

Shear rheological properties of fresh human faeces with different moisture content

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ABSTRACT

Dry sanitation requires the handling of faeces, which vary in age and degree of transformation. Rheological data are necessary to support the design of equipment to handle faeces. The rheological properties of fresh human faeces were measured using a variable-speed rotational rheometer. Samples were further tested for moisture content, total solids, volatile content, and ash content. Faecal samples were found to have a yield stress; there was a decrease in apparent viscosity with increasing shear rate. For any given shear rate, higher apparent viscosities are associated with lower moisture contents. Across a range of water contents of 58.5% to 88.7%, apparent viscosities of 27 Pa·s to 2 014 Pa·s were measured at a shear rate of 1 s⁻¹. During constant shear tests, the apparent viscosity of all faeces was found to decrease asymptotically, where the minimum apparent viscosity value increased with decreasing moisture content. A structural recovery test indicates that human faeces are thixotropic in behaviour, where the viscosity permanently decreases to 0.5% of the initial value after a 20 s exposure to a shear rate of 10 s⁻¹. A linear relationship between viscosity and temperature was found, with a recorded 30.6% decrease in viscosity for a 35.6 °C increase in temperature from 13.4°C.

Keywords: Human stool, mechanical properties, water content, flow curve, viscosity, yield stress

INTRODUCTION

The Bill and Melinda Gates Foundation have presented a Reinvent the Toilet Challenge to researchers (Global Development Program, 2012). The objective of the challenge is to provide a sanitation solution for poor unserved households at a user cost of less than USD 0.05 per person per day. A wide range of processes have been proposed. Some of these proposals involve the source separation of urine and faeces; each of these streams is then handled separately. This implies that these streams need to be mechanically handled prior to subsequent processing, e.g., drying, gasification or combustion. Viscosity data are needed for the design of the mechanical handling equipment.

Very little literature is available for the rheology of human faeces and the available information is not comprehensive. The information that is available on the properties of human faeces (Patel et al., 1973) and the rheology of similar matter, namely, cattle manure slurries (Chen, 1986; El-Mashad et al., 2005), has been used to estimate the behaviour of fresh human faeces. Moisture content has been identified as the most significant parameter in the variation of the rheological properties of faecal matter (Chen, 1986).

The composition of faecal matter can vary significantly among different people and from different faecal samples from the same person. This variation is attributed to subjects' diet, age, health, lifestyle, climate and geographical region (Lopez Zavala et al., 2002; Buzie-Fru, 2010).

This study investigated the rheological behaviour and rheological properties of fresh human faeces, with the purpose of informing the future design of faecal-handling equipment.

Viscosity data, fluid behaviour and physical property relationships of human faeces were investigated and established within the context of the requirements for mechanical handling equipment.

MATERIALS AND METHODS

Faecal samples

A total of 30 samples of fresh human faeces were analysed for rheological and chemical properties. Faecal samples were collected from Durban on the east coast of South Africa. The donors were young adults between 20 and 29 years of age. The donors were of mixed ethnicity, namely African, Caucasian, Coloured and Indian, and the diet was uncontrolled, but mostly included traditional western, Indian and South African diets.

To prevent degradation of faecal samples, they were immediately placed by the donor in a cooler box with frozen ice bricks, after they were produced, and transported to the laboratory. Faecal samples were stored in a cold room at 2°C, and tested within 1 week of production. Faecal samples were photographed, weighed and classified using the Bristol Stool Form Scale (BSFS) proposed by Lewis and Heaton (1997), which is considered to be a useful tool for categorizing fresh faecal samples prior to testing. The BSFS classifies human faeces into different categories based on their physical appearance. The scale ranges from a 'Type 1' stool which is described as 'separate hard lumps, like nuts' to a 'Type 7' stool which is described as 'watery, no solid pieces'.

Equipment

An Anton Paar Physica MCR 51 rotational rheometer was used to measure the rheological properties of faeces. For faecal samples with a BSFS factor of 1 and 2, a cone-plate setup was

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