Microbial Analysis of Woven Cotton Kitchen Towels

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Abstract

Kitchen towels are exposed to infestation by microbes during their use in multiple applications which include wiping dishes and utensils, drying hands and wiping spills from surfaces. These microbes can contaminate food meant for consumption. The purpose of this study was to determine the presence, degree and nature of microbes hazardous to health, that are contaminating kitchen towels. Nine cotton woven towels were distributed to nine households for use in their normal ways. Microbes were then extracted from towels daily through swabbing, before and after washing the used towels. The swabs were then analysed. Households were also given a questionnaire to indicate the daily application of the towel. A Standard Pour Plate Method with an advantage of counting colony forming units of live microbes only was adopted. Results showed that microbial levels increased with days of usage, from the order of 10^3cfu/ml to 10^5cfu/ml between second and ninth days, before laundering. Dangerous microbes such as *Staphylococcus aureus, Pseudomonas aeruginosa and Eschericha ecoli* were identified. Laundering could not remove all microbes from the towel. Only the laboratory chemical disinfection removed 100% microbes. It was concluded that washing and disinfecting towels through ultraviolet light was the best possible solution as disinfection chemical could remain on towels and passed on to the food.

Key words: contamination, kitchen towels, laundering, microbes

1. INTRODUCTION

Kitchen towels have a variety of uses in Zimbabwe that include wiping dishes and utensils, drying hands and wiping spills from surfaces. Their uses cause them to be damp and sometimes dirty creating a breeding environment for microbes. The microbes are most likely to leak to the food meant for immediate consumption. Kitchen towels are known as potential agents in the spread of microorganisms(Anna and Ashley, 2009). Whenever a kitchen towel is used on the skin, cells slough off the skin and stick to the towel and these cells serve as food for microbes(Scott and Bloomfield, 1990).

Microbes thrive in moist and warm environments where kitchen towels are usually used and stored. During the use, there can be a propagation of undesirable microorganisms through cross contamination during food processing and storage, which can result in an outbreak of food poisoning. The kitchen towels can provide a perfect breeding environment for microbes as they are usually used to absorb fluids from surfaces, plates, utensils or hands, and are not immediately washed.

Microorganisms are invisible to the naked eye and include bacteria, fungi, mildew, mould and yeast and are found in nature(Brian, 1998). Studies carried out at the University of Westminster have constantly shown that reusable kitchen cloths such as dishcloths, non-woven cloths, sponge cloths, rapidly become colonised with various types of microbes(Blomfield et al., 2011).. Infectious microorganisms that have the potential to spread via household textiles such as kitchen towels are :

a) *Eschericha ecoli:* which is rod-shaped with flagella or hair-like projections on its surface to enable it to move. This bacteria causes gastroenteritis which is an inflammation of the stomach and intestines resulting in

vomitingand diarrhoea (ArchChemicals, 2012).

b) *Salmonella typhimurium:* which is also rod-shaped with flagella. This bacteria can cause the inflammation of caecum and gut, and may cause typhoid fever and vomiting(Spicer, 1959).
c) *Staphylococcus aureus:* which has a twisted rod shape. The bacteria can cause boils and localised swollen areas of tissue. It can also enter the blood stream causing fever and malaise(Spicer, 1959).
d) *Bacillus aureus:* which is also a rod like shape with a nuclear matter, cell membrane and wall, a capsule and a flagellum. It causes diarrhoea and vomiting(Spicer, 1959).
e) *Compylobacter*: which has a twisted rod shape and can infect the gastrointestinal tract and caused diarrhoea, fever and cramps(Liam and Hudson, 2004,).

Most kitchen towels in Zimbabwe are made from cotton. Textile materials from natural fibres such as cotton and wool are susceptible to microorganisms as the microbes find these fibres palatable. Microbes thrive in warm and humid environments full of oxygen, under optimum conditions of 25-37^{o}C and a PH between 5-9(Liam and Hudson, 2004), the environments where most kitchen towels are found. To prevent the growth of microorganisms on towels, antimicrobial finishes can be used. However studies have shown that antimicrobial finishes have poor durability as disinfectants during laundry remove them from the towel(CDC, 2013). The long term use of antimicrobial finishes may lead to deadly consequences to human(Martha, 1987).

In Zimbabwe kitchen towels and dish cloths are used in almost every household, which means that most of the population in the country could be exposed to microorganisms that could be dangerous to health. There was therefore a need to conduct a study to assess the possibility of exposure to microorganisms.

1.1. Aim

The aim was to determine the presence, degree and nature of microbial contamination on kitchen towels that could be hazardous to health.

1.2. Objectives

The objectives were to

i) Determine the presence of microbes on kitchen towels
ii) Determine the nature of microbes that commonly contaminates kitchen towels
iii) To verify the effectiveness of laundering of kitchen towels

2. MATERIALS AND METHODS

Kitchen towels used for experiments were purchased from a local shop. Nine households were used for experiments.

