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Major Spice Usage Selection in Late 16th Century English Meat Recipes (1591 to 1597) Compared to Evolutionary Choices to Reduce Common Foodborne Pathogens and Their Gastrointestinal (GI) Symptoms

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1. Abstract

This paper compared the major individual spice usages in English meat recipes from 1591 to 1597 and their effectiveness to reduce bacteria and microbial growth of major meat foodborne pathogens, their gastrointestinal symptoms and improved digestion.

Previous research has hypothesized that despite taste issue with spices that these cultural traditions reduced the dangers of microbial contamination of food (Krebs n.d.) and even now some cultures still perceive medicinal value for spices resulting in high usages due to their traditional knowledge (Pieroni and Torry 2007). These reasons were compared to the statistically analyzed individual spice usage to determine if the late 16th century cooks ethnobotonically selected them for meat recipes.

Clove, cinnamon and nutmeg reduced at least 4 of the 5 major foodborne meat pathogens and in the case of cloves reduced all five. Cloves, cinnamon and nutmeg were all effective on the foodborne pathogens' gastrointestinal symptoms. The high usages of cloves (37%) and cinnamon (31%) along with the research with cultural communities that still use spices for medicinal value show that these spices most likely were chosen for these reasons. Also, the highly antimicrobial spice usage of cinnamon and cloves was 60% and was statistically different than Sherman and Hash's research of traditional English recipe with a usage of 18%. This again confirmed that the 16th century cooks chose these spices differently than the population today.

Mace although not as effective as an antimicrobial (reducing only one foodborne pathogen) does reduce all the gastrointestinal symptoms of the foodborne pathorgen. Mace's high usage at 46% may have been chosen for the symptom reduction which corresponds to the conclusions of Casagrande's; and Pieroni and Torry's recent research (2007).

Ginger's usage (35%) and pepper's usage (62%) were most likely chosen for the synergic effects with other spices which corresponded to recent research and potentially also for their improvement in digestion.

2. Introduction

This paper explored the major individual spice usages in English meat recipes from 1591 to 1597 in a variety of recipe documents/books. However, individual spice choice can be influenced its ability to assist with:

- Inhibiting Bacteria and Microbial Growth of the five main meat foodborne pathogens
- Reducing Gastrointestinal Symptoms of these foodborne pathogens
- Improving digestion

Previous research has hypothesized that despite taste issues with spices that these cultural traditions reduce the dangers of microbial contamination of food (Krebs n.d.). Specifically, human ‘evolutionary heritage is underlined by our anatomy and physiology” (Krebs n.d.) and that “our 5 senses of taste–sweet, salt, umami, bitter and sour – equip us for the consumption of the essentials for survivial –energy, salt and protein – as well for the avoidance of the dangers of poisonous or rotten food” (Krebs n.d.).

Spice usage was statistically analyzed to determine if the individual spice usage different as well as if the recipe books or documents and hence the author’s preferences were different. Also, high antimicrobial spices were statistically analyzed to determine if the late 16th century meat recipes differed from the traditional English meat recipes analyzed by Billing and Sherman; and Sherman and Hash.

Based on these analysis, the individual spice usage was compared to the literature review of the antimicrobial inhibition, gastrointestinal symptom reduction and digestion improvement to determine if the 16th century English cooks used these spices differently. Although the individual spices were correlated, the potential synergetic spice effects of low symptom or antimicrobial spices were discussed as potential additional reasons for these spice choices. Finally, the at-risk population for the foodborne illnesses and their spice choices were also discussed.

3. Background

3.1 Common Foodborne Pathogens in Meat

“Throughout recorded history, foodborne bacteria (especially species of Clostridium, Escherichia, Listeria, Salmonella, Shigella, and Vibrio) or their toxins have been serious health concerns, and they still are (Hui et al. 1994, WHO 1996).” (Sherman and Billing 1999). Foodborne Pathogens can seriously affect anyone but pregnant women and children are particularly susceptible. (U.S. Department of Health and Human Services n.d.). This paper focused on the five main foodborne pathogens associated with meat products:

- *Clostridium botulinum*
- *Escherichia coli (E. coli)*
- *Listeria monocytogenes*
- *Salmonella*
- *Staphylococcus aureus*

For each pathogen, Table 1 summarizes the basics, the typical meat sources (even though they could be from vegetables used in the dish), typical symptoms, the incubation period, and the duration until recovery.

Table 1: Foodborne Pathogens in Meat Summary

Pathogen	**Basics**	**Meat Sources**	**Symptoms**	**Incubation**	**Duration**
Clostridium botulinum	A bacterium that can be found in moist, low-acid food. It produces a toxin that causes botulism, a disease that causes muscle paralysis.	Meat products, seafood	Dry mouth, double vision followed by nausea, vomiting, and diarrhea. Later, constipation, weakness, muscle paralysis, and breathing problems may develop. Botulism can be fatal.	12 to 72 hours after eating contaminated food (in infants 3 to 30 days)	Recovery can take between 1 week to a full year.
Pathogenic *Escherichia coli (E. coli)*	A group of bacteria that can produce a variety of deadly toxins.	Meat (undercooked or raw hamburger), and contaminated water	Severe stomach cramps, bloody diarrhea, and nausea. It can also manifest as non-bloody diarrhea or be symptomless. Must-Know: *E.coli* 0157:H7 can cause permanent kidney damage which can lead to death in young children.	Usually 3 to 4 days after ingestion, but may occur from 1 to 10 days after eating contaminated food.	5 to 10 days
Listeria monocytogenes	A bacterium that can grow slowly at refrigerator temperatures. Must-Know: Listeria can cause serious illness or death in pregnant women, fetuses, and newborns.	Refrigerated, ready-to-eat foods (meat, poultry, seafood)	Fever, headache, fatigue, Muscle aches, nausea, vomiting, diarrhea, meningitis, and miscarriages.	9 to 48 hours after ingestion, but may occur up to 6 weeks after eating contaminated food.	Variable
***Salmonella* Enteritidis**	A bacterium that can infect the ovaries of healthy-appearing hens and internally infect eggs before the eggs are laid.	Raw meat, poultry, seafood	Diarrhea, fever, vomiting, headache, nausea, and stomach cramps Must-Know: Symptoms can be more severe in people in at-risk groups, such as pregnant women.	12 to 72 hours after eating contaminated food	4 to 7 days
***Salmonella* Typhimurium**	Some strains of this bacterium, such as DT104, are resistant to several antibiotics.	Raw meat, poultry, seafood,	Diarrhea, fever, vomiting, headache, nausea, and stomach cramps Must-Know: Symptoms can be more severe in people in the at-risk groups, such as pregnant women.	12 to 72 hours after eating contaminated food	4 to 7 days
Staphylococcus aureus	This bacterium is carried on the skin and in the nasal passages of humans. It's transferred to food by a person, as a result of poor hygiene, especially poor handwashing. When it grows in food, it makes a toxin that causes illness.	High-protein foods (cooked ham, raw meat and poultry), and humans (skin, infected cuts, pimples, noses, and throats)	Nausea, stomach cramps, vomiting, and diarrhea	Usually rapid - within 1 to 6 hours after eating contaminated food	24 to 48 hours

