

Nadji BELKHEIRI^{1*} and Mohamed Nadjib REBIZI¹

CHEMISTRY IN THE KITCHEN: PRACTICAL INSIGHTS FOR HIGH SCHOOL STUDENTS

Abstract: Chemistry plays a crucial role in everyday life, particularly in the kitchen, where its principles can enhance problem-solving skills and informed decision-making. This study aims to evaluate high school students' understanding of applied chemistry in culinary contexts. A questionnaire was administered to 76 students, revealing that 42.6 % provided correct answers regarding the application of chemistry in the kitchen. The methodology involved analysing students' responses to assess their awareness and appreciation of chemistry's practical value. The findings suggest that promoting the application of chemistry principles not only fosters responsible citizenship but also optimises daily life benefits. Future research should explore effective strategies to enhance students' engagement with chemistry in real-world contexts.

Keywords: kitchen, chemistry, learning, applied science, education

Introduction

Chemistry, as a foundational science, significantly affects numerous aspects of daily life, from food consumption to personal care products. Enhancing our knowledge of chemistry's practical applications offers substantial potential for boosting overall well-being and gaining deeper insights into the world around us [1]. Studying chemistry enables us to comprehend the composition, properties, and transformations of matter, as well as the interplay between substances and the critical role of energy in these reactions. Utilising this knowledge, we can apply chemistry principles to optimise daily activities, boost efficiency, and enhance comfort [2, 3]. By incorporating chemistry principles into everyday life, we can refine cooking techniques, extend food preservation, effectively sanitise surroundings, and support health and well-being. Chemistry forms the basis for pharmaceutical drug development, driving medical treatment advancements and facilitating the use of natural remedies in daily life [4, 5].

Exploring chemistry's practical and tangible aspects reveals limitless possibilities that strengthen our scientific concept understanding and empower us to make informed decisions about the products we use and consume. As we navigate various domains where chemistry plays a pivotal role in daily existence, we unravel its mysterious nature and develop a profound appreciation for its impact. In the following sections, we will discuss specific areas that underscore chemistry's significance.

¹ Organic Chemistry and Natural Substances Laboratory, Faculty of Exact Sciences and Computer Science, University of Djelfa, PO Box 3117, Djelfa 17000, Algeria, email: belkheirinadji@yahoo.fr, ORCID: NB 0000-0002-5499-6216

* Corresponding author: belkheirinadji@yahoo.fr

From cooking to health and remedies

Chemistry is a science that has a high relevance to our daily lives as it involves the study of matter, its properties, and the changes that occur in it. This knowledge enables us to understand materials and manipulate them.

In the kitchen, for example, understanding chemical processes helps us in cooking and preparing delicious and nutritious meals. Maillard reaction enhances the flavour in grilled meats, while emulsifiers improve the texture of salad dressings [6]. In the culinary world, understanding chemistry can significantly improve cooking methods and techniques. For example, mastering the balance of acids and bases contributes to perfectly cooked meats and vegetables [7].

Further, acquiring knowledge on emulsifying fats and oils can lead to the production of delightful sauces and dressings [8]. Moreover, chemistry significantly contributes to addressing health concerns, as understanding the chemical makeup of over-the-counter medications helps users make informed choices for symptom relief and well-being.

In addition, chemistry plays a vital role in first aid and home remedies. For instance, applying hydrogen peroxide (H_2O_2) on wounds aids in preventing infection, while using baking soda (NaHCO_3) to neutralise symptoms of acid reflux provides comfort and relief [9, 10].

Transforming ingredients into gastronomic delights

The dynamic kitchen setting highlights chemistry's pivotal role, as ingredients undergo various chemical reactions to transform into delectable and nutritious meals. Grasping food chemistry principles can significantly improve cooking techniques and elevate the dining experience to new heights.

A fundamental concept in food chemistry is understanding the Maillard reaction (Fig. 1), which arises when proteins and carbohydrates combine, forming a brown crust and delightful flavour on meats and baked goods. By skilfully managing temperature and cooking time, chefs can strike the ideal balance between a brown crust and tenderness in their dishes [11].