2.1. Experimentation

Ten identical towels were purchased for experimentation and one was used to determine the fibre composition and, method of manufacture of the towel. Natural fibres encourage growth; a compact structure encourages quick distribution of the microbes on the fabric surface. For instance woven structures tend to be more compact than knitted structures hence propagation of microbes is faster on woven structures than knitted structures.

The same towel was also used for a pre-usage microbial assessment. Nine towels were distributed to nine households in Bulawayo, for use in their usual way. After each day of use, microbes were extracted from the towel by swabbing after which the towels were laundered, sun dried and swabbed again. All swabs were then taken for microbial analysis. House owners were also given questionnaires to record the day to day application and maintenance of the towel.

2.1.1. Fabric analysis

To determine the nature of the fibre a burning test and a solubility test were conducted(Appleyard, 1976). For the

solubility test, three 5cm by 5cm towel pieces were cut and placed in three different alkaline or acidic environments(Kimberly and Species, 2003).. One piece was deposited into an alkaline environment of 10% sodium hydroxide at room temperature; another was placed in 10% sodium hydroxide at 40^{o}C; the final piece was deposited into an acid environment of 70% sulphuric acid at 40^{o}C[13]. The behaviour of each of the three samples in the three solutions was observed.

2.1.2. Preparation for microbial detection and enumeration experiments

To assess the presence and degree of microbial contamination on kitchen towels, the Standard pour plate method(Thomas, 1979) was employed. This method has an advantage over other methods such as microscopy and spectrophotometry, because only live colony

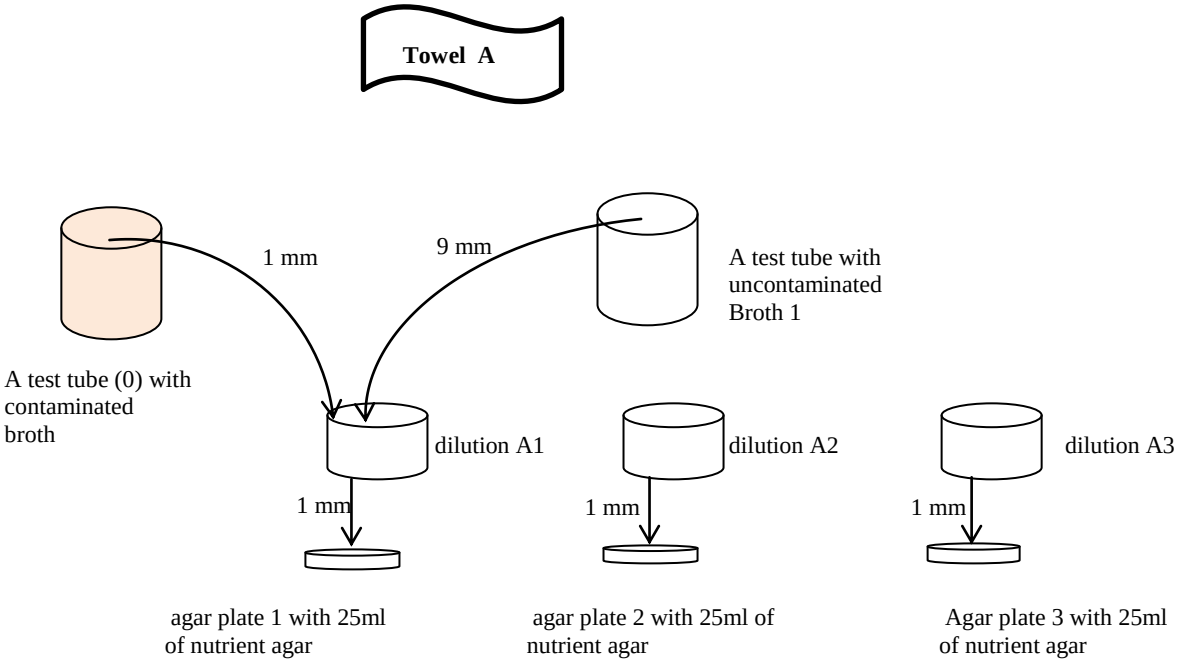

Figure 1: Daily experimental procedure per towel

forming units (CFUs) are counted hence bacteria injured and killed during laundering is not counted(Thomas, 1979) . Non selective nutrient agar was used as a complex enriched medium for general bacterial isolation because most common species and even some fastidious forms, will grow on this medium(Diffen, 2013). To provide nutrients and energy required for microbial growth a chicken broth was prepared by boiling chicken pieces for 10 minutes. To ensure that it remains fresh during experiments the broth was frozen in small separate quantities and only the amount required for a day was used for the day. The required broth for the day was placed in an autoclave to thaw at 37^{o}C(Diffen, 2013)

Nine towels for nine different households were labelled **A**; **B**; **C**; **D**; **E**; **F**; **G**;**H** and **I** (Figure 1) For each label, a corresponding test a tube was prepared with chicken broth. These were labelled *broth solution 1 for towel **A,** broth solution 2 for towel **B** up to broth solution 9 for towel **I.*** Three dilutions per broth solution were prepared, as well as three agar plates, labelled; agar 1, to agar 3 matching each dilution. These were prepared for later use to determine the presence of microbial growth (Figure 1).

