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Lemon, pH and Citric Acid for Kelaguen Safety Without Temperature Control

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Abstract—Kelaguen is a popular Chamorro food prepared by mixing meat with lemon, onions, hot peppers, and grated coconut. Unfortunately, kelaguen is one of the leading causes of foodborne illness on Guam because of improper handling practices, especially the practice of serving kelaguen without temperature control over a long period of time. This study determined the pH and acidity as well as the minimum amount of lemon juice and powder needed for kelaguen to be served safely without time and temperature control. A food not requiring temperature control for safety (non-TCS food) requires a pH below 4.2, as defined by the FDA/USDA. Seventeen kelaguen sampled from vendors and individuals on Guam exhibited an average pH of 4.5 for beef, 4.7 for chicken, 4.8 for fish, and 4.9 for shrimp. The estimated pH(s) of kelaguen from 26 recipes were 5.1 for beef, 5.4 for chicken, 4.8 for fish, and 5.8 for shrimp. The pH analysis of kelaguen confirmed that traditional kelaguen was a food requiring temperature control for safety. To prepare non-TCS kelaguen with a pH below 4.2, the minimum amount of lemon juice needed was 19% for beef, 22% for chicken, 21% for fish, and 25% for shrimp. The minimum amount of lemon powder needed for non-TCS kelaguen was 3.2% for beef, 3.0% for chicken, 3.4% for fish, and 3.6% for shrimp. We classified traditional kelaguen as low acid kelaguen when 0-15% lemon was added, and high acid kelaguen when 16-25% lemon was added. The high rate of foodborne illness on Guam may be attributed to low acid kelaguen because low acid kelaguen has a pH above 4.6. To enable consumers to prepare non-TCS kelaguen, which can be safely stored and/or served at parties or fiestas without temperature control, we provide practical recommendations on the minimum required amount of lemon, based on cups of lemon juice, teaspoons of lemon powder, and pounds or cups of kelaguen.

Introduction

Kelaguen is a popular Chamorro dish on Guam that is prepared by mixing meat with lemon juice, minced onions, grated coconut, and hot peppers.

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Chicken, beef, shrimp, and fish kelaguen are the most popular. Kelaguen is also prepared with deer, pork, spam, liver, sea snail, crab, octopus, clam, mussels, or seafood mix. Kelaguen is commonly consumed with rice or tortilla as an appetizer or a main dish at home, parties, or fiestas. Based on a survey of 200 consumers about kelaguen, we estimated that every month about 60% of all families prepare and consume kelaguen 1-2 times and about 15% of all families prepare and consume kelaguen 3-4 times.

Unfortunately, kelaguen is one of the leading causes of foodborne illness on Guam. The Guam Department of Public Health and Social Services reported that 82 outbreaks and 295 cases of foodborne illness were associated with kelaguen from 1983 to 2005 (Haddock 2007). During the last two decades, an average of 45 people reported becoming ill from kelaguen each year. Chicken, fish, and shrimp kelaguen each accounted for about 30% of the frequency of foodborne illness outbreaks and cases associated with kelaguen (Haddock 2007). However, the actual number of illness from chicken kelaguen was 4 and 6 times higher than that for shrimp and fish kelaguen, respectively. *Staphylococus aureus* and *Salmonella* were highly associated with chicken kelaguen, while *Vibrio spp*. was highly associated with shrimp and fish kelaguen (Haddock 2007). Including unreported cases, we estimated that the number of foodborne illnesses associated with kelaguen on Guam exceeded 1,000 cases per year.

Improper food handling practices during kelaguen preparation raise the risk of foodborne illness for consumers. One such practice is kelaguen often being prepared with raw or partially cooked meat to achieve a more tender texture and delicious taste. Kelaguen also is frequently subjected to temperature and time abuse when served at parties and fiestas. In the kelaguen survey of 200 consumers in the community, we observed that kelaguen was served outdoors without temperature control for 2-4 hours or 4-8 hours with a frequency of 43% or 34%, respectively. The same survey showed that 74% of consumers liked to eat kelaguen prepared with raw beef, fish, or shrimp. The percentage of consumers who used raw or partially cooked meat for kelaguen was 28% for beef, 24% for chicken, 24% for shrimp, and 19% for fish.

