Proposing a new physical quantity: the saucisity.

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Abstract

The right amount of sauce on a chicken nugget used to be difficult to quantify. With a new proposed physical quantity and its unit of measurement a standard sauce dose can be tuned to a persons personal preference. The saucisity s is defined as a volume of sauce per amount of nuggets. Introducing the Ronald, $[s]$ =Ron, a unit of saucisity referring strictly to McNuggets. One Ronald is defined as a litre of sauce per kilonugget. Furthermore, an analysis of the menu of McDonald's is done and a model that describes combinations of chicken nuggets is presented.

1 Introduction

In the physics department there is an active study association. Often members will enjoy a few drinks in the bar and when it closes, they will head to McDonald's. McDonald's is a 'restaurant' that serves fastfood. Its mascot used to be Ronald McDonald the clown[1]. A wide variety of food items are on the menu, but the chicken McNuggets are a favourite. Chicken nuggets are ground chicken scraps compressed into a shape, battered and fried. Upon their launch in 1979 they were so popular that there was a shortage[1]. More recently there was another shortage due to new trade policies from the Trump administration. McNuggets come in four shapes: the bell, boot, bone and ball. As the company puts it: "Three would've been too few. Five would've been, like, wacky."[2] Nuggets are in general consumed with a liberal amount of sauce. This leads to the question "How much sauce is right?" I propose a new unit of measurement to quantify a persons sauce needs and communicate it efficiently.

2 Proposed physical quantity and unit

Define the saucisity s as the volume of sauce per number of chicken nuggets. A proposed unit is the Ronald, where

$$1\text{Ron} \equiv \frac{1\text{l}}{\text{kilonugget}}. \quad (1)$$

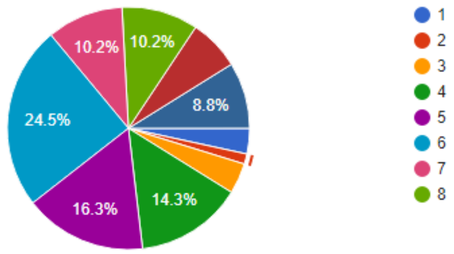
This is one litre of sauce per one thousand chicken nuggets. The choice for kilonugget is made such that values typically obtained are between 1 and 10 Ron. This avoids the need to use the milliron for most purposes.

3 Contents of McDonald's menu

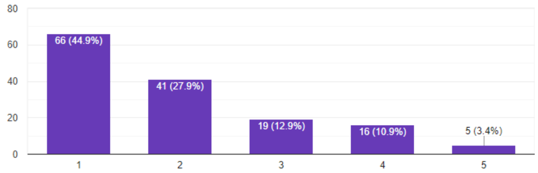
The McDonald's menu in the Netherlands has limited McNugget options. McNuggets are sold in packs of 6, 9 or 20 pieces[3]. A happy meal offers a box of 4 McNuggets. However this is not an economically viable option so it will not be considered in the analysis. The prices are respectively 2,00, 3,75 and 6,95 euros at the Leiden Beestenmarkt location as of 2019. These prices may vary from restaurant to restaurant as no price is indicated on McDonald's website. The most bang for your buck is the 6 piece box for 2 euros, the 9 piece box costs almost double that price, but you do get an extra sauce basket.

4 Survey data

In preparation for a lunch lecture a survey (N=147) was put up to gather the opinion of students on the right amount of sauce and their thoughts on chicken nuggets in general. The demographic is mostly undergraduate members of the physics, astronomy, maths and computer science study association. Chicken nuggets are consumed less than once a month by 53.7% of the participants. The opinions about the ideal amount of sauce are divided, however almost a quarter of the participants favour 6 chicken nuggets per basket of sauce (25 ml) which translates to a saucisity of 4,2 Ron (figure 1a). Unfortunately, no accurate measurement of the contents of the sauce basket are available. The 25 ml is what is printed on the label, there is no error margin available. However it is estimated to be 25 ± 2 ml. For the same price, 44,9% would



(a) Responses to the question 'How many chicken nuggets are ideal with one basket of sauce (25 ml)?'



