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Interaction of Gums and Antimicrobial Agents on Susceptibility of Selected Foodborne Pathogens

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Abstract

The objective of this study was to determine the combined effect of locust bean, xanthan, agar, carrageenan-maltodextrin and pectin gums on the growth, bacterial survival, and susceptibility of foodborne pathogens. The combine effect five different gums and antimicrobial agents (Tetracycline, Doripenem, Imipenem, Cefixime, Cipropoxacin, Ceftazidime, Kanamycin and Meropenem) on susceptibility of foodborne pathogens was tested using disc diffusion method. Amongst gums tested, treatment with carrageenan-maltodextrin (52.00 ± 2.00 mm) and pectin (51.00 ± 1.00 mm) resulted in a two-fold increased in susceptibility of *Salmonella enterica* to imipenem 10 µg, compared to the control (25.33 ± 1.00 mm). Treatment with locust bean and agar gums also led to a two-fold increase in susceptibility of *Salmonella enterica* to cefixime and xanthan also increased susceptibility *Escherichia coli* O157:H7 to doripenem. Addition of gums led to a slight increase or decrease on bacterial growth in treatment compared to control. Bacterial survival decreased in the presence of all gums during refrigerated storage with pectin producing a log 2.68 ± 0.10 CFUml^{-1} reduction. Tested gums could potentially be used in combination with antimicrobial medicines to improve their efficacy in the treatment of *Salmonella enterica*, *Staphylococcus aureus*, *Listeria monocytogenes* and *Escherichia coli* O157:H7 infections. Our findings could potentially lead to synergistic use of gums and antimicrobial agents to enhance the treatment and reduce recovery period of foodborne infections leading to less dependence on antimicrobial medicines and subsequently promoting health.

Introduction

Foodborne pathogens still remain one of the major causes of illness and fatalities in the world. In the United States food safety is still a problem as food contamination by pathogens, which are harmful to humans, has been estimated to lead to about 3000 fatally and 128,000 cases of hospitalization each year [1]. Enterohemorrhagic *Escherichia coli* O157:H7, *Listeria monocytogenes* and *Salmonella enterica* are the top three pathogens responsible for foodborne illnesses and deaths [2,3].

In addition to causing food safety issues, pathogens also target farm animals causing diseases and deaths. In some cases livestock such as cattle serve as major reservoirs for pathogens specifically *Escherichia coli* O157:H7 resulting in contaminated meat, fruit and vegetables for human consumption [3]. Antimicrobial agents are used in animals to treat diseases, to safeguard the health and safety of farm animals, and to promote growth and feed efficiency [4]. Continuous and indiscriminate uses of such antimicrobial agents often cause passage of antimicrobial medicines to humans through the food chain resulting in issues of antibiotic resistance.

Infections from foodborne pathogens are often treated with prescribed antimicrobial agents. Whereas some bacteria may be inherently resistant to different types of antimicrobial agents long-term exposure of such antimicrobial medicines to both humans and animals has resulted in increasing antimicrobial resistance in humans who depend on live stocks as sources of food [5]. Frequent use of antimicrobial agents for the treatment of infection generally result in declining levels of microflora in human gastrointestinal tract, causing the growth of pathogenic bacteria to reach high numbers [3].

Lactic acid, specifically, Lactobacillus, also known as probiotic are normal residents of the human gastrointestinal tract have been used for fermentation in the food industry with a high recognition for their beneficial therapeutic health effects [6-8]. To reduce the overdependence on antimicrobial agents, certain polysaccharides have gained attention as therapeutic products that can replace [9] or combine with antimicrobial agents to improve improve gut health. Yamashita et al. [9] have studied the bacteriostatic effects of dietary polysaccharides on the growth of eight different pathogenic bacteria including *Salmonella enterica, Staphylococcus aureus, Listeria monocytogenes* and *Escherichia coli* O157:H7 and have found that pectin and carrageenan have antimicrobial properties. Recent studies by Daoud et al. [10] have also shown that pectin exerted antibacterial effect against *Helicobacter pylori* that causes gastritis and peptic ulcers [10].