2.1.3. Microbial extraction

To extract microbes from the kitchen towels and transfer them into the test tubes containing the chicken broth, the swabbing method was employed(Thomas, 1979)]. A contaminated broth (test tube (0), was created for each towel. To create the contaminated broth a sterile swab was dipped into the tube with saline solution and

the swab wringed to remove excess saline. Saline has a neutral P^H hence it does not denature microbes or injure them. The swab was then rubbed against the towel surface to contaminate it. The contaminated swab then dipped into test tube (0) with chicken broth and shaken to mix the microbes with the broth. Each towel had its own contaminated broth test tube (0) making it the tenth tube per towel (Figure 1). This experimental preparation was repeated on a daily basis (Figure 1).

For each of the 9 uncontaminated broth solution **(A-I),** three test tubes labelled dilution A1; dilution **A2**, and dilution **A3**, for towel **A**, dilution **B1**, dilution **B2** and dilution **B3** for towel **B**, up to dilution **I1, I2** and **I3** for towel **I** were prepared. Nine millilitres of uncontaminated chicken broth and one millilitre of contaminated broth were deposited into each of the dilution test tubes, **A1** to **I3**. Each test tube was well shaken to mix the solutions. This resulted in three microbial culture solutions for each towel.

2.1.4 Standard Plate counting

A nutrient agar was melted in a conical flask and placed in an autoclave for 30 minutes to sterilise it, after which it was left to cool to 37^{o}C(Diffen, 2013). One millilitre of microbial culture solution from each dilution test tube was transferred to the corresponding agar plates, and 25ml of the melted nutrient agar was also added to the same agar plates and the solution mixed. The agar plates were then incubated at 37^o C for 24 hours(Diffen, 2013). Plates that had well spread microbial colonies were selected for analysis. The selected plates had the microbial colonies manually counted using a felt-tip pen to mark each colony so as to prevent counting the same colony twice. The estimated number of microbes on the kitchen towel surface tested was then computed using the following formula(Diffen, 2013).

- *Amount plated being countable plates containing between 30 and 300 colonies*
- *Dilution factor being final volume/sample volume which for this study is calculated:*

$$\textit{CFUs/ml} = \frac{\textit{Number of colonies on the plate X Amount plated}}{\textit{Dilution factor}}$$

$$= \frac{1}{10} \times \frac{1}{10} \times \frac{1}{10} = \frac{1}{1000}$$

(total dilution for three agar plates)

$$= \frac{1}{\frac{1}{1000}} = 1000$$

The computed number of colony forming units per millilitre was taken as the degree of microbial contamination of the kitchen towels.

2.1.5 Home Laundering of the Kitchen Towels.

Comparison of efficacy of laboratory laundering with home laundering was conducted during the tenth day (last day of conducting experiments). Before the tenth day, the nine households were monitored to ensure that the towels were laundered on a daily basis. The households recorded the type of soap used (powdered or bar). Before their use the following day, the towels were checked for the presence of microbes that could have remained after laundering. On the tenth day, all towels were swabbed and then cut into half before laundering. One half was laundered by households while the other was laundered in the laboratory where a powdered soap and bleach were used. The results of laundering the towels by households and at the laboratory were compared.

2.1.6 Nature of microbial contamination of the kitchen towels

Isolated cells were determined whether they were Gram-positive or Gram-negative. Gram positive cells take up the violet stain used in the Gram staining method. This distinguishes them from the other large group of bacteria, the gram-negative bacteria, which cannot retain the crystal violet stain. Instead the Gram negative take up the counterstain (safranin or fuchsine) and appear red or pink. Gram-positive bacteria are able to retain the crystal violet stain due to their thick peptidoglycan layer in the cell wall that encases their cell membrane, whereas, in gram-negative bacteria, this peptidoglycan layer is much thinner and is located between two cell membranes(Button, 2013). The cell morphology of the isolated

microbes were analysed using an optical microscope.

2.1.6.1 Gram stain reaction

Colonies different in shapes, colour and sizes were enumerated from the plates and transferred to prepared glass slide. Each colony was put on its own slide'(NemoursFoundation, 2013). The prepared slides were carefully placed into a beaker with crystal violet and allowed to stand for 1 minute. Free staining was removed by placing the slide in a beaker of water for 2-3 seconds(NemoursFoundation, 2013). The slides were then placed into a beaker with Gram's iodine and allowed to stand for 1 minute. The iodine served as a mordant, to increase the affinity of the cell to crystal violet. Iodine forms large complexes with crystal violet and these complexes combine with the peptidoglycan in the cell wall(NemoursFoundation, 2013).

