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# Studies in chemistry education under the perspective of the animal issue: a review on the international literature

## Estudos em educação química pela perspectiva da questão animal: uma revisão na literatura internacional

## Estudios en educación química desde una perspectiva de la cuestión animal: una revisión de la literatura internacional

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**Abstract**
Guided by the questioning about how issues related to animals are addressed in research aimed at teaching chemistry, we conducted a review in international journals in science, chemistry, education and animal ethics, seeking to identify a possible dialogue between the themes. Highlighting the novelty of these possible relations, the objective was to assemble a panoramic impression of it, assuming that inserting the animal theme in chemistry classes would improve learning, the development of values generally associated with a critical citizen, and would promote significant practices linked to the questioning of reality. In line with the themes of the works found, we built a theoretical basis on the issue between animal consumption and the future of the environment, followed by the methodology and analysis of the selected articles, divided into three categories: environmental chemistry as driving issue to construct scientific concepts, discussions on food and nutrition through a scientific view, and introduction of concepts, analysis and methods through food chemistry. The analyzed texts brought several aspects of the investigated relations, dealing with both food health and environmental problems. Along with that, they explored numerous pedagogical possibilities in order to raise awareness and make the teaching-learning process more attractive and effective. Among the conclusions, there is that animal ethics, through its various aspects, is either not contemplated or appears in a veiled way by publications in the area of chemistry education. We recognize that there is a long way to go in search of a new perception.
**Keywords:** Chemistry education; Animal ethics; Environmental chemistry; Nutrition.

**Resumo**
Guiados pelo questionamento sobre como as questões relacionadas aos animais são abordadas nas pesquisas voltadas para o ensino de química, realizamos uma revisão em periódicos internacionais de ciência, química, educação e ética animal, buscando identificar um possível diálogo entre os temas. Destacando a novidade dessas possíveis relações, o objetivo foi construir um panorama, assumindo que inserir o tema animal nas aulas de química melhoraria o aprendizado, a formação de cidadãos críticos e promoveria práticas significativas ligadas ao questionamento da realidade. Em consonância com as temáticas dos trabalhos encontrados, construímos um embasamento teórico sobre a questão entre o consumo animal e o futuro do meio ambiente, seguido da metodologia e análise dos artigos selecionados, divididos em três categorias: química ambiental como questão motriz para a construção de conceitos científicos; discussões sobre alimentação e nutrição através de uma visão científica; e introdução de conceitos, análises e métodos através da química dos alimentos. Os textos analisados trouxeram vários aspectos das relações investigadas, tratando tanto da saúde alimentar quanto dos problemas ambientais. Junto a isso, exploraram diversas

possibilidades pedagógicas a fim de conscientizar e tornar o processo de ensino-aprendizagem mais atrativo e eficaz. Dentre as conclusões, está a de que a ética animal, em seus diversos aspectos, não é contemplada ou aparece de forma velada pelas publicações da área de ensino de química. Reconhecemos que há um longo caminho a percorrer em busca de uma nova percepção.
**Palavras-chave:** Educação química; Ética animal; Química ambiental; Alimentação.

**Resumen**
Guiados por preguntas acerca de cómo las cuestiones relacionadas a los animales son abordadas en investigaciones destinadas a la enseñanza de la química, realizamos una revisión en periódicos científicos internacionales acerca de ciencia, química, educación y ética animal, buscando identificar un posible diálogo entre las temáticas. Destacando la novedad de estas posibles relaciones, el objetivo fue construir un panorama, asumiendo que la inserción del tema animal en las clases de química mejoraría el aprendizaje, la formación de ciudadanos críticos y promovería prácticas significativas vinculadas al cuestionamiento de la realidad. En línea con las temáticas de los trabajos encontrados, construimos una base teórica sobre el desafío entre el consumo animal y el futuro del medio ambiente, seguida de la metodología y análisis de los artículos seleccionados, divididos en tres categorías: la química ambiental como tema impulsor para la construcción de conceptos científicos; debates sobre alimentación y nutrición desde una visión científica; y introducción de conceptos, análisis y métodos por la química de los alimentos. Los textos analizados trajeron varios aspectos de las relaciones investigadas, tratando tanto la salud alimentaria como los problemas ambientales. Junto a ello, exploraron diversas posibilidades pedagógicas con el fin de sensibilizar y hacer más atractivo y efectivo el proceso de enseñanza-aprendizaje. Entre las conclusiones se encuentra que la ética animal, en sus diversas vertientes, no es contemplada ni aparece de manera velada por las publicaciones en el área de la enseñanza de la química. Reconocemos que hay un largo camino por recorrer en busca de una nueva percepción.
**Palabras clave:** Educación química; Ética animal; Química ambiental; Alimentación.

## 1. Introduction

Dealing with the animal issue, and therefore the view through which the non-human animal is considered based on its sentience and intrinsic value, has become increasingly complex and pertinent. Although discussions about the welfare of these animals date back to Pythagoras (570-495 BC), a well-known vegetarian of his time, technological advances of recent years, including the increasing ease of access to information, have been largely responsible for popularizing the topic.

It is first important to highlight the novelty of the possible relations between animal ethics and science education developed in the classroom, as there is a notorious lack in terms of theoretical foundations. Accordingly, it is possible to consider that Western culture is loaded with information and anthropocentric customs linked to speciesism, that is, to the subjugation of a being due to its species. This reality reinforces the bias in which animals are seen solely from the perspective of their usefulness to the human being, an angle propagated in school and university environments, since they reflect the culture in which they are inserted. On the other hand, a certain number of people have chosen to undertake adaptations in order to mitigate the mistreatment of these animals, an area of study of the animal issue.

