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INTERRUPTED CASE STUDY: HOT POTATO

Authors: Ricardo Matos and Salete Linhares Queiroz

Part I – Dangerous Portion

Fábio is a Chemistry student who chose to finish his course with an emphasis on food, and this semester, his favorite subject, Food Chemistry, is being taught by Professor Carmen. In today's class, the class discussed the concept of browning food and the Maillard reaction. Triggered by high temperatures, the reaction occurs between the carbonyl group of reducing sugars and the amino group of proteins, peptides or amino acids, obtaining products that give flavor, odor and, above all, color to food. The golden appearance of foods after roasting or frying, such as grilled bread, french fries, and well-done meat, is due to the Maillard reaction. However, one of its by-products is acrylamide, a risk factor with carcinogenic potential for humans. The subject aroused the curiosity of the whole room.

After class, Fábio meets his mother, Maria, and his younger sister, Ana, for lunch at the mall. Once there, they sit down in front of one of the fast-food chains, *Emecê Donais*, and Ana says:

- I want French fries, Mommy!

Fábio promptly interrupts his sister's request and warns his mother.

- This girl eats a lot of French fries. This is not good!

- But you, when you were little, also only lived eating potatoes. Let the girl eat, no problem.

- Mom, I just had a class on this. An excess of this type of food is harmful.

Fábio explains some of what he learned in Professor Carmen's class earlier.

- Wow, now I'm worried, Fábio! But, do these French fries from *Emecê Donais* also have "crila"? What's the name again?

- It's acrylamide. And, I don't know, it depends on how they prepare the chips. I think I'll send an e-mail to the fast-food chain later. After all, if I do, I can help solve this problem.

Fábio contacted the fast-food chain, which informed him that the potatoes were fried in canola oil for approximately three minutes, with an initial temperature of 160 °C and a final temperature of 180 °C. Fábio also received the data presented in Table 1. Finally, *Emecê Donais* informed him that they do not have data about the acrylamide concentration in their potatoes.

Table 1. Types of potatoes and storage times and storage temperature used in *Emecê Donais'* French fries.

Potato Varieties	Type A: low level of asparagine Type B: high level of asparagine Type C: low level of reducing sugars
Storage Time	6, 12 and 18 weeks
Storage Temperature	4 °C

Given the data in Table 1, Fábio is still uncertain about the presence and amount of acrylamide in the potatoes from *Emecê Donais*.

Classroom activities

1. What do you already know about the case study's problem? Have you come across similar situations in your reading? Could you share any personal experiences related to the subject discussed in the case study?

2. Formulate hypotheses about factors that could influence the formation of acrylamide in *Emecê Donais*' French fries and explain why these factors are significant.

3. Propose a research question for your group to explore.

Homework activities

1. Search and choose a review article that pertains to the subject discussed in the case.

2. What information do you think would be valuable for solving the case, both within the field of science and from other knowledge domains?

3. Is there any additional information about the context of the case that could help the group create more precise hypotheses and a clearer research question? If so, indicate what they are.

Part II – Passing the Potato

After his conversation with his mother about acrylamide, Fábio decided to turn to Professor Carmem to ask for help.

- Hey, Professor Carmem. After the last class, I went with my family to the mall. My sister wanted to eat fries from *Emecê Donais*, and I ended up commenting on the presence of acrylamide in the fries.

- OK. What's your concern?

- I contacted the restaurant chain, and they don't have acrylamide concentration data in French fries. They also sent me some information about what types of potatoes are used and how they are stored and fried. I would like to know more about quantifying acrylamide and whether reducing its formation in these potatoes is possible.

- This would be a subject for our next class, but I can give you a little advance. Acrylamide can be determined by liquid chromatography coupled with mass spectrometry (LC-MS). And the decrease in its production can occur due to changes in some factors, such as temperature, pH, storage time, and concentration of precursors of the Maillard reaction, among others.

- It's good to know that this problem can have a solution!

