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# Quality attributes and reduction in total microbial population of fresh Malawian Tilapia (*Oreochromis* species) treated with dried buffered vinegar and stored on ice

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*Research Paper*

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## ABSTRACT

**Fish provide major nutritional and economic benefits to the people of Malawi. Unfortunately, fresh fish spoils rapidly because of limited availability of refrigeration and ice, and extensive distances traveled to market. This study was conducted to determine antimicrobial properties of dried buffered white vinegar (DV) on whole ungutted and gutted Malawian Tilapia, and ascertain the effects of DV treatments on quality attributes and pH. Whole fish were either gutted (GF) or left ungutted (UGF), treated with 0, 5, 8 or 10% (w/v) DV solutions, stored on ice and analyzed for pH, aerobic plate count (APC), total coliform (TCC), generic *Escherichia coli* (ECC), and quality attributes for 5 days. The pH values were similar (P > 0.05) for all treatments. At least 5% DV was necessary to achieve 2 log reductions (P <0.05) in APC and generic *E. coli* on day 5 when compared to controls. Gutting had no effect on APC, pH, and quality attributes, but resulted in reduced DV antimicrobial activity for ECC. The data suggested that at least 8% DV solutions should be used to treat fresh Tilapia to insure safety and maintain quality attributes for 5 days storage on ice.**

**Key Words:** Antimicrobials, dried Vinegar, Microbiology, quality, Tilapia.

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## INTRODUCTION

Malawi is a landlocked country with a population of 15,906,483 people (http://countryeconomy.com/ ,2014) and total area of 118,484 km$^2$, of which 20% (24,405 km$^2$) is covered by water supporting over 800 species of fish. Fish provides over 60% of the dietary animal protein intake of Malawians and 40% of the total protein supply. The leading fishery in terms of commercial importance is the Chambo fishery, which consists of three Oreochromis species namely; *Oreochromis karongae, O. lidole, and O. squamipinnis*. Other commercially important fish species include *Haplochromis species*, *Engraulicypris sardella, Copadichromis species, Bargrus meridionalis*, and *Clariid gariepinus* (Government of Malawi and GTZ, 2007).

A major issue in Malawi is minimal refrigeration and availability of ice, which results in the accelerated spoilage in fish immediately after harvest and total spoilage within 48 hours or less of harvest (Ashie et al., 1996; Hara and Mkoka, 1993). The development of the fish processing industry in Malawi is still in its infancy stages and lacks modern technology and equipment for shelf life extension and value addition. Approximately 20% of fresh fish is marketed as fresh fish due to onset of

spoilage, and the remaining 80% is sundried (50%) and smoked (30%) (Russell et al., 2008).

In general, the muscles of healthy finfish are sterile and microorganisms reside at the surfaces such as skin, gills, and gastrointestinal tract (Gram, 2010). The number of microorganisms varies depending on the area of catch. However, the skin typically contains $10^4$ CFU/cm$^2$, the gills $10^6$ cfu/g, and the digestive tract up to $10^8$ cfu/g (Austin, 2002). The number of microorganisms in the digestive tract may vary from $10^4$ to $10^9$ cfu/g (Spanggaard et al., 2000). The challenge is to retard the growth of spoilage microorganisms as long as possible in an effort to control spoilage and enhance storage stability. One solution to extending the shelf life of fresh fish could be the application of buffered vinegar, which is approved for use as an antimicrobial in the food industry. *DV* is an all-natural, water-soluble, buffered vinegar powder with maximum moisture content of 15%, and pH of 5.90 ± 0.30 in 5% solution. To minimize shipping costs, dried buffered vinegar powder would be the product of choice. Stelzleni et al. (2013) treated beef trimmings prior to use in ground beef production with 2.0% buffered liquid vinegar or 2.5% buffered dried vinegar (final product weight basis). The researchers reported 4.0 and 4.5 log cfu/g reductions in psychrotrophic bacteria for liquid buffered vinegar and dried buffered vinegar, respectively. Ponrajan et al. (2011) reported 2.0 log cfu/g reductions in *E. coli* O157:H7 for beef top rounds and top sirloins that were inoculated with *E. coli* O157:H7 prior to treatment with 2.0% (final product basis) buffered liquid vinegar. Treatment of fish with DV was not documented in the literature.

The hypothesis of this study was that the application of dried white buffered vinegar treatment solutions on fresh Tilapia stored on ice would reduce the growth of the total bacteria population. The researchers also hypothesized that gutting fish prior to application of dried white buffered vinegar would increase the reduction of bacteria in the total microflora to a greater extent than when no gutting of the fish was conducted. The objectives of this study were to determine antimicrobial properties of dried buffered white vinegar (DV) on whole ungutted and gutted Malawian Tilapia, and ascertain the effects of DV treatments on quality attributes and pH.