Polysaccharides, specifically gums are hydrophilic agents obtained from plants (both land and seaweeds), animals, and microbial fermentation that comprise many hydroxyl groups, high molecular weight, and highly branched structure [11,12]. Gums are used either singly or in combination with proteins, lipids or other gums in various food products to enhance viscosity, mouth feel, texture and as a preservative [13]. Gums have also been used in other industries, namely pharmaceutical, cosmetic, paint, inks, paper, color, and

adhesive industries [14]. Gums have also served as growth and viability enhancers of certain probiotic *Lactobacillus* strains [12,15-18].

Although many studies reported the impact of gums on the growth of probiotics [12,17,18] the combined effect of these gums on the growth, fatality and antibiotic susceptibility of pathogens, have not been studied. Therefore the aim of this study is to investigate the effect of gums on the growth of pathogenic microorganisms. Additionally, we analyzed the synergistic impact of gums and antimicrobial agents on susceptibility and resistance of selected pathogenic microorganisms.

Materials and Methods

Culture activation

Stock culture of *Escherichia coli* O157:H7 (ATCC 700927), *Salmonella enterica* (ATCC 4345111), *Listeria monocytogenes* (ATCC 19116), and *Staphylococcus aureus* (ATTC 49775) strains were previously purchased from ATCC and store at -80°C in the Microbiology laboratory at the Center for Excellence in Post Harvest Technologies (Kannapolis, NC, USA). Bacterial cultures were activated in tryptic soy broth (TSB, BBL, Sparks, MD, USA) and incubated at 37°C for 16 h in a shaker. Activated culture was streaked plated on tryptic soy agar (TSA, BBL, Sparks, MD, USA) and incubated at 37°C for 24 h to obtain pure colonies which were then used immediately for growth study.

Treatment preparation with different gums

Five gums including carrageenan-maltodextrin (CM), pectin (PE), locust bean gum (LB), xanthan (XA), and agar (AG) (TIC GUMS Inc., Maryland, GA) were each gradually dissolved into the 200 ml batches of TSB at 0.5% (w/v), pasteurized at 110°C for 15 min and cooled to 50°C before use. Sterile TSB without gum served as a negative control [17,18].

Determination of bacterial growth

Growth study was conducted according to the method by Karlton-Senaye et al. [17,18] with a slight modification. Bacterial inoculum was prepared by serial dilution in 0.1% peptone water (BBL, Sparks, MD, USA). Aliquots (1 ml) from appropriate serial dilutions were aseptically added to each 200 ml batch of TSB (BBL, Sparks, MD, USA). Batches of sterilized TSB containing 0.5% of different gums were inoculated with 0.05 % of inoculum at a final inoculum level of 3 log CFUml^{-1} and initial counts were determined. Samples without gum served as the control. Inoculated samples were spiral plated on TSA, and incubated at 37°C for 16 h to determine initial bacterial counts. Inoculated samples were then incubated at 37°C for 16 h, serially diluted and aliquots were spiral plated on TSA, incubated at 37°C for 24 h. Bacterial enumeration was carried out using a color QCount® Colony Counter (Advanced Instruments Inc., MA, USA) to determined the final bacterial population [17,18].

Determination of bacterial population during refrigerated storage (4°C)

After the final bacterial population were determined, the inoculated samples containing 0.5% of different gums were refrigerated at 4°C to determine bacterial survival under refrigerated condition in the presence of the different gums. Refrigerated samples were spiral plated on TSA bi-weekly for 45 days and then incubated at 37°C for 24 h to determine the final bacterial population using a color QCount® Colony Counter (Advanced Instruments Inc., MA, USA).