Temperature and time abuse and using raw or partially cooked meat are the two main causes for foodborne illness from kelaguen. To prevent foodborne illness from kelaguen, pathogens in meat must be eliminated or reduced to a safe level and the pathogen growth in kelaguen must be controlled. The Food and Drug Administration (FDA) and the United States Department of Agriculture (USDA) classifies a food with a pH below 4.2 as not requiring temperature control for safety, or as non-TCS, because vegetative cells and spores in the product can be controlled at this pH (IFT/FDA 2003). Lemon, an essential ingredient in kelaguen, lowers the pH of kelaguen. Therefore, adding an adequate amount of lemon can make kelaguen a non-TCS food with a pH below 4.2, allowing it to being safely served at parties or fiestas without temperature and time control. Consequently, the risk of foodborne illness from kelaguen would be significantly reduced. However, the pH of kelaguen and the amount of lemon needed for kelaguen to have a pH of 4.2 is currently unknown.

To provide guidelines for preparing and serving kelaguen safely, it is essential to have information about the pH of kelaguen and the minimum amount of lemon needed to prepare non-TCS kelaguen. The objective of this study is to determine the pH and acidity of kelaguen and to determine the minimum amount of lemon juice and powder needed for kelaguen to be served safely without time and temperature control.

Materials and Methods

MATERIALS

Citric acid and sodium hydroxide were purchased from Sigma-Aldrich (St. Louis, MO, USA). Raw beef, chicken, fish, shrimp, lemons, onions, and salt were purchased from local grocery stores. The lemon powder "Yours Lemon Flavored Powder", produced by Yands Trading Co., Ltd., Japan, also was purchased from local grocery stores. Red hot peppers were bought from local vegetable markets.

SAMPLE KELAGUEN FROM VENDORS AND INDIVIDUALS

Beef, chicken, fish, and shrimp kelaguen were sampled from 6 local kelaguen vendors and 5 individuals. The number of kelaguen samples were as follows: 5 for chicken, 5 for beef, 5 for shrimp, and 2 for fish. The collected kelaguen samples were stored in the refrigerator at 4 °C for pH measurement and titratable acidity assays within 24 hours.

PH AND ACIDITY MEASUREMENT

A 25 gram sample of beef, chicken, fish, or shrimp kelaguen was mixed with 225 mL of distilled water in an Osterizer 6646 blender (Sunbeam Products, Inc., Boca Raton, FL.) for 2 minutes. The pH of the 250 mL blended kelaguen samples were measured with a Corning Scholar 425 pH meter (A. Daigger and Company, Vernon Hills, IL.). For the acidity assay, 10 mL of blended kelaguen sample was titrated with 0.1 M NaOH solution and phenolphthalein was used as an indicator. The acidity of kelaguen was calculated based on a citric acid standard curve and expressed as g citric acid/100g kelaguen.

The effect of added amount of lemon on the pH and the acidity of kelaguen was studied with beef, chicken, fish, and shrimp kelaguen, which was prepared with various amounts of added lemon. The added amount of lemon juice was ranged from 0 to 31% (vol/vol). The added amount of lemon powder was ranged from 0 to 10% (g/g). The pH and the acidity of kelaguen were then measured as described above.

KELAGUEN PREPARATION

Before kelaguen preparation, frozen beef, chicken, fish, and shrimp were thawed in the refrigerator for 4 hours. Onions and peppers were chopped and fresh lemons were squeezed for juice. The beef kelaguen was prepared by first cutting the beef into 2-4 mm thick slices and then mixing the beef with fresh lemon juice or lemon powder, minced onions, hot peppers, and salt. The chicken kelaguen was prepared by first boiling, deboning, and chopping the chicken. The chopped chicken was then mixed with fresh lemon juice or lemon powder, minced onions, hot peppers, and salt. The fish kelaguen was prepared by cutting the fish fillets into 2-4 mm thick slices and then mixing the fish with fresh lemon juice or lemon powder, minced onions, hot peppers, and salt. The shrimp kelaguen was prepared by first blanching the shrimp in boiling water for 1 minute. The shrimp was then de-veined, de-shelled, and then mixed with fresh lemon juice or lemon powder, minced onions, hot peppers, and salt. The final added amount of lemon mixed with the beef, chicken, fish, and shrimp ranged from 0 to 32% (w/w) for lemon juice and 0 to 10% (w/w) for lemon powder. The percentage of lemon was based on the total weight of kelaguen. The beef, chicken, fish, and shrimp kelaguen was tested within 30 minutes after preparation for pH and acidity measurements, or stored in the refrigerator at 4 °C for pH and acidity assays within 24 hours.