## MATERIALS AND METHODS

### Fresh fish harvesting, treatment and evaluation

Fresh Tilapia fish (*Oreochromis species*) were harvested from Lake Malawi and used in this study. The Tilapia were purchased from Maldeco Fisheries Limited 24 hours after landing on Lake Malawi shores. The fish were transported to the Microbiology laboratory at Chancellor College at the University of Malawi for treatment application, storage and analysis. Upon arrival at the laboratory, dried buffered white vinegar powder (DV, WTI, Inc., Jefferson, GA U.S.A) was reconstituted in tap water to produce 0, 5.0, 8.0 and 10.0% (w/v) DV treatment solutions. Based on preliminary experiments, 2% to 4% DV treatments were ineffective (less than 1 log cfu/g reduction) in reducing the total microbial population of fresh tilapia. Therefore, researchers concluded to evaluate higher levels of DV which included 5, 8 and 10% solutions.

The fish were divided into two equal batches. Fish in batch no. 1 were whole ungutted and treated with 0, 5.0, 8.0 or 10.0% (w/v) DV solutions by spraying to completely drench the fish. The fish were allowed to drain for 10 seconds on a sterilized wire rack and placed in layers of ice in cooler boxes. Cooler boxes are the usual transportation containers for fresh fish from the pier in Malawi to markets and consumers. Fish in batch no. 2 were gutted with the head and gills left intact and treated in the same manner as described for batch no. 1. The gills were left intact to evaluate gill color. The fish were gutted using clean sanitized knives in a manner that avoided cutting the intestinal tract.

The cooler boxes were assigned letters for identification where coolers A, K, W, and M were used for un-gutted whole fish and coolers D, G, Q, and J were used for gutted whole fish. Each cooler box contained an equal number of fish layers. Initially, the bottom of each cooler was covered with a layer of ice, followed by a layer of fish, and a final top layer of ice. The thickness of ice layers was standardized at approximately 15 cm. The experiment was repeated two times.

Fish internal temperature was recorded after every 24-hour period, and the ice was replenished. A thermometer was inserted into one fish from each layer in the cooler and the average internal temperature was recorded. The cooler boxes were stored at 25°C (ambient/room temperature) and 2 fish per box were analyzed after 0, 1, 3, and 5 days for microbiology (aerobic plate count, total coliforms and generic *Escherichia coli*) and pH, and after 0, 3 and 5 days for quality attributes (Table 1).

### Microbiological analyses

The official methods for Aerobic Plate Count (APC), no. 966.23B,(AOAC International,2005a) and Total Coliforms (TCC) and generic *E. coli* counts (ECC) using *E. coli* and Total Coliform Petrifilm® Plates , no. 991.14 (AOAC International, 2005b) were employed in this study. Two fish per treatment were randomly selected per cooler box for analysis on each sampling day. Duplicate 25 gram samples were collected by cutting the flesh below the dorsal fin using sterilized knife and forceps, placing the samples into sterile stomacher bags (Stomacher lab system, Seward Limited, U.K) that contained 225 ml of

**Table 1**. Scoring scale for evaluating quality attributes of fresh Malawian Tilapia (*Oreochromis species*) stored on ice in cooler boxes for 5 days.

| Attribute | Highest quality (4) | Good quality (3) | Fair quality (2) | Unacceptable (1) |
|---|---|---|---|---|
| Skin | Very intense pigmentation, transparent mucus | Insignificant pigmentation losses, milky mucus | Pigmentation without shine, slightly greyish mucus | Important pigmentation losses, widely opaque mucus |
| Exterior odor | Sharply sea weedy and shell fish | Weakly sea weedy and shellfish | Incipiently sour and putrid | Sour and putrid |
| Gills | Brightly red without odor, lamina perfectly separated | Rose colored without odor, lamina adhered in groups | Slightly dark red, lamina adhered in groups | Dark red with bad fish odor, lamina totally adhered |
| Flesh color | Red pigmentation in flesh | Pinkish pigmentation | Pale flesh color | No pigmentation |
| Fish eyes | Completely clear, glassy, sparkling, turgid | Somewhat clear, non-glassy, non-sparkling | Cloudy, traces of bloody spots | Unclear, pigmented and fuzzy |

0.1% sterile Peptone water (Beckon Dickinson and Company, Sparks, MD, U.S.A) and manually massaging the mixture for 1 minute. Serial dilutions of $10^{-1}$ to $10^{-6}$ were prepared, and 100µl aliquots were pipetted onto pre-hardened Tryptic Soy Agar (TSA) for APC. One ml aliquots of the sample homogenate were pipetted onto 3M Total Coliform Petrifilm and *Escherichia coli* Petrifilm (Petrifilm™, St. Paul, MN, U.S.A.) for TCC and ECC, respectively. All plates were incubated at 35 ± 1°C for 48 hours. The bacterial colonies on plates were counted, recorded and averaged.

### Sensory analysis of quality attributes for uncooked Tilapia

A sensory panel consisting of 6 members was trained to evaluate the uncooked Tilapia for quality attributes that included skin, exterior odor, gills, flesh color, and fish eyes appearance, using a 4-point quality scale where 4 = highest quality, 3 = good quality, 2 = fair quality, and 1 = unacceptable (Campos et al., 2005) (Table 1).

