Journal of Agricultural Economics, Extension and Rural Development: ISSN-2360-798X, Vol. 5(5): pp, 632-641, May, 2017.

Full Length Research Paper

Assessment of Effectiveness of Garlic Extract from Laikipia County, on Shelf-Life of Meat

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Accepted May 3rd , 2017.

The study was undertaken to determine shelf life of meat using goat limbs, using garlic extract; acetic acid and sodium hypochlorite as positive controls. Total viable counts were performed at different times in a week, (0h, 1h, 24h, 48h, 72h and 96h), temperature range (23-24^{0}C). The following parameters were observed and recorded; weight of meat samples, microbial load, pH, color of meat, room temperature, texture and smell. The total bacterial load in meat treated with garlic extract reduced from log 6.85 to 3.35 within the first 1 h, then to 3.15 after 24 h. After 48h, 72h and 96h the microbial load increased to log 3.38, 4.03 and 6.35 respectively. The total bacterial load on meat treated with acetic acid reduced from log 6.26 to 3.79 within the first 1h. However, the load increased to log 6.93, 9.39 after 48h and 72h respectively. The bacterial load in meat treated with sodium hypochlorite reduced from log 6.45 to 4.25 microbial load within the first 1 h. Thereafter increased exponentially up to 96h. Based on the results, garlic extract was significantly more effecting in prolonging shelf life of meat (p= 0.016) than others and can be used as a meat decontaminant/preservative.

Keywords: Ethyl acetate, garlic, Shelf life, Decontaminant

INTRODUCTION

Fresh meat is considered to be the food of choice for many people due to its nutritional value Agrisystems, (2003). Fresh beef is rich in vitamins and minerals and provides an important source of high quality protein. It has a short shelf life of one day or less at ambient temperature (15-30°C) (Acuff, 2006) and a few days at refrigerated temperature (0-10°C) due to microbial spoilage of both pathogenic and non-pathogenic Agrisystems, (2003). (Acuff, 2006) and/or lipid oxidation (Hunt, 2004). The maximum shelf life of fresh beef depends on several factors such as pH, water activity, microbial growth and temperature Dilbaghi and Sharma, 2007). Due to its high nutrient composition, fresh beef has biological and chemical properties which represent an optimum medium for microbial growth. It undergoes deterioration progressively from slaughter until consumption. The shortened shelf-life is due to microbial growth and/or rancidity development which is strongly influenced by initial beef quality, package parameters and storage conditions (Riches and Derrick, 2011). Microbial growth is the most important factor in spoilage of fresh beef and this is followed by color deterioration. Different types of spoilage and pathogenic microorganisms may be introduced into and on the surface of fresh beef during slaughtering and processing, which causes rapid spoilage, great loss of valuable protein and also affect human health (Acuff, 2006).

Meat contamination by microorganisms mainly occurs through operations carried out in animal husbandry, processing, preparation, treatment, packaging and transporting and also from the environment (WHO, 2002). The essential purpose of decontamination is to extend shelf life by reducing the initial bacterial load (Singh and Singh, 2005). The reduction of microbial load is the most effective means to extend the shelf life of fresh beef. The determination of total viable bacteria effectively evaluates the hygienic quality of foods. (Singh, 2005). At the time of slaughter, the meat is almost sterile so that the primary contamination concerns in particular the meat surface. Later the microorganisms penetrate into deeper layers of meat. When this primary contamination is reduced, the shelf-life of meat can be significantly prolonged. Thus it is advantageous to decontaminate the surface of carcasses to increase their shelf-life and to enable the safe distribution.

