Recipes for simulated vomitus

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Journal of Infection Prevention

2018, Vol. 19(3) 141–143

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DOI: 10.1177/1757177417741972

jip.sagepub.com

Abstract

We developed and demonstrated the stability of recipes for simulated vomitus for use in experiments characterizing occupational exposures to body fluid during simulated healthcare activities. The recipes can be easily adapted to make other simulated bodily fluids at low costs and surrogates added to facilitate detection.

Keywords

Simulation, infectious diseases, exposure assessment, bodily fluids

Date received: 13 June 2017; accepted: 9 October 2017

Background

Vomiting is a common symptom of acute gastritis and involves the ejection of matter (vomitus) from the stomach through the mouth. When acute gastritis is caused by an infectious disease, such as norovirus, vomitus may contain high concentrations of pathogens (Atmar et al., 2013; Kirby et al., 2016) and pose an infection risk to people who contact the vomitus directly (such as during cleaning) or are nearby (Evans et al., 2002; Marks et al., 2003; Thornley et al., 2011; Zheng et al., 2015).

To understand how healthcare personnel are exposed to pathogens in vomitus during care delivery, we undertook a study of vomitus cleaning by environmental service workers. As part of this process, we developed a recipe for simulated vomitus and tested its stability over time and relative to temperature with the goal of making large batches for use in experiments over several days. Previous investigators have used simulated vomitus for related studies, but none have described the recipe details or stability (Bell et al., 2015; Makison Booth, 2014; Tung-Thompson et al., 2015). The objective of this work is to describe the recipes and their stability to facilitate the work of others.

Methods

Based on the work of Tung-Thompson et al. (2015), we set two target viscosity levels that reflect the viscosity of vomitus: 6.24 mPa*s (gastric fluid) and 177.5 mPa*s (vomitus with undigested matter). Three materials were considered: instant pudding powder (Jell-O, Glenview, IL, USA); gelatine powder (Knox®, Kraft Foods Global, Inc., Northfield, IL, USA); and carboxymethylcellulose (CMC) powder (Tic Gums, WhiteMarsh, MD, USA). Instant pudding

powder and CMC powder were used by Tung-Thompson et al. (2015). Each of these powders was mixed, in various quantities, with 500 mL of water (deionised water or sodium phosphate buffer at pH 9). A trial and error approach was used to reach the target viscosity levels, with recipes tested in triplicate. We transitioned to the sodium phosphate buffer because the simulated vomitus will be spiked with fluorescein in our research, and the decay of fluorescein is slowed when pH > 7; this change was not found to affect the viscosity of the solution.

Stability testing was performed on two recipes with CMC powder. Six solutions were made separately, cooled to room temperature, and the viscosity measured (day 1). The solutions were held at room temperature and the viscosity measured once daily over five days. On day 2, three of the six solutions for each recipe were cooled and then heated, and the viscosity measured at 12, 16, 20, 24 and 28 °C. Thereafter, these solutions were held at room temperature.

All viscosity measurements were performed using a rotational viscometer (NDJ-1, Dongguan Liyi Test Equipment Co., Ltd). The minimal rotation durations used to read viscosity of simulated vomitus were 30 s and 40 s for low and high viscosity levels, respectively. Three sequential measurements were made.

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Table 1. Candidate materials and recipes for simulated vomitus.

Agent	Low viscosity target			High viscosity target		
	Recipe	Viscosity (mPa-s) Mean $\pm$ SD		Recipe	Viscosity (mPa-s) Mean $\pm$ SD	
		Day 1	Day 3		Day 1	Day 3
Instant pudding	22 g per 325 mL water	6.2 $\pm$ 0.1	6.8 $\pm$ 0.3	100 g per 440 mL water	178 $\pm$ 0	*
Gelatine	1.7 g per 500 mL water	5.4 $\pm$ 0.4	7.0 $\pm$ 0.4	*	*	*
CMC	0.19 g per 500 mL buffer	5.9 $\pm$ 0.3	6.2 $\pm$ 0.2	2.51 g per 500 mL buffer	167 $\pm$ 10	176 $\pm$ 10

*Not tested due to stability problems.