### Statistical analysis

The data were analyzed in a randomized block design. A 2 x 4 x 4 x 2 (microbiology and pH) or 2 x 4 x 3 x 2 x 2 (quality attributes) factorial treatment arrangement, with two levels of fish (whole un-gutted and whole gutted), four levels of DV (0%, 5.0%, 8.0% and 10.0%), four storage days (0, 1, 3, and 5 days) or three storage days (0, 3, 5 days) for quality attributes, two replications per treatment and 2 trials, was employed. A total of 128 samples were analyzed for microbiology and 96 were analyzed for quality attributes. Data were analyzed using SAS General Linear Model procedure (SAS, 2002). The model included the main effects of DV treatments, gutting, storage days, and treatment by day interaction. Comparisons among means were performed using SAS Duncan Multiple Range test. Treatment effects and differences were considered significant when $P < 0.05$.

## RESULTS AND DISCUSSION

### Microbiological analyses

### Aerobic plate count

In general, APC increased as storage time increased ($P < 0.05$) for all treatments. Initial APC for chilled fresh fish in this study were similar to APC (5.78 log cfu/g) reported by Ahmed et al. (2014) for fresh tilapia stored on ice. UGF treated with 10% DV had lower ($P < 0.05$) APC than the control on all storage days (Table 2). All UGF treated with DV had lower ($P < 0.05$) APC than the control on days 3 and 5. At 5 days storage, the 10% DV treatments resulted in 3.58 log reductions, and the 5 and 8% DV treatments resulted in 2 log reductions, when compared to the control. All UGF treated with DV remained less than 7 log cfu/g through 5 days storage which was not in the range of spoilage. The UGF control treatment had APC of 9 log cfu/g on day 5 which was indicative of spoilage. Barnes (1976) and Cunningham (1979) reported that meat spoils when bacteria counts reach at least 8 log cfu/g. The ICMSF (1986) reported APC counts of 5 log cfu/g as standard for fresh fish, and 6 log cfu/g or higher for fish as it begins to spoil (Yousef et al., 2007).
In comparison, GF treated with 10% DV resulted in lower ($P < 0.05$) APC when compared to the control on day 0, and all DV treatments had lower ($P < 0.05$) APC on day 5

**Table 2**. Aerobic plate counts for fresh whole ungutted and gutted Malawian Tilapia (Oreochromis species) treated with dried buffered vinegar and stored in cooler boxes on ice for 5 days.

| Gutting Process[1] | DV[2] (%) | Aerobic plate counts (log cfu/g) Days on Ice | | | | |
|---|---|---|---|---|---|---|
| | | 0 | 1 | 3 | 5 | SEM[3] |
| UGF | | | | | | |
| | 0 | $6.20^{az}$ | $6.28^{az}$ | $7.96^{ay}$ | $9.32^{ax}$ | 0.13 |
| | 5 | $5.46^{abz}$ | $5.67^{az}$ | $5.65^{by}$ | $6.67^{bx}$ | 0.13 |
| | 8 | $5.38^{aby}$ | $5.47^{aby}$ | $5.99^{bxy}$ | $6.87^{bx}$ | 0.13 |
| | 10 | $4.64^{by}$ | $4.65^{by}$ | $5.28^{bxy}$ | $5.74^{cx}$ | 0.13 |
| | SEM | 0.13 | 0.13 | 0.13 | 0.13 | |
| GF | | | | | | |
| | 0 | $5.63^{ay}$ | $6.57^{ay}$ | $6.70^{ay}$ | $9.29^{ax}$ | 0.13 |
| | 5 | $5.92^{ay}$ | $6.15^{axy}$ | $6.44^{axy}$ | $7.04^{bx}$ | 0.13 |
| | 8 | $5.53^{ay}$ | $5.63^{ay}$ | $6.04^{axy}$ | $6.93^{bx}$ | 0.13 |
| | 10 | $4.70^{by}$ | $6.31^{ax}$ | $6.44^{ax}$ | $6.59^{bx}$ | 0.13 |
| | SEM | 0.13 | 0.13 | 0.13 | 0.13 | |

[1]UGF = Whole ungutted fish; GF = Whole gutted fish
[2]DV = Dried white buffered vinegar (w/v), [3]SEM = Standard error of the mean.
[a- c] Means in the same column with the different superscript are significantly (P < 0.05).
[X-Z] Means in the same row with different superscript are significantly different (P < 0.05).