Such bias, which focuses on the consideration of non-human animals as subjects-of-a-life (Regan, 2004) worthy of rights, has progressively gained space in the world's daily life, which includes formal and non-formal spaces of education. When dealing with the theme through its different areas of application, we defend not only its potential to contextualize teaching, but also to favor learning, support values for the development of critical citizens and promote practices full of meaning linked to the problematization of reality. To this end, social, ethical, food, environmental, economic, labor and daily issues related to leisure and health can be involved.

Through the topics covered in this article, mostly related to the environment and nutrition, we understand that educational institutions should accept their social and humanistic role, which includes Chemistry courses and disciplines, since the way in which modern society deals with animals plays a significant part in the future of the planet as a whole. Therefore, the education focused on future chemists must recognize its immediate relation with global justice issues:

Relevancy also remains elusive in the chemistry classroom, where real-world issues of social justice, health, and the

> environment are largely missing from chemistry curricula. As a result, students struggle to understand their role as change agents and global citizens with leadership responsibility toward developing solutions to these justice issues, particularly as they relate to chemistry and manufacturing industries (Lasker et al., 2017, p. 983).

In order to emphasize the importance of this theme, and therefore the need to investigate its presence in the field, we built a reference that links human food, which involves the consumption of animal products, to the proposal of environmental sustainability. Then, we sought to show what the literature in the field of chemical education has been addressing in this regard.

## 2. Weaving Relationships Between Animals, Food and Environment

Food production affects every system of the planet: habitat loss is majorly connected to land conversion for crop and animal agriculture, which is directly related to the threat to biodiversity, most of the tropical deforestation in the last 40 years is due to the expansion of plantations and ranches. Moreover, 80% of the freshwater resources appropriated for human use is claimed by agriculture, at least one-fifth of greenhouse emissions are attributed to this system and coastal seas are critically endangered primarily as a result of overfishing and trawlers. Large ocean animals are in risk of extinction and there are steep population declines of small fish, big herbivores and carnivores (Crist et al., 2017).

It is well known that the food system is a major driver of environmental problems such as emissions of greenhouse gases, loss of biodiversity, land clearing, species extinctions, pollution of waters, among others. Crist et al. (2017) are examples of authors who explore the relations between human population, food production and biodiversity protection. They conjecture on many approaches that have been proposed toward maintaining biodiversity in a world with a global population rapidly growing, such as reducing food waste and changes in diet. In their review, the authors argue about how the continuing population growth is related to the destruction of biodiversity, as well as "whether feeding the world and maintaining biodiversity are even compatible objectives" (Crist et al., 2017, p. 260).

Tilman and Clark (2014) link global diets to environmental and human health. According to the authors, global agriculture and food production release more than 25% of all greenhouse gas (GHG), pollute fresh and marine waters with agrochemicals and use about half of the ice-free land area of Earth as cropland or pastureland. Correspondingly, meaningful solutions depend on the efforts of nutritionists, agriculturists, public health professionals, educators, policy makers and food industries.

They conjecture that, if unchecked, diets rich in refined sugars, refined fats, oils and meats would be the major contributor to an esteemed 80% increase in global agricultural greenhouse gas emissions from food production and to global land clearing by 2050. Alternative diets such as mediterranean, pescatarian and vegetarian can not only bring substantial health benefits but, if widely adopted, could reduce land clearing, species extinctions and global agricultural GHG once there would be no net increase in food production emissions (Tilman & Clark, 2014).

Godfray et al. (2018) also associate meat consumption to health and environment. They begin by linking population growth and increasing individual income to the rising amount of the total meat consumed. Following that, they present the historical growth in the global consumption of meat from 7 to 30 million metric tons between 1960 and 2010, as well as a robust general tendency that consumption is either static or declining in high-income countries and increasing in middle or low-income countries. One estimate suggests that the average global consumption of all meat is 122 grams per day, mostly distributed among pork, poultry, beef, sheep and goat. Moreover, the forecast is of an increase of 62% to 144% until mid-century. Although it varies from study to study, there is an agreement on the substantial increase.

Several variables must be considered when analyzing the projections, which include socioeconomic change, productivity growth and climatic drivers. The authors consider that at a point in history it was the case that the desire of

energy-dense and nutrient-rich food was central to promote survival, but today, for a majority of people, it can lead to diseases of overconsumption. It is important to say that the authors are careful to mention cases where there is no alternative to diets high in meat, such as with nomadic pastoralists in desert environments and traditional communities in the Arctic. On the other hand, it was possible to say, in 2018, that "many people are too poor to buy more than small amounts of meat. But for a large proportion of the global population, the price of meat today, relative to their average income, is less than it has ever been in history" (Godfray et al., 2018, p. 2).

As annual incomes increased from 1961 to 2009, the per capita daily demand for meat protein increased as well. According to Tilman and Clark (2014), in 2009, compared to the 24 poorest nations, the richest 15 had a 750% greater per capita demand for meat from ruminants, seafood, poultry and pork. In opposition, the legume protein demand decreased, India being, due to its low rates of meat consumption, an exception (Tilman & Clark, 2014; Godfray et al., 2018). They estimate that, in 2050, the

> global-average per capita income-dependent diet would have 15% more total calories and 11% more total protein, with dietary composition shifting to having 61% more empty calories, 18% fewer servings of fruits and vegetables, 2.7% less plant protein, 23% more pork and poultry, 31% more ruminant meat, 58% more dairy and egg and 82% more fish and seafood (Tilman & Clark, 2014, p. 519).

