Mathematics and biosciences: An interaction from exemplifications

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ABSTRACT
In this paper, we aim to present some mathematical concepts, applied in examples related to Biosciences, for a better discussion and understanding of the interaction of these two areas. In fact, since the second half of the twentieth century, Mathematics has played an important role, and even a protagonist, in the study of Biosciences. In such a way that studies of mathematical elements, with applications to bioscientific problems, constitute an interesting theme of studies and research. Thus, we seek an interaction, based on the exemplification, of the application of mathematical concepts in important problems in the areas that make up the body of Biosciences.

Keywords: Mathematics, Bioscience, Interaction between areas of knowledge, Related issues.

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INTRODUCTION

The research we present is configured as bibliographic-documentary, which, in the sense of Gil (2008), uses materials already elaborated, consisting mainly of scientific texts (books and papers) (in printed or digital formats), and which allowed us to investigate other studies related to the theme. In addition, we used documents in a descriptive/interpretative study for a re-elaboration of this knowledge in accordance with our research objectives. This material is an important part of our theoretical framework,

Thus, we aim to present some mathematical concepts, applied in examples related to Biosciences, for a better discussion and understanding of the interaction of these two areas, since, according to Batschelet (1979), since the second half of the twentieth century, Mathematics has been playing an important role, and even a protagonist, in the study of Biosciences.

In the following sections, we present a discussion about the importance of relating elementary concepts of Mathematics in solving problems in the Biosciences and we explicitly describe this interaction between these two areas of scientific knowledge, based on examples.

We infer that this interaction between Mathematics and the biosciences has potentialities, both for the teaching of Biosciences contents, and for an expansion of the field of teaching mathematical contents, when a possible development of new techniques from the existing mathematical knowledge, as well as the emerging possibilities of the new technologies of the XXI century.

ABOUT MATHEMATICS FOR BIOSCIENCES

In this section, we seek to relate mathematical conceptual elements, by their applicability, through examples, to contents related to Biosciences.

Following the line of what Sampaio e Silva (2024) argues, we seek to emphasize an interactive relationship between Mathematics and Biosciences, in a problem-solving procedure, characterizing what is now called Biomathematics, that is, an existing mathematics, produced or recreated for use in the Biosciences. (Rashevsky, 1940) and (Berezoskaya; Toni, 2019)

Initially, we will present some mathematical rules and/or concepts, which later allow us a more illustrative and/or elucidative representation of the processes or methods involved in solving bioscientific problems.

The elements of mathematics initially dealt with go more specifically in the direction of the representation of numerical quantities associated with problems typical of the biosciences, such as percentages and proportionality. In addition, it is necessary, in some problems, to deal with polynomial and/or exponential functions. To solve some problems, for example, that involve specific measures, it may be interesting to establish the use of scales (ordinal, proportional or graded).

According to Batschelet (1979, p. 2-4), such elements can be used to solve problems involving, for example, organ deficiency, animal growth or temperature variations. A discussion about these possibilities is presented by Batschelet (1979), when concluding a result.

In the medical case, a diagnosis. Batschelet (1979, p. 2) points out that even assuming the effective importance of considering mathematical results, which must be weighed, an interpretative component is necessary in the finalization of a result (diagnosis), as he seeks to exemplify, in a problem that involves the use of a nominal scale in the diagnostic interpretation of kidney problems, due to the excessive use of certain chemical products.

In his example, Batschelet (1979, p. 2) presents us with a researcher, a physician, who considers a classification of the problem into categories, according to severity. Thus, "For convenience, it suffices that he designates by the number 0 the *absence of renal deficiency* , by the number 1 the *weak deficiency*, by the number 2 the *medium deficiency* and by the number 3 the *severe deficiency*". In this way, the researcher introduces an ordinal scale with rank numbers or scores of 0, 1, 2, 3.

For Batschelet (1979, p. 2), it is presumable to observe that "*it is not possible to conclude that the increase from weak to medium disability is the same as from medium to severe disability*", although the numerical difference between the positions is the same in any of the cases considered.

It is important to note that the applications of mathematics to the biosciences can be treated, both from an advanced point of view, as prescribed in Rashevsky (1940) and Berezoskaya and Toni (2019), intermediate, aiming at graduation, as in Batschelet (1979), Smith (1968) and Murray (2002), to more elementary concepts such as in Batschelet (1979), Santiago and Paiva (2015) and Mancera (2024).

For these applications, it is necessary to use technical texts, which bring some specific methods and tools, such as Boldrini et. al. (1986) and Gomes (2013), as well as specific manuals such as Gonçalves (2019) and Calculus... (2021).