Today, decontamination systems using chemical agents are approved by Food Safety and Inspectorate Services (FSIS) for use as a component of a Hazard Analysis and Critical Control Points (HACCP) Plan if the chemicals are Generally Recognized as Safe. (GRAS) by the Food and Drug Administration, do not create an adulterant situation, do not create labeling (i.e., added ingredients.) issues, and can be supported with scientific studies as being effective (Keith, 2001). A number of methods can be used to decontamination meat and thus prolong the shelf-life of meat and meat products. The mostly used methods are organic acids such as acetic acid, lactic acid, formic acid and propionic acid which act by decreasing pH, and due to their bactericidal properties, stop growth of bacteria. Organic acids are generally recognized as safe (GRAS) antimicrobial agents, and the dilute solutions of organic acids (1-3%) are generally without effect on desirable sensory properties of meat when used as a carcass decontaminant (Raftri *et al*.,2009).

These acids are often used for surface decontamination as they are natural component of meat produced during postmortem glycolysis and thus they are not typical additives (Raftari *et al*., 2009). The antibacterial efficacy of organic acids depend on several factors such as the type of the acid used, pH of the medium, concentration and temperature of the acid solution, type of the food product, initial microbial load (Gomez-Lopez *et al*., 2009), the methods of application, dipping time (Pipek *et al*., 2004) and the inherent resistance of the target microorganism to the acid used (Davidson, 2001). They are most useful as warm (50-55^{0}C) rinses, using hot water or steam (Keith, 2001; Ransom *et al*., (2001). Potential concerns associated with use of organic acids include selection for presence of acid resistant bacteria that may accelerate rates of product spoilage, increase undesirable effects on product appearance, and speed equipment corrosion (Gill,1998). It is clear that the surface treatment of carcasses by spraying with organic acids solution reduces the surface microbial counts and thus increases the shelf-life and provides food safety.

There are also chemical solutions that have been proposed and tested for use in meat and poultry decontamination systems. Such chemicals include common chlorine and chlorine dioxide, hypochlorite, trisodium phosphate, hydrogen peroxide, sodium hydroxide, ozone, sodium bisulfate, sodium chloride, acidified sodium chlorite, nisin, potassium sorbate, cetylpyridinium chloride, and activated lactoferrin (Dilbaghi and Sharma. 2007). However, high residual level of chlorides are considered excessive for human consumption (Riches and Derrick , 2011). Sodium hypochlorite, an oxidizing agents, is a good broad-range disinfectant that is only effective at a neutral to moderate pH of 6-9, and has a diminished effect in the presence of organic material(Armcanz, 2000). However Hypochlorite are toxic to the eyes and skin, and corrosive to many metals (Geering *et al*., 2001).

Vacuum packaging is the most common method of packaging beef after processing, throughout the beef chain. Vacuum packaging is where a bag or pouch that has very low moisture and oxygen transmission rates. The oxygen source is removed from the package via a vacuum chamber and the package is heat sealed. With the elimination of oxygen, the growth of typical spoilage organisms is significantly reduced, thereby extending product shelf-life. However, with vacuum packaging, myoglobin remains in the native form and has a purple color with little moisture loss (shrink) and extended shelf-life. Savell *et al*., (1981), noted that the color of the packaged product (purple color) differs significantly from the color expected by consumers.

High oxygen packages contain 80% oxygen (O_2) and 20% CO_2 (Belcher, 2006). This high level of oxygen allows for an extended period of bloom and the CO_2 prevents the growth of

Spoilage bacteria. Beef packaged in a high oxygen modified atmosphere typically retains a shelf-life of 12 to 16 days for whole-muscle beef cuts(Cornforth, 2008; Belcher, 2006). This method is very expensive and very few can afford it. Low oxygen modified atmosphere packages containing 70% N_2 and 30% CO_2 are used to prolong the shelf-life of fresh meat for an extended period of time. Nitrogen isa n inert gas; it does not react with the meat or container and is only used to fill space. Carbon dioxide is used to prevent the growth of bacteria. The only drawback with this form of packaging is that there is no oxygen to react with

myoglobin to cause blooming. This results in the formation of deoxymyoglobin is the predominant pigment present (Hunt 2004), resulting in a dark-purple color. U.S. consumers are not accustomed to this dark-purple color so this is a potential disadvantage of low oxygen. This method is very expensive and very few can afford it.