Determination of synergism and antimicrobial activity

Each bacterial strain was treated with 0.5% gums according to Karlton-Senaye et al. [17] as previously described and tested by agar disk diffusion method on Mueller Hinton II Agar (MHA, BBL, Sparks, MD, USA) according to the methods by Clinical and Laboratory Standards Institute for susceptibility to the following antimicrobial agents [19]: tetracycline (TET) 30 μg; doripenem (DOR) 10 μg; imipenem (IMP) 10 μg; cefixime (CFM) 5 μg; cipropoxacin (CIP) 5 μg; ceftazidime (CAZ) 30 μg; kanamycin (KAN) 30 μg; and meropenem (MEM) 10 μg (BBL, Sparks, MD, USA. Standard antibiotic disks (BBL, Sparks, MD, USA) containing the following recommended minimum inhibitory concentrations of each antimicrobial agents were placed in duplicates in appropriate intervals on MHA in duplicates: tetracycline (TET) 30 μg; doripenem (DOR) 10 μg; imipenem (IMP) 10 μg; cefixime (CFM) 5 μg; cipropoxacin (CIP) 5 μg; ceftazidime (CAZ) 30 μg; kanamycin (KAN) 30 μg; and meropenem (MEM) 10 μg (BBL, Sparks, MD, USA). Susceptibility of the foodborne pathogens to the antibiotic agents and sterile water were also tested as negative control and positive control, respectively. Zones of inhibition were measured in millimeters and their average determined. The experiments were performed in duplicates and replicated three times.

Data analysis

Each experiment was conducted multiple times in a randomized block design. The mean and standard deviation values were calculated from duplicate tested samples from three replicates.

Results

Results of the growth study of *Escherichia coli* O157:H7 (ATCC 700927), *Salmonella enterica* (ATCC 4345111), *Listeria monocytogenes* (ATCC 19116), and *Staphylococcus aureus* (ATTC 49775) in the presence of 0.5% gums during 16 h incubation at 37°C are shown in Figure 1. Compared to the control (8.36 ± 0.11 log CFUml^{-1}), treatment with the different gums resulted in a slight decrease in the growth of *Salmonella enterica* with locust bean affecting the least growth of *Salmonella enterica* (8.22 ± 0.06 log CFUml^{-1}). Similar to *Salmonella enterica*, the population of *Escherichia coli* O157:H7, *Listeria monocytogenes* and *Staphylococcus aureus* decreased slightly with treatment with xanthan, locust bean, and pectin carrageenan-maltodextrin, showing little effect of gums on bacterial population (Figure 1). However, the addition of carrageenan-maltodextrin (8.55 ± 0.16 log CFUml^{-1}) and locust bean (8.54 ± 0.17 log CFUml^{-1}) caused a slight increase in the population of *Listeria monocytogenes*. No differences were observed in the population of *Listeria monocytogenes* in the presence of agar and pectin at 8.49 ± 0.10 log CFUml^{-1}.

During refrigerated storage, bacterial population decreased in the presence of all gums with pectin yielding the most pronounced reduction at 2.68 ± 0.10 log CFUml^{-1} (Table 1). However, bacterial population remained relatively stable in the control throughout the storage period (Table 1).
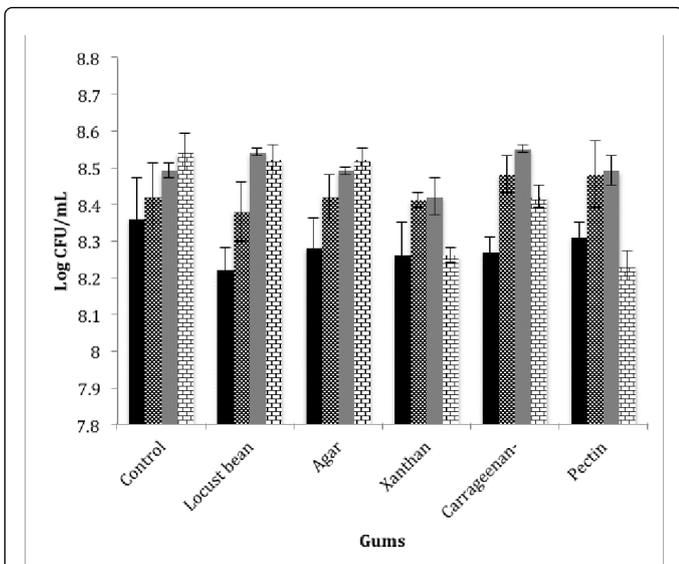
Figure 1: The growth of foodborne pathogens in tryptic soy broth containing different gums (0.5%) incubated at 37°C for 16 h. Mean ± SD of three independent measurements. Keys: Salmonella enterica (Bar 1), Escherichia coli O157:H7 (Bar 2), *Listeria monocytogenes* (Bar 3) and, *Staphylococcus aureus* (Bar 4) (Bars from left to right represent the strains of foodborne pathogens tested)

