of raw chicken cubes for baking and sampling. The chicken cubes were divided evenly between two Ziploc bags, one for control wrapped samples and the other for antibacterial wrapped samples. The bags were weighed, and the weights were noted on each corresponding bag. The bags were then labeled control and antibacterial treated, respectively. The amount of film needed to marinate each bag of chicken cubes was determined using the chicken/film ratio (19 g of film for each bag containing 600 g of chicken cubes).

Each control and antibacterial film wrap was blended with water separately at a ratio of 1:10 film (g)/water (mL) in a high-speed blender until completely emulsified. To make the chicken more palatable but not enough to interfere with the flavor of the films, salt was added to each bag of chicken cubes at a ratio of 400:1 chicken (g)/salt (g). Each film−water solution was then poured into the corresponding bag of chicken breast cubes; the air was squeezed out; and the bags were tightly sealed. The bags were then massaged well to evenly disperse and coat the chicken with the salt and film solution. The chicken was left to "marinate" in the film solution for ∼30 min before cooking.

For cooking, the chicken was evenly distributed onto a sheet pan lined with aluminum foil, lightly sprayed with non-stick cooking spray, then covered with aluminum foil, and baked in a 400 °F oven for 30 min, with stirring halfway through the cooking time. After baking, the samples were held in a covered bowl to keep them warm. They were then handed out to the sensory participants as needed. The samples in each pair were served at the same temperature, warm to lukewarm.

Sensory Evaluation of Baked Chicken Pieces Wrapped with Film. Paired preference qualitative affective tests[28,29] were conducted using an in-house volunteer panel. The paired preference tests were done randomly in a sensory laboratory setting for each of seven edible film wrap formulations during a period of 2 months. Testing was performed in 1 day for each formulation from 10 a.m. to 12 p.m. and from 1 to 3 p.m. The panel consisted of 52−63 individuals (62.4 ± 8.2% females and 37.6 ± 8.2% males) ranging in age from 20 to 65 years. Paired samples, control and treated (tomato- or apple-based edible wrap without and with carvacrol or cinnamaldehyde, respectively), were given to each judge in a tray, which included unsalted crackers and water to reduce aftertaste between each tasting.

Figure 1 indicates the instructions for tasting each pair of samples and reporting the preference choices. Judges also described reasons for their choices and were instructed to make force-choice preference decisions. The order of presentation of control and treated samples in each pair was randomized to avoid the tendency by judges to choose as preferred the last sample tasted. Samples were tasted in individual booths under red light to reduce slight differences in color of the wrapped baked chicken pieces because of the addition of the two antimicrobials. Color changes in tomato- and apple-based films by the addition of carvacrol and cinnamaldehyde antimicrobials are described in our previous publications.[22−24]

Statistical Analysis. Minimum agreeing judgments necessary to establish significant preference (a two-tailed test) at $p < 0.05$ was used for analysis of paired preference test results.[28,29] To ensure that there was not an effect of the order of tasting, the data for control and treated samples were analyzed either when the choices of the control samples were presented first for tasting or the samples with carvacrol or cinnamaldehyde were presented first.

RESULTS AND DISCUSSION

Carvacrol and Cinnamaldehyde Concentration in Tomato- and Apple-Based Edible Films. The apparent increase on percent concentration of the antibacterial carvacrol and cinnamaldehyde added to the film-forming solution compared to the detected percent concentration in the cast film shown in the first column of Tables 1−3 is due to the removal of water during film casting. Assuming null evaporation of the two antibacterials and differences in total solids in these two films, it is estimated that 0.75% carvacrol or cinnamaldehyde added to film-forming solutions should correspond to 5.9 and 4.4% carvacrol or cinnamaldehyde in dried tomato and apple films, respectively. However, because, carvacrol and cinnamaldehyde are volatile compounds with high vapor pressures, we estimate based on the HPLC data that 60.1 ± 6.5 and 57.9 ± 11.4% of these compounds were lost during the solution mixing, vacuum degassing, and film casting, assuming no losses in cast films (Tables 1−3). These tables show that carvacrol detected by the HPLC analysis was higher in tomato-based films than apple-based films. The higher carvacrol concentration found in the tomato films is related to the lower total solids compared to the apple film as dried films.[22,23] We estimate that the carvacrol concentration should be 34.1 ±