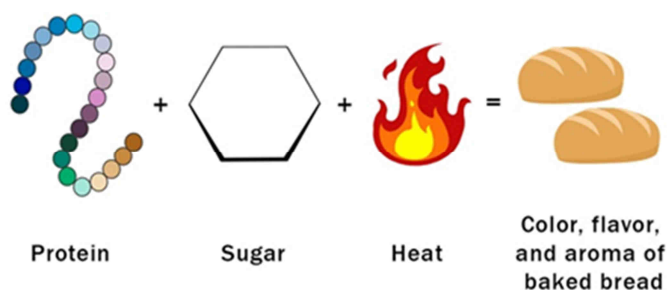


Fig. 1. Maillard reaction in food chemistry

Food chemistry highlights the importance of acidity in the culinary world. Acidic ingredients like vinegar or citrus juice serve various purposes, such as:

- balancing flavours
- tenderising meat
- contributing to food preservation.

Conversely, basic components, such as baking soda, facilitate the leavening of baked goods by generating carbon dioxide gas [12].

In the culinary realm, chemistry plays a significant role in various aspects. For instance, the understanding of dispersion principles aids in the preparation of:

- creamy salad dressings
- smooth sauces
- stable mayonnaise

Emulsifiers, such as egg yolks or mustard, stabilise the mixture by enveloping fat droplets in a protective layer [13].

Moreover, chemical knowledge enhances food preservation techniques, including canning, pickling, and fermentation. This understanding extends the shelf life of perishable items like fruits, vegetables, and others, enabling individuals to savour seasonal flavours year-round [14]. Applying food chemistry principles empowers individuals to elevate their cooking skills, explore flavours, and create not only delicious meals but also display their comprehension of the scientific processes taking place in the kitchen.

The science of food chemistry

The key to unlocking the potential of raw ingredients in the cooking and crafting of gourmet foods lies in understanding food chemistry. By exploring the scientific principles governing kitchen reactions, chefs can refine their techniques and create unique culinary creations.

A fundamental concept in food chemistry is the "Maillard reaction", which enhances the appealing sweet and savoury aroma of flawlessly grilled meat or rich, golden-brown freshly baked bread.

Another vital aspect of food chemistry is understanding acidity. Acidic ingredients, such as vinegar or citrus juice, perform multiple functions:

- balancing flavours
- tenderising meat [15]
- enhancing salad flavours with lemon juice's brightness
- serving as a natural preservative for pickled vegetables [16]

Achieving the right acidity balance in a dish can elevate it from an ordinary meal to an explosion of vibrant flavours, demonstrating the importance of food chemistry in culinary creations.

By harnessing the principles of food chemistry, individuals can take their cooking skills to new heights. Experimenting with flavours, understanding the science behind cooking techniques, and applying chemical principles can lead to remarkable meals that display the culinary artist's understanding of the scientific processes occurring in the kitchen.

Using chemistry to enhance food preservation

Food preservation, essential for maintaining freshness and quality, benefits significantly from chemistry's role in improving and extending the shelf life of various food products. Preservation techniques can prevent spoilage, bacterial growth, and oxidation by utilising active chemicals, materials, and methods.

Preservative additives, a widely used chemical approach, inhibit microorganism growth, including bacteria, yeast, and mould. Common preservatives include salt, sugar, vinegar, and citric acid [17].

These chemicals work by creating an unhealthy environment for microorganisms to thrive and prevent their growth and food contamination.

Another use of chemicals in food preservation is the use of antioxidants such as vitamin C or tocopherol (Fig. 2). They act as scavengers of free radicals, preventing or slowing down the oxidation process that leads to the spoilage of food products, resulting in quality spoilage and undesirable taste and odour [18]. This process helps preserve food colour, flavour and texture, especially in the presence of perishable substances such as fats and oils.

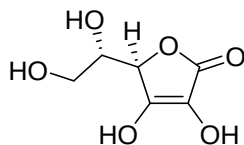


Fig. 2. Molecular structure of vitamin C

In addition, packaging materials and methods using chemical principles can further enhance food storage. Oxygen absorbers or desiccants are commonly used in packaging to control moisture or oxygen levels, reduce microbial growth and extend the shelf life of consumer products another method of food preservation is vacuum sealing, which works by removing oxygen from packaging materials, reducing impurity growth and improving food quality [19].