**Table 3**. Aerobic plate counts for fresh whole ungutted and gutted Malawian Tilapia (*Oreochromis species* treated with dried buffered vinegar and stored on ice for 5 days: effect of gutting).

| DV[1](%) | Gutting Process[2] | Aerobic plate counts (log cfu/g) Days on ice | | | | |
|---|---|---|---|---|---|---|
| | | 0 | 1 | 3 | 5 | SEM[3] |
| 0 | GF | $5.63^{az}$ | $6.57^{ayz}$ | $6.70^{ay}$ | $9.29^{ax}$ | 0.13 |
| 0 | UGF | $6.20^{az}$ | $6.28^{az}$ | $7.96^{by}$ | $9.32^{ax}$ | 0.13 |
| | | | | | | |
| 5 | GF | $5.92^{ay}$ | $6.15^{axy}$ | $6.44^{axy}$ | $7.04^{ax}$ | 0.13 |
| 5 | UGF | $5.46^{ay}$ | $5.67^{ay}$ | $5.65^{ay}$ | $6.67^{ax}$ | 0.13 |
| | | | | | | |
| 8 | GF | $5.53^{ay}$ | $5.63^{ay}$ | $6.04^{axy}$ | $6.93^{ax}$ | 0.13 |
| 8 | UGF | $5.38^{ay}$ | $5.47^{ay}$ | $5.99^{axy}$ | $6.87^{ax}$ | 0.13 |
| | | | | | | |
| 10 | GF | $4.70^{ay}$ | $6.31^{ax}$ | $6.44^{ax}$ | $6.59^{ax}$ | 0.13 |
| 10 | UGF | $4.64^{ay}$ | $4.65^{by}$ | $5.28^{bxy}$ | $5.74^{bx}$ | 0.13 |

[1]DV = Dried white buffered vinegar (w/v); [2]UGF = Whole ungutted fish; GF = Whole gutted fish
[3]SEM = Standard error of the mean.
[a- b]Means in the same column with the different superscript are significantly different (P < 0.05).
[x-z]Means in the same row with different superscript are significantly different (P < 0.05).

and resulted in 2 log reductions when compared to the control (Table 2). APC for all GF treated with DV remained less than 7.5 log cfu/g through 5 days storage which was not in the range of spoilage.

## Effect of gutting on APC

The data revealed that except for day 3, gutting had no effect (P > 0.05) on APC for the control fish (Table 3). On day 3, the UGF control had higher APC (P < 0.05) than GF. The 10% DV treatment resulted in lower (P < 0.05) APC for UGF on days 1, 3 and 5 when compared to GF, which suggested that the lower APC could be attributed largely to the concentration of DV instead of the gutting procedure employed.

## Total coliform counts

In general, TCC increased (P < 0.05) as storage time increased from 0 to 5 days for all treatments (Table 4). UGF treated with 8% DV had lower (P < 0.05) TCC on days 1 and 3 when compared to the control, and the 5%

**Table 4**. Total coliforms and *Escherichia coli* counts for fresh whole ungutted and gutted Malawian Tilapia (*Oreochromis species*) treated with dried buffered vinegar and stored on ice for 5 days.

| Gutting[1] Process | DV[2] (%) | Days on ice | | | |
|---|---|---|---|---|---|
| | | 0 | 1 | 3 | 5 |
| **Total Coliforms (log cfu/g)** | | | | | |
| UGF | 0 | $0.80^{ay}$ | $1.78^{ax}$ | $2.06^{ax}$ | $2.32^{ax}$ |
| | 5 | $0.59^{ay}$ | $1.17^{abxy}$ | $1.88^{abx}$ | $1.95^{ax}$ |
| | 8 | $0.55^{ay}$ | $0.65^{by}$ | $1.09^{bxy}$ | $1.78^{ax}$ |
| | 10 | $0.54^{ay}$ | $0.93^{aby}$ | $1.27^{abxy}$ | $1.93^{ax}$ |
| | SEM[3] | 0.02 | 0.02 | 0.02 | 0.02 |
| GF | 0 | $1.21^{ay}$ | $2.04^{axy}$ | $2.32^{ax}$ | $2.46^{ax}$ |
| | 5 | $1.18^{aby}$ | $1.50^{abxy}$ | $1.75^{axy}$ | $2.16^{ax}$ |
| | 8 | $1.08^{aby}$ | $1.38^{abxy}$ | $1.63^{axy}$ | $2.11^{ax}$ |
| | 10 | $0.45^{by}$ | $1.13^{bxy}$ | $1.50^{ax}$ | $1.64^{ax}$ |
| | SEM[3] | 0.02 | 0.02 | 0.02 | 0.02 |
| **Generic *Escherichia coli* (log cfu/g)** | | | | | |
| UGF | 0% | $1.74^{abz}$ | $2.63^{ayz}$ | $3.12^{ay}$ | $4.78^{ax}$ |
| | 5% | $2.38^{ax}$ | $2.24^{ax}$ | $2.65^{ax}$ | $2.74^{bx}$ |
| | 8% | $1.47^{bz}$ | $1.72^{abyz}$ | $2.62^{axy}$ | $2.77^{bx}$ |
| | 10% | $0.45^{cy}$ | $1.35^{bxy}$ | $1.38^{bxy}$ | $2.22^{bx}$ |
| | SEM[3] | 0.09 | 0.09 | 0.091 | 0.09 |
| GF | 0% | $1.99^{aby}$ | $2.79^{axy}$ | $3.09^{ax}$ | $3.19^{ax}$ |
| | 5% | $2.71^{ax}$ | $2.72^{ax}$ | $3.02^{ax}$ | $3.08^{ax}$ |
| | 8% | $1.71^{bx}$ | $1.63^{bx}$ | $2.44^{ax}$ | $2.45^{abx}$ |
| | 10% | $1.24^{bx}$ | $0.93^{bx}$ | $0.94^{bx}$ | $1.67^{bx}$ |
| | SEM[3] | 0.09 | 0.09 | 0.09 | 0.09 |