- That gave me an idea! Are you interested in undergraduate research? I think we can establish a partnership with *Emecê Donais* and work on mitigating the acrylamide concentration in their potatoes.

- I would love to!

To start the work, Professor Carmen asked Fábio to collect samples of French fries produced by the *Emecê Donais* snack bars in different types and storage times at 4 °C, according to the data in Table 1, provided in Part I of the case.

Table 1. Types of potatoes and storage times and storage temperature used in *Emecê Donais'* French fries.

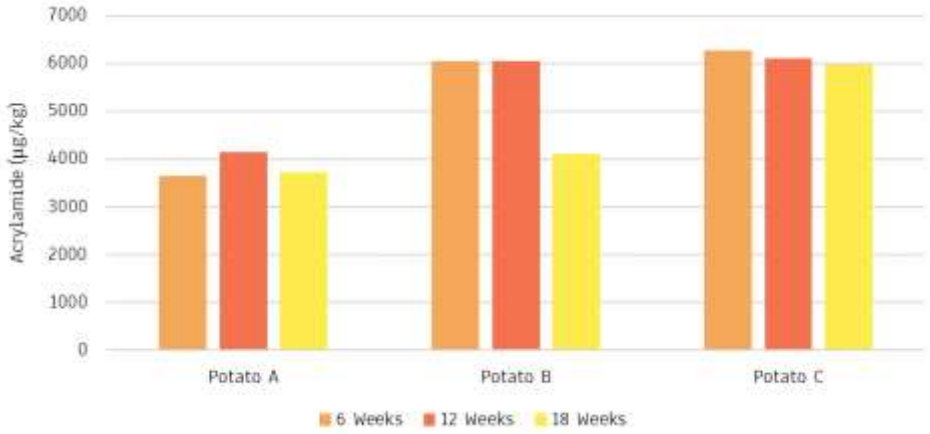
Potato Varieties	Type A: low level of asparagine Type B: high level of asparagine Type C: low level of reducing sugars
Storage Time	6, 12 and 18 weeks
Storage Temperature	4 °C

With the samples in hand, Fábio had the opportunity to analyze them. For 2 g of French fries (1.5 mm thick) macerated in a mortar, extraction was performed with 40 mL of ultrapure water, adding 40 µg of deuterated acrylamide (internal standard). After centrifugation, samples were

prepared by solid phase extraction (SPE) and quantified with LC-MS.

From these experiments, Fábio obtained the results shown in Figure 1 and began to ponder ways to mitigate the acrylamide in French fries.

Figure 1. Acrylamide content in *Emecê Donais*' French fries prepared from potatoes stored for varying durations (6, 12 and 18 weeks) at 4°C. Potatoes A: low level of asparagine; Potatoes B: high level of asparagine; Potatoes C: low level of reducing sugars food.



Classroom activities

1. How does the data collected by Fábio assist the group in addressing the question posed in Part I? Can the hypotheses be supported or refuted?

2. Analyze the data and elaborate statements about the quality of *Emecê Donais*' French fries.

Homework activities

1. Part of the group's task is to aid Fábio in reducing the acrylamide concentration in *Emecê Donais*' French fries. Identify two strategies for minimizing acrylamide formation and present arguments in favor of the strategy considered most suitable by the group.

2. Which key societal groups are impacted by the occurrence of acrylamide in food? Support your answer by researching and presenting data concerning eating habits within the population and the significance of the Maillard reaction in gastronomy.

Part III –Washing the Potatoes

Based on the results reported in Parts I and II of the case, Fábio decides to use an experimental procedure called bleaching as an alternative to mitigate the acrylamide concentration in the French fries at *Emecê Donais*, and this is justified for Professor Carmen.

- Professor, I've been researching and believe bleaching is an interesting technique to mitigate acrylamide formation.

- Interesting, but explain to me how you reached that conclusion.

- Bleaching is an economically viable technique since it works as a "thermal shock", which does not require sophisticated equipment or demand a long time. The snack bar needs to put the potatoes in boiling water for no more than 3 minutes; then, the potatoes are immersed in a cold water bath for 2 minutes. The technique aims to inactivate the enzymes that cause enzymatic browning and reduce the levels of reducing sugars.