Sensory Evaluation is a scientific discipline used to analyze reactions to stimuli perceived through the senses – Sight, Smell, Touch, Taste and Sound. Sensory Analysis is a vital tool for the Food Industry and can be used in a number of applications like New Product Development, Quality Control/Assurance and Shelf life Evaluation. Affective testing is concerned with obtaining *subjective* data, or how well products are likely to be accepted. Usually large (50 or more) panels of untrained personnel are recruited for this type of testing, although smaller focus groups can be utilised to gain insights into products. The range of testing can vary from simple comparative testing (e.g. Which do you prefer, A or B?) to structured questioning regarding the magnitude of acceptance of individual characteristics (e.g. Please rate the "fruity aroma": dislike|neither|like), (Lawless and Heymann, 2010; Meiselman and MacFie, 1996)). Effective testing is concerned with obtaining *objective facts* about products. This could range from basic discrimination testing (e.g Do two or more products differ from each other?) to descriptive profiling (e.g. what are the characteristics of two or more products?). The type of panel required for this type of testing would normally be a trained panellist (Lawless and Heymann, 2010).

Ethyl acetate is an organic solvent which extracts non-polar, medium and polar natural compounds from plant materials quite efficiently. It can help to extract many biological compounds for evaluation of their activities. Due to its low cellular toxicity it is more preferred for extraction of organic compounds (Sell and Charles, 2006).

Garlic (*Allium sativum*) is one of those plants that has been seriously investigated over the years. Since long time, Garlic, a spice in the family *Liliaceae,* has been used as flavoring agent and in folk medicine (Rivlin, 2001). Garlic ethyl acetate extract contains metabolites such as diallyl disulfide, 6-(methylthio) hexa-1,5-dien-3-ol, trisulfide,di-2-propenyl, 2-vinyl- (4H)-1,3- dithiin, tetrasulfide,di-2-propenyl, hexadecanoic acid, 2,3-dihydroxypropyl ester, oleic acid, 5-cyno-7-methyl-6-(methylthio) benzo (c) carbazole and abietic acid which which work synergistically against a range of bacteria, fungi and viruses (Avato *et al*., 2000; Seong soo *et al*., 2010; Arunkumar and Muthuselvam, 2009).

The aim of this study was to determine shelf life of meat treated with garlic (*Allium sativum*) extract. These results stipulate significant capacity and future scope for the use of garlic extract for a new decontaminant development.

MATERIALS AND METHODS

Preparation of garlic ethyl acetate extract

One hundred grams of the peeled garlic cloves were weighed on a clean aluminium foil using a weighing balance (Mettler pm 4600, Deltarange, Zurich). They were then put in an electric blender (Ohms, Internationalfzc,China) and 125ml of 99.9% ethyl acetate (AR) was added. The mixture was homogenized by blending to a paste and put in a 1000 ml flat bottomed using a glass funnel and then covered with an aluminium foil. This procedure was repeated six times to yield a total weight per volume of 600g of garlic in 750ml ethyl acetate , and the total volume put in the same flask. Three such volumes in 1000ml flat bottomed flasks were prepared and a total of 1800g of garlic in 2250ml of ethyl acetate was prepared, kept in a dark cabinet for 24h. Shaking was done in the morning and in the evening to homogenize all the flask contents. The contents were filtered using whatman's paper No.1. The resulting filtrate was evaporated using rotary evaporator (Rotor Vapour Pump, Laboratoriums-Technic Ag, Buchi) at 50°C to remove ethyl acetate. This process yielded 710g of extract.

Determination of effect of garlic ethyl acetate extract on shelf life of meat

Purchase and transportation of meat samples

The effect of garlic extract on shelf life of meat was determined using goat limbs from freshly slaughtered goats bought from butcheries in Nairobi County. The limbs had stayed for 6h. after slaughter The limbs were each wrapped in polythene bag and transported in cool boxes at 5^0 C to the laboratory within an hour.