Using a wash bottle, the slides were flooded with 95% ethanol and then shaken for about 5 seconds to allow the ethanol to contact all the cells on the slide(NemoursFoundation, 2013). Ethanol served to dissolve the lipids in the outer membrane of the Gram negative cell wall causing the crystal violet-iodine complex to leave these cells. However if the cells were in contact with the ethanol for more than 10 seconds, Gram-positive organisms would have appeared to be Gram-negative(NemoursFoundation, 2013). The slides were dipped in a beaker of water for 2 seconds to remove any excess iodine, then placed in a beaker with Safranin, and allowed to stand for 1 minute. Safranin served as a counter stain, it stains the Gram-negative cells that lost the stain during the ethanol wash. Free stains were then removed by dipping the slides in a beaker with water for 2 seconds, and allowing them to dry in air in preparation for cell morphology analysis using an optical microscope(NemoursFoundation, 2013).

2.1.7 Cell morphology analysis

After air-drying, morphology analysis of the Gram stained slides was conducted. Two drops of immersion oil were added on the slide at the spot where the light from the condenser was to be focused. The immersion oil was added to obtain clear images of the cells. The cells on the Gram stained slides were then focused with the magnification of 10 and then of 40(NemoursFoundation, 2013). The obtained micrographs and Gram stain reactions of each of the cells were examined and compared with those of known microbial species.

3 RESULTS AND DISCUSSION

3.1 Application areas of kitchen towels and their laundering

Nine households were used for study and they all used the kitchen towels in different ways (Figure 2). It was noted that some of the applications of kitchen towels overlapped.

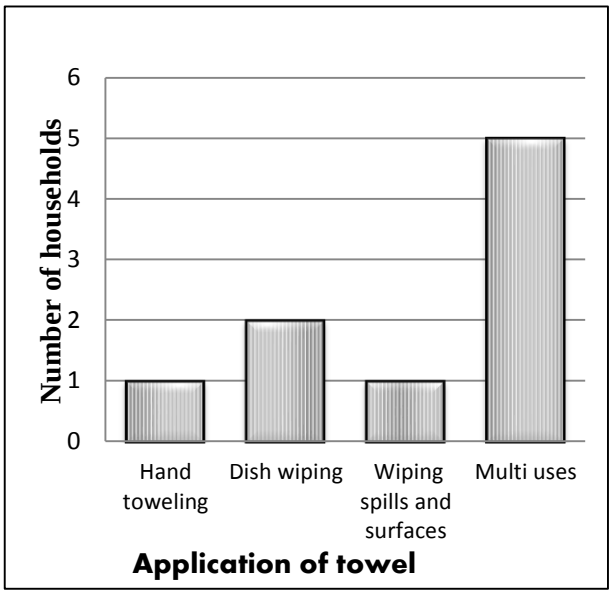

Figure 2: Application areas of kitchen towels

Figure 2shows that one towel was used for drying hands before and after meals. Another one was used for whipping spills on surfaces. These spills included fluids such as water, tea, juices or any other fluid that may have been deposited on top or inside kitchen cupboards or stoves. Two of the towels were used for wiping dishes while five of the kitchen towels were used for multi purposes which included among those already mentioned, cleaning fridges, wiping stoves and as filter material for fluids. The households were not instructed on how they should use the towels as they were expected to use them in any way they desired usually as they use their own on a daily basis. The

results could reflect how kitchen towels are generally used in different households in a daily basis. Six of the nine households used powdered soap for washing the towels, while three used bar soaps. The towels were washed daily after use All households hand washed their towels and sun dried them.

3.2 Microbial contamination of kitchen towels

3.2.1. Pre usage microbial levels

The results showed that brand new towels picked from the shelves tested positive for microbes. An average of 73 colony forming units per millilitre (**CFUs/ml**) were present on unused towels when 1ml of the bacteria culture solution was plated using nutrient agar. The main source of microbes on new kitchen towels could have been human skin of merchandisers or customers during the shopping activities. Contamination during experimentation was minimal because sterile surgical gloves were used to handle the towels while conducting experiments. Human skin harbours approximately 1 x 10^5 colony forming units per cm^2 of *Staphylococcus aureus(Spicer, 1959)*. The presence of microbes on the towels indicated that kitchen towels either did not contain antimicrobial finishes or were treated with antimicrobial finishes that could not eliminate all microbes. However antimicrobial finishes can actually be damaging to health as their overuse can create a drug-resistant microbes that will not respond to any prescription available because the microbes such as bacteria mutate to create "super germs"(Ministry of Health, 1997).

3.2.2. Microbial levels during usage

The results (Figure 3) show that the level of microbial contamination increases with time of usage. During the first two days of kitchen towel usage, microbial levels were found to be in the order of 10^3cfu/ml before home laundering. Between the third day and the sixth day the microbial level increased to the order of 10^4cfu/ml. From the seventh day to the tenth day the microbial level before home laundering was found to be in the order of 10^5cfu/ml.