(U.S. Department of Health and Human Services n.d.)

3.2 Spices Used and Common Foodborne Pathogen Inhibition

A preliminary literature review of the major spices and their foodborne pathogen inhibition was conducted and has been summarized in Table 2.

Table 2: Anti-Microbial Inhibiting Effect on Common Foodborne Pathogens

Spice	*Staphylococcus aureus*	*Salmonella*	*Listeria monocytogenes*	*Clostridium botulinum*	*Escherichia Coli*
Cinnamon	Inhibiting	Inhibiting	Inhibiting		Inhibiting
Cloves	Inhibiting	Inhibiting	Inhibiting	Inhibiting	Inhibiting
Ginger	Inhibiting				
Mace	Inhibiting				
Nutmeg	Inhibiting	Inhibiting	Inhibiting		Inhibiting
Pepper	Inhibiting			Inhibiting	

(Parthasarathy, Chempakam and Zachariah 2008) (Latha, et al. 2005)

3.3 Spices Used and Gastrointestinal Illness Symptom Reduction and Digestion Improvement

A preliminary literature review of the major spices and their effectiveness to reduce the symptoms of foodborne pathogen or to improve digestion was conducted and has been summarized below.

Cinnamon/Canel (Cinnamomum Verum)

"Cinnamon is very effective for indigestion, nausea, vomiting, upset stomach, diarrhea and flatulence." (Vangalapati, et al. 2012). Cinnamon was also used to improve stomach functions and increase appetite by traditional medicinal practitioners of Bangladesh. (Akber, et al. 2011)

Cloves (Syzygium aromaticum)

Cloves were used by the Chinese as a digestive aid specifically for nausea, flatulence and diarrhea (Parthasarathy, Chempakam and Zachariah 2008). Cloves have also been specifically used to treat upset stomachs, diarrhea, intestinal gas, nausea and vomiting. (Bhowmik, et al. 2012)

Ginger (Zingiber officinale)

Ginger was also used to help with digestive inability and flatulence and also for intestinal pain in children according to the traditional practitioners of Bangladesh. (Akber, et al. 2011) Fresh ginger has also been used for nausea and loss of appetite. (Banerjee, Mullick and Banerjee 2011). "Ginger compounds are active against specific types of diarrhea" (Hasan, et al. n.d.)

Mace (Myristica fragrans aril)

"Asian Indians traditionally have treated stomach pains, dysentery, vomiting and the symptoms of malaria with mace. It is also chewed to prevent foul breath (Uhl, 2000)." (Parthasarathy, Chempakam and Zachariah 2008)

Nutmeg (Myristica fragrans)

Nutmeg has been used to treat flatulence and nausea. (Shafiei, et al. 2012). Nutmeg has also been used to treat vomiting historically (Conley 2002). Nutmeg has been used treat diarrhea. (Parthasarathy, Chempakam and Zachariah 2008)

Pepper (Piper nigrum L and Pepper sp)

Research indicates that piperine has also an anti-diarrheal property (at least in experimental mice) and reduces small intestine fluid retention. This supports peppercorns usage by herbal practioners for diarrhea for all ages (Ahmad, et al. 2012).

However, pepper has other digestive properties. Black pepper oil "increases the flow of saliva, stimulates appetite, encourages peristalsis, tones the colon muscles and is a general digestive tonic" (Pruthi, 1993) (Parthasarathy, Chempakam and Zachariah 2008). The pungent component of black pepper, piperine, also "increases the production and activation of salivary amylase[43]" (Ahmad, et al. 2012) which is used to break down starches and could aid with digestion. Ahmad, et al (2012) indicates from animal research that "the ingestion of *P. Nigrum* probably stimulates the liver which further digests food substances". Finally, Adhmad, et al, (2012) also indicated that piperine as a food additive increases protease activity which an enzyme that can break down protein.

3.4 Recipe Books/Documents

Four different late 16th century English documents from 1591 to 1597 were used for the recipe spice analysis. Prior research conducted by Billing and Sherman (1998) and most recently with the flavour pairing and network analysis by Ahn, et al. (2011); Teng, Lin and Adamic (2012); and Varshney, et al. (2013) showed regional differences. Although the analysis of regional differences will be the focus of further research, this paper focuses on the major spice usage in English Meat recipes found in the recipe books in Table 3. These four documents were used to minimize the influence of other factors (pricing, availability, monopolies) which was the focus of the author's other paper.

Table 3: Recipe Books and Documents Used for Analysis

Recipe Book/ Document	*Year*
A Book of Cookrye (STC 24897)	1591
Good Huswife	1594
Good Huswife	1596
Good Huswife	1597

([Edited by] Waks n.d.)([Digital text and notes] Wallace n.d.) ([Digital version] Gloning n.d.) ([edited by] Dawson n.d.)

Either translated and transcribed documents were used for the analysis. Although errors can occur, normally the spelling (cubeb or Quibebes) or the general term (cinnamon instead of canel a specific type of cinnamon) would be the issue. Both Grieg (1996) and Varshney, et al. (2013) had no issues with the translated or transcribed documents using this strategy.

4. Methodology

4.1 Data Collection

Using the recipe documents described in the recipes, spices and spice mixes were selected based on past acceptance research practices for food pairing, ingredient network analysis and ingredient usage.