Labeling and determination of physico-chemical parameters of meat samples

Each limb was weighed using a balance (Mettler pm 4600, Deltarange, Zurich), weights recorded (initial weight of the meat samples), and then labeled according to the test treatments i.e. Extract, Acetic acid, Sodium hypochlorite and nothing added (negative control). The pH of each limb was determined by making an incision

on the meat with a sterile scapel and inserting a litmus paper. The color change was marched with the pH meter and recorded. Temperature of the room was determined by a thermometer placed in a beaker with water in the controlled demonstration room. The color, texture and smell of the meat were all evaluated subjectively. Red and white color of meat was considered normal whereas brown, dark and green colors were considered contaminated. Smooth and soft texture by hand feel was considered normal, whereas hard and dry feel was considered not normal. No off odors was considered normal. Off odor including odors of the treatments was considered not normal.

Determination of total microbial load on meat surface

The initial total bacterial load was determined by swabbing an area of 100cm^2 marked using templates. Swabbing was done 3 times, vertically, horizontally and diagonally by use of sterile swabs which were then put in 10ml of pre-prepared buffered peptone water in culture tubes. The culture tubes with 10ml peptone water and swabs were vibrated by vortexing to release microorganisms from the swabs into water. This was followed by serial dilutions up to 10^8. Inoculation was done on sterile plate count agar (PCA) using pour plate method. Plates were then incubated at 37°C for 48h and bacterial counts recorded.

Decontamination of goat limbs

Three goat limbs were then decontaminated separately by wrapping each of them in an aluminium foil containing either 90 ml of garlic extract, 90 ml of 1% sodium hypochlorite, 90 ml of 3% acetic acid and nothing was added on the other one (negative control). Wrapping was preferred because the meat parts were quite large and the amount of extract was not much enough for dipping, In wrapping all parts of the meat parts came in to contact with the extract, The limbs were thereafter hanged on a hook in a sterile room for 1hour. Most antibiotic are effective between 30min and 1h. Meat samples were kept at room temperature of 24^0 C, The Initial meat sample Ph was 7.5 in all cases. There after they were unwrapped and then swabbed to determine the bacterial load as described above. Swabbing of each of the goat limbs was repeated 24 h, 48h, 72h and 96h and the bacterial load determined as described.

Sensory evaluation of treated meat

Sensory evaluation of meat treated with garlic extract, acetic acid, sodium hypochlorite and the one added nothing was done to ascertain the consumer acceptability of the treated meat. The treated limb with garlic extract was cooked after 96h and thereafter small portions were cut aseptically and served to a group of 50 untrained panelists picked randomly at College of Agriculture and Veterinary Sciences (CAVS). They were supposed to give their opinion on taste and smell of meat by indicating either bad or good. The panelists comprised of lecturers, students and support staff.

RESULTS

Effect of treatment on bacterial load on meat surface

Treatment with Crude garlic ethyl acetate extract

The total bacterial load in meat treated with crude garlic extract reduced from $\log_{10}$ 6.85 to 3.35 microbial load within the first 1 h, then to 3.15 after 24 h. After 48h, 72h and 96h the microbial load increased to $\log_{10}$ 3.38, 4.03 and 6.35 microbial load respectively (Figure 1 and Table1 and 3). Garlic extract was significantly more effective in controlling microorganisms than others, with a mean of $\log_{10}$ 4.0150 ±2.12 and p= 0.016 (Table 1). The total bacterial load on meat treated with acetic acid reduced from $\log_{10}$ 6.26 to 3.79 microbial load within the first 1h (Table 4). However, the load increased to $\log_{10}$ 6.93, 9.39 and 15.99 microbial load after 48h, 72h and 96h respectively. Molds had developed by the 72h (Figure 1 and Tables 2 and 4). The bacterial load in meat treated with sodium hypochlorite reduced from $\log_{10}$ 6.45 to 4.25 microbial load within the first 1h. Thereafter bacterial load increased drastically to $\log_{10}$ 10.21, 15.12, 18.57 and 24.46 microbial load after 24h, 48, 72 and 96h respectively (Figure 1 and Tables 2 and 5). Microbial load in meat with distilled water behaved differently in that it increased from $\log_{10}$ 6.45 to 4.25 microbial loads within the first 1h. The bacterial load increased to $\log_{10}$ 15.39, 2015, 27.96 and 28 microbial load after 24h, 48h, 72h and 96h respectively. The meat was already dark in color and molds had developed by 24h (Figure 1 and Table 2 and 6). Garlic extract and acetic acid were significantly more effective in controlling microorganisms compared to distilled water p=.03 0.17 respectively (Table 2).