The problem resides in the fact that meat produces more emissions per unit of energy than plant-based foods, once energy is lost at each trophic level. Meat production is also the single most important source of methane, as well as an important source of pollutants such as $CO_2$, $N_2O$ and phosphorus, affecting biodiversity. Furthermore, the industry is known for converting land by cutting down forests into pasture and arable feed crops. In this regard, for instance, livestock is responsible for nearly a third of the use of freshwater related to agriculture, this latter using more freshwater than any other human activity. To summarize, meat production is one of the most important ways through which human beings affect the environment. One other perspective is that "Livestock may in addition act as reservoirs for pathogens that can also infect humans […]. Furthermore, antibiotics are used widely in meat production, both as veterinary medicines and as growth promoters. There is serious concern that genes for antibiotic resistance may be selected in agricultural settings […]" (Godfray et al., 2018, p. 4).

The information gathered converges to indicate that food production is going to need to increase by 70% by 2050 and double or triple by 2100. The importance of these numbers resides in the fact that food production profoundly intersects the human and ecological worlds, since escalating human stressors drive extinctions, decline of wild species population and habitat destruction. The estimate of 55% increase in demand for water by 2050, growth in global pesticide use and a steady increase of greenhouse gases all foreshadow a mounting ecological impact with agriculture as a major contributor in the reflex of growing meat consumption (Crist et al., 2017).

Poore and Nemecek (2018) consider that the current food supply chain produces about 13.7 billion tons of carbon dioxide, corresponding to 26% of anthropogenic greenhouse gas emissions. In order to contrast the origin of these foods, the authors complement their statements by pointing out that the impacts of animal products far exceed those of their plant substitutes.

Meat, aquaculture, eggs and dairy use about 83% of the world's cultivated acreage and contribute 56%-58% of different food-related emissions, despite providing only 37% of the protein and 18% of the calories consumed by people. Likewise, emissions related to the production of feed exceed those of the production of vegetable proteins, which occurs since the rates of conversion of feed into edible protein are greater than 2 for most animals. This is due to several factors, such as the fact that 67% of deforestation for agriculture is geared towards feed production, emissions from processing, particularly from

slaughterhouse effluents, and additional GHG emissions from enteric fermentation, manure and aquaculture ponds (Poore & Nemecek, 2018).

Tilman and Clark (2014) present detailed estimates for 2050 of per-year GHG emissions and change in cropland area between different diets. They compare the vegetarian, pescatarian and Mediterranean diets as well as their omnivorous, income-dependent projected global diet for 2050. The latter will produce an increase of 32% in emissions and an average 600 million hectares more cropland in comparison to the global diet in 2009. On the other hand, alternative diets could actually produce a reduction in GHG emissions, with the per capita reduction being 45% for vegetarian diets, for instance, besides requiring in average no increase in cropland.

The authors also examine lifecycle GHG emissions for 22 different food types per kilocalorie, per serving (United States Department of Agriculture-defined) and per gram of protein, and indicate that "as is well known, relative to animal-based foods, plant-based foods have lower GHG emissions. This difference can be large; the largest we found was that ruminant meats (beef and lamb) have emissions per gram of protein that are about 250 times those of legumes […]". They point out, however, that "when sustainably grazed on lands unsuitable for cropping and fed crop residues" (Tilman & Clark, 2014, p. 518), this production can bring benefits. Another case that exemplifies the difference between models of production is that of seafood caught by trawling, whose emissions are about 3 times those of non-trawling seafood.

Today, the shift to a diet that excludes animal products has transformative potential, reducing food-related greenhouse gas emissions by 49% and land use by 76%. In addition to this mitigation, such areas, once no longer used for this purpose, can remove about 8.1 billion tons of $CO_2$ from the atmosphere per year for more than 100 years, once the natural vegetation is re-established and the carbon re-accumulated by the soil. What we see, in the midst of environmental, climate and public health disasters, are tangible possibilities for us to circumvent relevant impacts related to land use, water scarcity, GHG emissions, acidification and eutrophication (Poore & Nemecek, 2018).

Approaches such as increasing efficiency in freshwater use, applying fertilizers and pesticides more cautiously and reducing meat consumption in the developed world, once animal products are ecologically costly to produce, are valuable. Nevertheless, the trends point to an increasing consumption of meat, fish, dairy and eggs. The authors also alert that landless livestock are not a solution, once the vulnerability to diseases and epidemics, the pollution, the ethically unjust ways of treating farm animals and the demand of croplands and water won't change (Crist et al., 2017).

Although the data exposed is concerning by itself, the environmental perspective related to the consumption of animals is broader still. We can cite, as examples, the emergence of strains of bacteria resistant to antibiotics, origins and transmission of pathogens, species extinction, criminal bushfires and pollution by pesticides, as well as socio-environmental and cultural issues. According to Arruzzo et al. (2022), the expansion of modern agriculture is accompanied by both a strong component of denial of productive. social, cultural and territorial diversity. In Brazil, conflicts between agribusiness and indigenous peoples take on legal and legislative proportions, involving indigenous territorial invasions, environmental conflicts related to the extraction of natural resources and the lethality of violence practiced against these populations. Although it is not within the scope of this review to delve into these issues, their relevance is self-evident.

## 3. Methodological Paths

With the purpose of outlining how animals are brought into the chemical education area, we aim to build a review in international scientific journals whose themes mainly involve chemistry, education, teaching, science and animals. This review is classified as narrative, whose importance is given when seeking updates on a given subject, culminating in the creation of an overview. This type of methodology, due to its less systematized character, does not demand rigorously detailed procedures and criteria, and may vary with the analysis (Casarin et al., 2020). As an example, Lima et al. (2021), whose research theme is

plant-based food, uses a narrative review to identify the role of this type of diet in health, its relationship with sustainability and foods consumed as an alternative to animal-based products.