4.1.1 Selection of Recipes

This analysis selected only recipes with meat which was the similar methodology used by Billings and Sherman's initial research (1998). Also only recipes that included at least one spice were included. This reduced the dilution of the data and was also the method used for the vegetable only recipes analysis conducted by Sherman and Hash (2001).

4.1.2 Selection of Spices

Although other individual spices were used, this paper analyzed only the following spices because they were used in each of the four recipe books/documents:

- Cinnamon or Canel
- Cloves
- Ginger
- Mace
- Nutmeg
- Pepper

4.1.3 Data Collection of Spices Used

Billing and Sherman (1998) considered "only spices regardless of quantity or form" for their ingredient analysis for meat only recipes and Sherman and Hash (2001) continued that methodology with their analysis of vegetable only recipes. Also, the new ingredient network and flavour analysis research uses only the ingredient in "any form and quantity" (Ahn, et al. 2011) (Varshney, et al. 2013)

There was an "issue resolving that names of ingredients that refer to the same entity" which resulted in some interpretation. In particular, similar to Grieg, the author also assumed that Quibebes was assumed to be *Piper Cubeb* or Cubeb Berries. Some interpretation with the old English was required and was also done by both Grieg (1996) and Varshney, et al. (2013).

4.2 Statistical Analysis

A two way Analysis of Variance was used to determine if:

- Individual Spice usages in meat recipes were significantly different
- The recipe books/documents were significantly different

Then, one way Analyses of Variance were used to determine the statistical differences of:

- Individual spice usage in the 16th century meat recipes
- Usage of highly antimicrobial spices in the 16th century meat recipes
- Usage of highly antimicrobial spices in the 16th century meat recipes compared to traditional English meat recipes (Sherman and Hash 2001)

4.2.1 Two Way Analysis of Variance (ANOVA)

A two way Analysis of Variance (ANOVA) is a method to compare two variables on the resultant outcome variable. The two variables are setup as either rows or columns. In this case, rows represent the recipe books/documents and the columns represent the spices or spice mixes.

The null hypothesis is that there was no statistical difference between the books/document (for the rows) and no difference between spice or spice mixes (for the columns).

If the result P value for the row and/or columns was less than the specified significant (normally 5% would be considered statistically significant), then that null hypothesis is rejected. This means that there is a difference. Further analysis is normally conducted with additional one way analyses of variance which is described below to determine the actual differences.

The two-factor ANOVA function on Excel™ was used on the averages of the spice and spice mix uses and the results are in Appendix A: Two Way Statistical Analysis Results.

4.2.2 One Way Analysis of Variance (ANOVA)

A one way analysis of variance (ANOVA) is a method to compare the sample means for at least three conditions. The null hypothesis is that all the sample means are the same. If the resultant P value is less than the specified significance (normally 5% would be considered statistically significant), then the null hypothesis is rejected. This means that at least one of the sample means is different; however the one-way ANOVA does not determine which one.

The single-factor ANOVA function on Excel™ was used and the results are in Appendix B: One Way Analysis of Variance Results.

4.3 Anti-Microbial Hypothesis

Previous research by Sherman and Hash (2001) used the hypothesis that spice concentrations are sufficient to produce the desirable effects. They found that:

> “recipes generally call for 0.25-3.0 g of spice/kg of the primary ingredients (i.e. 250-bacteria in laboratory tests (e.g. Hirasa & Takemasa, 1998; Ismaiel & Pierson, 1990) This implies that concentrations of spices used in cooking are sufficient to yield useful antibacterial effects, as suggested by Giese (1994), Hirasa and Takemasa (1998), Liu and Nakano (1996), and Shelef (1984).

This paper used this assumption for the basis for the analysis of spice usage for the 16th century English meat recipes.

Also, Sherman and Hash (2001) evaluated whether or not there was a concern that spices were destroyed during cooking. Their literature review indicated that some spices’ antimicrobial effects were eliminated with cooking and some were not. However, they found that:

> “commercial extraction of spice oleoresins and essential oils often involve steam distillation at extremely high temperatures. Gas chromatograms that compare steam distilled spice chemicals against CO2 [cold liquid carbon dioxide] extracted products typically show similar patterns (Moyler, 1994), indicating that those spices are thermostable. Further, Diebel and Banawarrt (1984) found that oregano, sage, and ground cloves still inhibited *Campylobacter jejuni* (a major cause of gastroenteritis) after 16 h of simmering at 25ºC and 42 ºC.”

Sherman and Hash concluded that spices are not usually destroyed by cooking. However, recent research (Adetunde, et al. 2014) indicates that ginger is heat sensitive and cooking reduces its effectiveness against *Staphylococcus aureus*.

However, depending on when the ginger is added to the meat (or used as a marinate) may still reduce the microbial issues. Because the spice usage analysis did not distinguish when the spice was added in the recipe, this correlation would be difficult. Also, in the case of ginger and pepper, spice synergic effects have been seen with other spices and ingredients (oils, salt) even during cooking (Billing and Sherman 1998) (Islam, et al. 2014). For simplicity, this paper followed Sherman and Hash’s methodology and correlated the anti-microbial reduction with spice usage.

4.4 Gastrointestinal Symptom Reduction and Digestive Enhancement Hypothesis

Mann's (2011) research stated that:

> "Using the tools and techniques of contemporary physiology, researchers are now elucidating mechanisms justifying the traditional use of dietary spices as appetite enhances, digestives, carminatives, ntifalulents, secretagogues, as well as in both diarrhoea and constipation (Clair, 1961; Farnsworth, 1985; Pruthi 1976)."

However, cooking may have influenced dietary spices' ability to provide gastrointential symptom reduction and digestive enchancement. Specifically, recent research (Adetunde, et al. 2014) indicated that ginger is heat sensitive and suggested that it is not cooked if used for medicinal purposes.

Depending on when the ginger is added to the meat, it may still reduce the gastrointestinal symptoms or enhance digestion. Because the spice usage analysis does not distinguish when the spice was added in the recipe, this correlation would be difficult. For simplicity, this paper followed Sherman and Hash's methodology and correlated with symptom reduction and digestion enhancement.