(b) Responses to the question 'At the same price, would you rather have more nuggets or a better nugget-sauce ratio?' The numbers indicate the amount of chicken nuggets (1-8).

Figure 1: Graphs of survey data. Figure 1a shows the distribution of nuggets per 25 ml of sauce. The largest part prefers 6 McNuggets, although the opinions are divided. Figure 1b shows the preference for chicken nuggets over sauce, although a good sauce ratio is very important to 5.4% of the participants.

rather have more chicken nuggets than a better sauce ratio. The other 50,1% mostly still prioritise chicken over sauce, as can be seen in figure 1b.

5 Results

The saucisity is calculated in table 1. In figure 2a the saucisity is plotted up to 300 McNuggets as linear combinations of box sizes. As can be seen, due to the discrete

Table 1: Amount of McNuggets and volume of sauce that comes with it.

# nuggets	Sauce [ml]	Saucisity [Ron]
6	25	4,2
9	50	5,6
20	75	3,75

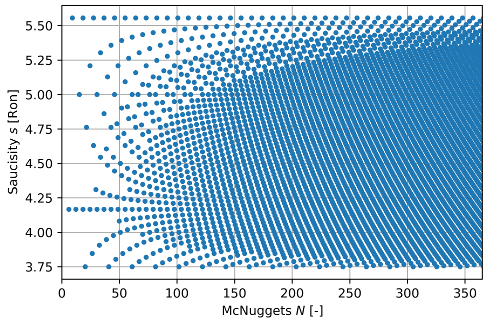
box sizes the saucisity is quantized for low amounts of McNuggets. The saucisity behaves as a continuous band at high numbers of McNuggets. Some would call this a quantum theory of McNuggets. Without buying additional sauce packets a maximum saucisity of 5,6 Ron can be reached. Without discarding them, the lowest possible saucisity is 3,8 Ron.

6 A mathematical model

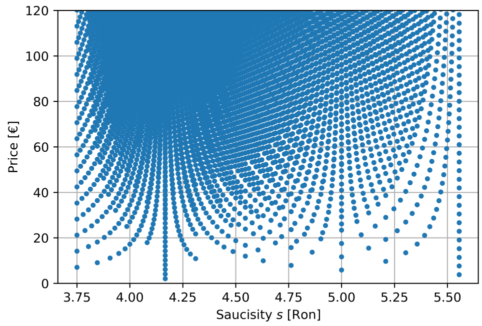
All of these results are easily brought into a mathematical model. We will work with the unusual set $\{\vec{x} \in \mathbb{R}^3 | x_i \geqslant 0\}$, which is not a vector space. Start by defining the following three vectors

$$\vec{c} = \begin{pmatrix} 6 \\ 9 \\ 20 \end{pmatrix}$$
$$\vec{V} = \begin{pmatrix} 25 \\ 50 \\ 20 \end{pmatrix}$$
$$\vec{p} = \begin{pmatrix} 2,00 \\ 3,75 \\ 6,95 \end{pmatrix}.$$

The vector $\vec{c}$ denotes the amount of chicken nuggets. $\vec{V}$ is the volume of sauce associated with the component in millilitres. $\vec{p}$



(a) The saucisity plotted against number of McNuggets.



(b) Saucisity plotted against price of that combination.

Figure 2: Some plots that can be made using the model. Figure 2a shows the behaviour of the saucisity when varying the number of nuggets. Figure 2b shows the behaviour when varying the price. In both subfigures we can see that at low values, the saucisity is discrete. At higher values what appears to be a continuous distribution is seen. In all figures only allowed combinations of nugget boxes are plotted (i.e. $\{\vec{x} \in \mathbb{Z}^3 | \vec{x} \cdot \vec{c} \leqslant 300\}$).