For this review, we chose 14 journals: Science & education; Animal welfare; Animal sentience; American journal of education; Alternatives to animal experimentation; Journal of animal ecology; Journal of applied animal welfare science; Journal of chemical education; International journal of educational research; Nature; Science; Actualidades investigativas en educación; Revista Electrónica de Investigación en Educación en Ciencias. The determined period of the analysis was from 2012 to 2020. The date was chosen due to the event of The Cambridge Declaration on Consciousness, publicly proclaimed on July 7th of 2012 during the conclusion of the Francis Crick Memorial Conference in the University of Cambridge. The Declaration, written and edited by a group of neuroscientists, neuropharmacologists, neurophysiologists, neuroanatomists and signed by the conference participants in the presence of Stephen Hawking, grounded in comparative research on the topic, declare that:

> The absence of a neocortex does not appear to preclude an organism from experiencing affective states. Convergent evidence indicates that non-human animals have the neuroanatomical, neurochemical, and neurophysiological substrates of conscious states along with the capacity to exhibit intentional behaviors. Consequently, the weight of evidence indicates that humans are not unique in possessing the neurological substrates that generate consciousness. Non- human animals, including all mammals and birds, and many other creatures, including octopuses, also possess these neurological substrates (Low, 2012).

The described event is known as one of the most important in the field of the animal rights, ergo an appropriate mark to dictate the initial year of this review. As for the search terms involving the titles of the articles, five strands were covered: the animals in a general way, food, environment, veganism and education/science. The keywords were chosen according to the main theme of the journal and its language. Empirically, we found out that some journals related to animals came out with a great number of results related to terms like environment and food, but that was of no interest to the research. In the same way, searching for terms such as chemistry and teaching would result in multiple articles not related to our aims if looked for in journals like “Journal of Chemical Education”.

Therefore, the keywords used for the animal-related journals were: vegan, veganism, vegetarian, vegetarianism, chemistry, chemical, education, teach and teaching; for the ones related to science and education, the keywords used were: animal, food, dietary, nutrition, environment, vegan, veganism, vegetarian and vegetarianism; and for the ones whose main language was Spanish, in addition to the aforementioned, the keywords used were: alimento, alimentario, comida, alimentación, dieta, nutrición, ambiental, vegetarianismo, vegetariano, vegano and veganismo.

We reinforce that five generic categories, as well as the keywords used, are not enough to encompass the universe present in the selection, even less so to define the animal issue. However, for the given moment, those will be satisfactory since organization is what is sought. Further along the development of the research, each publication will be approached in a more individualized manner. By searching for the terms in the titles of the articles, it was possible to find the total number of 298 papers, distributed along the journals and the categories as can be seen in Table 1.

**Table 1** - List of the papers found.

| Journal | Category | | | | | Total of papers found |
|---|---|---|---|---|---|---|
| | Animals | Veganism | Environment | Food | Science/ Education | |
| Science & education | 1 | 0 | 12 | 1 | - | 4,69% |
| Animal welfare | - | 0 | - | - | 4 | 1,34% |
| Animal sentience | - | 0 | - | - | 2 | 0,67% |
| American journal of education | 0 | 0 | 2 | 0 | - | 0,67% |
| Alternatives to animal experimentation | - | 0 | - | - | 27 | 9,06% |
| Journal of animal ecology | - | 0 | - | - | 9 | 3,02% |
| Journal of applied animal welfare science | - | 0 | - | - | 2 | 0,67% |
| Journal of chemical education | 0 | 0 | 63 | 29 | - | 30,87% |
| International journal of educational research | 0 | 0 | 10 | 1 | - | 3,69% |
| Nature | 18 | 1 | 20 | 34 | - | 24,49% |
| Science | 24 | 0 | 15 | 13 | - | 17,45% |
| Actualidades investigativas en educación | 0 | 0 | 9 | 0 | - | 3,02% |
| Revista electrónica de investigación en educación en ciencias | 0 | 0 | 1 | 0 | - | 0,33% |
| **Sum** | 14,43% | 0,33% | 44,29% | 26,17% | 14,76% | 298 |

Source: Authors.

It is also worth mentioning that there were cases in which a single paper fit in two strands – since its title had terms related to both – and so this number cannot be represented in the sum of the quantity of papers found, but in the portion of classifications, though the difference was small. Furthermore, repeated papers were counted only once.

Considering the data already collected, even though it is complex to define and consider a certain number of papers significant, the low number related to the veganism category can mean that there is an incipient exploration dealing with the animal issue. Nevertheless, there isn't enough criteria, nor was this research engaged in answering this question, to affirm if the theme has or hasn't been acquiring space.

In possession of the papers found by means of the search terms, the next step will be to analyze their titles, abstracts and, when necessary, the full document, aiming at selecting those that would go on to the next phase. Through the criteria used in this screening, we seek to reach educational practices related to chemistry, whether in formal or informal spaces, from high school to the post-graduation and certificate programs modalities. At the end of the pre-selection, we will pick the ones that at least approach, directly or indirectly, the animal issue.

In total, through separating the papers according to the parameters determined, we selected 14 texts (Table 2), which indicates that, in 8 years of publications encountered in the bibliographical bases aiming for these specific themes and in spite of the attempts to increase the animal movement visibility, it appears that this kind of problematization has not arrived at the institutions of higher education. As it can be seen by the discussions to follow, the topic vegetarianism is mentioned once and there were no discussions involving the animal issue. For clarification, we provide, at the end of this topic, an illustrative scheme summarizing the steps taken (Figure 1).