5. Results

5.1 Overall Results

The two-way ANOVA for the spice usage (Table 8) indicate that there was no significant difference between the recipes books with P<0.9508; however, there was a difference between the spices with P<2.15E-04.

However, pepper had a significant higher average usage at 62% than the other spices ranging from 31% to 45% on average (Table 5). When the pepper usages were eliminated, the two-way ANOVA was reanalyzed (Table 9) and indicate no statistical difference between the recipes books with P<0.5827 and the spices with P<0.0874.

5.2 Individual Spice Usage

The one-way ANOVA for the spice usage (Table 4) indicated that there was no significant difference between the recipes books for any of the spices except for nutmeg which was significant with P<0.0032. See Table 10 to Table 14 in Appendix B: One Way Analysis of Variance Results The usages are summarized in Table 5.

Table 4: Individual Spice Usage One-Way ANOVA

Spice	ANOVA P Value
Cinnamon/Canel	<0.1616
Cloves	<0.5836
Ginger	< 0.2728
Mace	<0.4350
Nutmeg	<0.0032
Pepper	<0.3939

Table 5: Individual Spice Usage (Cinnamon, Cloves, Ginger, Mace and Pepper)

	Cinnamon/ Canel	Cloves	Ginger	Mace	Nutmeg	Pepper
Cookyre	24.00%	42.70%	31.46%	43.82%	2.25%	64.04%
Good Huswife 1594	35.05%	37.11%	39.18%	49.48%	8.25%	55.67%
Good Huswife 1596	40.00%	32.31%	41.54%	36.92%	18.46%	60.00%
Good Huswife 1597	26.92%	34.62%	26.92%	48.08%	5.77%	69.23%
Average	31.49%	36.68%	34.77%	44.58%	8.68%	62.24%

5.3 Highly Antimicrobial Spice Usage

The 16th century highly antimicrobial spice usages varied from 54% to 66% (Table 6) and the one-way ANOVA indicated that no significant difference existed in the 16th recipe books/documents with P<0.6573 (Table 15). However, when compared to Billings and Sherman's and Sherman and Hash's research, these usages were low at 18% and were statistically significant with P<4.48E-19 (Table 16).

Table 6: Highly Antimicrobial (Either Cinnamon or Cloves) Spice Usage

	High Antimicrobial Spice Usage (Either Cinnamon or Cloves)
Cookyre	66.03%
Good Huswife 1594	59.79%
Good Huswife 1596	60.00%
Good Huswife 1597	53.85%
Sherman & Hash	18.36%

Since the no statistically difference in the 16th century recipe books/documents, the 16th century data was pooled to compare to Billings and Sherman's and Sherman and Hash's results (Table 7). Sherman and Hash's and the 16th century recipe book/documents data were statistically significant with P<1.79E-21 (Table 17).

Table 7: Highly Antimicrobial (Either Cinnamon of Clove) Spice Usage 16th Century Pooled Compared to Sherman and Hash

	High Antimicrobial Spice Usage (Either Cinnamon or Cloves)
16 century pooled	59.92%
Sherman & Hash	18.36%

6. Discussion

In this section, the spice usage for both individual spices, no spices and highly anti-microbial spices was compared to the foodborne pathogens and their potential improvements on symptoms of these pathogens. This provided insight into the evolutionary choices of the 16th century cooks compared to current traditional English recipes.

However, individual spices were both combined in recipes with other spices as well as other ingredients (such as salt) that may have further assisted in microbial inhibition or killing and an initial discussion about these potential synergic effects was discussed.

Finally, the at-risk populations (pregnant women and children) for the foodborne pathogens and spice usage were discussed. In particular, the food aversions of meat and spices were discussed and how this could have influenced spice choices in the 16th century recipes for those at-risk populations compared to the general public.

6.1 Spice Usage Analysis

Although the recipe books/documents were chosen to minimize other factors, both pepper and nutmeg were different that the other individual spice usages. In all cases, spices could be chosen to reduce the foodborne pathogens and/or their symptoms. See section 6.1.1 for more details.

6.1.1 Individual Spice Usage

Cinnamon/Canel (Cinnamonum Verum)

Cinnamon’s usage was between 24% and 40% with an average of 31% in the late 16th century meat recipes (Table 5). Cinnamon specifically inhibits four of five meat associated foodborne pathogens of this study but is not effective on *Clostridium botulinum.* Cinnamon reduces the gastrointestinal issues of all of the five foodborne pathogens including nausea, vomiting, upset stomach and diarrhea.

Recent research compared three segments of the population, English, Gujarati and Kashmiri groups, to determine taste and medicinal perceptions of cinnamon and four other herbal drugs. The current English population of the survey had a low medicinal perception when compared to bitter/spicy or tasteless perception of cinnamon indicating no link. The Gujarati and Kashmiri groups showed a strong link between the perception of the bitter/spice taste of cinnamon and the perceived medicinal perception. The Kashmiri group continued to have a strong link between the perception of the sweet taste of cinnamon and the perceived medicinal perception (Pieroni and Torry 2007).

The combining of taste and treating of the symptoms associated with the foodborne pathogens follows previous research conclusions:

> "In 2000, Casagrande clearly showed in his studies on taste and cognition among the Tzeltal Maya that the use of medicinal plants cannot be predicted based on taste alone. He suggests that the role of taste is more likely to be mnemonic rather than chemical-ecological, hence the combination of plant attributes with illness experiences could explain the occurrence of prototypical groups of plants used to treat specific groups of illnesses [12]." (Pieroni and Torry 2007)

Also, a recent food ethnobotonical study reached similar conclusions:

> "where findings showed that the influence of the bitter taste perception in the food versus medicinal classification of wild botanicals, and the existence of prototypical ethnolinguistic categories of weedy food plants, seem to be the result of morphological, functional and also chemosensoric perceptions of bitterness [2]." (Pieroni and Torry 2007)

Therefore, English population of the 16th century could have followed this ethnobotonical selection for cinnamon even though the current English segment of the population now does not perceive cinnamon as medicinal. Previous research indicated that these choices can change over time and between different cultures:

> "Shepard introduced in his study of two Amazonian societies the new concept of "sensory ecology" to define a new theoretical perspective, in which sensations can be understood as bio-cultural phenomena rooted in human physiology, and also constructed through individual experiences and culture [14]. These findings are important because Shepard reinforces how organoleptic properties can change over time and across and between different cultures." (Pieroni and Torry 2007)

Cloves (Syzygium aromaticum)

Cloves' usage was between 32% and 43% with an average of 37% in the late 16th century meat recipes (Table 5). Cloves inhibit all five foodborne pathogens associated with meat, poultry and seafood. Cloves reduces the gastrointestinal issues of all five foodborne pathogens including nausea, vomiting, upset stomach and diarrhea.