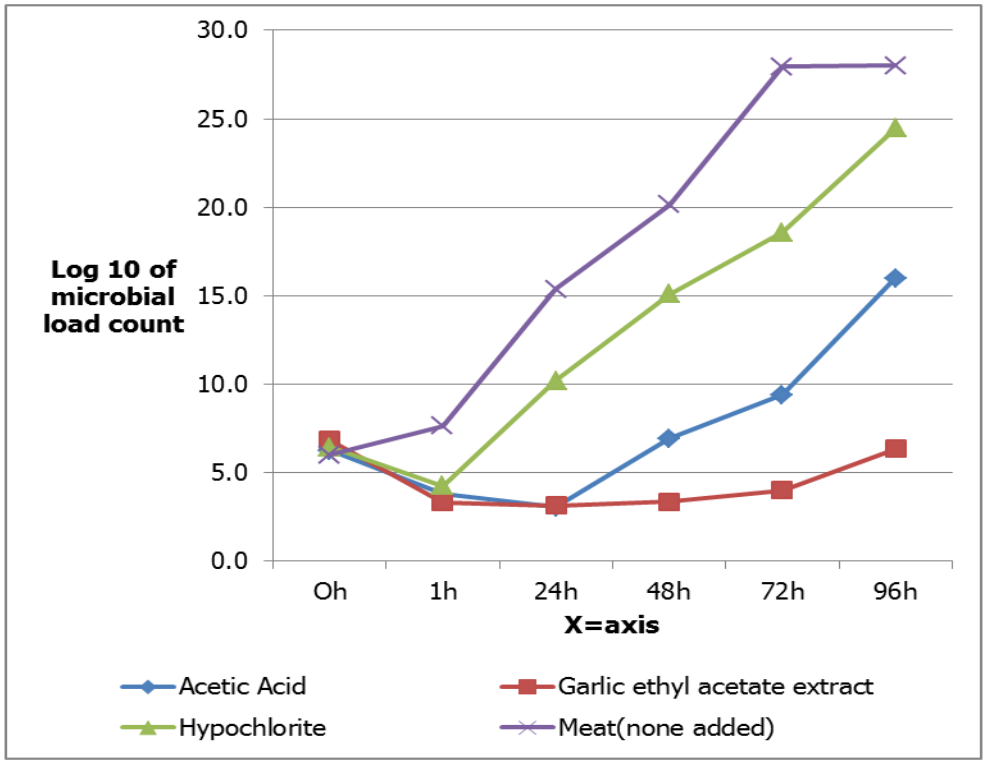

Figure 1: Effectiveness of, Crude garlic ethyl acetate extract, Acetic acid and Sodium hypochlorite on shelf life of meat.

Table 1: Ranked table of the effects of the Test treatments on the microorganisms