The stability of viscosity over time was tested by one-way repeated measurement ANOVA, followed by paired t-tests with the Bonferroni correction to test for differences between each day. Simple linear regression was used to test the relationship between viscosity and the temperature of the solution. R Studio (Version 0.99.879) was used for the statistical data analysis.

Ethical approval was not required for this study.

Results

The recipes for each of the three materials that attained a target viscosity are shown in Table 1. Gelatine powder could attain the low target viscosity, but the viscosity of solution increased over two days. As the gelatine solutions approached the high target viscosity, the viscosity was very sensitive to small additions of gelatine and became more viscous over several hours (data not shown). The CMC powder attained the target viscosities and was stable over three days. Due to the strong odour of the instant pudding powder, and the instability of the pudding powder and gelatine, further testing proceeded only with the CMC powder.

Viscosity measurements made in triplicate are shown for each solution on each day of the five-day study in Table 2. Precision of the viscometer is high, indicated by coefficient of variation (CV) $\leq$ 10% for triplicate measurements of each solution on each day. The recipe reliably yields the target viscosity, indicated by the low CV among the mean values for each solution on day 1 (CV = 1.2% and CV = 4.1% for low and high target viscosities). The repeated measures ANOVA analysis with factors of day and target viscosity indicates the day variable is a significant factor ($P < 0.05$), with differences in viscosity occurring only the high viscosity solutions on some days. Inspection of Table 2, however, suggests that differences from day to day are modest, with CV $\leq$ 2.9% for each solution.

The viscosity of the solution is significantly negatively ($P < 0.001$) affected by increasing solution temperature for both viscosity levels. The slopes are -0.1 ($y = 8.3 - 0.1x$, $R^2 = 0.923$)

and -8.3 ($y = 350 - 8.3x$, $R^2 = 0.871$) for the low and high viscosities, respectively, which means that for 1 °C change of solution temperature, the viscosity of solution changes 0.1 and 8.3 mPa-s for low and high viscosity levels, respectively.

Discussion

Our objective was to develop a recipe for simulated vomitus that could be made in a large batch, stored for several days for use in experiments, and was less expensive than commercially available products. Ultimately, the CMC powder was found to be the best material tested: able to attain the target viscosities for at least five days and respond predictably and reversibly to temperature changes. In addition, the simulated vomitus made with CMC powder was odour-free. While the ANOVA analysis indicated day-to-day variation, the magnitude of these viscosity changes is small relative to other source of experimental variability. Day-to-day temperature variation in the laboratory likely explains the observed variation in viscosity and represented a limitation of the study. In our research, similar to the work of others (Bell et al., 2015; Makison Booth, 2014; Tung-Thompson et al., 2015), we add a fluorescein powder to the simulated vomitus, which does not change the viscosity, but allows the material to fluoresce under black light and can be sensitively measured in the environment. In our simulations of vomitus cleaning, we have observed that two levels of viscosity yielded different patterns of environmental contamination (Su et al., 2017). Overall, this study indicates that CMC powder can be used to make simulated vomitus and other bodily fluids, like blood and diarrhoea.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by cooperative agreement 1U54CK000445-01

Table 2. Stability of CMC-based recipes for simulated vomitus.