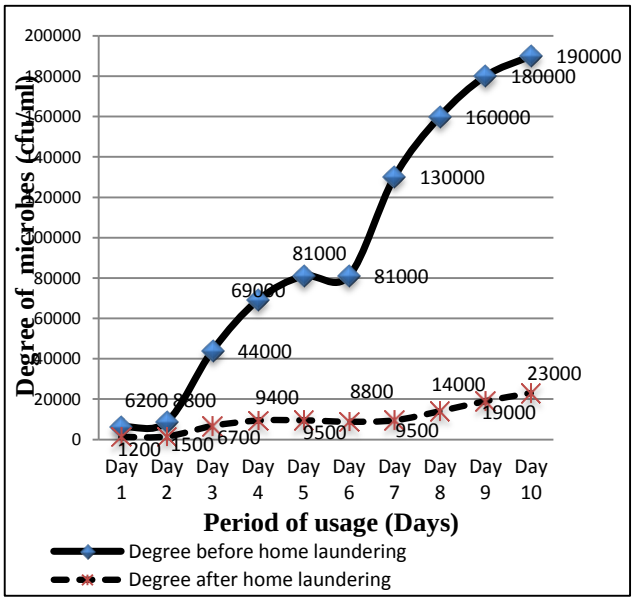

Figure 3: Contamination of kitchen towel by day, before and after home laundering.

It was observed that the degree of microbial contamination after home laundering during days 8, 9 and 10 were 14000cfu/ml, 19000cfu/ml and 23000cfu/ml respectively. According to the regulations governing the microbial standards for food stuffs and related matters such as drinking water(Rutala and Weber, 1997), the suggested bacteria counts that could have a possibility of food poisoning are as shown in Table 1.

Table 1. Microbe counts suggestive food poisoning: a product has become unsafe [18].

Case	The total colony count of organisms tested by the pour-plate method.
Cooked sea-water and freshwater foods.	Total colony count of organisms shall not exceed 100 000 per gram
Cooked poultry	Total colony count of organisms shall not exceeds 10 000 per gram
Edible ice	Total colony count of organisms shall not exceed 50 000 per millilitre.
Natural mineral water or bottled water	Shall not exceed 100 per millilitre.

Taking the values in Table 1 into account, home disinfection of kitchen towels (washing), as from day 8 could not keep the

microbial level below the required standards, especially, of cooked poultry and water, which most households consume on a daily basis, hence there was a high possibility of contamination of the food exposed to the towels, making the food unsafe for consumption(Table 1).

When microbial levels were in the order of 10^5cfu/ml, from the seventh to the tenth day (Figure 3), the microbes generated detectable odours on kitchen towels before home laundering, however, the odours were eliminated by home laundering. The odours were probably due to increased waste metabolites from microbial activities. The ability of the towels to shelter bacteria increased with time of their usage even though they were washed daily. This could have been due to increased moisture conditions and more food molecules accumulating between threads, which made the kitchen towels conducive environments for microbial growth. Dust could have accumulated between threads during sun drying in an open environment, as was the case with all households. Drying in warm and humid open environments accelerate microbial growth as indicated by Rodger et al (1979). Although literature has indicated that microbes can be destroyed by the sun's ultraviolet (UV) rays, the requirement will be that the environment in which the towel is dried, is enclosed(Liam and Hudson, 2004,).

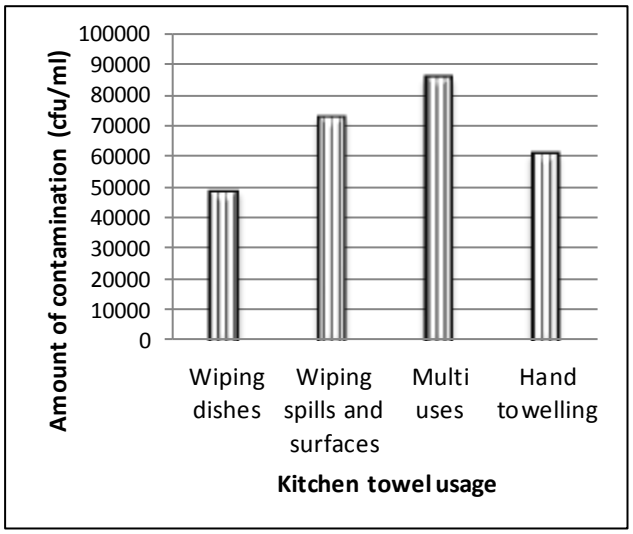

Figure 4: Effect of kitchen towel usage on the amount of microbial contamination

Figure4 shows that the towels for multipurpose use had the highest degree of contamination. The least source of microbial contamination was the towel used to dry kitchen dishes since the dishes had been washed hence some microbes had already been removed from the dishes during washing.

3.2.4. Efficacy of home laundering.

The average disinfection efficacy of home laundering was found to be 87.4%. The disinfection efficacy was calculated as a percentage of the microbial population removed through home laundering of the towels.

Disinfection efficacy = 100% (Number of microbes before laundering - Number of microbes after laundering) / (Number of microbes before laundering)

This formula was employed based on the assumption that the reduction in microbial population is due to home laundering only. Laundry efficacy of home laundering varied depending on the number of days the towels had been used (Figure 5). None of the washed towels exhibited 100% removal of microbes. This reflects that both the powdered and bar soaps (commonly used in Zimbabwe) were not effective enough to remove microbes in kitchen towels.