It is noteworthy that several previous studies have addressed the role of the kitchen in enhancing chemical concepts and their applications among high school students [20, 21]. These studies have demonstrated a significant improvement in students' practical science skills, as kitchen chemistry activities were considered enjoyable and meaningful by the learners.

Practical activities in the kitchen serve as an effective means of transferring chemical knowledge from theory to application, allowing students to see the connections between what they learn in the classroom and its practical applications in their daily lives.

To emphasise the significance of the kitchen in direct educational processes, I would like to present two examples from different studies. Recent studies have indicated that while remote education during the COVID-19 pandemic may offer some advantages, it has had a detrimental impact on students' ability to grasp concepts and develop educational skills. This is particularly evident when comparing online learning to direct instruction in a kitchen or healthcare setting, where students can interact with materials and experience the reactions that occur between them. The hands-on nature of these environments fosters a deeper understanding of chemical phenomena, which is often lost in a virtual classroom [22].

Additionally, another study explored the use of microwave technology to facilitate a chemical reaction between aniline derivatives and formic acid. This research highlighted how this technology, commonly utilised in our daily kitchens, can enhance the efficiency of chemical reactions. By examining the practical applications of such techniques, we can better appreciate their relevance in both educational contexts and everyday life [23].

Through our study, we aim to explore the extent to which high school students in certain secondary schools in the Djelfa region of Algeria connect the chemical knowledge

they acquire in the classroom with its practical applications, particularly in the context of daily activities within the kitchen.

Methodology

Data were collected from April 15, 2024, to May 12, 2024, using a questionnaire to assess students' understanding of applied chemistry in the kitchen. Students were selected from two different high schools in Djelfa: November 1 High School and Ibn Khaldun High School. A random sample of 76 students was used, consisting of 40 males and 36 females. The participants' ages ranged from 15 to 18 years. The primary data collection tool was a well-structured questionnaire designed to assess students' knowledge and comprehension of chemistry in everyday situations, particularly in the kitchen. Each item in the questionnaire offered four possible answer options. The administration of the questionnaire encouraged student participation in a quiz format, fostering engagement and promoting critical thinking regarding the underlying scientific principles present in their culinary experiences. Subsequent data analysis involved calculating the percentage of correct responses for each question, summarised in a table to provide a clear overview of student performance and facilitate the identification of trends in their understanding of chemical concepts. The findings were intended to inform educators, administrators, and policymakers about areas where students might require additional support, thereby enhancing chemistry education by pinpointing specific concepts needing further clarification and training. Overall, this methodology integrated a structured questionnaire with a focus on real-world applications of chemistry, enabling a comprehensive assessment of students' knowledge and understanding in a relatable context.

Questionnaire

Do you know the hidden science in your kitchen? All high school students are invited to participate in our thought-provoking quiz that aims to open up your understanding of the relationship between chemistry and cooking (Table 1). Get ready to embrace your inner chef and journey into the culinary wonders of chemistry!

Table 1

A questionnaire on secondary school students' understanding of kitchen chemistry

No.	Question
1	What is the primary function of baking soda in baking? a) Leavening agent for rising dough b) Enhancer of flavour and stability c) Deodoriser for neutralising odours d) Colour preservation
2	Which cooking process involves the caramelisation of sugars? a) Sautéing b) Braising c) Roasting d) Broiling
3	What causes the Maillard reaction, resulting in the savoury flavour and brown colour of cooked meat? a) Interaction between proteins and carbohydrates b) Thermal analysis and decomposition c) Sodium chloride breakdown d) Oxidation of fat molecules
4	Which of the following chemical reactions is necessary for bread dough to rise? a) Reduction b) Hydrolysis c) Fermentation d) Polymerisation
5	What is the role of emulsifiers in salad dressings? a) Enhance taste and colour b) Bind water and oil together c) Act as a preservative d) Raise pH levels
6	What gas is produced during the process of fermentation in bread making? a) Carbon dioxide b) Oxygen c) Hydrogen d) Nitrogen