Test treatments	Means	Ranked (most effective)
Crude garlic ethyl acetate extract	4.0150 ±2.12	1
Acetic acid	7.5723±4.71	2
Sodium hypochlorite	13.3189±7.83	3
Distilled water	19.6508±12.99	4

p < 0.05

Table 2: Multiple Comparisons of treatments

Treatment	Mean Difference	Std. Error	Sig.	
				.451
	Sodium hypochlorite	-9.30395	4.62612	.058
	Distilled water	-15.63579*	4.62612	**.003**
	Garlic ethyl acetate extract	3.55736	4.62612	.451
Acetic acid	Sodium hypochrorite	-5.74659	4.62612	.229
	Distilled water	-12.07844*	4.62612	**.017**
	Garlic ethyl acetate extract	9.30395	4.62612	.058
Sodium hypochrorite	Acetic acid	5.74659	4.62612	.229
	Distilled water	-6.33185	4.62612	.186
	Garlic ethyl acetate extract	15.63579*	4.62612	**.003**
Distilled water	Acetic acid	12.07844*	4.62612	.017
	Sodium hypochrorite	6.33185	4.62612	.186

Table 3: Changes observed on the various parameters on meat treated with Crude garlic ethyl acetate extract.

Parameters observed	Time in hours					
	0h	**1h**	**24h**	**48h**	**72h**	**96h**
Weight of meat sample	2.09 kg	2.19 kg	2.01 kg	1.95 kg	1.89 kg	1.88
Bacterial load in Log_{10}	6.85	3.35	3.15	3.38	4.03	6.35
pH	7.5	5.5	5.5	5.5	5.5	5.5
Room Temperature	24^0C	24^0C	23^0C	24^0C	24^0C	24^0C
Meat color	Red/ white	Red/ white	Red/ white	Red/ mild brown/ white	Red/brown/ white	Red/brown/ white
Texture	Smooth/soft	Smooth/soft	smooth	Dry	Dry	Dry
Odor	Normal	Garlic Odor	Garlic odor	Faint garlic odor	Faint garlic odor	Normal

Table 4: Changes observed on the various parameters on meat treated with Acetic acid.

Parameters observed	Time in hours					
	0h	**1h**	**24h**	**48h**	**72h**	**96h**
Weight of meat sample	2.16 kg	2.23 kg	2.06 kg	1.98 kg	1.91 kg	1..90
Bacterial load in Log_{10}	6.26	3.79	3.06	6.93	9.39	15.99
pH	7.5	5.0	5.5	5.5	5.5	5.5
Room Temperature	24^0C	24^0C	23^0C	24^0C	24^0C	24^0C
Meat color	Red/ white	Red/ white	Red/ white	Red/brown/ white	Red/brown/ white	Red/brown/ white
Texture	Smooth/soft	Smooth/soft	Smooth	Dry	Dry/molds	Dry/molds
Odor	Normal	Normal	Normal	Normal	Normal	Smelly

Table 5: Changes observed on the various parameters on meat treated with Sodium hypochlorite

Parameters observed	Time in hours					
	0h	**1h**	**24h**	**48h**	**72h**	**96h**
Weight of meat sample	1.29 kg	1.34 kg	1.09 kg	0.98 kg	1.04 kg	1.01 kg
Bacterial load in Log_{10}	6.45	4.25	10.21	15.12	18.57	24.46
pH	7.5	5.0	5.5	5.5	5.5	5.5
Room Temperature	24^0C	24^0C	23^0C	24^0C	24^0C	24^0C
Meat color	Red/ white	Red/ white	Red/ white	Red/ white	Red/ white	Dark/white
Texture	Smooth/soft	Smooth/soft	smooth	Dry	Dry/molds	Dry/molds
Odor	Normal	Normal	Normal	Normal	Normal	Odor

Table 6: Changes observed on the various parameters on meat not treated with distilled water

Parameters observed	Time in hours					
	0h	**1h**	**24h**	**48h**	**72h**	**96h**
Weight of meat sample	1.79 kg	1.86 kg	1.69 kg	1.63 kg	1.60 kg	1.56 kg
Bacterial load in log_{10}	6.02	7.64	15.39	20.15	27.96	28.00
pH	7.5	5.0	5.5	5.5	5.5	5.5
Room Temperature	24^0C	24^0C	23^0C	24^0C	24^0C	24^0C
Meat color	Red/ white	Red/ white	Red/ white	Dark/Red/ white	Green/Red/ white	Dark
Texture	Smooth/soft	Smooth/soft	smooth	Dry	Dry/molds	Dry/molds
Odor	Normal	Normal	Normal	Normal	Odor	Odor

