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A4_9 Buffalo Wings

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Abstract

'Buffalo wings' are a popular type of fried chicken wings. In this paper we examine the difference in size between these wings and the hypothetical wings that an actual buffalo would need in order to be able to fly. Using a fixed wing approximation, we determine that to produce sufficient lift a buffalo would need a pair of wings 31 times larger than those of a chicken, or 31 separate pairs of chicken-sized wings.

Introduction

Buffalo wings are a type of seasoned, deep fried chicken wings originating in Buffalo, New York [1]. A buffalo, on the other hand, is a large bovine animal which does not have wings.

Given that a buffalo is significantly larger and more massive than a chicken, it seems likely that if it was able to fly then it would have wings far larger than the so-called buffalo wings available today. Here, we attempt to ascertain approximately how large these hypothetical wings might be and, conversely, how many chicken wings would be needed to lift a buffalo.

Method and Results

In general, an object in flight is acted on by four forces, as shown in Figure 1. For the purposes of determining the conditions that must be met to allow something to fly, it is only the lift and weight which are relevant.

Bird flight is somewhat aerodynamically complex; however, it is possible to simplify the situation significantly by approximating both animals as utilising fixed-wing flight instead.

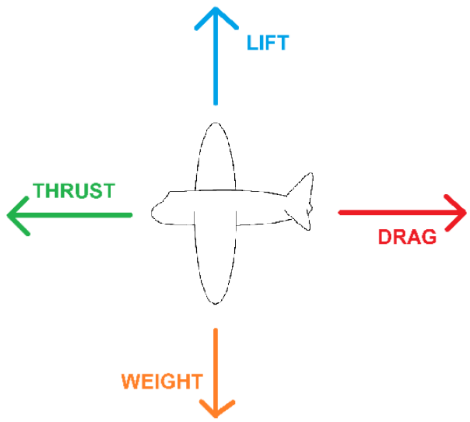

Figure 1: Free body diagram for an object in flight.

The lift produced in this mode of flight is given by:

$$L = C_L A \frac{\rho_{air} v^2}{2}, \tag{1}$$

where A is the wing area, ρ_{air} is the density of air ($1.225\ \mathrm{kgm^{-3}}$ at 15 °C [2]), v is the velocity with which the wing moves through the air, and C_L is the lift coefficient, which is normally determined experimentally [3].

From Figure 1, we can see that for something to take off and fly without losing altitude it must have lift greater than or equal to its weight:

$$C_L A \frac{\rho_{air} v^2}{2} \geq mg, \quad (2)$$

where m is the mass of the aircraft or animal, and $g = 9.81$ ms^{-2} is the acceleration due to gravity.

To determine how many chicken wings would produce a lift equal to the weight of a buffalo, we must first have a value for the lift coefficient for chicken wings. Chickens have masses in the range 1 kg to 3 kg, a maximum speed of 2.78 ms^{-1}, and a wingspan of 45 cm to 60 cm [4]. Taking each wing to be approximately 20 cm long and 5 cm wide gives an area of 0.01 m^2 for each wing. Using a mass of 2 kg leads to a value for the lift coefficient of 207, from equation 2. This value is far larger than is typical for fixed wing flight. This is because the chicken's wings are not actually fixed; in fact the bird flaps its wings to produce additional lift, and the large lift coefficient incorporates this effect. By using this lift coefficient in the fixed wing lift equation we aim to approximate the true relationship between lift and wing area for bird flight.

Using the above value for C_L, we attempt to determine the wing area necessary to lift a buffalo. Buffalo have a top speed of 9.72 ms^{-1} and masses in the range 600 kg to 907 kg [5], so we take the mass of a typical buffalo to be 754 kg. This gives a minimum wing area of 0.616 m^2, which is 62 times larger than the area of a single chicken wing.

Discussion and Conclusion

If a buffalo had two wings, then each wing would have to have an area of 0.308 m^2 in order to produce sufficient lift for the buffalo to take off when running at maximum speed. This is 31 times larger than a chicken wing, meaning that a buffalo with wings the same size as chicken wings would not be able to take off unless it had at least 31 separate pairs of wings. This value seems relatively small considering that a buffalo is around 377 times heavier than a chicken; however, the buffalo has a significantly faster top speed, which allows it to generate much more lift from a given wing area.

In attempting to simplify our model by using the lift equation for fixed wing flight, it is possible that we have introduced significant uncertainty into our estimate of the necessary wing area. We assume that the buffalo would be flapping its wings in exactly the same way and at the same rate as a chicken, and that this flapping has the same effect at different scales. If this is not the case then there may be a very large uncertainty in the value of the lift coefficient. As a result, it may be that a buffalo would actually need much larger wings in order to fly. Attempting to remove this approximation and model the chicken and the buffalo as using a more complex mode of flight could be an area for future research.

However, considering the large difference in mass between a chicken and a buffalo, there is little doubt that a buffalo would still require much larger wings than a chicken regardless of the mode of flight employed. Therefore, the Buffalo wings that are currently available for purchase can not come close to the size of the hypothetical wings of an actual buffalo.

References

[1] `http://time.com/3957370/buffalo-wings/` [Accessed 21 November 2018]

[2] `https://www.engineersedge.com/calculators/air-density.htm` [Accessed 21 November 2018]

[3] `https://www.grc.nasa.gov/www/k-12/airplane/lifteq.html` [Accessed 21 November 2018]

[4] `https://a-z-animals.com/animals/chicken` [Accessed 21 November 2018]

[5] `https://a-z-animals.com/animals/buffalo` [Accessed 21 November 2018]