3.2.3. Effect of kitchen towel usage on the degree of bacterial contamination

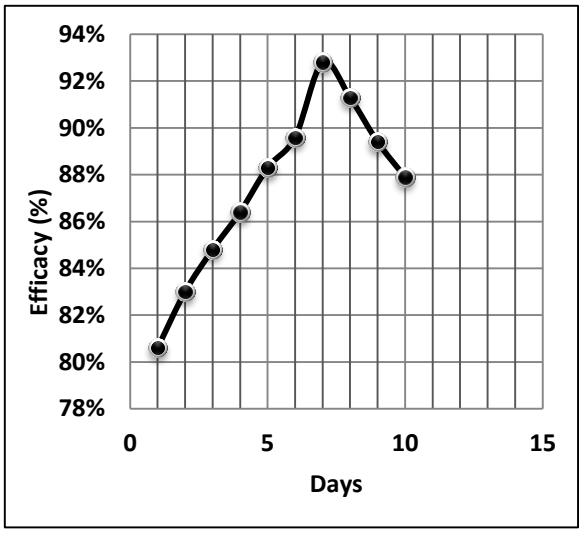

Figure 5: Average home laundering efficacy.

As the microbial levels increased on kitchen towels from day one to the seventh day, the disinfection efficacy also increased, that is, the towels washed easily and microbes easily removed. However it was noted that the disinfection efficacy decreased by day 8 of kitchen towel usage as the microbial population increased to the order of 10^5cfu/ml, becoming more difficult to remove a more sizable number of the microbes that could increase risk of contamination. After 8 or more days of usage there was an increase in food molecules and dust accumulation that penetrated the fibres as repeated laundering (which in this case could be after 7 days of daily washing) was likely to untwist the yarn in the woven structure of the towels, creating spaces between fibres where microbes could hide causing them to spread.

An average degree of 5.2 x 10^3 colony forming units per millilitre were found to persist on towels laundered using powdered soaps while 4.4x 10^3 colony forming units per millilitre were found to persist on towels laundered using bar soaps. This shows that the bar soaps have a better disinfection efficacy than powdered soaps. This may be due to the rubbing process as the soap is being applied to the kitchen towel during laundering. As the soap is being rubbed on to the fabric some microbes are killed and injured thereby reducing microbial levels as compared to powder soaps.

3.2.5 Efficacy of laboratory laundering

The average degree of microbial contamination on all the 9 kitchen towels before laundering on the 10th day was found to be 1.8 x 10^5cfu/ml (Figure 3). Laboratory laundering involved soaking the towel pieces in chlorine based bleach (3.5% Sodium hypochlorite) at 60°C for 15 minutes(Spencer1 et al., 2007). Sodium hypochlorite has a wide range of antimicrobial activity. Generally, viruses and vegetative bacteria are more susceptible to hypochlorite(Spencer et al., 2007). Sodium hypochlorite was found to have a 100% disinfecting efficacy. Figure 6 shows a comparison between the efficacy of home based laundering and laboratory laundering. The bar soap removed 85.3% of the microbes while the powdered soap removed 77.4% of the microbes

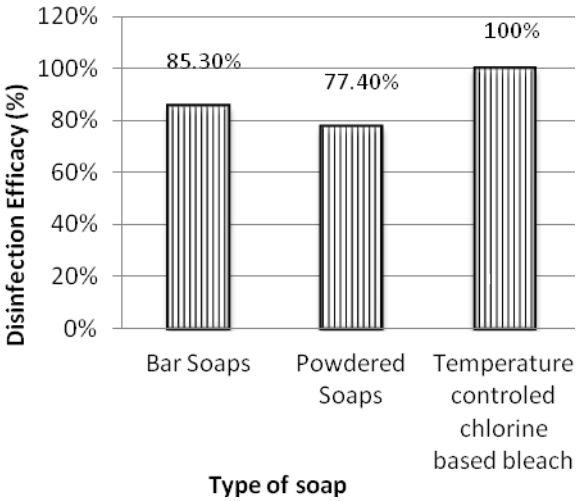

Figure 6: Comparison between home and laboratory laundering.

When microbes are not completely removed, they will quickly multiply as soon as the towel is used again.

Although using sodium hypochlorite eliminated all the microbes on all towels, the hypochlorite (or any other bleaching chemical) could remain on the towel which could be hazardous to health(Moyo and Baudi, 2004). Although it has been used for the disinfection of drinking water or water systems, there has been some controversy on its use due to the formation of small quantities of harmful by products such as chloroform(Moyo and Baudi, 2004). Use of bleaching agents such as sodium hypochlorite on textile materials could also

lead to their disintegration.

3.2.6 Nature of microbes contaminating kitchen towels

Table 2. Nature of microbes' contamination on kitchen towels

Colony Morphology (from agar plates)		Gram reaction (+/-)	Cell Morphology	Probable species
Colour of colony	**Elevation of colony**			
White	Convex	+	Coccus	Staphylococcus
Cream	Flat	-	Rod	Escherichia
Green	Umbonate	-	Rod	Pseudomonas

The Gram stain tests were conducted in order to determine the nature of microbes found on kitchen towels. Gram stain reaction Table 2 shows that kitchen towels were colonised by species which were suspected to be:

a) Staphylococcus aureus

The *Staphylococcus aureus* cells are characterised by white colonies with flat when cultured in non selective nutrient agar. These appeared purple on the optical microscope when observed after the Gram stain reaction.