Sensory evaluation of meat

After 50 untrained panelists tasted meat 40/50 (80%) accepted the meat with garlic blend flavor, 7/50 (14%) recommended for the reduction of the garlic flavor and 3/50 (6%) lecturers did not accept the flavor claiming that they do not like it. All students and support staff accepted the flavor

DISCUSSION

The shelf life represents the useful storage time of food product. Beyond this period, changes in smell, color, taste, texture or appearance make the product unpalatable or unfit for human consumption because of the growth of spoilage microorganisms (Singh and Singh, 2005). There are various factors that influence the shelf life of meat such as temperature, pH, oxygen, pressure and light. Oxidation of beef to metmyoglobin is essentially affected by myoglobin oxidation rate, oxygen availability and reducing capacity of the muscle (Brooks, 2007). The activity of spoilage microorganisms reduces the shelf life of meat. The rate of spoilage and signs of spoilage depend on the number of microorganisms involved and storage temperature (Bacon *et al.* 2000; Koohmaraie *et al.* 2005).

In this study, shelf life of meat was determined by treating meat samples with the test treatments and hung them in a clean and disinfected environment with 70% ethanol. Meat hung improves flavor and tenderness of meats by allowing the natural enzymes in the meat to break down the tissue through dry aging aging (Riches and Derrick, 2011). The process also allows the water in the meat to evaporate, thus concentrating the flavor. It also allows processes to continue in the meat that would normally cease in dead animals. For example, the muscles in the meat continue to use the oxygen that is in the proteins of the blood. This normal biological process creates a chemical by-product known as lactic acid which breaks down the muscle and connective tissues around it, making the meat to taste better (Riches and Derrick, 2011). However, the meat shrinks and changes color from red to brown, green and dark indicating spoilage. This was the case with meat treated with sodium hypochlorite, acetic acid and distilled water (Tables 2, 3 and 4).

A low microbial load of log 6.35 was noted in meat treated with crude garlic ethyl acetate extract even after 96h. The meat was therefore still good for consumption after 96 hrs. Heijden *et al*., (1999) stated that the meat size with not more than1 × 10^5 cfu (Log 5) of microorganisms per one gram, or a surface area of $1cm^2$, was considered fit for human consumption. For an area of 100 cm^2**,** which was swabbed requires not more than 1×10^7 cfu Colony forming units (log 7) to be considered as unfit for human consumption. The microbial load was lower for garlic treated meat compared to acetic acid and sodium hypochlorite treated meat indicating powerful antimicrobial effect of garlic extract. Total bacterial load for meat treated with acetic acid was log 6.93 microbial load (beyond the recommended value) after only 48h. Sodium hypochlorite treated meat had log 15.12 microbial load after 48 h, while for untreated meat the counts had surpassed 10^5 mark after 1h. Garlic extract contains both sulphur and non sulfur containing compounds such as diallyl disulfide, 6-(methylthio) hexa-1,5-dien-3-ol, trisulfide,di-2-propenyl, 2-vinyl- (4H)-1,3- dithiin, tetrasulfide,di-2-propenyl, hexadecanoic acid, 2,3-dihydroxypropyl ester, oleic acid, 5-cyno-7-methyl-6-(methylthio) benzo (c) carbazole and

abietic acid which work synergistically against a range of bacteria, fungi and viruses viruses (Avato *et al*., 2000; Seong soo *et al*., 2010; Arunkumar and Muthuselvam 2009). The role of the above compounds in warding off infection may be particularly valuable in light of the growing bacterial resistance to antibiotics. It is unlikely that bacteria would develop resistance to garlic extract because this would require modifying the very enzymes that make their activity possible possible (Tsao *et al*., 2003).