ESTIMATION OF PH AND ACIDITY FROM KELAGUEN RECIPES

Kelaguen recipes were collected from various publications, websites, and individuals, including 3 beef kelaguen, 8 chicken kelaguen, 8 shrimp kelaguen, and 7 fish kelaguen recipes. The percentage of lemon juice was estimated based on the weight of kelaguen in the recipes. The pH of kelaguen was estimated by converting the amount of lemon juice in the recipes to the pH of kelaguen based on the correlation curve of added amount of lemon and the pH of kelaguen. The acidity of kelaguen was estimated by converting the amount of lemon juice in the recipes to titratable acidity (g citric acid/100 g kelaguen) based on the correlation curve of added amount of lemon and the acidity of kelaguen. The correlation curve of added amount of lemon with pH or with the acidity of kelaguen was obtained from experiments on the effect of added amount of lemon on the pH and the acidity of kelaguen described in PH AND ACIDITY MEASUREMENT.

STATISTICAL ANALYSIS

Three replications of kelaguen preparation or kelaguen samples were performed in all experiments. Analysis of variance and least-significant-difference tests conducted with SPSS 13.0 for Windows (SPSS, 2004) were used to identify differences among means. Mean differences were considered significant at the $P < 0.05$ level.

Results and Discussion

THE PH AND ACIDITY OF SAMPLED KELAGUEN

Kelaguen sampled from vendors and individual consumers exhibited an average pH of 4.5-4.9 and titratable acidity of 1.35-1.66 g citric acid/100 g kelaguen (Table 1). The pH of shrimp kelaguen was significantly higher than that of beef kelaguen (Table 1).

Table 1. The pH and titratable acidity (g citric acid/100 g) of kelaguen sampled from vendors and individuals*

Kelaguen Characteristics	Types of Kelaguen			
	Beef	Chicken	Fish	Shrimp
Number of samples	5	5	2	5
pH	4.47 ± 0.23^{b}	4.73 ± 0.19^{ab}	4.80 ± 0.33^{ab}	4.91 ± 0.13^{a}
Acidity	1.66 ± 0.22^{a}	1.48 ± 0.26^{a}	1.35 ± 0.13^{a}	1.59 ± 0.60^{a}

* Data are mean ± standard deviation; a, b means with no common letters in the same column are significantly different ($p < 0.05$).

Although microbial growth can be controlled by a low pH environment and citric acid, as a weak acid, exhibits antimicrobial effects (Beales 2004), the pH (4.5-4.9) or the acidity (1.36-1.66%) of sampled kelaguen was not enough to inhibit pathogen growth or kill pathogens in kelaguen. Lin et al. (1995) observed that the minimum growth pH was 4.0 for *Salmonella* Typhimurium, 4.4 for *Escherichia coli,* and 4.8 for *Shigellar flexneri*. Conner & Kotrola (1995) observed a growth of *E. coli* O157:H7 both at pH 5.0 and 25°C and at pH 4.5 and 37°C after 21 days in citric acid acidified tryptic soy broth. Zaika (2002) reported that *Shigella flexneri* survived at pH 4.0 for 27 and 762 hours at 37 and 4°C, respectively, in brain heart infusion broth acidified with 0.04 M (about 0.8%) citric acid. Sengun & Karapinar (2004) reported that achieving a 4 log reduction of *Salmonella* Typhimurium on carrots required a 1 hour treatment dip in fresh lemon juice with 4.46% citric acid. Bjornsdottir et al. (2006) reported that achieving a 5 log reduction of *E. coli* O157:H7 at pH 3.6 and 25°C required a 50 mM concentration of protonated citric acid for 6 hours, which was equivalent to about 3.8% total citric acid. Bjornsdottir et al. (2006) also observed a pH of 3.2 was required to reduce 4 logs of *E. coli* O157:H7 in a non-inhibitory gluconic acid buffer without citric acid. Therefore, pathogens can survive or grow at the pH and citric acid levels observed in kelaguen.