[1]UGF = Whole ungutted fish; GF = Whole gutted fish; [2]DV = Dried white buffered vinegar (w/v %); [3]SEM = Standard error of the mean.
[a-c]Means in the same column with the different superscript are significantly different.
$P < 0.05$); [x-z]Means in the same row with different superscript are significantly different
($P < 0.05$).

and 10% DV were similar ($P > 0.05$) to the control on all storage days. Except for days 0 and 1, GF in all treatments had similar ($P > 0.05$) TCC and ranged from 0.45 to 2.46 log cfu/g. In general, the control and all DV treatments for UGF and GF were in the acceptable range of 2 log cfu/g for TCC as reported by The International Commission on Microbiological Specifications for Foods (ICMSF, 1986) for fresh fish (Yousef et al., 2007) on all storage days.

## Generic *Escherichia coli*

Fecal coliforms and *E. coli* in fresh fish are indicators of fecal contamination due to contaminated water or post-harvest handling and poor hygiene. *E. coli* is found predominantly in the gastrointestinal tract of humans (Doyle et al., 2001). ICMSF (1986) reported that ECC below 11 cfu/g (1.04 log cfu/g) are considered good microbial quality, counts greater than 500 cfu/g (2.70 log cfu/g) are considered unacceptable microbial quality, and counts between 11 cfu/g (1.04 log cfu/g) and 500 cfu/g (2.70 log cfu/g) are considered marginally acceptable microbial quality.

In general, ECC for UGF increased ($P < 0.05$) as storage time increased for all treatments except 5% DV (Table 4), where ECC remained similar ($P > 0.05$) through 5 days. ECC for UGF treated with 10% DV were lower ($P < 0.05$) than the control on all days, and lower ($P < 0.05$) than 5% and 8% DV treatments on days 0, 1 (5% only) and 3.

ECC for control were in the “good microbial quality” range on day 0, but decreased to ‘marginally acceptable quality on day 1, and deteriorated to unacceptable quality on days 3 and 5. Fish treated with 10% DV had good quality on days 0 through 3, and marginally acceptable quality on day 5. UGF treated with 5% and 8% DV deteriorated to marginally acceptable on day 1 (5% DV only) and days 3 and 5 (5% and 8% DV).

In comparison, ECC remained similar ($P > 0.05$) during storage for all GF treated with DV, and increased ($P < 0.05$) as storage time increased for the control (Table 4). As was observed for the UGF fish treated with DV, except for day 0, GF treated with 10% DV had lower ECC ($P < 0.05$) than the control on all storage days, and maintained good quality through 5 days. GF treated with 8% DV had similar ECC ($P > 0.05$) as 10% DV on days 0, 1, and 5, and resulted in good quality on days 0 and 1 and marginally acceptable microbial quality on days 3 and 5.

**Table 5.** Panelists' quality attributes ratings for fresh whole ungutted and gutted Malawian Tilapia (*Oreochromis species*) treated with dried buffered vinegar and stored on ice in coolers for 5 days.