With these considerations, when we bring our examples, below, we seek to list problems of the Biosciences, where the mathematical result, usually numerical or even functional, can minimize difficulties of interpretation, when presenting *a priori conclusions*.

AN INTERACTION BY EXAMPLES

We can point to an interaction between these two areas of scientific knowledge, Mathematics and Biosciences, elements that are in line with our initial presentation. Thus, to reinforce our argument, in this section we bring some examples.

In our exemplification, we seek to cover at least six of the areas that make up the biosciences and that we believe to be the most representative for this moment, which we are aiming for. We understand that we cannot present them all, and that the possibilities of application are greater and often more complex. However, we affirm that these six examples can bring greater understanding in this interaction.

AN EXAMPLE IN BIOLOGY

In Batschelet (1979, p. 4), we find a representation of the concept of Percentage applied to an example that deals with the growth rate of an animal. Where quantities are related, such as: height and body mass (weight), with respective measurements in meters (m) and kilogram (kg). Which, below, we rewrite: consider that "*at the beginning of the experiment the animal weighs 50kg of body mass. We use a simplified number to make it easier to introduce and bill. In a period of one month, the weight increases by 20%, reaching 60kg. Assuming that in the second month the weight increases again by 20%.*" (Batschelet, 1979).

Batschelet (1979, p. 4)) states that we can erroneously infer that "*the total increase is 40% of the initial weight*". Thus, the animal would have a body mass (weight) of 70kg. However, the calculations lead us to a different result: the final weight is 72kg, which is 22kg or 44% more than the original weight.

It is worth commenting here on the importance of this example, since an accurate description of the body mass (weight) of an animal is a factor to be considered, effectively, when prescribing dosages of medications, supplements or foods.

AN EXAMPLE IN BIOMEDICINE

A classic example, which we bring here, considers the velocity of arterial or venous blood flow. Such a phenomenon, even in its complexity, we affirm, in agreement with Batschelet (1979, p. 95), can be represented and/or visualized from the use, a modeling of the phenomenon, of a polynomial function of the second degree.

To wit: we have the function $v(r) = \frac{P}{4\eta l}(R^2 - r^2)$, where the values of P, η, l are given (known). We have that R is the radius of the circular cross-section to the tube, P it is the pressure difference between the ends of the tube (model for a human vein or artery segment), η it is the viscosity of the fluid (blood), l it is the length of the model tube (in centimeters) and r it is the distance between any point of the fluid and the axis of the tube. Let's consider a laminar blood flow in this experiment. We observe that $R = r$ if the speed $v = 0$. If $r = 0$ we have a maximum value for velocity (Batschelet, 1979).

Let's take the following example, configured numerically, for the sake of the best possible realism, let's take arterial blood with viscosity $\eta = 0{,}027\ poise$ flowing into an arterial capillary of length $l = 2cm$ and radius $R = 8 \cdot 10^{-3} cm$. At one end the pressure is greater than at the other, and this difference is $P = 4 \cdot 10^3\ dina/cm^2$. We have,). $v = \frac{4\cdot 10^3}{4\cdot 0{,}027\cdot 2}(64 \cdot 10^{-6} - r^2)$ from where $v = 1{,}185 - (1{,}85 \cdot 10^4)r^2$, in centimeters per second. Note that the graphical representation is given by a parabola segment and the maximum value of the velocity is $v(0) = 1{,}185 cm/s$ (Batschelet, 1979).

We note that in our example, we consider a laminar blood flow, i.e., where the fluid particles move parallel to the tube (model) and their velocity increases uniformly. Thus, to conclude, when a blood sample is collected, for example, for a complete blood count, it is the pressure difference when puncturing that allows the blood to be inserted into the syringe (Willianson; Snyder, 2016).

AN EXAMPLE IN BIOCHEMISTRY - PHARMACY

Along these lines, from what Rashevsky (1940) and Batschelet (1979) pointed out, we can bring an example, in pharmaceutical biochemistry, when producing a syrup well known in the drug market and composed of two active ingredients: Dexcloferniramin Maleate (MdD), an anti-allergy, and Betamethasone (Bt), a corticosteroid.

The syrup, sold in 120 ml capacity bottles, has the following values: 0.4 mg/ml of MdD and 0.05 mg/ml of Bt.