The Guam Department of Public Health and Social Services reported chicken, fish, and shrimp kelaguen resulted in 33.7, 32.6, and 29.3% of the frequency of foodborne illnesses associated with kelaguen, respectively, but few incidences of beef kelaguen occurred (Haddock 2007). The pH of chicken, fish, and shrimp were above 4.6, while the pH of beef kelaguen was below 4.6 (Table 1). The pH 4.6 is a critical pH in determining a potentially hazardous food because harmful bacteria can grow rapidly and progressively in food with a pH above 4.6 (IFT/FDA 2003). For example, Conner & Kotrola (1995) observed no growth of *E. coli* O157:H7 at pH 4.5 and 25°C, but a growth at pH 5.0 and 25°C after 21 days in tryptic soy broth acidified with citric acid. The pH of chicken, fish, and shrimp kelaguen being greater than 4.6 may result in their high incidences of foodborne illness because pathogens can multiply rapidly to unsafe levels at this pH level, especially when kelaguen is served for hours at the ambient temperature at parties or fiesta. Few incidences of foodborne illness associated with beef kelaguen observed in the community may be attributed to the low pH of beef kelaguen compared to the pH of other kelaguens.

Instead of pH 4.6, the FDA and USDA recommended the pH 4.2 to define a food as non-TCS because microbial vegetative cells and spores can be controlled in a food without temperature control for safety when the food has a pH of less than 4.2 and a water activity above 0.92 with no protection from recontamination (IFT/FDA 2003). Kelaguen has a water activity at about 0.97 and no protection from recontamination after preparation. However, the results of sampled kelaguen showed that the pH of all four types of kelaguen is above 4.2 (Table 1). Therefore, kelaguen, including beef, chicken, fish, and shrimp kelaguen, is a TCS food and must have temperature control for safety. Without temperature control, kelaguen must be consumed within 2 hours or stored at 4°C after preparation.

Effect Of Lemon On The pH And Titratable Acid Of Kelaguen

To achieve a pH of 4.2 for non-TCS foods, the amount of lemon juice needed for kelaguen was 19% for beef (Fig. 1), 21.5% for chicken (Fig. 2), 20.5% for fish (Fig. 3), and 25% for shrimp (Fig. 4). The needed amount of lemon powder for kelaguen was 3.2% for beef (Fig. 1), 3.0% for chicken (Fig. 2), 3.4% for fish (Fig. 3), and 3.6% for shrimp (Fig. 4). To reach a pH of 4.2 in kelaguen, the required amount of lemon juice was about 6-7 times higher than the required amount of lemon powder because the citric acid concentration in lemon powder was about 6-7 times higher than that in lemon juice. The raw meat exhibited various pH values following the order: beef < chicken < fish < shrimp. Raw shrimp had an initial pH above 7.0, which is much higher than that of beef, chicken, and fish (Fig. 1-4). Consequently, shrimp kelaguen required an amount of lemon higher than that of the other kelaguens to reach a pH of 4.2. The correlation of pH versus lemon concentration in kelaguen was not linear. Decreasing the pH of kelaguen from 5.5 to 4.2 required much more lemon that that to decrease the pH of kelaguen from 7.0 to 5.5. The buffer capacity of proteins in meat mitigated the pH changes of kelaguen. Therefore, a high amount of lemon was needed to prepare a non-TCS kelaguen.

To acidify kelaguen to a pH of 4.2 with lemon juice, the titratable acidity was at 1.5-1.7 g citric acid/100 g kelaguen (Fig. 1-4). To acidify kelaguen to a pH of 4.2 with lemon powder, the titratable acidity was at 1.8-2.2 g citric acid/100 g kelaguen (Fig. 1-4). The titratable acidity of kelaguen was linearly correlated to the added lemon. At the equivalent pH of kelaguen, such as at pH 4.2, the acidity of kelaguen acidified by lemon powder was slightly greater than that of kelaguen acidified by lemon juice. Other weak acids, such as ascorbic acid, in commercial lemon powder may contribute to this phenomenon. When kelaguen was acidified to a pH of 4.2, a small difference in titratable acidity was observed among beef, chicken, fish, and shrimp kelaguen. The difference in acidity and buffer capacity among raw beef, chicken, fish, and shrimp affected the difference in titratable acidity of kelaguen. At pH 4.2, citric acid has a molar