- But is the advantage only economic, or can we say that nutritionally it is pretty viable?

- Professor, from what I understand, nutritionally, the technique reduces the formation of acrylamide and helps to maintain the color, aroma and flavor of the vegetable so the food can be frozen and does not lose its characteristics.

- Well done, Fabio. You've done excellent research, that's right. So, get to work.

Fábio then followed a protocol that Professor Carmen indicated and developed the following steps: he took 100 g of potato slices with a thickness of 1.5 mm and a length between 5 cm and 8 cm, and these were immersed in a bath of 10 L of water heated to 80 ± 1.0 °C for 3 min. Soon after, the potatoes were immersed in ice water for two minutes and dried. Then, 90 g of potatoes were fried in four liters of canola oil for three min, using laboratory-scale equipment, conditioned to imitate an industrial process. The initial temperature of the oil was 180 °C, and the final temperature was 160 °C. The moisture content of French fries ranged from 1.8% to 2.0%. After being fried, the potatoes were stored at 18 °C until acrylamide quantification, according to the same experimental procedure described above (SPE/LC-MS).

Fábio carried out the bleaching for the various potato species and storage conditions described above. Furthermore, all experiments were performed in duplicate.

Classroom activities

1. From the debate that took place between groups that studied the same case study: a) What relationships (similarities, differences, curiosities, among others) are possible to establish between Fábio's proposal and the one chosen by your group for mitigating acrylamide in potatoes fries from

Emecê Donais? b) What criteria did he use that were not contemplated by your group and vice versa? c) Given what was discussed in the debate, do you think it is appropriate to change the proposed procedure? Argue in favor of the answers.

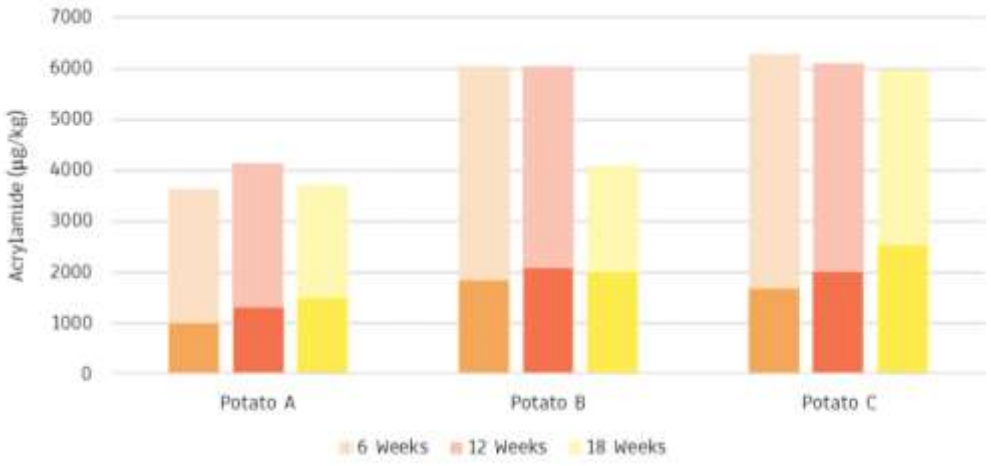
Homework activities

1. Considering the question posed by your group in Part I of the case study, what trends can be predicted for acrylamide analysis after bleaching? Argue in favor of the answers.

Part IV – French Fries, 1, 2, 3!

Based on the experimental procedure indicated in Part III of the case study, briefly described below, Fábio found the results shown in Figure 1: blanching for different potato species and storage conditions. Furthermore, all experiments were performed in duplicate.

Figure 1. Acrylamide content in *Emecê Donais*' French fries prepared from potatoes stored for varying duration (6, 12 and 18 weeks) at 4°C, depicted by both untreated (light shades) and bleached (dark shades) samples. Potatoes A: low level of asparagine; Potatoes B: high level of asparagine; Potatoes C: low level of reducing sugars food.