Gums	Bacterial population (log CFUml^{-1})
Day 1	
Control	8.39 ± 0.10
Locust bean	8.25 ± 0.04
Agar	8.31 ± 0.04
Xanthan	8.30 ± 0.05
Carrageenan-maltodextrin	8.33 ± 0.06
Pectin	8.32 ± 0.03
Day 15	
Control	8.39 ± 0.05
Locust bean	8.51 ± 0.03
Agar	8.45 ± 0.09
Xanthan	8.34 ± 0.05
Carrageenan-maltodextrin	8.53 ± 0.06
Pectin	7.75 ± 0.06
Day 30	
Control	8.38 ± 0.02
Locust bean	8.44 ± 0.04
Agar	8.32 ± 0.04
Xanthan	8.39 ± 0.08
Carrageenan-maltodextrin	8.51 ± 0.07
Pectin	7.50 ± 0.03
Day 45	
Control	8.38 ± 0.08
Locust bean	8.26 ± 0.06
Agar	8.09 ± 0.07
Xanthan	8.27 ± 0.06
Carrageenan-maltodextrin	8.30 ± 0.02
Pectin	5.64 ± 0.03
Mean ± SD of three independent antimicrobial testing	

Table 1: Effect of gums on survival of Salmonella enterica during refrigerated storage at 4°C for 45 d.

Effect of gums on antimicrobial susceptibility of *Salmonella enterica* is presented in Table 2. The results showed that the effects of antimicrobial agents were enhanced against the pathogens that were treated with gums compared to the control that were not treated with gums. Treatment with carrageenan-maltodextrin improved the susceptibility of *Salmonella enterica* against the eight antimicrobial agents tested (Table 2).

Gums/Antimicrobial agents	Zone of inhibition (mm)			
	TET	**DOR**	**IMP**	**CFM**
Control	23.33 ± 0.58	30.33 ± 0.58	25.33 ± 1.15	14.67 ± 0.58
Locust bean	25.33 ± 1.53	31.00 ± 1.00	28.67 ± 1.53	31.33 ± 2.31
Agar	32.33 ± 2.52	42.33 ± 1.73	42.33 ± 0.58	30.67 ± 0.58
Xanthan	25.00 ± 1.73	30.33 ± 2.08	28.33 ± 1.53	29.00 ± 1.73
Carrageenan-maltodextrin	36.00 ± 1.00	44.33 ± 2.15	52.00 ± 2.00	28.00 ± 1.73
Pectin	37.33 ± 2.31	50.33 ± 3.51	51.00 ± 1.00	28.00 ± 0.58

H$_2$O (negative control)	0.00	0.00	0.00	0.00
	CIP	**CAZ**	**KAN**	**MEM**
Control	32.67 ± 1.53	24.33 ± 1.15	23.67 ± 1.15	31.00 ± 1.73
Locust bean	33.33 ± 3.21	28.33 ± 1.53	24.67 ± 1.15	35.00 ± 3.00
Agar	39.67 ± 1.53	29.33 ± 0.58	27.00 ± 3.61	40.33 ± 0.58
Xanthan	35.67 ± 1.15	28.33 ± 1.15	27.00 ± 3.46	32.33 ± 2.08
Carrageenan-maltodextrin	34.00 ± 2.00	31.67 ± 1.15	29.33 ± 3.21	40.67 ± 3.06
Pectin	36.00 ± 1.00	28.67 ± 1.15	26.67 ± 2.31	44.33 ± 2.08
H2O (negative control)	0.00	0.00	0.00	0.00
Key: Tetracycline (TET-30 µg); Doripenem (DOR-10 µg); Imipenem (IMP-10 µg); Cefixime (CFM-5 µg); Cipropoxacin (CIP-5 µg); Ceftazidime (CAZ-30 µg); Kanamycin (KAN-30 µg); and Meropenem (MEM-10 µg). Means ± SD of three independent antimicrobial testing				

Table 2: Effect of gums on antimicrobial agents on susceptibility of *Salmonella enterica* (ATCC 4345111) incubated at 37°C for 16 h.