| Quality attribute[1] | DV[2] (%) | Whole ungutted fish (Days on ice) | | | Whole gutted fish (Days on ice) | | |
|---|---|---|---|---|---|---|---|
| | | 0 | 3 | 5 | 0 | 3 | 5 |
| Skin | 0 | 3.67$^{ax}$ | 2.00$^{cy}$ | 1.33$^{by}$ | 4.00$^{ax}$ | 2.33$^{bcy}$ | 2.00$^{bcy}$ |
| | 5 | 4.00$^{ax}$ | 2.63$^{bcy}$ | 2.33$^{ay}$ | 4.00$^{ax}$ | 1.65$^{cy}$ | 1.67$^{cy}$ |
| | 8 | 4.00$^{ax}$ | 3.00$^{by}$ | 2.33$^{ay}$ | 3.67$^{ax}$ | 3.00$^{aby}$ | 3.00$^{ay}$ |
| | 10 | 3.67$^{ax}$ | 4.00$^{ax}$ | 2.33$^{ay}$ | 3.67$^{ax}$ | 3.67$^{ax}$ | 2.67$^{aby}$ |
| | SEM[3] | 0.12 | 0.12 | 0.12 | 0.13 | 0.14 | 0.13 |
| Odor | 0 | 4.00$^{ax}$ | 2.00$^{cy}$ | 1.67$^{by}$ | 4.00$^{ax}$ | 1.67$^{cy}$ | 1.67$^{by}$ |
| | 5 | 3.67$^{ax}$ | 1.00$^{dz}$ | 2.00$^{by}$ | 4.00$^{ax}$ | 1.67$^{cy}$ | 1.00$^{by}$ |
| | 8 | 4.00$^{ax}$ | 3.00$^{by}$ | 3.30$^{axy}$ | 4.00$^{ax}$ | 3.67$^{az}$ | 3.00$^{ay}$ |
| | 10 | 4.00$^{ax}$ | 4.00$^{ax}$ | 2.33$^{aby}$ | 4.00$^{ax}$ | 2.67$^{by}$ | 2.67$^{ay}$ |
| | SEM[3] | 0.12 | 0.13 | 0.12 | 0.13 | 0.14 | 0.13 |
| Gills | 0 | 3.67$^{ax}$ | 1.67$^{cy}$ | 1.00$^{cy}$ | 4.00$^{ax}$ | 2.00$^{by}$ | 1.67$^{by}$ |
| | 5 | 4.00$^{ax}$ | 2.66$^{by}$ | 2.33$^{by}$ | 3.67$^{ax}$ | 2.33$^{by}$ | 1.67$^{by}$ |
| | 8 | 3.67$^{ax}$ | 3.00$^{abx}$ | 2.00$^{by}$ | 4.00$^{ax}$ | 3.67$^{axy}$ | 3.00$^{ay}$ |
| | 10 | 4.00$^{ax}$ | 3.67$^{axy}$ | 3.00$^{ay}$ | 4.00$^{ax}$ | 3.33$^{axy}$ | 2.67$^{ay}$ |
| | SEM[3] | 0.12 | 0.12 | 0.12 | 0.12 | 0.13 | 0.12 |
| Flesh color | 0 | 3.67$^{ax}$ | 2.33$^{by}$ | 3.33$^{ax}$ | 3.67$^{ax}$ | 1.67$^{by}$ | 1.33$^{cy}$ |
| | 5 | 3.33$^{ax}$ | 2.00$^{by}$ | 3.67$^{ax}$ | 3.67$^{ax}$ | 1.67$^{by}$ | 1.66$^{bcy}$ |
| | 8 | 3.33$^{ax}$ | 3.33$^{ax}$ | 4.00$^{ax}$ | 3.66$^{ax}$ | 3.33$^{ax}$ | 2.33$^{aby}$ |
| | 10 | 3.67$^{ax}$ | 3.66$^{abx}$ | 4.00$^{ax}$ | 4.00$^{ax}$ | 2.67$^{ay}$ | 3.00$^{ay}$ |
| | SEM[3] | 0.14 | 0.14 | 0.14 | 0.13 | 0.14 | 0.13 |
| Eyes | 0 | 3.33$^{ax}$ | 1.67$^{cy}$ | 1.00$^{cy}$ | 4.00$^{ax}$ | 1.33$^{by}$ | 1.33$^{by}$ |
| | 5 | 3.67$^{ax}$ | 2.33$^{bcy}$ | 1.33$^{bcz}$ | 3.66$^{ax}$ | 1.66$^{by}$ | 1.33$^{by}$ |
| | 8 | 4.00$^{ax}$ | 3.00$^{aby}$ | 2.00$^{abz}$ | 4.00$^{ax}$ | 2.66$^{ay}$ | 2.66$^{ay}$ |
| | 10 | 4.00$^{ax}$ | 3.33$^{ay}$ | 2.67$^{ay}$ | 3.67$^{ax}$ | 2.67$^{ay}$ | 2.67$^{ay}$ |
| | SEM[3] | 0.13 | 0.14 | 0.13 | 0.13 | 0.13 | 0.13 |

[1]Quality scores: 4 = highest, 3 = good, 2 = fair, 1 = unacceptable.
[2]DV = Dried white buffered vinegar (w/v). [3]SEM = Standard error of the mean.
[a,b,c]Means in columns within an attribute bearing different superscripts differ significantly ($P < 0.05$).
[x,y,z]Means in rows within an attribute bearing different superscripts differ significantly ($P < 0.05$).

## pH

All pH values were similar ($P > 0.05$) and ranged from 7.10 to 7.23 for all treatments (Data not shown). The DV treatments did not affect the pH of UGF and GF ($P > 0.05$). Very small amounts of lactic acid are produced post mortem in fish which results in a high pH of > 6 for fish muscle (Gram and Huss, 1996; 2000). The data revealed that DV treatments did not negatively alter the pH of fish but maintained it.

## Sensory evaluation of quality attributes for uncooked Tilapia

The Alaska Seafood Marketing Institute (2014) reported that the skin of high quality fresh seafood should be shiny and void of dullness, the scales should adhere closely to the skin and be largely intact, odor should be pleasant and minimal, gills of most fresh finfish should be blood red, the flesh should be firm and resilient, and the eyes should be bright and clear. The skin, odor, gills, flesh color, and eyes of all UGF and GF were rated similar ($P > 0.05$) and in the range of good to highest quality on day 0. Differences between UGF and GF for each attribute included the following (Table 5).