**Table 2 -** List of the selected texts by category.

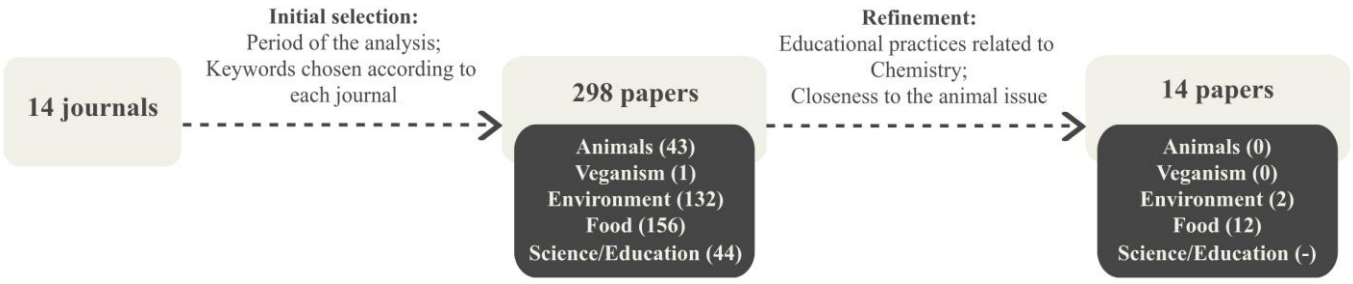
| Journal | Category | | | | | Total of selected papers |
|---|---|---|---|---|---|---|
| | Animals | Veganism | Environment | Food | Science/Education | |
| Science & education | 0 | 0 | 1 | 1 | - | 2 |
| Journal of chemical education | 0 | 0 | 1 | 11 | - | 12 |
| **Sum** | 0 | 0 | 2 | 12 | - | 14 |

Source: Authors.

By the categories above, the contribution of the food strand to the results is clear, which changes the path demonstrated by the data Table 1. It can be justified by the great number of "environmental" themes, not as natural environment, but as learning environments, classroom environments, school environments, online environments and laboratory environments, for instance. Although it wasn't our objective to observe tendencies, since none of the texts aimed discussions about animals in any sense, and the secondary themes were very diverse, it is not possible to observe any trends about the period observed. Regarding the chosen journals, the movement of selection revealed that the only ones with realistic possibilities to provide papers with the specifications here desired were science & education, journal of chemical education and revista electrónica de investigación en educación en ciencias, all focused on science education.

Even if one does not take sides with the animal abolitionist perspective, both in these and in other highly prestigious journals, it would be appropriate, from the point of view of novelty and relevance, to put an emerging and transversal subject such as the animal issue on the agenda. What is revealed is that articles on the subject are not being written or, if they are, they are not being submitted. Thus, it is necessary that research in science education goes beyond the themes already historically established, creating an opening for other themes. In search of more concrete results, it is now necessary to analyze the selected texts and classify them in a particular way in order to dialogue with their qualitative character.

**Figure 1** - Summary of methods and results found.




Source: Authors.

## 4. Results and Discussion

All the papers selected until then (Table 3) were read in their entirety and as many times as necessary in order for possibilities of categorization to emerge. As will be seen in this section, we defined 3 categories, based on the objectives of the present work and the main themes of each of the texts. This review did not aim to present a complete summary of the works, but to carry out a weaving aiming at the themes-selection criteria, such as the students covered, the teaching practices and the presence of animals, directly or indirectly. Thus, it is possible that only part of the methodology and results will be discussed, focusing on the one that concerns the present objectives.

**Table 3 -** Selected papers.

| Journal | Paper |
|---|---|
| Science & education | Teaching energy concepts by working on themes of cultural and environmental value (Besson & Ambrosis, 2013) |
| | Navigating alarming media messages about nutrition and health: How students engage in critical examination of science in news media (Wiblom et al., 2020) |
| Journal of chemical education | Computational chemistry laboratory: Calculating the energy content of food applied to a real-life problem (Barbiric et al., 2014) |
| | Design of a food chemistry-themed course for nonscience majors (Bell, 2014) |
| | A teaching laboratory for comprehensive lipid characterization from food samples (Bendinskas et al., 2014) |
| | Innovative food laboratory for a chemistry of food and cooking course (Cheng et al., 2020) |
| | Introducing students to rheological classification of foods, cosmetics, and pharmaceutical excipients using common viscous materials (Faustino et al., 2015) |
| | Box-and-whisker plots applied to food chemistry (Ferreira et al., 2016) |
| | Discovering the chemical elements in food (Franco-Mariscal, 2018) |
| | Social and environmental justice in the chemistry classroom (Lasker et al., 2017) |
| | Surveying iodine nutrition using kinetic spectrophotometry: An integrative laboratory experiment in analytical chemistry for population health (Macedo et al., 2018) |
| | Laboratory development and lecture renovation for a science of food and cooking course (Miles & Borchardt, 2014) |
| | Determination of mercury in fish: a low-cost implementation of cold-vapor atomic absorbance for the undergraduate environmental chemistry laboratory (Niece & Hauri, 2013) |
| | Phospholipids, dietary supplements, and chicken eggs: An inquiry-based exercise using thin-layer chromatography (Potteiger & Belanger, 2015) |

Source: Authors.

**4.1 Environmental chemistry as driving issue to construct science concepts**

This category aims to deal with papers whose main theme, linked to environmental chemistry, was developed in order to bring scientific knowledge. As initially informed, the reference to animals contemplated by the analysis may vary from a brief mention to the main theme, something that will be noticed in the course of the categories.

Besson and Ambrosis (2013) seek to teach energy concepts through themes considered important culture and environment-wise. To do so, even though the topic is studied by means of physics, the authors make clear that the concept concerns multiple and complex connections with different areas such as the chemical one. In this matter, starting from the proposal to select driving issues that promote motivation for the construction of science concepts and models, they describe the path taken toward discussions about greenhouse effect and global warming with high school students.