Figure 7 shows that the cells isolated from kitchen towels were *Staphylococcus aureus* since a purple stain was observed after the grain stain reaction which means they were Gram positive [14]. The round shape of cells

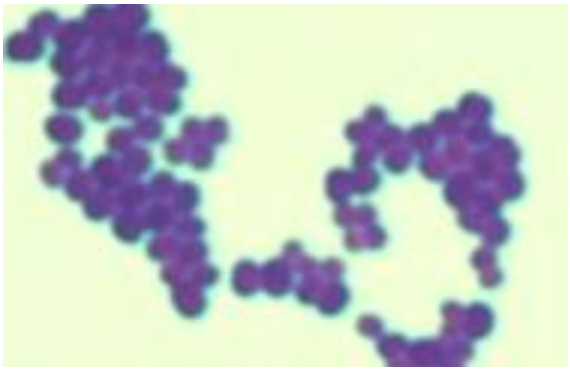

Figure 7: Micrograph showing staphylococcuc aureus cells after Gram stain reaction.

is another indication that they are likely to be *Staphylococcus aureus* cells (Kimberly, 2003). The presence of *Staphylococcus aureus* on kitchen towels means that kitchen towels can be sources of food poisoning since *Staphylococcus aureus* is pathogenic. This bacterial species causes boils and localized swollen areas of tissue. It can also lead to blood stream invasion, fever and general malaise(Chakwana and Nkiwane, 2014). According to the regulations governing the microbial standards for food and drinking water, no coagulate-positive *Staphylococcus aureus* shall be present in 20 grams of partly cooked or uncooked sea-water and freshwater foods such as prawns, shrimps, crayfish, lobsters, crab meat, oysters, mussels, clams or fish. Its presence in food indicates that the food has become unsafe for consumption(Ministry of Health, 1997)**.**

The fact that this bacteria was found on kitchen towels, means that kitchen towels are suitable vehicles for staphylococcal food poisoning since their degree of bacterial contamination particularly in the second week was found to be in the odour of 10^5 before home laundering and 10^4 after home laundering.

b) Pseudomonas aeruginosa

The Pseudomonas cells cultured in non selective nutrient agar appeared pink on the optical microscope when observed after the Gram stain reaction.

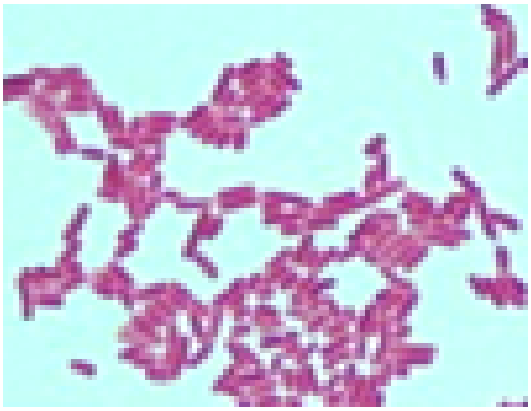

Figure 8: Micrograph showing Pseudomonas cells after Gram stain reaction.

Figure 8 indicates the cells are Pseudomonas cells since *Pseudomonas aeruginosa* is a Gram-negative, rod-shaped, asporogenous, and monoflagellated bacterium(Kimberly, 2003)**.** The cells isolated from kitchen towels were Gram negative since they could not retain the purple colour of crystal violet and were counter stained and turned pink. The micrograph in Figure 8 also shows that the cells were rod shaped which suggest that they are likely to be *Pseudomonas aeruginosa* cells(Kimberly, 2003).

The presence of Pseudomonas aeruginosa on kitchen towels shows that kitchen towels can be vehicles for the transmission of disease(Kimberly, 2003). Pseudomonas aeruginosa is an opportunistic pathogen which causes toe mob infection characterized by thick white scaling areas between toes(Kimberly, 2003). It also causes Green nail syndrome which is the greenish coloration of nail plates (Kimberly, 2003).

Pseudomonas aeruginosa is an opportunistic human pathogen. It is "opportunistic" because it seldom infects healthy individuals. It is pathogenic if it enters the body via wounds, abscesses and burns(Blomfield et al., 2011). The kitchen towel users with wounds such as minor cuts are therefore susceptible to toe mob infection and green syndrome since *Pseudomonas aeruginosa* cells were found in kitchen towels. The towel users are vulnerable when they come in contact with the bacteria during hand drying before or after a meal or even during laundering.

Eschierichia coli

The cells characterised as *Eschierichia coli* cells formed cream colonies with flat elevation when cultured in non selective nutrient agar. These apeared pink on the optical microscope when obsrved after the Gram stain reaction.