The shelf life of meat treated with Acetic acid was found to be at 48h. Organic acids act by undissociated acid penetrating the cell of microorganisms. After acetic acid penetrates the cell wall it dissociates and acidifies interior of the cell. This pH changes in the cellular environment interferes with cellular metabolism or decreases the biological activity (Cherrington, *et al.,* 1991). The dissociation of the acid renders the meat products ineffective. Sodium hypochlorite was ineffective in controlling microbial growth on the meat surface. This probably could be as a result of the low pH (5.5) of meat. Sodium hypochlorite is a good broad-range disinfectant that is only effective at a neutral to moderate pH of 6-9, and has a diminished effect at lower pH and in the presence of organic material (Armcanz, 2000). A high total viable microbial count in the negative control indicates severe contamination during slaughter and transport which shortens the shelf-life of meat samples even in ideal conditions (Table 6). This indicates unhygienic of meat with possibility of contamination with meat-poisoning bacteria.

Aerobic spoilage by bacteria results in undesirable odors and flavors (Table 4, 5and 6) represent results after 48h, 72h and 96h for meat samples treated with acetic acid, sodium hypochlorite and none treated meat. Color changes and rancidity occur from the breakdown of lipids. Color changes as a result of pigment oxidation may be grey, brown or green discoloration. Aerobic spoilage by molds results in black or green discoloration (Anower *et al*., 2004). The growth of spoilage organisms renders the product organoleptically undesirable but not necessarily unsafe. The color change from the bright, cherry-red color of beef to another color, such as brown, is caused by a change in the protein myoglobin (Brooks, 2007). Myoglobin is the color pigment in muscle and is responsible for binding oxygen (Brooks, 2007).

Consumer acceptability can be affected by factors that are not microbiological. They include: meat color and appearance; rancidity caused by chemical oxidation of fats, changes in texture caused by extended enzyme activity or product drying during storage. Browning of meat due to oxidation of the meat pigment myoglobin occurs in meat with pH of 5.5 and lower, (Tables 2, 3, 4 and 5). Meat with low pH seems to be more susceptible to color deterioration (Steele, 2004). Meat treated with garlic extract had a color change from red/white to red/brown/white at 72h. The one treated with acetic acid became red/brown/white at 48h. This could have resulted due to the acids in reagents. Meat treated with sodium hypochlorite did not change to brown. The color change is however not harmful and does not denote spoilage (Tsao *et al.,* 2003).

The initial pH of all meat samples before treatment was 7.5 and after 1h of treatment, the pH dropped to 5 - 5.5 (Tables 3, 4, 5 and 6). During the first day after slaughter of an animal, glycolysis continues in meat until the accumulation of lactic acid causes the pH to reach about 5.5. The remaining glycogen, about 18 g per kg, is believed to increase the water-holding capacity and tenderness of the flesh when cooked (Lawrie and Ledward, 2006).

The range of temperature at the controlled room was 23°C -24°C. This temperature allows meat spoilage bacteria to multiply rapidly and especially on the untreated meat (Table 6) resulting to putrefaction of proteins and rancidity of fats (Lawrie and Ledward, 2006). This leads to unpleasant smell and taste making meat unfit for human consumption.

Molds developed on meat samples treated with Aceti acid, Sodium hypochlorite and negative control (Tables 4, 5 and 6) but not in garlic treated meat (Table 3). Molds for example *Penicillium, Aspergillus, Mucor* are sometimes found on the surface of meat products after prolonged storage. Growth of molds on meat can result to spoilage of the affected meat parts and production of mycotoxins which are released into the meat which when consumed precipitate carcinogenic effects on consumers (Acuff, 2006).

CONCLUSIONS

Garlic ethyl acetate extract was significantly more effective in prolonging shelf life of meat up to 96h p= 0.016. 80% of the test panelists accepted the flavor of the meat treated garlic ethyl acetate extract; however 20% of the test panelists were not comfortable with the flavor of meat after cooking.

RECOMMENDATIONS

- Further work should be done to optimize garlic extract for consumer acceptability.
- Further work should be done to formulate garlic extract for use as a commercial preservative/decontaminant of meat.

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