No.	Question
7	Which commonly used spice is known for its antioxidant properties and natural food preservative qualities? a) Turmeric b) Paprika c) Cinnamon d) Basil
8	What chemical reaction occurs when yeast is added to bread dough? a) Acid-base neutralisation b) Redox reaction c) Combustion d) Fermentation
9	Which chemical compound is responsible for the spicy sensation in chili peppers? a) Caprylic acid b) Capsaicin c) Caffeine d) Citric acid
10	Which cooking method results in the denaturation of proteins? a) Boiling b) Steaming c) Grilling d) Poaching

By analysing results, we can design instructional and curricular efforts to better meet students' needs. In addition, by displaying the results in a table, we provided a clear picture of student performance, making it easier to identify trends. This information can be used to inform faculty, administrators, and policy makers of areas where students may need additional support or guidance, enabling them to make data-driven decisions about chemistry education and curriculum design.

Overall, the survey was tool for assessing students' knowledge and understanding of chemistry in an everyday setting.

Results and discussion

Figure 3 summarises the number and percentage of correct answers we obtained from the high school students to whom we presented the questionnaire.

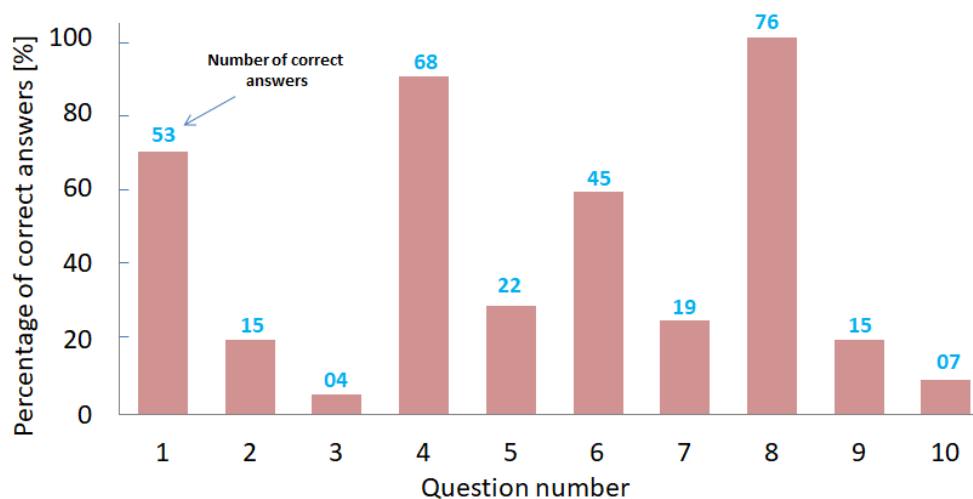


Fig. 3. Number and percentage of correct answers

The chart reflects a variation in the percentages of correct answers to a survey on the relationship between cooking and chemistry. The results indicate that some questions were easier, leading to higher percentages of correct responses, while others proved more challenging, resulting in lower percentages. This variation highlights the differences in understanding and knowledge among students regarding the topics presented.

Based on the results of the previous table, the students' answers can be re-divided into four sections according to the following Table 2.

Table 2

Analysis the results of the questionnaire

Analysis	Results
It appears that students vary in their level of knowledge in chemistry related to cooking	Varied level of chemical knowledge in the kitchen
There is a difference in the percentages of correct answers among students for different questions	Differences in the rate of correct answers
This indicates the difficulty students face in understanding and answering questions related to the concepts of chemical equilibrium and chemical changes in cooking. It also reflects difficulty in identifying the compound responsible for a specific property in a substance	Questions 3, 9, and 10: Misunderstood concepts
It shows that students have a good understanding of the concept of fermentation and its impact on chemical processes in the context of cooking	Questions 4 and 8: Understood concepts