Pieroni and Torry's research (2007) again showed the same low medicinal perception of cloves in the current English population. The Gujarati and Kashmiri groups continued to show a strong link between the perception of bitter/spice taste of cloves and the perceived medicinal perception.

Cloves are a highly effective antimicrobial and it does reduce all the gastrointestinal issues of the five foodborne pathogens. Therefore, the English population of the 16th century may have ethnobotonically selected cloves for these reasons which were similar to the conclusions of Casagrande's research. (Pieroni and Torry 2007) This again shows an evolutionary change since the current English segment of the population now does not perceive cloves as medicinal.

Ginger (Zingiber officinale)

Ginger's usage was between 37% and 42% with an average of 35% in the late 16th century meat recipes (Table 5). Ginger only inhibits *Staphylococcus aureus* and only reduces the gastrointestinal issues of nausea and diarrhea.

Pieroni and Torry's research (2007) continued to show the same low medicinal perception of ginger in the current English population but the English population did perceive ginger to be associated with digestive disorders. The Gujarati and Kashmiri groups continued to show a strong link between the perception of the bitter/spice taste of ginger and the perceived medicinal perception. The Kashmiri group perceived ginger more than the other two groups as being helpful for digestive disorders.

Although ginger has limited antimicrobial inhibition and does not reduce all the gastrointestinal issues of the five foodborne pathogens, ginger may have been used to improve appetite but ginger usage for these reasons only is weak. Other potential reasons for ginger's high usage are further explained in Section 6.2 Spice Usage Synergy.

Mace (Myristica fragrans aril)

Mace's usage was between 27% and 49% with an average of 45% in the late 16th century meat recipes (Table 5). Mace only inhibits *Staphylococcus aureus*. Mace, however, reduces the gastrointestinal issues of all of the five foodborne pathogens including nausea, vomiting, upset stomach and diarrhea.

Pieroni and Torry's research (2007) did not study mace. However, based on their research, we could extend that the survey may have resulted in similar results to ginger, cinnamon and cloves because of mace's spicy taste.

Although mace is a limited antimicrobial, it does reduce all the gastrointestinal issues of the five foodborne pathogens. Therefore, the English population of the 16th century may chosen to use mace which is again similar to the conclusions of Casagrande's research. (Pieroni and Torry 2007)

Nutmeg (Myristica fragrans)

Nutmeg's usage was between 2% and 18% with an average of 9% in the late 16th century meat recipes (Table 5). Nutmeg was the only spice that was statistically significant through the recipe books/documents with a $P<0.0032$ (Table 4). Further research is needed to confirm if the variation is caused by either the author preference and/or the different meat types (beef, pork, chicken, etc).

Nutmeg inhibits four of five meat associated foodborne pathogens but is not effective on *Clostridium botulinum*. Nutmeg does reduces the gastrointestinal issues of all of the five foodborne pathogens including nausea, vomiting, upset stomach and diarrhea.

Pieroni and Torry's research (2007) did not study nutmeg. However, based on their research, we could extend that the survey may have resulted in similar results to ginger, cinnamon and cloves because of nutmeg's spicy taste.

Nutmeg is an effective antimicrobial, and it does reduce all the gastrointestinal issues of the five foodborne pathogens. Therefore, the English population of the 16th century could have selected nutmeg but the usage was low and may have been affected by other selection reasons.

Pepper (Piper nigrum L and Pepper sp)

Pepper's usage was between 56% and 69% with an average of 62% in the late 16th century meat recipes (Table 5). According to Billings and Sherman (1998), pepper by itself has a low antimicrobial level (38% inhibiting growth or kill). Pepper inhibits only *Staphylococcus aureus* and *Clostridium botulinum*. Pepper is used to treat only diarrhea but does have other digestive properties.

Piperine in pepper increases protease activity which break downs proteins and previous animal research indicates that pepper stimulates the liver to further improve digestion (Ahmad, et al. 2012). Both of these are important to the digestion of meat dishes. Again, the use of pepper may be associated with a symptom reduction (improved digestion) and follows the conclusion of Casgrande's research. (Pieroni and Torry 2007). Therefore, the English population of the 16th century may have chosen to use pepper for this reason; however, other potential reasons for pepper's high usage are further explained in Section 6.2 Spice Usage Synergy.

6.1.2 Highly Antimicrobial Spice Usage

Billings and Sherman (1998); and Sherman and Hash's (2001) research included 15 highly inhibiting spices and flavourings (garlic, onion, allspice, oregano, thyme, cinnamon, tarragon, cumin, cloves, lemon grass, bay leaf, chilis, rosemary, marjoram and mustard). This paper only included cinnamon and cloves in the analysis. Despite not including in particular garlic, onion and the herbs, the antimicrobial spice usage in the 16th century recipes is still statistically significant from their work with $P<1.79E-21$ (Table 17). However, it may be necessary to expand the research to include these flavourings and reconfirm that the usage is still high.

Also, these two highly antimicrobial spices, cinnamon and cloves, have a low medicinal perception by the current English population (Pieroni and Torry 2007) compared to the 16th century English population. Pieroni and Torry chose their three segment populations to compare the traditional knowledge variation and found that spice perceptions were linked to this knowledge. This can be extrapolated to the 16th century English populations who would be more inclined to use this traditional knowledge as well.

6.2 Spice Usage Synergy

Billings and Sherman (1998) also indicated that pepper had synergic anti-microbial reduction with other ingredients such as garlic, salt, acetic acid and citric acid (from sources of vinegar and citric juices). Further research is needed to statistically determine if there is a correlation between pepper usage and other ingredients that provide this microbial reduction.