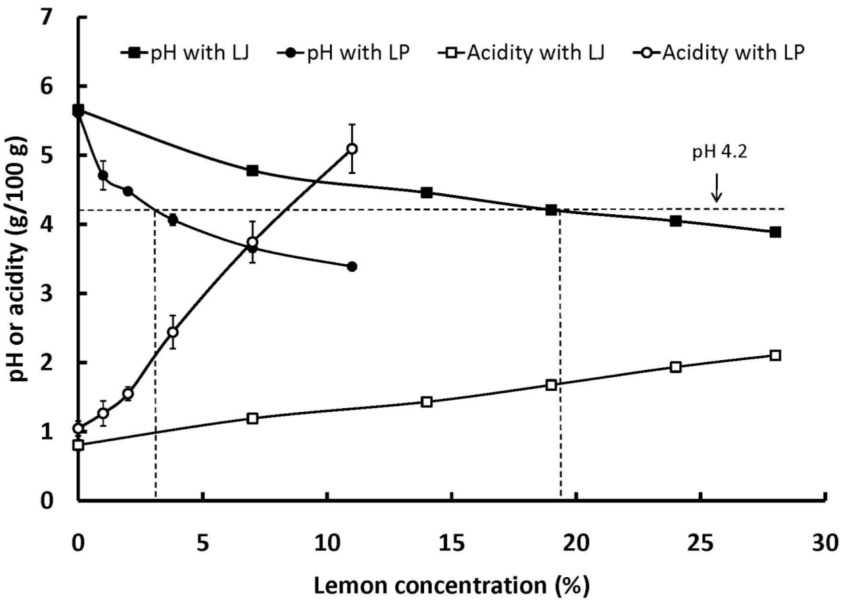

Figure 1. Effects of lemon juice (LJ) and lemon powder (LP) on the pH and titratable acidity (g critic acid/100 g) of beef kelaguen.

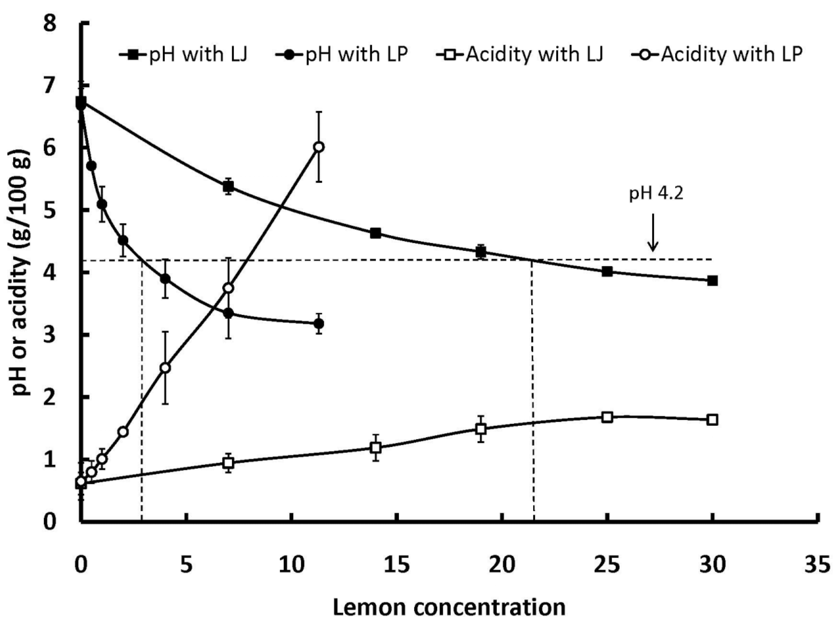

Figure 2. Effects of lemon juice (LJ) and lemon powder (LP) on the pH and titratable acidity (g critic acid/100 g) of chicken kelaguen.

