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The Bacteria with the Lowest Infectious Dose to cause Meat Food Poisoning

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Abstract
In this paper we will investigate the minimal infectious dose of three different common forms of bacteria that cause meat food poisoning. For *E.coli* it was found that the infectious dose given the minimal inoculum size of 1 bacterium was 6.28 x10^{57} bacteria cells. For *Campylobacter jejuni* the infectious dose was 2.88 x10^{44} bacteria cells and for *Listeria* this value was 2.41 x10^{462}. Therefore *Campylobacter jejuni* was found to have the lowest infected dose that causes the symptoms of food poisoning.

Introduction
It is well known that consumption of raw or undercooked meat can cause food poisoning. This is due to the presence of bacteria in the meats which can have toxic effects in the body and cause symptoms such as vomiting and diarrhoea. However, a threshold number of bacteria need to be present in the body before the symptoms related to the food poisoning occur. This number is known as the 'infectious dose' [1]. In this paper the infectious dose of three common meat contaminants of *E.coli*, *Campylobacter* and *Listeria* will be investigated [2].

Bactria grow and divide in a series of stages. There is a *lag phase* (where there is no significant cell division as the bacteria are adjusting to the medium), *log phase* (where the bacteria exponentially divide by undergoing binary fission at a constant rate), *stationary phase* (where no division takes place due to a limitation of either space or nutrients) and a *death phase* (where the bacteria in the population start dying off) [3]: see figure 1 [4]. Usually only the *log phase* is observed under laboratory conditions [5]. This *log phase* is also known as the *exponential growth phase* and the rate of this growth is the generation time for a particular bacteria type.

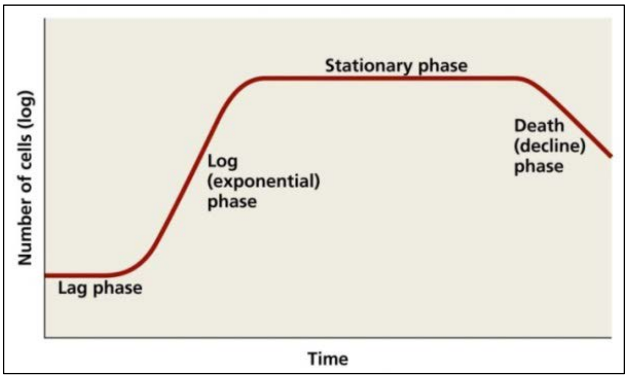

Figure 1) Stages of bacteria population growth [4]

Assumptions
The initial number of bacteria present in the consumed contaminated meat that then enter the body (inoculum size) is very difficult to predict as this value can vary significantly [1]. Therefore for the calculations presented within this paper the minimum inoculum size of 1 bacterium is assumed.

Food poisoning symptoms produced as a result of the bacteria can appear after a range of days (incubation period). As it has been assumed that only one bacterium is initially present, it is also reasonable to assume that one bacterium would take the longest possible time (upper limit of the incubation period) to divide to the extent to produce the symptoms associated with food poisoning.

The calculations also do not take into consideration the factors that limit the growth of bacteria in the body. These include nutrient and space limitations as well as the death of some of the bacteria as a result the body's immune system response (such as the process of phagocytosis) [3]. These factors were not accounted for as the effect of these limitations on the specific number of bacteria is very hard to quantify in an uncomplicated way.

E.coli

The generation time for E.coli at 37°C in a rich medium in laboratory conditions is 20-40 minutes [5]. For the calculation the generation time is taken to be the median value of 30 minutes. The symptoms of E.coli poisoning appear after 3-4 days of the bacteria entering the body [6]. Therefore it is assumed that the symptoms appear after 4 days (incubation period) for the minimal inoculum size of just one bacterium [3].

$$Generation\ Time = \frac{Time\ interval}{Number\ of\ gnerations\ 'n'}$$

To calculate the number of bacterial generations '*n*', the time interval (incubation period) is initially converted from 4 days to 5760 minutes.

$$Number\ of\ generations\ '\boldsymbol{n}' = \frac{Time\ interval}{Generation\ Time}$$

$$\boldsymbol{n} = \frac{5760\ mins}{30\ mins} = 192\ (3\ s.f)$$

As bacterial cells grow by binary fission [3]:

$$b\ = B \times 2^n = 1 \times 2^{192} = 6.28\ \times 10^{57}\ (3\ s.f)$$

Where *b* is the number of bacteria at the end of the time interval and *B* is the number of bacteria at the start of the time interval. Therefore 6.28×10^{57} bacterial cells are present after 4 days.

Campylobacter

Symptoms usually appear after 2-5 days, but can appear after 10 days [7]. The strain *Campylobacter jejuni* NCTC 11168, grown at 37 °C in laboratory conditions, has a generation time of 97.5 mins [8]. It is assumed that symptoms appear after 10 days (upper limit of incubation period range) and the minimum inoculum size applies. As before 10 days is converted to 14,400 minutes.

$$\boldsymbol{n} = \frac{14{,}400\ mins}{97.5\ mins} = 147.7\ (3\ s.f)$$

$$b = 1 \times 2^{147.7} = 2.88 \times 10^{44}\ (\ 3\ s.f)$$

Therefore 2.88×10^{44} bacterial cells are present after 10 days.

Listeria

Symptoms appear after 4 to 8 weeks with type of infection. This infection needs to be treated with antibiotics as the bacteria can affect the immune system and thus affect recovery from food poisoning [9]. The generation time of *Listeria monocytogenes*, which is the strain of listeria bacteria that causes food poisoning, is 45-60 mins [10]. The generation time for the calculation is taken as the median value of 52.5 mins. It is assumed that symptoms appear after 8 weeks (upper limit of incubation period range) and that the minimal inoculum size applies. As before 8 weeks is converted to 80,640 minutes.

$$\boldsymbol{n} = \frac{80{,}640\ mins}{52.5\ mins} = 1536$$

$$b = 1\ \times\ 2^{1536} = 2.41\ \times 10^{462}\ (3\ s.f)$$

Therefore 2.41×10^{462} bacterial cells are present after 8 weeks.

This value is extremely large and seems unfeasible when taking into consideration the fact that there are roughly 7×10^{27} atoms in the human body for an adult of 70 kg [11], around 1.33×10^{50} atoms on Earth [12] and roughly 10^{82} atoms in the universe [13]. However, as the values calculated are an estimation for the ideal conditions for bacterial growth and do not consider the limitations of space, nutrients and other such factors, this value of 2.41×10^{462} could still be feasible for non-limiting conditions.

Conclusion

In conclusion, the bacteria with the lowest infectious dose under the ideal, non-limiting conditions are *Campylobacter* bacteria which have a value 2.88×10^{44} bacteria. In contrast, the bacteria with the largest infectious dose under non-limiting are *Listeria*, which have a value of 2.41×10^{462} bacteria. This shows that there is significant variation in the number of bacteria required to onset the symptoms of food poisoning in the same contaminated food depending on the type of bacteria present.

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