## Skin

The skin for all UGF treated with DV was rated acceptable (that is fair to highest quality) through 5 days storage. The control deteriorated to unacceptable on day 5. The 8 and 10% DV treatments resulted in higher scores than the control on day. All DV treatments resulted in higher and acceptable scores than the control

on day 5. In comparison to the UGF, except for 5% DV on days 3 and 5, all DV treatments resulted in acceptable fish through 5 days. GF treated with 5% DV was rated unacceptable on days 3 and 5. GF treated with 10% DV resulted in higher scores ($P < 0.05$) than the control and 5% DV treatment on day 3, and the 5% DV treatment on day 5. Skin ratings were similar ($P > 0.05$) on all storage days for GF treated with 8% and 10% DV.

### Odor

Except for the 5% DV treatment on day 3 and the control on day 5 which were rated unacceptable, the odor of all UGF was rated "fair' to "highest quality" during 5 storage days. The 8% and 10% DV treatments resulted in higher scores for odor than the control and 5% DV treatment on day 3; and the 8% was rated higher than the control and 5% DV treatment on day 5. In comparison to UGF, on days 3 and 5, the control and GF treated with 5% DV were rated similar ($P > 0.05$) and unacceptable, and lower ($P < 0.05$) than the 8% and 10% DV treatments. The odor of GF treated with 8% and 10% DV was rated good, and fair, respectively, on days 3 and 5.

### Gills

Except for the control on days 3 and 5, all UGF were rated fair to good quality through 5 days storage. Panelists rated the gills of all UGF treated with DV good to fair, and higher ($P < 0.05$) than the control (rated unacceptable) on days 3 and 5. In comparison to UGF, except for the control and 5% DV treatment on day 5, all GF were rated fair to good quality through 5 days storage. Gill color for GF treated with 8 and 10% DV was rated higher ($P < 0.05$) than the control and 5% DV treatments on days 3 and 5.

### Flesh color

Flesh color for all UGF was rated fair to good quality through 5 days storage. UGF was similar ($P > 0.05$) for all treatments on days 0 and 5. The 8% DV treatment was scored higher ($P < 0.05$) than the control and 5% DV treatment and similar to 10% DV treatment on day 3. In contrast, on days 3 and 5, the control and 5% DV treatment for GF were rated unacceptable, and the 8% and 10% DV treatments were rated fair to good. The 10% DV treatment was rated higher ($P > 0.05$) than the control and 5% DV treatments on days 3 and 5.

### Eyes

Except for the control on days 3 and 5, and the 5% DV treatment on day 5, all UGF were rated fair to highest quality through 5 days storage. The eyes of UGF treated with 8% and 10% DV were rated higher ($P < 0.05$) than the control on days 3 and 5. Eye color for the control was scored unacceptable on days 3 and 5, and unacceptable on day 5 for the 5% DV treatment. In comparison, eye color for GF treated with 8% and 10% DV was rated fair and higher ($P < 0.05$) than the control and 5% DV treatment on days 3 and 5.

## CONCLUSIONS

This study revealed that at least 5% DV was necessary to achieve 2 log reductions ($P < 0.05$) in APC on day 5 when compared to controls. The pH values were similar ($P > 0.05$) for all treatments. Gutting had no effect on APC and quality attributes, but resulted in reduced DV antimicrobial activity for ECC. The data for ECC revealed that 10% DV was necessary to achieve 1.52 log reductions on day 5 for the UGF, compared to 5% DV used to achieve 2.0 log reductions for UF. This finding disagreed with the hypothesis that gutting fish prior to application of dried white buffered vinegar would increase the reduction of bacteria in the total microflora to a greater extent than when no gutting of the fish was conducted. However, the study supported the hypothesis that DV treatments would function to decrease the total microbial population of the Malawian Tilapia. The data for ECC suggested that gutting might have resulted in cross contamination of the fish carcass with viscera material that could minimize the antimicrobial efficacy of the DV treatment. Therefore, in future studies, care must be taken to rinse the UGF with potable water to remove any viscera material that might be present on the surfaces of the fish carcass due to the gutting process**.** The data suggested that at least 8% DV solutions should be used to treat fresh Tilapia in order to insure safety and maintain quality attributes of the fish for 5 days.

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## REFERENCES

Ahmed SH, Eldien KB, Abdella R (2014). Survey of contaminant bacteria on *Oreochromis niloticus* and *lates niloticus* at Elmourda fish market. Direct. Res. J. Agric. and Food Sci., 2 (7):98-101.