Thus, using the properties of proportionality and representation in mathematical language, we have the following relations,

$$0{,}4mg/ml \Rightarrow 4mg/10ml \Rightarrow 40mg/100ml$$
$$0{,}05mg/ml \Rightarrow 0{,}5mg/10ml \Rightarrow 5mg/100ml$$

Therefore, in proportional terms for a composition with 120ml of syrup, we have:

For Dexcloferniramine Maleate (MoD),

$$(MdD) \Rightarrow \frac{40}{100} = \frac{x}{120} \Rightarrow x = \frac{40 \cdot 120}{100}$$
$$x = 48mg/120ml$$

For betamethasone (Bt),

$$(Bt) \Rightarrow \frac{5}{100} = \frac{y}{120} \Rightarrow y = \frac{5 \cdot 120}{100}$$
$$y = 6mg/120ml$$

We have a total of 54 mg of active ingredient(s), in a 120ml bottle of syrup. Composed of MdD and Bt.

$$\frac{48}{54} = 0{,}89 = \frac{89}{100} = 89\%\ de\ MdD$$
$$\frac{6}{54} = 0{,}11 = \frac{11}{100} = 11\%\ de\ Bt$$

In percentage terms, in the syrup we have described, we have $89\%\ of\ MdD$ and $11\%\ of\ Bt$, which in addition to giving us a better view of the form of composition, can offer us more information about the cost of producing this drug.

We observed that in this composition the components are combined, however, they are independent, that is, the change in the amount of one does not directly interfere with the other. However, according to Gonçalves (2019, p. 10), it is essential to control the dosage, ranging from a minimum effective value to a maximum, non-toxic, acceptable value, considering the unit of measurement referred to.

AN EXAMPLE IN MEDICINE

In Medicine, we bring an example that translates the prescription of the dosage of a drug, specific for use in cases of neuropsychiatric diseases, such as Anguish, Anxiety, depression or even for Epilepsy. Known in the pharmacological industry as "Diazepam", generally, its dosage, prescribed by a doctor, must consider the usual composition, which is $5mg/ml$.

Thus, for a prescribed dose of the "remedy", in a case of Epilepsy, considering the value of $0{,}5mg/kg$, for a patient's body mass, it would be of $60kg 60 \cdot 0{,}5 = 30mg$, or even $\frac{30}{5} = 6ml$.

We note that this is considered a "high" dose and, therefore, should be applied according to medical prescription and under the supervision of nurses. Medications such as sedatives, anxiolytics, and antibiotics, even if in the calculations of their dosages use a simple mathematical tool, which involves proportionality properties, the administration and preparation of dosages must be very careful (Gonçalves, 2019).

Due to the need for these precautions, many of these drugs are produced and marketed with specific dosages, so that they can be administered at home, including the use of dispensers. However, in some cases, it is necessary to have a comprehensive reading of the prescribed values and to know the units of relative quantities.

AN EXAMPLE IN NURSING

As we have been discussing, the concepts of proportionality that involve ratios between quantities and the calculation of percentages, generally, with the use of the mathematical tool of the Rule of Three, are effective in the four previous examples, and are fundamental when applying drugs in the hospital environment.

Thus, according to Melo, Struchiner and Frant (2022), these elementary concepts of Mathematics should be an integral part of the training curriculum for nurses and nursing technicians, since these professionals effectively deal with the administration (application) of medications.

For Melo, Struchiner and Frant (2022, p. 2), due to the complexity in administration, mastering this mathematical knowledge should minimize the occurrence of errors, such as errors in dilution and/or dosages, which in Brazil has a high percentage of occurrence. Such failures in these processes can expose the patient to unnecessary risks or even the possibility of death.

Thus, one of the most effective actions occurs when determining the volume of the drug to be administered, in doses, when in liquid form, whether oral (syrups, suspensions or elixirs) or even injectable (serums).

For the dilution of drugs in intravenous application, as in the case of saline being the diluent and/or vehicle, the relationship between the amount of drug and the volume of serum should be observed. A simple calculation of proportions is often sufficient.

For our example, let's bring the administration of the two-gram intravenous antibiotic Ceftriaxone, which can be diluted in 40 ml of water for injections or saline solution (0.9% hate chloride). Generally, the administration is done by diluting the powder in a 50 ml serum and applied in a time of approximately 10 minutes.

Thus, we can determine the concentration of the active ingredient when this antibiotic is administered, diluted. Calculating the ratio and changing the units, we have the following result: $\frac{2g}{50ml} = \frac{2000mg}{50ml} = 40mg/ml$. Thus, the concentration of the drug in this example is $40mg/ml$.

As we have been discussing, for liquid dosage forms, when prescribed by a qualified professional, the care in administration involves the calculation of the volume to be determined by dosage.

A well-known solution in pharmacology is Amoxicillin, a beta-lactam antibiotic. Since the Amoxicillin solution does not necessarily need to be administered in a hospital environment, therefore, for administration at home, it is important to observe the concentration indicated on the package, which is usually $250mg/5ml$.