With both ginger and pepper, Billings and Sherman (1998) did indicate spice usage could have synergetic effects such as:

> “the French “quatre epics” (pepper, cloves, ginger and nutmeg) which often is used in making sausages. Sausages (*botulus* in Latin) are a rich medium for bacterial growth, and frequently have been implicated as the source of death from botulism toxin; the value of antibacterial compounds in spices for sausage preservation and prevention of toxin production is obvious. Use of multiple spices, especially when combined with citric or acetic acid and salt, and then heated, produces the most powerful antimicrobial effects (Kulrita and Koike 1982; Gould 1992; Liu and Nakano 1996; Ziauddin et al. 1996)”

Ginger synergetic effect with other ingredients can be shown by comparing the recent ginger antimicrobial inhibition research by Adetunde, et al (2014) and by Islam, et al. (2014). When ginger is extracted and heated in water (aqueous solution) at 100ºC for about 45 minutes, no antimicrobial inhibition occurred for *Staphylococcus aureus* and *Escherichia coli* (Adetunde, et al. 2014). However, when ginger mixed with soybean oil and heated in a boiling water batch at 100ºC (similar to a double boiler) for 30 minutes, good antimicrobial activity against *Staphylococcus aureus*, *Escherichia coli* and *Salmonella spp* was observed (Islam, et al. 2014). Clearly, the heating effect does not destroy the antimicrobial properties of the ginger if paired with correct ingredient. Similar results by:

> “Onyeagba et al. (2004) found the synergistic effect of ethanol extract of ginger and garlic against Bacillus spp. and Staphylococcus aureus. They also found the antimicrobial activity of the ethanol extract of ginger, lime and garlic against broad range of bacteria including Bacillus spp., Staphylococcus aureus, Escherichia coli, and Salmonella spp.” (Islam, et al. 2014)

Although not a focus of this current paper, further research in spice synergic effects with other ingredients is highly recommended.

6.3 Meat Recipes, Spice Usage and At Risk Populations

As indicated in Section 3.1 Common Foodborne Pathogens in Meat, the at-risk populations are children and pregnant women to these illnesses. The symptoms are more severe up to and including death:

- "*E.coli* 0157:H7 can cause permanent kidney damage which can lead to death in young children" (U.S. Department of Health and Human Services n.d.)
- *Listeria monocytogenes* "can cause serious illness or death in pregnant women, fetuses and new borns" (U.S. Department of Health and Human Services n.d.)
- *Salmonella Enteritidis* "can be more severe in people in at-risk groups, such as pregnant women" (U.S. Department of Health and Human Services n.d.)
- *Salmonella Typhimurium* "can be more severe in people in the at-risk groups, such as pregnant women" (U.S. Department of Health and Human Services n.d.)

For children, Sherman and Flaxman's article (2001) indicated although spices (and hence phytochemicals) do have an antimicrobial inhibition or killing:

> "when eaten in sufficient amounts, many phytochemicals act as allergens, mutagens, carcinogens, teratogens and abortifacients. This may suggest why pre-adolescent children typically dislike spicy foods. Children are particularly susceptible to mutagens because some of their tissues are undergoing rapid cell divisions. Their alternative is to avoid food that might contain pathogens or phytochemicals – perhaps this is why children have acquired a reputation as "picky eaters".

As girls mature and become pregnant women, Sherman and Flaxman further explained that:

> "rapid cell division also takes place within the body of a pregnant women. Moreover, pregnant women are more susceptible to foodborne illnesses and infectious diseases because their cell-mediated immune response is depressed – lest the woman's body reject the foreign tissue that is her baby-to-be. The risks for the mother create even greater dangers for the embryo. Miscarriages and birth defects can result if a pregnant woman contracts an illness especially during the first trimester."

The Sherman and Flaxman's study reviewed "20 studies of food aversions among 5432 women and 21 studies of food cravings (among 6239 women) which were based on questionnaires administrated to women during pregnancy or soon after" delivery. "Pregnant women were most often averse to food caterogized as "meat, fish, poultry and eggs" and "non-alcoholic beverages", mostly caffeinated ones. They also found "vegetables" and "alcoholic beverages to be aversive." (Sherman and Flaxman 2001). In comparison, "the pattern for food cravings was virtually the opposite: the categories "fruits and fruit juices", "sweets, dessert and chocolate" and "dairy" were the most sought after."

