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CONCEPT MAPS AS A TOOL FOR BUILDING RESEARCH MODELS OF MASTER'S STUDENTS IN CHEMISTRY

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Abstract. Basic research in chemistry is the source for the development of new technologies and innovations in various fields that include industry, medicine and environmental remediation, to name a few. A constant evaluation of its approach is necessary to improve research projects and thus contribute to the solution of current problems. From this point of view, concept maps serve as a strategic tool in the consolidation of existing theories and important experimental designs to establish the relevance of each research project and its potential application. The use of concept maps allows to organize the concepts of a specific field of research, leading to the formation of interconnections of ideas and theories. The relationships between concepts can be represented as networks, which provide a robust set of tools with the ability to shape, combine, analyze, represent and compare information, generating new perspectives so useful that they can become the resolution of research problems. The following is the result of applying the methodology of concept maps, in three research projects in a Master's in Chemistry, and includes a detailed description of the parameters that led to the construction of these information tables and their contribution to each piece of research.

Keywords*:* concept maps, research projects, chemistry

1 Introduction

Chemistry is a science that requires the application of various methodologies for its study and understanding, for example, existing theory based on previous studies or experimentation and deductions based on statistical design. However, in some high-impact research, it is necessary to search for alternatives that explain the behavior of the study variables in a graphic, explicit and didactic way that will determine the scope of the project, since the understanding of many of the phenomena that are investigated in this field depend on it. Chemical sciences are part of the areas that involve meaning-making processes, since the deduction of physicochemical phenomena, and respective explanation and application, are the main axis for the construction of knowledge. To enable this, the research requires a multimodal approach, which is based on the theory that the use of spoken and written languages is not enough to understand phenomena that cannot be perceived at first sight, therefore communication must occur through multiple modes of semiotic representation. The role of multiple representations in the construction of knowledge has also been identified as a research area that will contribute to the construction of broader and potentially applicable research, with added value for the improvement of basic science learning processes (Jaipal, 2010).

The application of concept maps in the development of research allows the integration of multiple semiotic representations, which in turn facilitates the search for explanations of the different chemical phenomena. The application of tools such as concept maps in research provides certain advantages. For example: the expression of research objectives that encompass a problem defined by the relationships between the different variables of the molecules under study, can lead to a broader explanation about the choice of the synthesis method, while the schematized information also serves as a tool in the verification of the characteristics of the obtained compounds. Finally, a concept map developed under the correct terms and interconnections has the capacity to highlight the positive impact of the research that it represents (Kozma, Chin, Russell, & Marx, 2000).

The objective of this paper is focused on the use of knowledge models based on concept maps as infrastructure for the creation of student research projects in scientific and applied fields. The tools based on a constructivist approach to learning allowed Chemistry students to construct concept maps, connect them to each other through links with semantics, and complement the propositions with other media such as images, photos, graphics, text, etc., thereby generating a vision and a real scope of each research project.

2 Reach of Aid Model

Concept maps, developed by Novak (Novak & Gowin, 1984), are used as a medium for the description and transmission of concepts within the theory of assimilation, a theory of learning that has had an enormous influence on education. The theory is based on a constructivist model of human cognitive processes. The concept map is the main methodological tool in the theory of assimilation to determine what the student already knows. According to Novak and Gowin, concept maps have helped people of all ages to examine the most varied fields of knowledge in educational environments (Ausubel, Novak, & Hanesian, 1978).

The concept map is a graphic representation of a set of concepts and their relationships within a specific domain of knowledge, constructed in such a way that the interrelationships between the concepts are evident. In the following schemes, the concepts are represented as labeled nodes and the relationships between concepts as connected labeled arcs. As such, concept maps represent the significant relationships between concepts in the form of propositions or simplified sentences: two or more concepts linked by words to form a semantic unit (Cañas *et al.*, 2000). The concise and graphic representation of knowledge through concept maps and the possibility of links, whether hierarchical or horizontal, result in ideal surroundings in which to create a navigable environment, where students can find the information they need by browsing the environment, researching various topics. The concept maps presented below were made by students of the Master's Degree in Chemistry from the Pedagogical and Technological University of Colombia, each subject with a totally different approach and application, but with a remarkable scientific quality.