For example, an adult patient with approximately seventy kilograms of body mass should take the usual dose, usually prescribed, of $500mg$ every eight hours for seven days. As the vials of this medicine, in the pharmaceutical market, have measurements of $60ml, 90ml$ and $150ml$, using a simple rule of three we can determine the necessary amount of the medicine to be used, as follows: $\frac{1}{500} = \frac{21}{x} \rightarrow x = 10500mg$. Taking the equivalence that a dose of $500mg$ corresponds to that $10ml$ of the solution, we will use, precisely, $\frac{10}{500} = \frac{y}{10500} \rightarrow y = 210ml$.

A result, which allows the companion (technician, caregiver, guardian, relative, friend), or even the patient himself, to acquire the necessary amount of the medication. In this case, it would be a bottle of $150ml$ and another of $60ml$, of the drug. Such action ensures correct dosing and possible reduction of waste. In addition, it can provide some cost savings.

AN EXAMPLE IN NUTRITION

To conclude, we bring an important example, aiming to ensure good nutrition, based on a balanced diet and considering the Brazilian Table of Food Composition (Tabela..., 2011).

It is worth mentioning that for a healthy and balanced diet it ensures a good functioning of the body. Thus, a balanced and sufficient diet should contain the following nutrients in its composition: proteins, carbohydrates, good fats, vitamins and fiber. In addition to good hydration (Table..., 2011).

In this way, a person with about 70 kilograms of body mass, in addition to drinking about two and a half liters of water, needs a daily diet of 1950 to 2400 calories. If we consider three main meals, we have an average of 650 to 800 calories per meal.

Let's consider, as an example, the amount of protein to be consumed at lunch. According to the Brazilian table, an individual should $70kg$ consume protein at lunch $50{,}2g$, in terms of beef, it is equivalent to $150g$. If we consider a dish of $400g$, we have $250g$ about for carbohydrates (rice, pasta, potatoes) and vitamins and minerals (salads). According to the Brazilian table we should have 40% carbohydrates in the meal, that is $160g$. About $90\ g$ left for salads (source of vitamins). (Table..., 2011).

Thus, in a dish made for a balanced lunch of a healthy individual, that is, without dietary restrictions, we must have 150 grams of beef, 160 grams of rice and 90 grams of salads, in other words 37.5% of protein source, 40% of carbohydrate source and 22.5% of vitamin and mineral salt sources,

As we have been presenting, our dish will have $50{,}2g$ proteins and $45g$ carbohydrates to be absorbed by the body. We observed that the vitamins present in salads, for example, in a raw green salad, are measured in a micro unit, being important in the diet, but considered in a separate count, in nutritional terms.

In the same way, our dish, as we have described, has about 650 calories of the form $650kcal = 379kcal + 208kcal + 63kcal$, about of 81% the designed. Multiplying by three we would have a diet of $1950kcal$. An acceptable value, which can be improved, generally, by considering adding or reducing 5% the expected amount of calories to the diet. For the values obtained, we considered the proportionality of calories related to a 100-gram portion of food, in this case, beef, rice and green salad, respectively (Table..., 2011).

Malnourished individuals, diabetics or even athletes should be considered particular cases when establishing a diet, where new relationships will be established between the components considering these initial variables.

CONSIDERATIONS

Our arguments allow us to consider that the interactive relationship between Mathematics and Biosciences, as we have exemplified, can occur from elementary applications of mathematical techniques, such as the use of a simple (or compound) rule of three, in its arithmetic or functional aspects, to the use of more advanced concepts that comprise modeling that involves concepts of Differential and Integral calculus. such as the use of partial derivatives in modeling the scattering of molecules of a substance in a solubility medium.

We consider reporting that in our initial examples, however, what we present are calculations of procedures and not of functioning, except in example 3.2, performed in actions in these areas of the biosciences. Thus, as we initially discussed here, we present only elementary calculations, especially those related to the concept of proportionality, in its various guises.

We infer that our exemplification seeking the interaction between problems present in the Biosciences and the appropriate mathematical tool should allow undergraduate students in areas of Biosciences and/or Mathematics a better use and greater clarification when solving problems, when confronted in their courses, or even in future actions of their training.

We design, to deal with more problems of operation, where the functional calculations, as the nomenclature itself indicates, use the important mathematical concept of Function and where the properties and relations involved in the processes, refer to a calculation in the direction of the continuum. Thus, we will have a passage from the procedural to the functional aspects, which translates into an analogy from discrete (arithmetic-algebraic) to continuous (analytical) calculus.

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