In the introduction, they propose and discuss possible research approaches in science education. In one of them, once reflecting on the history of energy is necessary, the starting point is the newborn industry and the economic need of comparing human, animal and machine work. Concerning the practice, the initial data collected through questionnaires on the greenhouse effect showed that the problem of global warming was often confused with the ozone layer depletion. Beyond that, the origin of the warming was generically attributed to pollution, injurious gases and deforestation.

During the learning sequence, the functioning of the greenhouse effect was discussed: the earth surface absorbs the incident radiation and emits infrared radiation; the atmosphere absorbs most of the infrared radiation emitted by the earth and emits infrared radiation. Some of the substances responsible are water vapour, $CO_2$, $O_3$, $N_2O$, $CH_4$ and $CFCl_3$. It is also

stablished that the danger resides not in the effect itself (because of its fundamental role in keeping the temperature in Earth's surface warm enough for life), but in an increase of greenhouse gases that can lead to the anomalous effect, therefore the consequent change of the average global temperature.

As it can be seen, the animal subject was only mentioned as a possibility to introduce the problem of greenhouse gases concerning animal work during the industrial revolution and its efficiency. Furthermore, the paper prioritized the physical education through the themes mentioned, not exploring its interdisciplinary potential. Finally, we believe that exploring student's positions as citizens and consumers directly related to the anomalous greenhouse effect could be a conscious and potentially high-powered way to try and minimize its effects. Examples of this approach can be found in Tilman and Clark (2014), Poore and Nemecek (2018), Crist et al. (2017) and Godfray et al. (2018), research investigated in the early topics of this paper.

Niece and Hauri's (2013) experiment aimed at determining mercury in fish as an undergraduate environmental chemistry laboratory to suggest exposure limits. They begin their writing explaining that the consumption of contaminated fresh and saltwater fish is an important route for mercury exposure, a neurotoxin particularly harmful to children and unborn fetuses. One major way of mercury release is as a byproduct of burning coal, dispersed through the air to contaminate otherwise relatively unimpacted water bodies, unknowingly exposing consumers. Also, through biomagnification, top-of-the-food-chain fish often have the highest amount of the organic metal. The seafood used, specifically swordfish and tuna, was purchased at a local supermarket. After the analysis, in both types of fish, the quantity of mercury in 85 grams serving was higher than the suggested daily intake for a 150 lb adult.

In this paper, it is already possible to see a greater concern with the theme of contextualization, since the mercury problem was much better explored compared to global warming in the last text, which appeared mostly as a starting point or an example. Even so, none of them seem to have brought the perspective of accountability or change, that is, of what, from the knowledge of these realities, can be done in search of remediation. For instance, the second text takes place in the United States, where a significant amount of energy production actually comes from coal.

**4.2 Discussions on food and nutrition through a scientific view**

The second category, discussions on food and nutrition through a scientific view, embraced the largest number of papers, including those whose main theme was nutrition. Similar to the previous topic, the researchers sought to teach by exploring scientific concepts through a driving issue. When dealing with food, however, the connection between the theme and animals is more direct, although it is not necessarily explored in depth.

Wiblom's et al. (2020) paper focused on the emerging need to critically respond to alarming messages in media, specifically the ones concerning potential benefits or harms of certain foods. The authors expose that "advancements in the field of nutrition reported in media are often of tentative and speculative character, primarily selected and constructed on the basis of their news value rather than as representing established knowledge" (p. 75). Thereby, the study aims at investigating, in the context of science education, how upper secondary students navigate through those kinds of texts. To do so, they examined a controversial message about cow's milk found in a Swedish public service news media.

In order to raise scientific literacy, and consequently improve democracy and awareness about their cultural identity, values and beliefs, the teaching sequence was divided into two lessons. The first one was a preparatory task to engage the students in a critical examination of news articles about meat consumption. The texts highlighted perspectives such as economy, health, ethics and vegetarianism, for example. As for the second one, the students should scrutinize an ongoing controversy between cow's and oat milk. According to the authors, the oat milk, like other plant-based options, is promoted as a healthy and environmentally friendly substitute to cow's milk, having become a popular option among consumers. On the

other hand, the historical-cultural position that this latter one occupies in Sweden as natural, healthy and light (image built through propagandas traced back to 1923) was visible through the debates that followed the news whose headline was "Swedish study: milk consumption is associated with increased mortality".

> Cow's milk is commonly served with lunch in Swedish schools; however, during the last few decades, the image of cow's milk as a healthy and sustainable choice of beverage has been challenged. Both the production and the consumption of milk in Sweden are declining, partly replaced by an increased consumption of vegan and lactose-free plant-based substitutes such as nut, soy, and oat milk […]. Yet cow's milk production is still the highest-grossing agricultural sector in Sweden, and the national consumption of milk per capita significantly exceeds the European average […] (Wiblom et al., 2020, p. 82-83).

According to the authors, some of the information presented on the news article was the connection between the amount of milk consumed daily and the risk of bone fractures and death by cardiovascular diseases. In an interview, one of the researches anticipated that the study would not be well received by all and recognized its limitations being a single study. The discussions among the students were categorized concerning themes like the design of the study, the physiological mechanisms related to the results published, the need for further research, the trustworthiness of Swedish service media as communicator of science, the consequences of new scientific knowledge, their culture, history and economy. They were able to question what they knew about milk, how it was constructed and how it is maintained by family traditions, education and the dairy industry. Furthermore,

> Rather than deciding whether the scientific claims about milk were "true or false", the students' inquired how the new findings had been produced, validated, and explained. They demonstrated an awareness that research findings are constructed within communities of science and therefore important to examine in relation to the accumulated knowledge in the field (Wiblom et al., 2020, p. 94).