Table 1. Preference of Cooked Chicken Wrapped with Tomato-Based Films with Different Concentrations of Antibacterial Carvacrol

carvacrol concentration (%)	control preferred	treated preferred	positive descriptors for treated chicken	negative descriptors for treated chicken
added to film-forming solution: 0.5 detected in dried film: 1.76 ± 0.04	33[a]	29	taste: nice, herbal seasoning, tangy, spicy, saltier odor: oregano-like, herbal texture: firmer, juicy, less slimy (33.6%)	taste: unpleasant aftertaste, bitter, metallic, paper-like, chemical, woody, less chicken-like, too salty, less sweet, pungent odor: repulsive, medicinal, overly herbal smell texture: less tender, soft, moist, driest (66.4%)
added to film-forming solution: 0.75 detected in dried film: 4.80 ± 0.17	46[b]	9	taste: natural flavor, good taste, spicy, herbal, like dried oregano, salty, less sour texture: soft, tender (15.5%)	taste: strong oregano flavor, bad, funny unpleasant aftertaste, smoky, less chicken taste, unpleasant artificial and strange flavor, bitter, astringent, less sweet, stale, inedible, metallic, mint, herbal odor: funny, weird, rubbery, strange odor texture: more dry (84.5%)

[a]No statistical difference. [b]Statistical difference at $p < 0.001$.

Table 2. Preference of Cooked Chicken Wrapped with Apple-Based Films with Different Concentrations of Antibacterial Carvacrol

carvacrol concentration (%)	control preferred	treated preferred	positive descriptors for treated chicken	negative descriptors for treated chicken
added to film-forming solution: 0.5			taste: very tasty, herbal, oregano flavor, more flavorful, cleaner aftertaste, spice flavor, right saltiness	taste: slight herbal bitter aftertaste, more salty, odd, strange, funny, plastic, medicine taste and flavor, oregano-like, taco seasoning, not chicken-like
	40[a]	22		odor: unpleasant smell, herbs scent, oregano odor
detected in dried film: 1.05 ± 0.08			texture: juicy, moist, tender, less granulated, better consistency	texture: less juicy and creamy
			(36.5%)	(63.5%)
added to film-forming solution: 0.75			taste: tangy, herbal, oregano-like, spicy, saltier	taste: less chicken taste, unpleasant aftertaste, strong herbal taste, bitter weird, chemical, metallic, paper-like, smoky, too salty, bad taste, overpowering plastic or medicine flavor
	35[a]	18	odor: flavorful	odor: bad smell
detected in dried film: 1.95 ± 0.07			texture: firmer, juicy	texture: dry, less tender, soft, moist
			(34.9%)	(65.1%)

[a]Statistical difference at $p < 0.05$.

Table 3. Preference of Cooked Chicken Wrapped with Apple-Based Films with Different Concentrations of Antibacterial Cinnamaldehyde

cinnamaldehyde concentration (%)	control preferred	treated preferred	positive descriptors for treated chicken	negative descriptors for treated chicken
added to film-forming solution: 0.5			taste: right, good flavoring; more complex, slightly better flavor, sweeter, salty, more spicy, less chicken aftertaste, stronger chicken flavor	taste: slight bitter aftertaste, altered, not as chicken, too salty, slight sweeter
	21[a]	31		odor: cinnamon smell, not as chicken, slight unpleasant odor
detected in dried film: 0.72 ± 0.48			texture: more tender, moist, easier to chew, juicy	texture: less tender, slightly drier, crumble after chewing
			(37.7%)	(62.3%)
added to film-forming solution: 0.75			taste: pleasant, distinct, salty enough, less bitter, sour, plain, raw	taste: unusual, funny, strange, cinnamon-like, apple-like, like candy and spices (nutmeg, mint, anise, clove), maple, musty/earthy aftertaste, licorice off-taste, bitter, less sweet, chemical, unpleasant lingering after several bites, not chicken-like
	49[b]	14		odor: cinnamon-like, bad smell, not as chicken smell
detected in dried film: 1.50 ± 0.78			texture: firmer, moist, softer, chewy, juicy, less dry, hard	texture: dry, flaky, less tender, smooth, juicy
			(23%)	(77%)

[a]No statistical difference. [b]Statistical difference at $p < 0.001$.

0.5% higher in tomato films compared to apple films at the same initial concentration added to the film-forming solutions. As expected, the percent carvacrol content detected was higher than the percent cinnamaldehyde content found in the apple-based films (Tables 2 and 3). The differences between apple and tomato films are also affected by the fact that apple films contain greater amounts of hygroscopic pectin, sugars, and glycerol that equilibrates at a higher moisture content to the ambient percent relative humidity, resulting in lower concentration percentages on a weight basis for both carvacrol- and cinnamaldehyde-containing films.