Treatment wtih carrageenan-maltodextrin and pectin in combination imipenem (52.00 ± 2.00 mm) against *Salmonella enterica* resulted in a two-fold increase in zone of inhibition compared to the control (25.33 ± 1.15 mm) with carrageenan-maltodextrin affecting the largest zone size (Figure 2). Treatment of *Salmonella enterica* with locust bean and agar gums also led to a two fold increased the efficacy of cefixime at 31.33 ± 2.31 mm and 30.67 ± 0.58 mm, respectively, compared to their control (Table 2). Treatment with pectin-doripenem (50.33 ± 3.51 mm) and carrageenan-maltodextrin-doripenem (44.33 ± 2.15 mm) also increased the zone of inhibition by 1.7 and 1.5 fold, respectively, over the control (30.33 ± 0.58 mm) (Table 2).

Figure 2: Comparing the synergistic effect of carrageenan-imipenem-10 µg (A) and pectin-imipenem-10 µg (B) on susceptibility of *Salmonella enterica* to the control (C) without gum.

Table 3 shows the effect of gums on susceptibility of *Escherichia coli* O157:H7 to different antimicrobial agents. Similarly, with the exception of kanamycin and meropenem, the susceptibility of *Escherichia coli* O157:H7 to tetracycline, doripenem, imipenem, cefixime, cipropoxacin, and ceftazime was slightly enhanced with the treatment with gums. Treatment of *Escherichia coli* O157:H7 with xanthan was found to cause the most increase in the zone of inhibition by doripenem (33.67 ± 0.58 mm) and cipropoxacin (37.67 ± 0.58 mm) against *Escherichia coli* O157:H7 compared to their control at 24.67 ± 0.58 mm and 33.33 ± 1.15 mm, respectively. There was no difference in susceptibility of *Escherichia coli* O157:H7 between the treatments and control with the use of kanamycin (30 µg) and meropenem (10 µg) in control and treatments (Table 3).
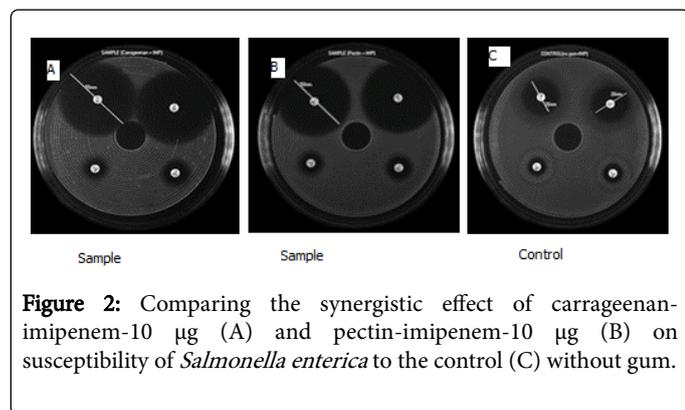
Both *Staphylococcus aureus* (Table 4) and *Listeria monocytogenes* (Data not shown) were found to be resistance to tetracycline, cefixime, cipropoxacin and kanamycin and susceptible to doripenem, imipenem, and meropenem showing little or no difference between the control and treatments. Susceptibility of both *Staphylococcus aureus* and *Listeria monocytogenes* to imipenem, doripenem and kanamycin displayed 1 mm to 5 mm increase in the zone of inhibition amongst treated samples compared to their respective control. Again, the zone of inhibition was found to be highest in samples treated with carrageenan-maltodextrin and pectin with the use of imipenem (24.67±0.58 mm) and doripenem (24.67 ± 0.58 mm) showing most susceptibility effect on *Staphylococcus aureus* to these antimicrobial agents.