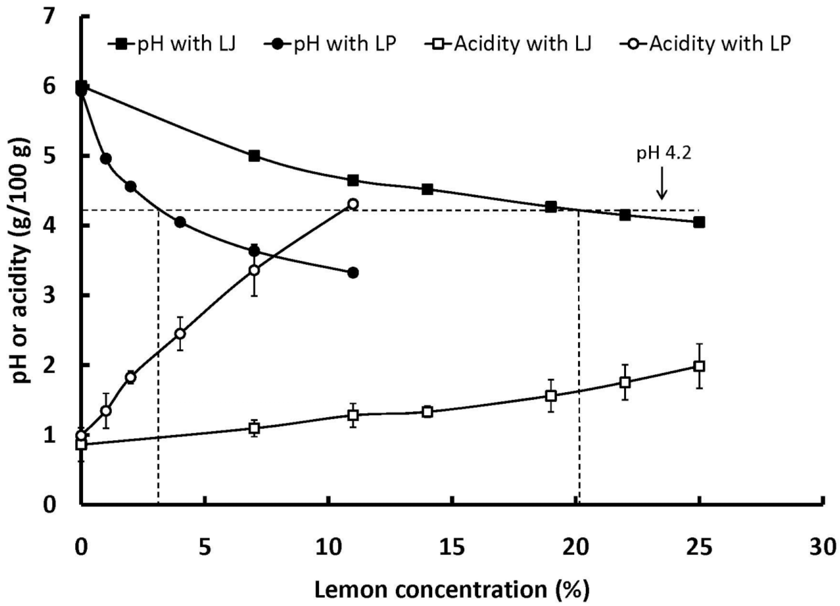

Figure 3. Effects of lemon juice (LJ) and lemon powder (LP) on the pH and titratable acidity (g critic acid/100 g) of fish kelaguen.

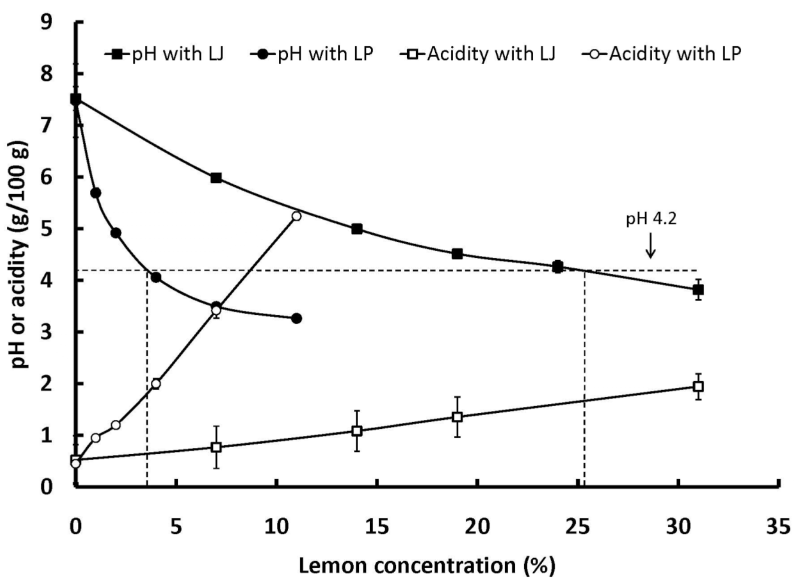

Figure 4. Effects of lemon juice (LJ) and lemon powder (LP) on the pH and titratable acidity (g critic acid/100 g) of shrimp kelaguen.

fraction of full protonated acid at 0.0622 (Gutz 2007). Based on the titratable acidity of kelaguen, the available full protonated citric acid in kelaguen was about 4.5-6.3 mM. Bjornsdottir et al. (2006) reported that to reduce 5-logs of *E. coli* O157:H7 in a treatment at pH 3.2 and 25°C for 6 hours the concentration of full protonated citric acid required is 50 mM. Therefore, the concentration of full protonated citric acid in non-TCS kelaguen was far less than that required to kill pathogens in kelaguen.

ESTIMATED pH AND ACIDITY OF KELAGUEN BASED ON RECIPES

The amount of lemon juice used in kelaguen recipes varied greatly not only among different types of kelaguen, but also among different recipes of the same type of kelaguen (Table 2). Among 26 kelaguen recipes, 17 recipes required an amount of lemon juice at 3-12% and 9 recipes required an amount of lemon juice at 16-24% (Table 2).

Table 2. Amount of lemon juice (%) used in recipes and estimated pH and titratable acidity (g citric acid/100 g) of kelaguen*

