Journal of Interdisciplinary Science Topics

Analysing Gragas's drinking problem

Nassim-Eddine Assassi
Natural Sciences (Life and Physical Sciences), School of Biological Sciences, University of Leicester
15/04/2024

Abstract
Within the video game League of Legends, there is a character known as Gragas. This character is known as a drunkard, as he is constantly drinking alcohol in both the lore and the actual game. While the game goes on and he continues drinking, his movement and body control are not impaired. In fact, after drinking, he seems to gain strength. In this paper, I will explore the science of what is happening inside his body because of this consumption and theorise how this consumption may be possible.

Keywords: *Computer game; Physics; Biology; Fluid Dynamics; Alcohol Metabolism; League of Legends; Gragas*

Introduction
The game League of Legends contains many characters with different magical powers and abilities. Among these abilities, many cannot be easily explained using realistic science, such as a dragon breathing fire or an undead warlord transporting you to a different dimension. While these abilities seem mystical and magical, some abilities in the game share a close relationship with concepts and situations experienced in real life. Among these is the human character Gragas, who drinks alcohol throughout the game. Gragas's 'E' ability sees him take a big gulp from his barrel of ale and then unleash a strong attack, swinging his barrel over his head and slamming it down on his opponents [1].

How much does Gragas drink?
Assumptions:

- The barrel is always full and never depletes.
- The barrel is a perfect cylinder of height ~1.3m and diameter ~0.8m [2].
- The spout is a circular hole of diameter ~0.2m.
- The barrel is tilted flat horizontally with the spout at the bottom while drinking.
- Gragas drinks for 1 second [1].
- The discharge coefficient of the spout is ~ 0.6 (sharp edge aperture) [3].
- Gragas spills 50% of what he attempts to drink
- His 'E' ability takes 3.25 seconds to complete after which the cooldown is 5 seconds [4]. Cooldown reduction is ignored.
- The ability is used immediately on cooldown all game which lasts 30 minutes or 1800 seconds.


Figure 1 – Video frame of Gragas drinking from his barrel [1].

The flow of liquid from the spout is calculated using a modified version of Torricelli's law [3]:

$$V = \frac{2}{3} C_d b \sqrt{2g} \left(H_2^{3/2} - H_1^{3/2} \right),$$

Where V is the volume flow (m^3s^{-1}), C_d is the discharge coefficient, b is the width of the aperture (m), g is the acceleration due to gravity (ms^{-2}), H_1 is the height of the liquid at the top of the aperture (m) and H_2 is the height of the liquid at the bottom of the aperture (m).

$$V = \frac{2}{3} \times 0.6 \times 0.2 \sqrt{2 \times 9.81} \left(0.8^{3/2} - 0.6^{3/2} \right)$$
$$V = 0.0889\, m^3 s^{-1}$$

Because Gragas spills 50% of what is poured and drinks for 1 second the amount he drinks per cast is:

$$0.0889 \times 0.5 = 0.0445 m^3$$

This is the number of times that the cast can recharge in one game:

$$\frac{1800\ s}{8.25\ s} = 218.18 \approx 218$$

The total number of casts in a game is ~219. After this Gragas will have consumed this much Ale:

$$0.0445 \times 219 = 9.75 m^3 = 9.75 \times 10^6 ml$$

Blood alcohol level

Gragas is drinking ale [1], which has an average Alcohol by Volume (ABV) range of approximately 3-16% [5]. In the lore of the game, Gragas loves drinking strong drinks, so we can assume his barrel contains a strong alcoholic beverage. For the sake of this paper, we will assume the ABV of this beverage is 16% This means that in a period of 30 minutes, Gragas has consumed this much alcohol:

$$9.75 \times 10^6 \times 0.16 = 1.56 \times 10^6\ mL$$
$$\frac{1.56 \times 10^6}{10[6]} = 1.56 \times 10^5\ UK\ units$$
$$0.79[7] \times 1.56 \times 10^6 mL = 1232000 g = 1232 kg$$

In this Reddit post [8], the author suggests that due to Gragas's immense size and weight, he has an increased volume of blood. They propose that this leads to a reduced blood alcohol level, allowing him to survive. I will test this by looking at how heavy Gragas would need to be to survive all this drinking. A lethal dose of alcohol in humans is approximately 2 g per kg of body mass. For Gragas to be below this level, his weight would need to be higher than 616000 kg. As stated in this Reddit post [9], Gragas weighs 333.4 kg, which is much lower than the required weight for his survival.

That answer would also not explain his ability to move and fight coherently throughout the game. Both light and heavy alcohol drinkers have been shown to experience impairments in fine motor and dexterity skills following alcohol consumption [10].

Human liver function

The liver is the organ in the body tasked with degrading toxic substances. It carries out this function by chemically converting them into other less- or non-harmful chemicals. Ethanol is metabolised in the liver primarily by a two-step reaction pathway. First, an enzyme known as alcohol dehydrogenase converts ethanol into acetaldehyde, a highly toxic and carcinogenic (cancer-causing) compound. Aldehyde dehydrogenase then converts that product into acetate, which finally breaks down into water and carbon dioxide [11].

The oxidation of ethanol to acetaldehyde, catalysed by alcohol dehydrogenase, reduces NAD+ to NADH. This NADH is fed to the mitochondrial electron transport chain (ETC), where its reoxidation facilitates ATP production. For this reason, alcohol metabolism produces 7 kcal of energy per gram of ethanol [11]. If he can rapidly digest ethanol, this energy production may explain why Gragas seems to become empowered after chugging from his barrel.

The average human, with a weight of 70 kg, can digest 7 g of alcohol per hour. [12] As Gragas weighs over 4.5 times this amount, we can assume that he would be able to digest at least 33 g of alcohol per hour with normal liver functioning. This, however, is negligible in comparison to the amount of alcohol he is consuming.

Gragas's physiology

While Gragas is human, he is part of a group of magical humans known as the Iceborn. These individuals have different physiology from normal humans that allows them to resist freezing cold temperatures. Some organisms, such as pentailed treeshrews, are more effective at alcohol detoxification and regularly survive with alcohol levels that would be life-threatening for humans [13]. If the physiological differences that provide cold resistance also provide changes that mimic those in this shrew, this would aid his alcohol tolerance. On the other hand, the human degradation rate and the amount of alcohol consumed differ by over 4 orders of magnitude, and it is unlikely that physiological changes could bridge this huge gap.

Gragas's enhanced alcohol metabolism may be accompanied by a reduced ability for the intestines to absorb alcohol or the ability for the kidneys to absorb alcohol from the blood to be excreted directly. This could explain his need to drink such immense amounts of alcohol to receive its effects, as most of the alcohol he consumes would be released in his stool or urine.

Conclusion

Gragas's alcohol tolerance cannot be explained using normal human physiology, as has been shown via the calculations in this paper. His alcohol intake is much higher than the human alcohol degradation rate, and his estimated required weight to be able to survive that much alcohol is over 2000 times his actual weight. I have also noted that Gragas is an iceborn and has a different physiology. This may mimic other organisms that have higher alcohol tolerance, such as pentailed treeshrews or may have unique alcohol-resistant adaptations. Alcohol may act as an energy source for Gragas as alcohol breakdown produces reduced NAD which is fed into the ETC to produce ATP. This may be able to explain Gragas's boost in strength after drinking his ale.

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