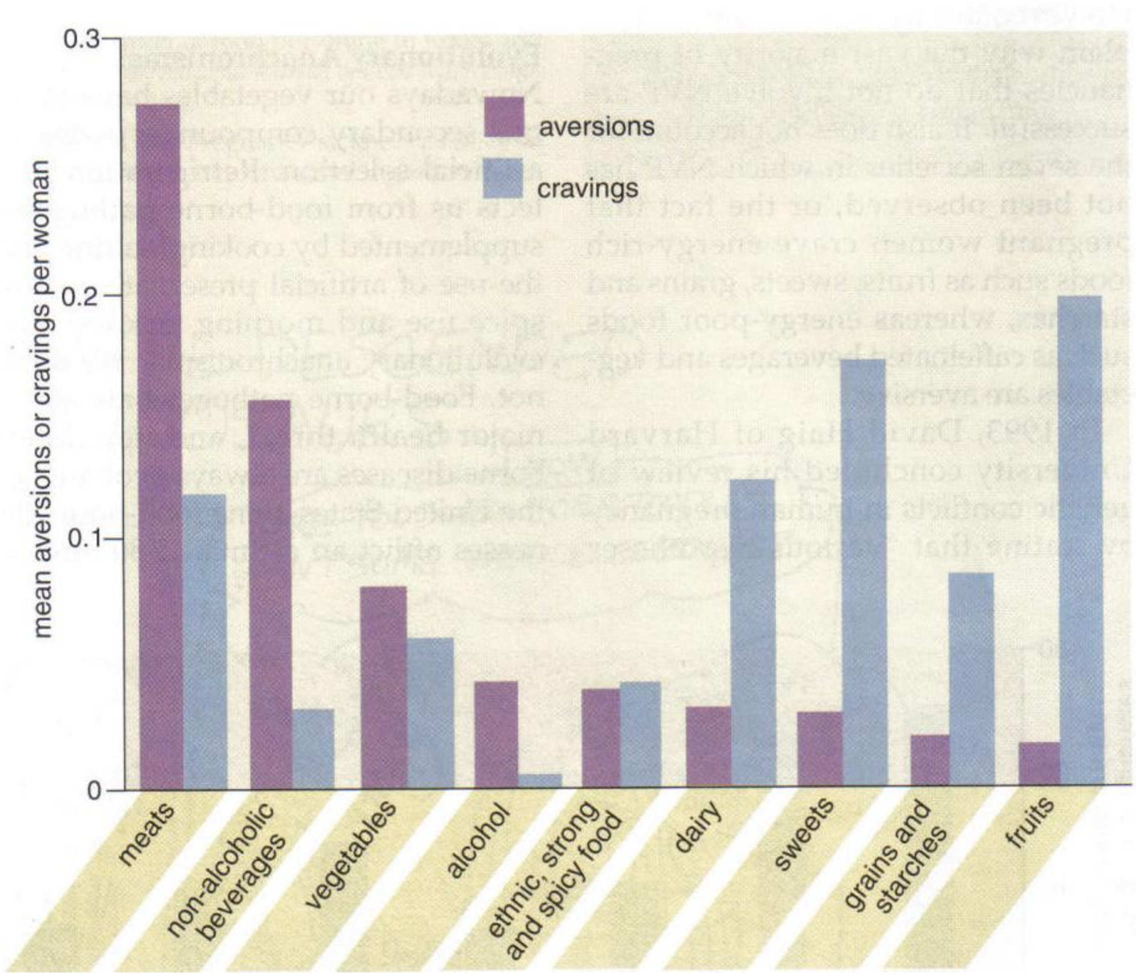
Sherman and Flaxman (2001) concluded that the "three most averse food categories that were the ones most likely to contain microorganisms (meat products) and phytochemicals (vegetable, coffee and tea)." Sherman and Flaxman (2001) further explained:

> "In contrast, the food categories that were most often craved than found aversive (fruits, grains, sweets and dairy products) were the ones least likely to contain microorganisms or phytochemicals. Surprisingly, however, aversions to "ethnic, strong and spicy" food were rare as cravings for them". (Figure 1)

and

> "Judith Rodin of Yale University and Norean Radke-Sharpe of Bowdoin College found that women in their first trimester report significantly more aversions than nonpregnant controls to all food categories, particularly to meat, fish, poultry and eggs". "Nausea and vomiting tends to peak between 8th and 12th weeks of pregnancy which the peak sensitivity of various fetal tissues to a chemical disturbance."

Figure 1: Cravings and Adversions



(Sherman and Flaxman 2001)

The "pickiness" of children and first trimester pregnant women suggested that meat avoidance supported the evolutionary theory that we choose not to consume food that could cause microbiological issues during high cell development. This also supported the rejection of the "cover up" hypothesis that medieval people used spices to disguise foul smells and tastes of spoiled food. (Sherman and Hash 2001) Since both at-risk populations (children and pregnant women) avoid meat sources, most likely the common person would make the evolutionary choice not to consume bad tasting meat dishes.

Although spices contain phytochemicals, there was neither a reduction or increase for pregnant women's cravings for ethnic, strong or spicy foods. "The medical community uses the acronym, NVP. short for Nausea and Vomiting of Pregnancy" and it has been studied along with diet and its occurrence rate within 27 traditional societies. "Interestingly, ethnographers reported that NVP did not occur in 7 societies". These societies "were significantly less likely to have meat as a dietary staple" and also "more likely to have corn as staple". Corn and other bland vegetables in these societies which rarely trigger the NVP symptoms but also these societies had the lowest NVP occurrence.

This evidence supports that the high phyochemical content of spices would invoke NVP or morning sickness and hence reduced the potential chemical impact on the embryo's cell development. Although pregnant women may or may not crave or avoid spicy foods, the high phyochemical response may cause morning sickness and thus reduce the frequency of issues.

Sherman and Flaxman's research supported this papers conclusion that medieval recipes used spices as an evolutionary choice to reduce the foodborne illness and their associated symptoms for the common person. However, in the case of children and pregnant women and others in high risk population for foodborne pathogens, spices or meat dishes may still have been avoided.

7. Conclusions:

High clove addition to 16th century English meat recipes with an average of 37% was most likely chosen due the high antimicrobial effect to all five foodborne pathogens and its reduction on all the gastrointestinal symptoms.

High cinnamon usage at 31% was also most likely chosen due the high antimicrobial effect on all except for *Clostridium botulinum* and is also effective on the gastrointestinal symptoms. Because of the high phytochemicals contents, these spices may not have been chosen by at risk population (sick, pregnant or children) but were used at higher usage than the current traditional English meat recipes now.

Mace with a 45% usage was most likely chosen due to the gastrointestinal symptom reduction which matches the conclusions of Casagrande's research. (Pieroni and Torry 2007)

Ginger's usage (35%) and pepper (62%) were most likely chosen for their synergic effects with other spices or ingredients and potentially for their improvement in digestion.

8. Recommendations for Further Study

Further research is recommended to determine if the meat type (poultry, beef, pork, seafood) correlates with either the spice usage and hence its foodborne pathogen inhibition and gastrointestinal assistance. However, this would require pooling recipes of other countries for this analysis.

Synergetic spice mixture usage should also be further studied to determine if their usage corresponds with foodborne pathogen inhibition. Again, pooling of recipes of other countries may be needed for this analysis.

Finally, the spice usage can be compared with different countries for meat recipes to see if there are regional differences which would be similar to the work by Billings and Sherman (1998) and Sherman and Hash (2001).