	Types of Kelaguen			
Kelaguen Characteristics	Beef	Chicken	Fish	Shrimp
*All available recipes (n**)*	3	8	7	8
Lemon juice	10.2 ± 1.3^{ab}	9.6 ± 5.0^{b}	16.9 ± 6.2^{a}	11.8 ± 6.8^{ab}
pH	5.13 ± 0.07^{ab}	5.40 ± 0.83^{ab}	4.80 ± 0.36^{b}	5.84 ± 1.05^{a}
Acidity	1.34 ± 0.05^{a}	1.10 ± 0.35^{a}	1.46 ± 0.45^{a}	1.44 ± 0.34^{a}
Low acid recipes (n)	3	6	2	6
Lemon juice	10.2 ± 1.3^{a}	7.1 ± 2.3^{a}	7.9 ± 0.5^{a}	8.3 ± 2.7^{a}
pH	5.13 ± 0.07^{b}	5.82 ± 0.37^{ab}	5.33 ± 0.04^{b}	6.32 ± 0.65^{a}
Acidity	1.34 ± 0.05^{a}	0.91 ± 0.09^{b}	0.81 ± 0.02^{b}	1.28 ± 0.20^{a}
High acid recipes (n)	–***	2	5	2
Lemon juice	–	17.1 ± 0.1^{b}	20.3 ± 0.7^{a}	22.1 ± 2.0^{a}
pH	–	4.15 ± 0.01^{b}	4.61 ± 0.04^{a}	4.40 ± 0.28^{ab}
Acidity	–	1.65 ± 0.00^{b}	1.71 ± 0.04^{b}	1.92 ± 0.09^{a}

* Data are mean ± standard deviation; a, b means with no common letters in the same row are significantly different ($p < 0.05$). ** Number of recipes. *** No recipes or data available

The average estimated pH of all kelaguen based on recipes was greater than the pH of 4.2 required for non-TCS foods (Table 2). The estimated pH of fish kelaguen was close to 4.6, while the estimated pH of beef, chicken, and shrimp kelaguen was above 5.0. The high pH of chicken and shrimp kelaguen indicates a high risk of foodborne illness if they are stored or served at ambient temperature for hours because pathogens can grow rapidly at a pH above 5. The estimated pH of chicken, beef, fish, and shrimp kelaguen in recipes was greater than or the same as the pH of chicken, beef, fish and shrimp kelaguen sampled from vendors and individuals, respectively (Table 1, 2). The estimated pH of kelaguen based on recipes further confirmed that traditional kelaguen is a non-TCS food and requires temperature control for safety.

Based on the amount of lemon juice used in kelaguen recipes, we generally classified kelaguen as low acid kelaguen, which requires 0-15% lemon juice or has a pH above 4.6, and high acid kelaguen, which requires 16-25% lemon juice or has a pH below 4.6. According to this criterion, among 26 recipes, 17 recipes were low acid kelaguen and 9 were high acid kelaguen. Among 17 low acid kelaguen recipes, the estimated pH of low acid kelaguen was 5.13 for beef (n = 3), 5.82 for chicken (n = 6), 5.33 for fish (n =2), and 6.32 for shrimp (n = 6). The pH of low acid beef, chicken, and fish kelaguen were above 5.0 and the pH of shrimp kelaguen was above 6.0. Among 9 high acid kelaguen recipes, the estimated pH of kelaguen was 4.2 for chicken (n = 2), 4.6 for fish (n = 5), and 4.4 for shrimp (n = 2). High acid kelaguen had a pH ≤ 4.6. Compared to high acid kelaguen, the high pH (at above 5.0) of low acid kelaguen may greatly contribute to the reported incidences of foodborne illness associated with chicken, fish, and shrimp kelaguen. From the 26 available recipes, about two thirds of the recipes are low acid kelaguen and one third of the recipes are high acid kelaguen. When kelaguen is served at parties or fiestas at the ambient temperature for hours, low acid kelaguen poses a great risk for foodborne illness because pathogens can favorably grow and/or produce toxins in such condition. Therefore, consumers should not prepare low acid kelaguen if they intend to serve and store it at the ambient temperature for hours. No high acid beef kelaguen recipes available may be attributed to the low pH of beef and the consequent smaller amount of lemon juice needed to make beef kelaguen with a sour taste.

The average acidity of kelaguen estimated from recipes was 1.1 to 1.5 g/100 g, following the order: chicken < beef < fish < shrimp (Table 2). Similar to the titratable acidity of sampled kelaguen (Table 1), the levels of estimated amount of citric acid in kelaguen recipes is not high enough to inhibit pathogen growth or kill pathogens in kelaguen. Therefore, kelaguen poses a great risk of foodborne illness to consumers if kelaguen is prepared with raw meats or partially cooked meats because pathogens in contaminated kelaguen can survive or grow after preparation.