Cheng et al. (2020) discuss about a food laboratory for a chemistry of food and cooking course for nonscience majors and under-represented students. The experiments covered topics in chemistry using food ingredients and kitchen equipment in order to motivate, reinforce key empirical chemistry concepts, highlight that scientific knowhow is a useful component of many professions, apply basic scientific concepts to improve everyday cooking and incorporate world cuisines and North American Indigenous food preparations. For instance, the authors explain that the latter is distinguished by food preparations reliant on plants and animals that are indigenous to the local landscape.

Among the food preparations for the pilot food laboratory there were "perfect poached eggs", "homemade caramels" and "miniature hamburger slider appetizers". Another possibility not included at the pilot was the oven-roasted chicken. For starters, it is interesting to notice a certain preoccupation about student's allergies and sensitiveness to certain constituents of the preparations as gluten and soy: "Students who were allergic or sensitive to gluten were warned against tasting the bannock" (Cheng et al., 2020, p. 562) and "We chose to use soybeans rather than nuts because more people are allergic to nuts than soybeans. That said, students should be warned that if they have never had soy products before, they should minimize the intake of the soymilk" (p. 563).

Regarding the poached eggs, it was explained that the yolk contains the majority of the essential nutrients such as the albumin protein, while the white contains mostly water. When submitted to boiling, the proteins denature. As second food preparation, the caramel was substantiated by the Maillard reaction in which, upon heating, amino acids freed from proteins in the cream react with reducing sugars to produce hundreds of new products, some with strong flavors and aromas. The third preparation was a hamburger made of raw ground beef, bun and sliced cheese. At the end, as a final project, the students were free to apply the concepts they had learned to prepare a food dish of their choice using ingredients like eggs, unsalted butter

and cream cheese.

As well as Cheng et al. (2020), Bell (2014) writes about a food chemistry-themed course for nonscience majors through its curriculum design, laboratory experiments and field trips during a one-semester experience. Concerning animal-based food, one of the modules included chemical structure of proteins, being correlated to types of seafood and coagulation of egg proteins, thus making an omelet as a laboratory activity. As a filling, students brought precooked ham. Moreover, they participated in a grocery store scavenger hunt at a local Asian supermarket. Some examples of activities were estimating the length of a cow tongue and comparing the eye color of several fish, live and dead.

Finally, when discussing about food problematics, it was brought to attention how the Gulf of Mexico oil spill affected the seafood industry, as well as the event of a recall of half a billion eggs and the pasteurization process. As for this discussion, although the authors only mentioned it, it was possible to notice that the sole worry was due to economic matters and not turned to the affected fish, for example. Ultimately, it is interesting that none of the practices involving food laboratories brought the possibility of including vegan or vegetarian students, which apparently wasn't necessary since none of the participants fit in those cases.

Miles and Borchardt (2014, p. 1637) also focus on a science of food and cooking course as "a suitable option for students who will likely not major in science but will develop the ability to understand and interact with scientific material and concepts". Compared to the other courses, one differentiation of this one was that there wasn't a food safe laboratory, so the students weren't allowed to taste any of the ingredients or preparations, these being considered laboratory chemicals.

In the early offerings of the course, "the topics were organized primarily by types of food (eggs, milk, meat, and so forth)" (Miles & Borchardt, 2014, p. 1639), covering concepts ranged from gas laws to protein structure. Later, the focus of one of the experiments was to identify biochemical nutrients, such as proteins, in foods such as meat. A second one aimed to analyze the amount of calcium in milk samples. Finally, a third one was the quantification of a colligative property associated with making ice cream. Topics also covered involved, for example, the concept of limiting reactant using s'mores; the creation and versatility of an egg white foam through baking cake and soufflé; and the differences in the properties of animal fats and vegetable oils. It is worth mentioning that, during the experiments with meat, according to the authors, the explanation of methods to preserve meat led to a discussion of food borne illnesses, although no further information was given on the topic.

Macedo et al. (2018) also discussed population health, focusing on iodine nutrition experiments for undergraduate students in analytical chemistry. Moreover, the essay adopted is "widely used for continuous monitoring of mandatory iodized table salt programs to prevent the risk of iodine deficiency disorders, including developmental delays and intellectual impairment in children" (Macedo et al., 2018, p. 1029), as iodine deficiency remains a major public health concern. The students analyzed mostly their own urine specimens, and it was emphasized that the recent dietary iodine intake would be indicated, which justified the request to record the ingestion of iodine-rich food such as seaweed, fish, dairy products and food prepared with iodized table salt. Despite systematic errors during the experiment, the median results were adequate based on the World Health Organization criteria.

Franco-Mariscal (2018) presents a project involving high school students and the study of chemical elements present in food organized by their roles: chemical food preservation and major, essential trace and toxic trace elements. At the end, students emphasized the need to secure a well-balanced diet with the essential elements and avoiding foods with toxic chemical elements.

Through the information gathered by the students, a list was discussed of 16 iron-rich foods: red meat, poultry, fish, mussels, liver, egg yolk (animal sources), lentils, beans, leafy vegetables, watercress, tofu, chickpeas, black-eyed peas, blackstrap molasses, spinach (vegetal sources) and iron-fortified cereals. Furthermore, the students related the element nitrogen to high-protein food such as meat and fish; phosphorus to fish, cheese and dry fruits; calcium to milk products, chickpeas and

beans; cobalt to clam, oyster and onion; zinc to salmon, lean meat and seafood; nickel to kiwi and oyster; and titanium as an additive in yogurt.

It was interesting to notice that some students pointed out that excessive consumption of any food is harmful - eating too much meat, for instance, could accumulate a great amount of iron in the body. Although they didn't present other perspectives related to the consumption of meat, we consider it an interesting reflection related to the amount of minerals present in the food, once the project only aimed at the elements. Another interesting piece of information is that, at first, the students related iron mostly to lentils, a vegetable source. Finally, the only element connected only to animal sources was nitrogen, in spite of the abundance of protein sources in the vegetal kingdom.