For a better evaluation of the data presented in Figure 1, Fábio searches for international parameters of maximum permitted concentrations of acrylamide in food since Brazilian legislation does not have such reference values.

Table 1 shows the reference values he found determined by the European Union to evaluate the acrylamide concentration.

Table 1. Reference levels for the presence of acrylamide in some potato-related foodstuffs.

Foodstuff	Reference Level (µg/kg)
French fries (ready to eat)	500
French fries made with fresh potatoes and potato mass	750
Other potato products based on potato mass	750

Source: European Union (2017)

[1]. Jornal Oficial da União Europeia, v. 304, p. 24-44, 2017. https://eur-lex.europa.eu/oj/direct-access.html?locale=pt

In addition to the information obtained so far, Fábio carried out some more research on the formation of acrylamide in French fries and discovered the following: In potatoes, acrylamide is formed through the Maillard reaction between reducing sugars and the amino acid asparagine (its

precursors) during thermal processing. At the same time, compounds are formed that give food color, flavor and aroma. Acrylamide precursors occur naturally in potatoes, varying according to species and storage conditions. A potato is not a static entity; during its storage, starch is converted into carbohydrates for respiration or germination. Sugars begin to accumulate when their production exceeds their use. When potato tubers are stored at low temperatures, they accumulate sugars through a "cold-induced sweetening" process in plant tissue. The duration of the dormancy period is related to genetic and environmental factors; however, its extension can be carried out from the storage of potatoes at low temperatures.

Classroom activities

1. Establish relationships between the data presented in Figure 1 and then elaborate statements that can be provided to both Fábio and Professor Carmem to help them in their purpose, mentioned in Part II of the case: I think we can close a partnership with *Emecê Donais* and work with the idea of mitigating the acrylamide concentration in their potatoes. The greater the number of statements and recommendations, with due justification, the more satisfactory the group's response will be.

2. Compare the acrylamide concentration values obtained by Fábio, illustrated in Figure 1, with the maximum concentrations allowed in the legislation, mentioned in Table 1, and present conclusions about it.

3. What can you say about the trends you explained in the exercise in Part III for analyzing acrylamide after bleaching? Justify the answer.

Homework activities

1. Construct and complete the summary table below, which summarizes the actions and results obtained in all stages of the study.

Problem situation: This item presents the existing problem in the case. That is, it is necessary to briefly describe the narrative and the problem that afflicts the main characters.
Problem: This item presents the problem/issue to be resolved. As every problem must start with a question, the statement must be formulated in such a way as to end with a question mark.
Hypotheses: This item presents the hypotheses formulated to solve the problem. Hypotheses are assumptions issued as preliminary answers to the problem at hand. The same problem can have many hypotheses, which are possible solutions for its resolution. In this perspective, indicate your basic hypothesis, which is the explanation you have chosen as being the main one for the proposed problem. Then, indicate the secondary hypotheses, which are complementary statements and/or other possible answers to the problem. These can cover in detail what the basic hypothesis states in general and aspects not specified in the basic hypothesis.
Mitigation planning: This item describes the steps and resources you used to propose a mitigation route to evaluate your hypotheses. Add pictures to make your answers more straightforward. Finally, conclude the answer by pointing out whether you changed the initial planning when confronted with the planning presented by the case characters or colleagues in Part III (Debate).

Data: This item presents empirical data or data from other sources (including data provided during classes) with which you worked that allowed you to evaluate your hypotheses and the range of responses to the problem. Add pictures to make the answer more straightforward.
Conclusions: This item presents the final conclusion of the group regarding the problem explained in the case and all the other conclusions reached during the resolution of the case.
Justifications: This item presents the justifications that support the explicit final conclusion and those that support the partial conclusions mentioned above. Try to gather the largest number of justifications and present them so that they are supported by available data (in this case, add images to make the answer more straightforward) and knowledge reported in the literature.