Table 3. The recommended amount of lemon needed to prepare kelaguen not requiring temperature control for safety

	Types of Kelaguen			
Recommendations	Chicken	Beef	Fish	Shrimp
Both lemon juice and powder				
½ cup (juice) and 4-½ teaspoons (powder*)	1.6 lb meat** or 5.0 cup klg***	1.6 lb meat or 6.0 cup klg	1.5 lb meat or 4.5 cup klg	1.5 lb meat or 5.0 cup klg
Lemon juice				
1.0 cup	1.1 lb meat or 3.5 cup klg	1.0 lb meat or 4.0 cup klg	1.0 lb meat or 3.0 cup klg	0.8 lb meat or 3.0 cup klg
Lemon powder				
1.0 package or 10 teaspoons	2.3 lb meat or 7.0 cup klg	2.3 lb meat or 9.0 cup klg	2.1 lb meat or 6.3 cup klg	2.1 lb meat or 7.3 cup klg

* powder, Yours Lemon Flavored Powder, Yands Trading Co., Ltd., Japan.

** meat, pounds of raw meat for kelaguen. *** cup klg, cups of prepared kelaguen.

RECOMMENDED AMOUNT OF LEMON FOR NON-TCS KELAGUEN

The amount of lemon juice (19-25%) (Fig. 1-4) needed to prepare a non-TCS kelaguen with a pH at 4.2 was much closer to the amount of lemon juice (17-23%) in high acid kelaguen recipes (Table 2). In our kelaguen survey about 30% of participants stated that they used about 20% lemon juice based on weight to prepare chicken kelaguen. Also about 80% of participants preferred kelaguen to be sour or tangy. Therefore, using high amounts of lemon to prepare non-TCS kelaguen would be likely feasible and acceptable for consumers.

To safely store and serve kelaguen at parties or fiestas without temperature control, we recommend that consumers use the minimum amount of lemon described in Table 3 to prepare kelaguen. The recommended amount of lemon was based on the amount of lemon needed to lower the pH of kelaguen to 4.2, which is the pH required for non-TCS foods. Kelaguen prepared with the lemon juice and powder recommendation exhibited a good sensory quality; the chicken, beef, and shrimp kelaguen prepared with this recommendation were well accepted by participants during informal testing at various "Safe Kelaguen Workshops" provided to the community. Kelaguen prepared using the lemon juice only recommendation appeared a little juicy, which might detract from its sensory quality. Kelaguen prepared with the lemon powder only recommendation appeared a little dry. However, using lemon powder to replace part of the lemon juice required to prepare non-TCS kelaguen will overcome this shortcoming because lemon powder contained about 40% citric acid, which is about 7 times higher than the citric acid content of fresh lemon juice. Consumers can select one of the recommendations in Table 3 to prepare kelaguen according to their desired kelaguen texture and flavor.

The recommended amounts of lemon provided in Table 3 can prevent pathogen growth and toxin production in kelaguen served at the temperature danger zone, which is between 40° and 140°F. The recommendations can protect consumers from foodborne illness when kelaguen is subjected to temperature and time abuse at parties or fiestas. However, the recommended amount of lemon in Table 3 cannot kill pathogens in kelaguen. To kill pathogens in meat for kelaguen, consumers must use heat or other approved methods.

Conclusions

Although traditional kelaguen is a food acidified with lemon, it still has a pH above 4.2. Thus, kelaguen is a food requiring temperature control for safety. Additionally, traditional kelaugen can be classified into two groups: (1) low acid kelaguen with 0-15% (w/w) lemon juice or a pH above 4.6; and (2) high acid kelaguen with 16-25% (w/w) lemon juice or a pH below 4.6. Low acid beef, chicken, fish, and shrimp kelaguen had a pH of 5.0-6.3, posing a high risk for foodborne illness when these kelaguen are stored or served without temperature control. Low acid chicken, fish, and shrimp kelaguen, which accounts for two thirds of all kelaguen, is suggested to contribute greatly to the incidences of foodborne illnesses associated with kelaguen on Guam. High acid chicken, fish, and shrimp kelaguen had a pH of 4.1-4.6, posing a lower risk for foodborne illness than that posed by low acid kelaguen. For kelaguen to be safely served at parties or fiestas without temperature control, consumers should use the recommended amount of lemon juice and/or powder provided in this article to prepare non-TCS kelaguen with a pH of 4.2.

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