Table 2 results indicate a variation in students' level of chemical knowledge in the kitchen. Some students demonstrate a better understanding of chemical concepts, while others may require further training and learning. Additionally, the results illustrate differences in the percentages of correct answers among different questions, indicating variations in students' comprehension of the presented chemical concepts. Furthermore, students appear to struggle with understanding and applying the concepts of chemical equilibrium and chemical changes in cooking, as well as identifying the compound responsible for a specific property in a substance. These concepts require further clarification and training. On the other hand, students seem to have a good understanding of the concept of fermentation and its impact on chemical processes in cooking. Based on these results, it is important to enhance chemistry education in the context of cooking for students by providing additional explanations for the more challenging chemical concepts and training them in material analysis and identifying factors influencing their chemical properties. Additionally, leveraging the well-understood concepts among students can serve as a foundation for understanding more complex concepts.

Furthermore, the study emphasised the effectiveness of hands-on activities in the kitchen as a valuable means of promoting experiential learning. These activities not only provide students with opportunities to apply theoretical knowledge but also help them grasp the connections between chemical phenomena and the reactions occurring during cooking. Compared to other studies conducted in the United States and South Africa regarding the kitchen-chemistry relationship, it is evident that all share a common emphasis on the necessity of harnessing the enjoyment derived from working with materials in the kitchen alongside the educational processes occurring in the classroom, while also clarifying that this knowledge extends beyond the school walls [20, 21].

Conclusion

The central role of chemistry in our daily lives is undeniable. It permeates our daily activities, from culinary adventures to personal care, housekeeping, and health concerns.

The article provides an in-depth analysis of the educational impact of chemistry in the home environment, indicating that chemistry is not merely an academic subject; rather, it

plays a crucial role in enhancing critical thinking and problem-solving skills among students. The study, which involved 76 students, revealed that 42.6 % of participants were able to provide correct answers regarding chemical applications in the kitchen, reflecting a diversity of awareness and chemical knowledge among them.

When analysing performance, a notable disparity in students' understanding of chemical concepts was observed. For instance, the results showed that the percentage of correct answers for the fourth question, related to fermentation reactions, was 89.47 %, indicating a good understanding of fermentation processes and their role in cooking. In contrast, the percentage of correct answers for the third question, concerning the Maillard reaction, was alarmingly low at 5.26 %, highlighting an urgent need for educational strategies that focus on these more complex concepts.

In light of these findings, the study concludes that integrating chemistry into everyday kitchen practices enhances students' understanding of fundamental concepts and contributes to improving the quality of education in this field. Therefore, utilising chemistry in the kitchen represents a powerful and effective educational tool for engaging students and enhancing their scientific knowledge.

Acknowledgements

The author would like to thank the Department of Organic Chemistry, Laboratoire de Chimie Organique et des Substances Naturelles, Université Ziane Achour, Djelfa, Algeria for funding.