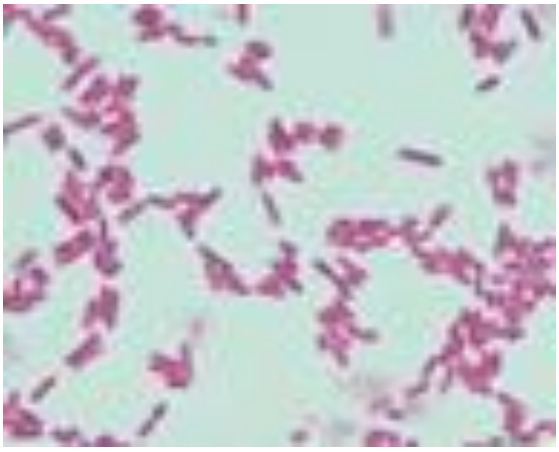

Figure 9 Micrograph showing Escherichia coli cells after Gram stain reaction.

The pink staining (Figure 9) indicates that *Eschierichia coli* (E coli) cells found on kitchen towels were Gram negative since the Gram stain is a differential stain which divides bacteria into two groups: Gram-positive and Gram-negative. Figure 8 also shows that the cell were rod shaped which suggest that they are likely to be *Escherichia coli* cells (Kimberly, 2003).

The presence of Eschierichia coli on kitchen towels means that kitchen towels can be sources of food poisoning since *Escherichia coli* is pathogenic. This bacterial species causes gastroenteritis which is an inflammation of the stomach and intestines and causing vomiting and diarrhoea(Chakwana and Nkiwane, 2014). Members of *Eschierichia coli* are almost universal inhabitants of the intestinal tract of humans and they may play a nutritional role in the intestinal tract by synthesising vitamins, particularly K(Moyo and Baudi,

2004). Though *Escherichia coli* species are rarely pathogenic they have shown some implications in diarrhoea in infants and urinary tracts in older people(Moyo and Baudi, 2004).

According to the regulations governing the microbial standards for food stuffs and related matters such as drinking water, *E coli* cells above 500 colony forming units per 100grams in the case of partly cooked or uncooked sea-water and freshwater foods such as prawns, shrimps, crayfish, lobsters, crab meat, oysters, mussels, clams or fish indicate that a product has become unsafe for use(Rutala and Weber, 1997)**.**

This shows that kitchen towels are suitable vehicles for E coli food poisoning since their degree of bacterial contamination particularly in the second week was found to be in the order of 10^5 before home laundering and 10^4 after home laundering.

Other microbes

Some of the microbes on the kitchen towels could not be characterized since they were not stained after the Gram stain reaction. Figure 10 shows a micrograph of some microbes which could not be characterized using the staining method

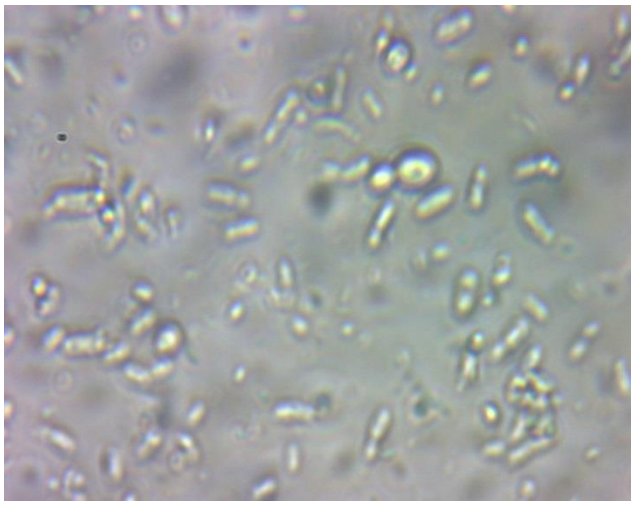

Figure 10 Microbes which could not be characterized.

Though the microbes were not characterized it can be seen that there were rod shaped and coccus cells. The presence of these species implies that there were more microbial species than those identified.

CONCLUSION

Kitchen towels could be hazardous to health if they are not laundered on a daily basis as they could harbour different types of microbes. There is need to have a towel for each specific purpose as evidenced by the results that showed that kitchen towels used for multipurpose were the most contaminated. Laboratory laundering could be a solution for households in order to continually remove microbes on kitchen towels. Disinfecting towels every other day with bleaching agents such as sodium hypochlorite, and rinsing them thoroughly over and over again would reduce the risk of poisoning due to chemicals and at the same time prevent the towels from becoming shelter to pathogenic microorganisms. Bleaching towels however would lead to their quick disintegration and the need to purchase new ones frequently. Households preferred using this method of laundering even though it led to the frequent purchasing of towels, as compared to home laundering which did not eliminate microbes completely. Using kitchen towels manufactured from synthetic microfibres could be another solution to reduce food poising because, microfibres have been engineered to possess properties such as good liquid absorption and wicking, easy wash-ability and quick drying, properties desired in kitchen towels(Chakwana and Nkiwane, 2014). Being synthetic microfibres, are not palatable to microbes and therefore do not provide a breeding environment for pathogenic microbes

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