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Appendix A: Two Way Statistical Analysis Results

Table 8: Spices and Books Two Way Analysis of Variance

Anova: Two-Factor Without Replication

Recipe Book/ Document	***Count***	***Sum***	***Average***	***Variance***
Cookyre	5	2.060225	0.412045	0.023042
Good Huswife 1594	5	2.164948	0.43299	0.007865
Good Huswife 1596	5	2.107692	0.421538	0.011195
Good Huswife 1597	5	2.057692	0.411538	0.032101
Spice	***Count***	***Sum***	***Average***	***Variance***
Pepper	4	2.489458	0.622365	0.003344
Mace	4	1.783048	0.445762	0.003183
Canal	4	1.259746	0.314937	0.005402
Cloves	4	1.467331	0.366833	0.001992
Ginger	4	1.390975	0.347744	0.004591

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Books	0.001525	3	0.000508	0.112971	0.950832	3.490295
Spices	0.2428	4	0.0607	13.48597	0.000215	3.259167
Error	0.054012	12	0.004501			
Total	0.298337	19				

Table 9: Spices and Books without Pepper Two Way Analysis of Variance

Anova: Two-Factor Without Replication

Recipe Book/ Document	***Count***	***Sum***	***Average***	***Variance***
Cookyre	4	1.419775	0.354944	0.008986
Good Huswife 1594	4	1.608247	0.402062	0.00411
Good Huswife 1596	4	1.507692	0.376923	0.001657
Good Huswife 1597	4	1.365385	0.341346	0.009954
Spice	***Count***	***Sum***	***Average***	***Variance***
Mace	4	1.783048	0.445762	0.003183
Canal	4	1.259746	0.314937	0.005402
Cloves	4	1.467331	0.366833	0.001992
Ginger	4	1.390975	0.347744	0.004591

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	0.008472	3	0.002824	0.686302	0.582673	3.862548
Columns	0.037087	3	0.012362	3.004259	0.087455	3.862548
Error	0.037034	9	0.004115			
Total	0.082593	15				

Appendix B: One Way Analysis of Variance Results

Table 10: Cinnamon Usage One Way Analysis of Variance

Anova: Single Factor

SUMMARY

Recipe Book/ Document	***Count***	***Sum***	***Average***	***Variance***
Cookyre	75	18	24.00%	0.184865
Good Huswife 1594	97	34	35.05%	0.230026
Good Huswife 1596	65	26	40.00%	0.24375
Good Huswife 1597	52	14	26.92%	0.200603

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.119559	3	0.373186	1.726782	0.161634	2.63628
Within Groups	61.59324	285	0.216117			
Total	62.7128	288				

Table 11: Cloves Usage One Way Analysis of Variance

Anova: Single Factor

SUMMARY

Recipe Book/ Document	***Count***	***Sum***	***Average***	***Variance***
Cookyre	89	38	42.70%	0.247446
Good Huswife 1594	97	36	37.11%	0.235825
Good Huswife 1596	65	21	32.31%	0.222115
Good Huswife 1597	52	18	34.62%	0.230769

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.459014	3	0.153005	0.649844	0.583596	2.634801
Within Groups	70.39907	299	0.235448			
Total	70.85809	302				

Table 12: Ginger Usage One Way Analysis of Variance

Anova: Single Factor

SUMMARY

Recipe Book/ Document	***Count***	***Sum***	***Average***	***Variance***
Cookyre	89	28	31.46%	0.21808
Good Huswife 1594	97	38	39.18%	0.240765
Good Huswife 1596	65	27	41.54%	0.246635
Good Huswife 1597	52	14	26.92%	0.200603

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.894724	3	0.298241	1.305246	0.272825	2.634801
Within Groups	68.3198	299	0.228494			
Total	69.21452	302				

Table 13: Mace Usage One Way Analysis of Variance

Anova: Single Factor

SUMMARY

Recipe Book/ Document	***Count***	***Sum***	***Average***	***Variance***
Cookyre	89	39	43.82%	0.248979
Good Huswife 1594	97	48	49.48%	0.252577
Good Huswife 1596	65	24	36.92%	0.236538
Good Huswife 1597	52	25	48.08%	0.254525

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.68033	3	0.226777	0.912886	0.435028	2.634801
Within Groups	74.27677	299	0.248417			
Total	74.9571	302				

Table 14: Pepper Usage One Way Analysis of Variance

Anova: Single Factor

SUMMARY

Recipe Book/ Document	***Count***	***Sum***	***Average***	***Variance***
Cookyre	89	57	64.04%	0.232891
Good Huswife 1594	97	54	55.67%	0.249356
Good Huswife 1596	65	39	60.00%	0.24375
Good Huswife 1597	52	36	69.23%	0.217195

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.712333	3	0.237444	0.998402	0.393901	2.634801
Within Groups	71.10945	299	0.237824			
Total	71.82178	302				

Table 15: Highly Antimicrobial (Either Cinnamon or Cloves) Spice Usage One Way Analysis

Anova: Single Factor

SUMMARY

Recipe Book/ Document	***Count***	***Sum***	***Average***	***Variance***
Cookyre	53	35	0.660377	0.228592
Good Huswife 1594	97	58	0.597938	0.242912
Good Huswife 1596	65	39	0.6	0.24375
Good Huswife 1597	52	28	0.538462	0.253394

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.390393	3	0.130131	0.537027	0.657302	2.638925
Within Groups	63.72946	263	0.242317			
Total	64.11985	266				

Table 16: Highly Antimicrobial (Either Cinnamon or Cloves) Spice Usage One Way Analysis of Variance compared to Sherman and Hash

Anova: Single Factor

SUMMARY

Recipe Book/ Document	***Count***	***Sum***	***Average***	***Variance***
Cookyre	53	35	0.660377	0.228592
Good Huswife 1594	97	58	0.597938	0.242912
Good Huswife 1596	65	39	0.6	0.24375
Good Huswife 1597	52	28	0.538462	0.253394
Sherman/Hash	207	38	0.183575	0.150603

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	20.53753	4	5.134382	25.41354	4.48E-19	2.390951
Within Groups	94.75361	469	0.202033			
Total	115.2911	473				

Table 17: Highly Antimicrobial (Either Cinnamon or Cloves) 16th Century Pool Spice Usage One Way Analysis of Variance compared to Sherman and Hash

Anova: Single Factor

SUMMARY

Recipe Book/ Document	***Count***	***Sum***	***Average***	***Variance***
Sherman/Hash	207	38	0.183575	0.150603
16c pool	267	160	0.599251	0.241052

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	20.14713	1	20.14713	99.94794	1.79E-21	3.861235
Within Groups	95.144	472	0.201576			
Total	115.2911	473				