References

- [1] Yamini S. Chemistry: The science behind common products. *Procedure International Journal of Science and Technology*. 2024;1(3):52-7. DOI: 10.62796/pijst.2024v1i307.
- [2] Vrvic MM, Miletic S, Lugonja N. How will chemistry help solve world hunger? *Proceedings*. 2023;91(1):235. DOI: 10.3390/proceedings2023091235.
- [3] Roy S. Chemistry in our daily life: Preliminary information. *Int J Home Sci*. 2016;2(3):361-6. <https://www.homesciencejournal.com/archives/2016/vol2issue3/PartF/2-3-26.pdf>.
- [4] Schlögl R. The role of chemistry in the energy challenge. *Chem Sust Energy Materials*. 2010;3(2):209-22. DOI: 10.1002/cssc.200900183.
- [5] Payal R, Saba N. Green chemistry and technology for sustainable development. *Int J Sci Res Arch*. 2023;8(2):161-5. DOI: 10.30574/ijrsra.2023.8.2.0225.
- [6] Yuxin G. Mechanism and examples of Maillard reaction. *Int J Food Sci Agric*. 2024;8(1):54-8. DOI: 10.26855/ijfsa.2024.03.008.
- [7] Brezonik PL, Arnold WA. C7 Principles of acid-base equilibria. *Water Chem*. 2022;241-70. DOI: 10.1093/oso/9780197604700.003.0007.
- [8] Bai L, Huan S, Rojas OJ, McClements DJ. Recent innovations in emulsion science and technology for food applications. *J Agric Food Chem*. 2021;69:8944-63. DOI: 10.1021/acs.jafc.1c01877.
- [9] McDonnell G. The use of hydrogen peroxide for disinfection and sterilization applications. *Patai's Chem Functional Groups*. 2014;1-34. DOI: 10.1002/9780470682531.PAT0885.
- [10] Urakov A. Creation of "necessary" mixtures of baking soda, hydrogen peroxide and warm water as a strategy for modernization bleaching cleaners of ceramic. *építőanyag - J Silicate Based Composite Materials*. 2020;72(1):30-5. DOI: 10.14382/EPITOANYAG-JSBCM.2020.6.
- [11] ALjahdali N, Carbonero F. Impact of Maillard reaction products on nutrition and health: Current knowledge and need to understand their fate in the human digestive system. *Crit Rev Food Sci Nutr*. 2019;59(3):474-87. DOI: 10.1080/10408398.2017.1378865.
- [12] Palav TS. Chemistry of Cake Manufacturing. *Encyclopedia of Food Grains (Second Ed.)*. 2016;3:367-74. DOI: 10.1016/B978-0-12-394437-5.00156-X.
- [13] Kiosseoglou V, Sherman P. Influence of egg yolk lipoproteins on the rheology and stability of O/W emulsions and mayonnaise. *J Texture Stud*. 2007;14(4):397-417. DOI: 10.1111/j.1745-4603.1983.tb00358.x.

-
- [14] Sudhanshu SB, Aly FE, Riadh H, Awanish K. Traditionally fermented pickles: How the microbial diversity associated with their nutritional and health benefits? *J Functional Foods*. 2020;70:103971. DOI: 10.1016/j.jff.2020.103971.
- [15] Burke RM, Monahan FJ. The tenderisation of shin beef using a citrus juice marinade. *Meat Sci*. 2003;63(2):161-8. DOI: 10.1016/S0309-1740(02)00062-1.
- [16] Yen PPL, Kitts, DD, Singh AP. Natural acidification with low-pH fruits and incorporation of essential oil constituents for organic preservation of unpasteurized juices. *J Food Sci*. 2018;83(8):2039-46. DOI: 10.1111/1750-3841.14277.
- [17] Kumari PVK, Akhila S, Srinivasa RY, Devi B.R. Alternative to artificial preservatives. *Sys Rev Pharm*. 2019;10(1):99-102. DOI: 10.5530/srp.2019.1.17.
- [18] Choe E, Min DB. Mechanisms of antioxidants in the oxidation of foods. *Comprehensive Rev Food Sci Food Safety (CRFSFS)*. 2009;8(4):345-58. DOI: 10.1111/j.1541-4337.2009.00085.x.
- [19] Upasen S, Wattanachai P. Packaging to prolong shelf life of preservative-free white bread. *Heliyon*. 2018;4(9):e00802. DOI: 10.1016/j.heliyon.2018.e00802.
- [20] Zimele NM. The effectiveness of kitchen chemistry in developing science process skills in high school physical sciences. Master's Degree. University of KwaZulu-Natal, Durban. 2022;1-124. DOI: 10.29086/10413/23030.
- [21] Chen C, Chen J, Ju L, Sonnert G, Sunbury S, Sadler PM. Kitchen chemistry boosts STEM identity and increases STEM career interests. *J Chem Educ*. 2024;101(7):2618-29. DOI: 10.1021/acs.jchemed.3c01141.
- [22] Prokša M, Drozdíková A, Haláková Z. "COVID-19 shock" and identified benefits for improved pre-service chemistry teacher education. *Chem Didact Ecol Metrol*. 2023;28(1-2):105-20. DOI: 10.2478/cdem-2023-0001.
- [23] Mycak M, Doležal R, Bílek M, Kolář K. Microwave-aided reactions of aniline derivatives with formic acid: Inquiry-based learning experiments. *Chem Didact Ecol Metrol*. 2022;27(1-2):135-51. DOI: 10.2478/cdem-2022-0008.