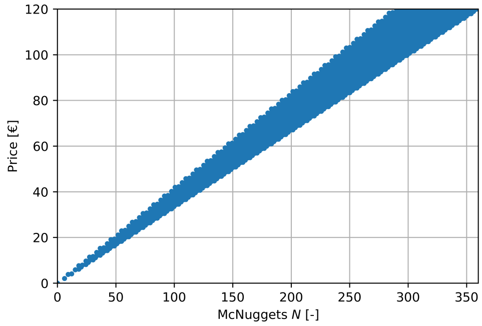
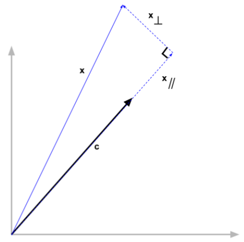
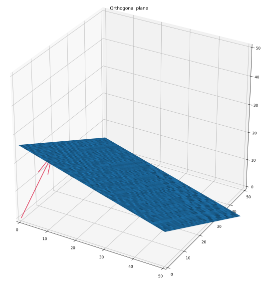


Figure 3: Nuggets plotted against their price. At high prices the difference in cost per nugget becomes very important, with a difference of about 20 euros for 300 nuggets.



(a) A drawing of the perpendicular and parallel component of $\vec{x}$ in two dimensions.



(b) The plane described by $\vec{x} \cdot \vec{c} = N$ in all three dimensions.

Figure 4: Two figures to illustrate the maths in section 6.

stores the price of the respective box. Now define the boxvector $\vec{x}$ to be the amount of boxes you buy with each component belonging to its respective nugget amount. Then, the total amount of chicken nuggets, price and volume of sauce can easily be calculated using a standard dot product between $\vec{x}$ and the respective vector. Notice however that since $\vec{x} \in \mathbb{Z}^3$ this is not a vector space as there is not necessarily an inverse. If it was a vector space, the spectral theorem could provide an interesting avenue to arrive at a solution. Unfortunately, McDonald's only sells integer boxes of McNuggets.

6.1 Calculating saucisity with the boxvector

The saucisity can be calculated using

$$s = \frac{\vec{V} \cdot \vec{x}}{\vec{c} \cdot \vec{x}}. \tag{2}$$

The saucisity can also be calculated trough making a saucisity vector obtained by dividing $\vec{V}$ over $\vec{c}$ component-wise. This was chosen against to keep the amount of vectors down. Figure 2 shows some plots of this model.

Whenever a specific saucisity is desired, it would be nice to know what combination of nugget boxes should be bought. In other words, given $\vec{V}$, $\vec{c}$ and s, can we find $\vec{x}$ (within specified tolerance from the desired s)?

This turns out to be a very difficult problem.

6.2 Amount of McNuggets

Another problem is a specific desired amount of chicken nuggets, N. There is an upper limit to the number of McNuggets you can not order; this is a specific case of the more general Frobenius coin problem [4] and is called the McNugget number [5]. One way to look at this problem is by considering the component parallel to $\vec{c}$. This has the property that, by its definition,

$$N = \vec{x}^{\parallel} \cdot \vec{c} = \vec{x} \cdot \vec{c}. \tag{3}$$

The boxvector can be written as $\vec{x} = \vec{x}^{\parallel} + \vec{x}^{\perp}$. Thus we are looking for a vector $\vec{x} \in \mathbb{Z}^3$

such that $\vec{x}^{\parallel} \cdot \vec{c}$ is equal to our desired N. That leaves $\vec{x}^{\perp}$ free. The solutions lie on the integer points on the plane described by $\vec{x} \cdot \vec{c} = N$, see figure 4b. For actually finding those points the greedy algorithm [6] can be used.

7 Discussion

From above results, the question is raised: would you rather have more chicken nuggets or a better saucisity? This is something you should decide for yourself. If you have a preferred saucisity you can calculate what combination of boxes to buy to get within tolerance of your ideal. The saucisity is an essential tool for communicating your preferences to McDonald's personnel.

Of course, the idea of saucisity need not be restricted to McNuggets. General chicken nuggets can be described by this model as well. Even more general, an adjustment to divide the volume of the sauce by the mass of the dipped object can be made to achieve a sauce density, which is incredibly versatile. This is of course explicitly different from the material density of the sauce. It can be applied to fries, meats, or even cucumber dipped in humus. The possibilities are endless. In the future, this might be an avenue worthwhile exploring.

References

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