Gums/Antimicrobial agents	Zone of inhibition (mm)			
	TET	**DOR**	**IMP**	**CFM**
Control (positive control)	24.67 ± 0.58	24.67 ± 0.58	27.67 ± 1.15	27.33 ± 0.58
Locust bean	25.67 ± 0.58	30.33 ± 1.15	31.00 ± 1.00	30.33 ± 1.15
Agar	25.67 ± 0.58	31.67 ± 1.53	29.67 ± 0.58	28.67 ± 1.15
Xanthan	26.00 ± 1.00	33.67 ± 0.58	28.67 ± 0.58	30.33 ± 0.58

Carrageenan-maltodextrin	26.00 ± 1.00	31.33 ± 1.53	30.33 ± 1.53	29.67 ± 1.15
Pectin H₂O (negative control)	26.00 ± 1.00 0.00	31.67 ± 0.58 0.00	30.33 ± 0.58 0.00	31.00 ± 1.73 0.00
	CIP	**CAZ**	**KAN**	**MEM**
Control (positive control)	33.33 ± 1.15	27.67 ± 0.58	27.33 ± 1.15	35.33 ± 0.58
Locust bean	36.33 ± 1.15	30.33 ± 0.58	27.33 ± 1.15	35.33 ± 0.58
Agar	35.33 ± 0.58	30.33 ± 0.58	27.33 ± 1.15	35.33 ± 0.58
Xanthan	37.67 ± 0.58	31.33 ± 1.53	27.33 ± 1.15	35.33 ± 0.58
Carrageenan-maltodextrin	36.33 ± 1.15	31.33 ± 1.53	27.33 ± 1.15	35.33 ± 0.58
Pectin H2O (negative control)	37.00 ± 1.00 0.00	31.67 ± 1.15 0.00	27.33 ± 1.15 0.00	35.33 ± 0.58 0.00

Key: Tetracycline (TET-30 µg); Doripenem (DOR-10 µg); Imipenem (IMP-10 µg); Cefixime (CFM-5 µg); Cipropoxacin (CIP-5 µg); Ceftazidime (CAZ-30 µg); Kanamycin (KAN-30 µg); and Meropenem (MEM-10 µg). Means ± SD of three independent antimicrobial testing

Table 3: Effect of gums and antibacterial agents on susceptibility of *Escherichia coli* O157:H7 (ATCC 700927) incubated at 37°C for 16 h.

Gums/Antimicrobial agents	Zone of inhibition (mm)							
	TET	**DOR**	**IMP**	**CFM**	**CIP**	**CAZ**	**KAN**	**MEM**
Control (positive control)	R	19.67 ± 0.58	18.33 ± 0.58	R	R	R	R	19.33 ± 0.58
Locust bean	R	21.00 ± 0.58	22.33 ± 2.52	R	R	R	R	21.33 ± 1.15
Agar	R	23.00 ± 0.58	22.33 ± 2.08	R	R	R	R	22.00 ± 1.00
Xanthan	R	22.00 ± 1.00	22.00 ± 2.00	R	R	R	R	22.67 ± 0.58
Carrageenan-maltodextirn	R	21.67 ± 0.58	24.67 ± 0.58	R	R	R	R	21.33 ± 0.58
Pectin H₂O (negative control)	R 0.00	24.67 ± 0.58 0.00	22.33 ± 1.53 0.00	R 0.00	R 0.00	R 0.00	R 0.00	21.33 ± 0.58 0.00

Key: Tetracycline (TET-30 µg); Doripenem (DOR-10 µg); Imipenem (IMP-10 µg); Cefixime (CFM-5 µg); Cipropoxacin (CIP-5 µg); Ceftazidime (CAZ-30 µg); Kanamycin (KAN-30 µg); and Meropenem (MEM-10 µg). Means ± SD of three independent antimicrobial testing

Table 4: Effect of gums and antibacterial agents on susceptibility of *Staphylococcus aureus* (ATCC 49775) during incubated at 37°C for 16 h.

Discussion

In this study we evaluated the effect of gums on the growth of four foodborne pathogenic microorganisms, bacterial death or survival during refrigerated storage and to the combine impact between gums and antimicrobial agents on susceptibility or resistance of selected pathogenic microorganisms.