Beside differences in film formulation, cinnamaldehyde has a slightly lower vapor pressure (0.0265 mmHg at 25 °C) and higher volatility than carvacrol (0.0296 mmHg at 25 °C). Tables 2 and 3 show that detected percent carvacrol is higher than percent cinnamaldehyde in apple-based films. However, a confounding factor is that HPLC analysis of cinnamaldehyde in the apple-based films showed higher variation compared to carvacrol analysis in the same type of film.

Effect of Carvacrol on the Preference of Baked Tomato-Based Film Wrapped Chicken. Adding 0.5% carvacrol in the tomato-based edible film formulation did not affect the preference of cooked chicken. Otherwise, increasing the carvacrol concentration to 0.75% in tomato wraps drastically reduced preference choice (Table 1).

Comments from judges indicated that there were serious negative connotations related to the sensory characteristics of the chicken pieces because of the addition of carvacrol at 0.75% to the tomato-based edible films. Scramlin and others[30] reported than oregano oil (with carvacrol as its main constituent) can effectively reduce lipid oxidation and extend shelf life of meat products but developed off-flavor and lower acceptability.

Effect of Carvacrol on the Preference of Baked Apple-Based Film Wrapped Chicken. Adding 0.5% and 0.75% carvacrol in the apple-based edible film formulation reduced the preference of wrapped cooked chicken compared to the control. Comments from judges indicated that there were serious negative connotations related to the sensory characteristics of the chicken pieces because of the addition of carvacrol to apple-based edible films. The negative effect of the added carvacrol on the preference on apple-based wrapped chicken even at the lowest 0.5% concentration added could be due to flavor incompatibility of the apple/carvacrol flavor blend compared to the tomato/carvacrol flavor blend. Tomato-based products (tomato sauce, pizza sauce, etc.) are commonly formulated with oregano (containing carvacrol), and consumers are widely exposed to these flavor blends but not to the apple/oregano flavor blend.

Effect of Cinnamaldehyde on the Preference of Baked Apple-Based Film Wrapped Chicken. As shown in Table 3, paired-comparison preference tests indicated that baked chicken wrapped with apple films containing 0.5% cinnamaldehyde was equally preferred over chicken wrapped with apple films without the antibacterial. Table 3 also shows that increasing the cinnamaldehyde concentration from 0.75 to 1.0% in film-forming solutions to make the apple wrap used in the baked chicken resulted in a similar lower preference for the baked chicken pieces. Comparisons of preference choice frequencies shown in Tables 1−3 indicate that baked chicken is less preferred by using apple films with 0.75% cinnamaldehyde than with 0.75% carvacrol. In contrast, baked chicken wrapped with tomato films containing 0.75% carvacrol are more preferred.

Tables 2 and 3 show that chicken pieces baked with apple wrap with cinnamaldehyde at a 0.5% concentration were more preferred than those using apple wrap with carvacrol at the same concentration. We, therefore, conclude that 0.5% carvacrol is a more compatible flavoring agent for antimicrobial tomato wraps, while 0.5% cinnamaldehyde is a more compatible flavoring component for antimicrobial apple wraps used on baked chicken pieces. Flavor incompatibility of tomato with cinnamaldehyde was the reason to cancel the study of this formulation. According to descriptors indicated in Tables 1−3, carvacrol increased saltiness, while cinnamaldehyde increased sweetness of baked chicken. These two increased sensations could be affected by simultaneous context effects by the incorporation of flavorful components.[31] Lawrence and others[32] indicated that well-selected odors could be used to compensate for sodium chloride reduction in food, while cinnamon was reported with least associated saltiness intensity.

Statistical analysis of the sensory data also indicates that the cinnamaldehyde (0.5 and 0.75%)-containing apple films were preferred over the corresponding carvacrol-containing films. Using apple wrap with cinnamaldehyde gave a sweet cinnamon fragrance but uncharacteristic chicken taste, smell, and flavor. Cinnamaldehyde inhibits the growth of *E. coli* O157:H7 and *S. typhimurium* and is perceived as a sweet cinnamon−honey odor.[33]

Edible films and coatings containing antibacterial essential oil active components with antibacterial properties can be used to protect raw chicken pieces against bacterial contamination without adversely affecting the sensory preference of the baked wrapped chicken. The apple and tomato films may contribute to the nutritional and health benefits of the wrapped chicken pieces.

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Notes

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