Alaska Seafood Marketing Institute (2014). A Foodservice Guide to Seafood Quality: Basic tips on handling fresh and frozen Alaska

Seafood.Retrieved at http://www.alaskaseafood.org/fishingprocessing/fsgsq.htm. Accessed on July 24, 2014.
AOAC International. (2005a). Aerobic Plate Count Method 966.23B. AOAC Official Methods of Analysis. Retrieved at
http://www.agriculture.gov.au/SiteCollectionDocuments/aqis/exporting/meat/elmer3/approved-methods-manual/Aerobic Plate Count-AOAC-966.23B.pdf. Accessed August, 2011.
AOAC International. (2005b). Escherichia coli and Coliforms Method 998.08. AOAC Official Methods of Analysis. Retrieved at http://www.agriculture.gov.au/SiteCollectionDocuments/aqis/exporting/meat/elmer3/approved-methods-manual/Generic-E-coli-E-coli-Petrifilm-AOAC-998.08.pdf. Accessed August, 2011.
Ashie INA, Smith JP, Simpson BK (1996). Spoilage and shelf life extension of fresh fish and shell fish. Crit. Rev. Food Sci. Nutr. 36(1-2): 87-121.
Austin B (2002). The bacterial micro flora of fish. The Sci. World J. 2:558–572.
Barnes EM (1976). Microbiological problems of poultry at refrigerator temperatures - a review. J. Sci. Food Agr. 27(8):777-782.
Campos CA, Rodríguez Ó Losada V, Aubourg SP, and Barros-Velázquez J (2005). Effects of storage in ozonised slurry ice on the sensory and microbial quality of sardine (*sardina pilchardus*). Int. J. Food Microbiol. 103(2):121-130.
Countryeconomy.Com. (2014). Malawi Population. Retrieved at http://countryeconomy.com/demography/population/malawi. Accessed May 5, 2014
Cunningham FE (1979). Shelf-life and quality characteristics of poultry parts dipped in potassium sorbate. J. Food Sci. 44(3):863-864.
Doyle MP, Beuchat LR, Montville TJ (Eds.) (2001). Food microbiology: fundamentals and frontiers (Vol. 475). Washington, DC: ASM Press.
Government of Malawi and GTZ (2007). ESA Meeting on Trade and sustainable approaches Fisheries. Labourdonnais Waterfront Hotel, Port Louis- Mauritius, 2-4 May 2007
Gram L (2010). Microbiological Spoilage of Fish and Seafood Products. Page 87-119 in Compendium of the microbiological spoilage of foods and beverages, Food Microbiology and Food Safety. Sperber, W.H. and Doyle, M.P. ed. Available at http://link.springer.com/chapter/10.1007%2F978-1-4419-0826-1_4?LI=true# Accessed Dec 2012
Gram L, Huss, HH (1996). Microbiological spoilage of fish and fish products. Int. J. Food Microbiol. 33: 121-137.
Gram L, Huss, HH (2000). Fresh and processed fish and shellfish. Pages 472-506 in Microbiological Safety and Quality of Food. B.M. Lund, A.C. Baird-Parker and G.W. Gould, eds., Chapman and Hall. London, U.K. provide page number
Hara M, Mkoka C (1993). In: CIFA Technical Paper. No. 21. Rome, FAO. 1993. 113p.Fisheries management in south-east Lake Malawi, the Upper Shire River and Lake Malombe with particular reference to Chambo (*Oreochromis* spp.) FAO Document Repository CIFA Technical Paper21. Retrieved from http://www.fao.org/docrep/005/t0783e/t0783e00.htm. Accessed January 2012.
ICMSF (1986). Chapter 14: Coliforms, Fecal Coliforms and *Escherichia coli*. Sea Grant Extension Program. Retrieved from http://seafood.oregonstate.edu/.pdf%20Links/Compendium/Chapter-14-Coliforms-Fecal-Coliforms.pdf. Accessed on November 21, 2013.
Ponrajan A, Harrison MA, Segers JR, Lowe BK, McLeish RO, Pringle TD, Martino K, Mulligan J, H and Stelzleni AM (2011). Effects of sodium citrate plus sodium diacetate and buffered vinegar on *Escherichia coli* O157:H7 and psychrotrophic bacteria in brine-injected beef. J. Food Protect. 74 (3): 359–364.
Russell AJM, Grotz PA, Kriesmers SK, Pamsl DE (2008). Recommendation domains for pond aquaculture, country case studies and Reviews No.1869. The Word Fish Center, Penang, Malaysia, p. 52.
SAS Institute, Inc. (2002). Gary, IN.Spanggaard B, Huber I, Nielsen J, Nielsen T, Appel KF, Gram L (2000). The microflora of rainbow trout intestine: A comparison of traditional and molecular identification. Aquaculture 182 (1-2):1–15.
Stelzleni AM, Ponrajan A Harrison MA (2013). Effects of buffered vinegar and sodium dodecyl sulfate plus levulinic acid on *Salmonella* Typhimurium survival, shelf-life, and sensory characteristics of ground beef patties. Meat Sci. 95(1):1-7.
Yousef AM, Asad MA, Lifat M, Hossain MM (2007). Organoleptic and Microbiological Assessment of Ten Commercially Important Dried and Fresh Fishes. South Asian J. Agric. 2(1&2):29-32.