In our growth study, treatment of pathogenic bacteria with gums caused little or no difference in growth promotion or inhibition. A slight decrease in growth inhibition could be caused by reduced bioavailability of nutrients, which, results from trapping of such nutrients in the culture medium by the polysaccharides [9]. In a study conducted by Yamashita et al. [9] treatment with carrageenan induced the most inhibition against *Listeria monocytogenes*. In our study, however, treatment with carrageenan-maltodextrin caused a slight increase of *Listeria monocytogenes* and *Escherichia coli* O157:H7. A slight increase in the growth of *Escherichia coli* O157:H7 and *Listeria monocytogenes* induced by carrageenan-maltodextrin could be due to

the ability of these bacteria to use carrageenan-maltodextrin as additional source of nutrient. These observations were expected, as pathogenic bacteria are able to metabolize many food products specifically in polysaccharides.

Decrease in bacterial survival during 45 days at 4°C storage period in the presence of all gums with pectin showing the most log reduction at 2.68 ± 0.03 log CFU/ml (Table 1) could be due to excessive acid production and nutrition depletion from the gums, which are long chain polysaccharides and the medium. Increased in the death of the foodborne pathogens during storage indicated that including gums specifically pectin in preservation of food for a period of time could potentially reduce the population of pathogens in the food.

With regards to increased in the susceptibility of foodborne pathogenic bacteria including *Escherichia coli* O157:H7, *Salmonella enterica*, *Listeria monocytogenes*, and *Staphylococcus aureus* to antibiotics with pectin-IMP being the most effective. It is not surprising that pectin affected the most susceptibility of *Salmonella*

enterica. This is because pectin is one of the most digestible and fermentable gums in the gut and could be the most bioavailable gum to the bacteria [19]. The increase in zone of inhibition leading to enhanced susceptibility of *Salmonella enterica* in the presence of all tested gums with the use of all antimicrobial agents was an indication that tested gums are capable of increasing the efficacy of all the antimicrobial agents tested.

Increased efficacy of antimicrobial agents used in combination of all tested gums for the treatment of shiga toxin-producing *Escherichia coli* O157:H7 infections, which is the most significant causative vehicle of hemolytic uremic syndrome leading to chronic kidney failure, will definitely be a milestone in antibiotic treatment therapy. In our study, although xanthan, pectin and carrageenan-maltodextrin were found to promote the growth of *Escherichia coli* O157:H7, it is to interesting to note that these gums also increased the efficacy of tetracycline, doripenem, imipenem, cefixime, cipropoxacin, and ceftazidime, confirming the antimicrobial properties of these gums. A study by Yamashita et al. [9] to determine the bacteriostatic effect of certain polysaccharides against *Escherichia coli, Listeria monocytogenes, Salmonella enteridis* and *Staphylococcus aureus* amongst other foodborne pathogens established the antimicrobial effect of pectin against *Escherichia coli* O157:H7. However, Daoud et al. [10] failed to demonstrate significant antibacterial activity of pectin against *Escherichia coli* O157:H7.

Our study confirms the susceptibility of *Staphylococcus aureus* to doripenem and meropenem at discs concentration of 10 µg that is in line with Clinical and Laboratory Standards Institute [19]. Although *Staphylococcus aureus* was also expected to be susceptible to tetracycline, cipropoxacin and kanamycin at the disk concentration used, our study showed otherwise, which is an indication of increasing resistance of *Staphylococcus aureus* to these antimicrobial agents leading to longer periods of recovery hence the need for alternative antimicrobial agents.

Conclusion

In conclusion, addition of gums exhibited little or no effect on bacterial growth during 16-hour incubation whereas during refrigerated storage treatment with pectin led to a pronounced decrease in the survival of *Salmonella enterica*. The treatment of the selected foodborne pathogens with gums showed enhanced efficacy of the antimicrobial agents against *Salmonella enterica* and *Escherichia coli* O157:H7 with pectin, carrageenanan-maltodextrin xanthan and agar gums producing most effect. Treatment with pectin and carrageenanan-maltodextrin also led to a slight increased in efficacy of some of the antimicrobial agents against *Staphylococcus aureus* and *Listeria monocytogenes*. These findings suggest that carrageenan-maltodextrin, pectin, xanthan, locust bean and agar gums could potentially be used in combination with antimicrobial agents to improve their efficacy in the treatment of foodborne pathogens such *Salmonella enterica, Staphylococcus aureus, Listeria monocytogenes* and *Escherichia coli* O157:H7 infections resulting in early recovery. This finding requires future studies to determine molecular basis behind this phenomenon.

Acknowledgement

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