**4.3 Introduction of concepts, analysis and methods through food chemistry**

Finally, here are texts whose focus is based on methods, concepts and chemical analyses, with food chemistry being a secondary theme used as a starting point for the determined objectives. There are no discussions beyond general characterizations of foods, such as the effects of these foods and the results found in food and human health.

Ferreira et al. (2016) aimed to illustrate the applications of box plots in food chemistry through the examples of the potassium content in fruits and vegetables, the amino acid content of egg white and yolk and the chemical composition of freshwater and saltwater fish. As a possibility of activity that was not applied, the authors elaborated it thinking it would be appropriate for upper-division undergraduate students.

Among the information seen in the data used to build the box plots was that "chicken eggs are one of nature's perfect protein foods" and that fish are important to "human nutrition as a source of biologically valuable proteins, fats, and fat-soluble vitamins" (Ferreira et al., 2016, p. 2030). Furthermore, the authors put forward, as additional possibilities to build the graphics, the fatty acid composition on meats as beef, chicken, pork and fish; as well as chemical compositions of different milks such as cow's, goat's, buffalo's and sheep's.

Bendinskas et al. (2014) discuss about lipid characterization from egg yolk and avocado, experiments performed in biochemistry teaching laboratories with upper-division students. To summarize, the paper was dedicated, in its almost completeness, to presenting the method and the results of the experiments, not relating it to nutrition or dietary habits, thus in a non-critical way. There were no further discussions on the participation of the students, and their experiences were limited to one paragraph. In conclusion, according to the authors, it was possible to compare the results and discover that these food sources contain very different lipid species.

Xu et al. (2018) describe a method for electrophoretic separation of food dyes, one of them being carmine. Although no origin was discussed in the paper, it is important to expose that carmine is a known animal derivative product (cochineal), thus the reason why this text was selected to compose this writing. The demonstration of the experiment was designed and used for students majoring in chemistry at the sixth semester, one of the objectives being to realize that materials in daily life could be used for analytical applications.

Faustino et al. (2015) aimed to introduce basic rheological (that which studies the flow and deformation of matter) concepts to undergraduate health science students of courses such as pharmacy and biochemistry. According to them, the application and acceptance of foodstuffs depend upon characteristics such as texture, consistency or viscosity, the latter being the main aspect analyzed in the referred experiment. As a parameter, the viscosities of some common fluids were presented, air being the lowest and honey the highest. Therefore, among the material used were yoghurt and solid yoghurt. In the end, it was verified that the students had gotten acquainted with the viscosity concept and measurement, as well as with nonideal fluid behavior of materials of everyday life.

Potteiger and Belanger (2015) discuss about an experiment designed for organic or biochemistry undergraduate

students to study phospholipids extracted from chicken eggs and dietary supplements (krill oil, fish oil and lecithin). As eggs were being handled, students with allergies weren't permitted to perform this lab. The authors conclude that the analysis required critical thinking skills to combine the information and arrive at a conclusion. There were no discussions on the meanings of the results for the consumer's life, nor the reason for the use of krill and fish on the supplements and chicken eggs as one of the protagonists of the experimentations.

Barbiric et al. (2014) discuss about a computational chemistry laboratory for students of food engineering and any general chemistry course. In this context, they calculated the nutritional value of common foods in order to answer everyday life questions such as "How many kilometers can an average person run with the energy provided by 100 g of beef?" (Barbiric et al., 2014, p. 881). During the analysis, the students worked in groups with two food items at least, among them being marshmallow, peanut, beef, bread, cheese and egg. It was possible to visualize, through the writing, the student's role and participation during all the stages.

## 5. Concluding Remarks

In summary, the analyzed texts brought several aspects of the investigated relations, dealing with both food health and environmental problems such as the greenhouse effect and mercury contamination of fish. Along with that, they explored numerous pedagogical possibilities in order to raise awareness and make the teaching-learning process more attractive and effective.

Regarding the articles related to food, it was interesting to note that three of the twelve papers focused on the topic were related to food laboratories (Miles & Borchardt, 2014; Bell, 2014; Cheng et al., 2020). In them, students were able to learn certain chemical subjects in a practical way through the preparation of different dishes. This number may indicate significant interest from teachers and students, both focused on more attractive classes.

Still, social and ethical discussions about such foods were not part of the goals of most texts. Classic relationships such as between animal products and proteins, dairy and calcium continued to be passed through without a more comprehensive view. On the other hand, Francisco-Mariscal's (2018) paper reports the students, at first, to have related iron mainly to lentils, which is a vegetable source, in contrast to meat.

Wiblom et al. (2020) were the only ones to problematize the consumption of animal products, specifically cow's milk. To this end, the vegetable alternative is contrasted, also referred to as "vegan and lactose-free plant-based substitutes". However, no connections are made regarding animal care and how human consumption, as well as other every-day seemingly harmless and invisible actions linked to animals, are harmful.

We conclude that animal ethics, through its various aspects, is either not contemplated or appears in a veiled way by publications in the area of chemistry education. Even so, considering the points raised in the opening of this text, as well as the opening presented in the papers aimed at the insertion of different themes favorable to the understanding of chemistry, we understand that there is room for the inclusion of the theme in the chemistry classroom and find it to be coherent.

From this brief scenario and its discussion, it was possible to bring to light evidence of the educational potential of the animal issue. We invite the academic community to include the topic in the educational environment, which includes, in addition to refining reviews and extending them geographically for diagnostic and guiding purposes, conducting empirical research so that the scenario studied is transformed.

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