Target viscosity level	Day	Temperature (°C)	Mean $\pm$ SD of viscosity (mPa*s), (CV (%))						
			Solution						
			A	B	C	D	E	F	Overall
Low	1	20.2	6.2 $\pm$ 0.3 (4.7)	6.2 $\pm$ 0.3 (4.3)	6.4 $\pm$ 0.2 (4.7)	6.3 $\pm$ 0.3 (4.6)	6.3 $\pm$ 0.1 (0.9)	6.2 $\pm$ 0.2 (3.3)	6.3 $\pm$ 0.1 (1.2)
	2	20.2	6.2 $\pm$ 0.3 (4.0)	6.1 $\pm$ 0.1 (1.9)	6.3 $\pm$ 0.3 (4.0)	5.9 $\pm$ 0.3 (5.5)	6.1 $\pm$ 0.4 (5.9)	6.2 $\pm$ 0.3 (4.7)	6.1 $\pm$ 0.1 (2.4)
	3	19.8	6.4 $\pm$ 0.5 (7.4)	6.2 $\pm$ 0.4 (5.8)	6.2 $\pm$ 0.3 (4.0)	6.3 $\pm$ 0.3 (4.0)	6.2 $\pm$ 0.6 (10)	6.3 $\pm$ 0.3 (4.6)	6.3 $\pm$ 0.1 (1.1)
	4	20.0	6.2 $\pm$ 0.2 (2.5)	6.1 $\pm$ 0.4 (5.9)	6.2 $\pm$ 0.3 (4.0)	6.3 $\pm$ 0.3 (4.0)	6.3 $\pm$ 0.2 (2.7)	6.3 $\pm$ 0.3 (4.0)	6.2 $\pm$ 0.1 (1.2)
	5	20.1	6.2 $\pm$ 0.2 (2.8)	6.2 $\pm$ 0.4 (6.5)	6.1 $\pm$ 0.5 (8.5)	6.1 $\pm$ 0.4 (5.9)	6.1 $\pm$ 0.4 (5.8)	6.3 $\pm$ 0.3 (4.0)	6.2 $\pm$ 0.1 (1.4)
	Overall		6.2 $\pm$ 0.1 (1.4)	6.2 $\pm$ 0.1 (0.9)	6.2 $\pm$ 0.1 (1.1)	6.2 $\pm$ 0.2 (2.9)	6.2 $\pm$ 0.1 (1.6)	6.3 $\pm$ 0.1 (0.9)	6.2 $\pm$ 0.1 (1.3)
High	1	19.0	173 $\pm$ 0.4 (0.2)	183 $\pm$ 0.2 (0.1)	166 $\pm$ 0.4 (0.2)	182 $\pm$ 0.7 (0.4)	168 $\pm$ 0.5 (0.3)	178 $\pm$ 0.4 (0.2)	175 $\pm$ 7 (4.1)
	2	19.1	175 $\pm$ 0.6 (0.4)	188 $\pm$ 0.2 (0.1)	172 $\pm$ 0.5 (0.3)	186 $\pm$ 0.3 (0.1)	176 $\pm$ 0.5 (0.3)	184 $\pm$ 0.5 (0.3)	180 $\pm$ 6 (3.5)
	3	20.2	167 $\pm$ 0.6 (0.3)	179 $\pm$ 0.8 (0.4)	166 $\pm$ 0.9 (0.5)	181 $\pm$ 0.5 (0.3)	172 $\pm$ 0.7 (0.4)	179 $\pm$ 0.3 (0.2)	174 $\pm$ 7 (3.9)
	4	19.1	175 $\pm$ 0.3 (0.2)	187 $\pm$ 0.4 (0.2)	173 $\pm$ 0.4 (0.3)	187 $\pm$ 0.4 (0.2)	178 $\pm$ 0.8 (0.5)	187 $\pm$ 1.0 (0.5)	181 $\pm$ 7 (3.7)
	5	20.0	170 $\pm$ 0.5 (0.3)	182 $\pm$ 0.7 (0.4)	168 $\pm$ 0.7 (0.4)	184 $\pm$ 0.7 (0.4)	174 $\pm$ 0.7 (0.4)	182 $\pm$ 0.5 (0.3)	177 $\pm$ 7 (3.8)
	Overall		172 $\pm$ 3.5 (2.0)	184 $\pm$ 3.7 (2.0)	169 $\pm$ 3.3 (2.0)	184 $\pm$ 2.5 (1.4)	174 $\pm$ 3.8 (2.2)	182 $\pm$ 3.7 (2.0)	177 $\pm$ 3.1 (1.7)

SD, standard deviation.

with the Centers for Disease Control and Prevention, the UIC Epicenter for Prevention of Healthcare Associated Infections.

Peer review statement

Not commissioned; blind peer-reviewed.

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