2.1 Evaluation of Porous Organomicas and Heterostructures based on Mica-type Layered Silicates as Adsorbents of Malathion Insecticide

Figure 1 shows the concept map of a piece of research entitled: "Evaluation of porous organomicas and heterostructures based on mica-type layered silicates as adsorbents of Malathion insecticide". The methodology of the concept map is applied with the objective of establishing relationships between study variables and materials that could improve the result of the investigation. The concept map has a hierarchical tree structure (Zydney & Warner, 2016). The map also has cross-links that allow to understand the interconnection between the properties of the starting material and the improvements that can be achieved from it, starting from the theory that the structure of the map affects the perception of the ideas that you want to communicate through it. The concept map was designed to initially present the properties reported in the theory, about the Na-n-Mica starting material; a summary was then made of the applications that will be given to the precursors, to conclude in the form of an evaluation of these applications by means of analytical chemical techniques.

As such, the construction of the concept map of figure 1, allowed to find the main research problem of the project through an arduous study of the state of the art by means of a structures-type concept map that allowed to evaluate the different panoramas that this reported. The construction of this map was a creative tool, applied with the objective of taking advantage of the possibility of constantly updating its information in order to find the best application for the Na-n-Mica materials described in it. One of the advantages of the application of the concept map to the research presented in figure 1, was that it allowed to establish the necessary limit to study and evaluate in each stage of the investigation (Conceição, Samuel, & Yelich Biniecki, 2017), and therefore raise awareness of the necessity to apply the organomicas and porous heterostructures in the adsorption and degradation of emerging contaminants such as Malathion.

This methodology of approach and development of the work was always governed by the choice of study points that were hierarchically pre-established by the importance of the lines of research in environmental remediation (Darder, Pérez, & Salinas, 2012). Basing its delimitation on the concept map favored the development of this basic research, since being able to navigate in a map of possibilities (and see these reflected at once) facilitated choosing a work route and led to a more assured analysis and better results. Furthermore, in the stages of investigative difficulty, the elaboration of alternative concept maps for different solutions improved the researcher's performance and optimized the development and finalization of the project.

In the particular case of figure 1, the concept map concept was applied to enable the use of the construction and organization of ideas for a common purpose, which was to generate an effective alternative solution for the

treatment of water contaminated with organophosphates. By creating visual representations of ideas and integrating and displaying information from different sources, it was possible to consolidate the most efficient research route (Conceição et al., 2017). A remarkable feature of this concept map is the level of interconnectivity that it presents, which reflects the great importance that the generation of links between ideas had in order to improve research. A case in point is the high cation exchange capacity (CEC), which is one of the properties of Na-n-Mica (Alba, Castro, Naranjo, & Pavón, 2006): By interconnecting this property with the obtention of organomics, it was possible to determine that this is a limiting factor for the adsorption capacity of organophosphorus contaminants. Based on this finding, the study gained added value by being able to determine the effect of the CEC of the materials on their potential applications for the remediation of contaminated water.

Therefore, the main function of this concept map has been to conduct a basic experimental research in chemical sciences. The exploratory analysis of the entire concept map for the assignment of experimental activities led to the setting of clear research objectives that cover all the work, analysis which would have been more arduous and led to a greater number of failures if tools had been applied less effectively, for example by describing the work by means of a written text (Zwaal & Otting, 2012). In addition, this presentation of the research has advantages in contrast to a written text given that it facilitates the understanding of the research to readers interested in this area of work.

Finally, the concept map of figure 1, reflects the development process that allowed this research project to be carried out and, taking it as a basis, facilitated the creation of a new proposal regarding the alternatives for the decontamination of water sources with pesticides.

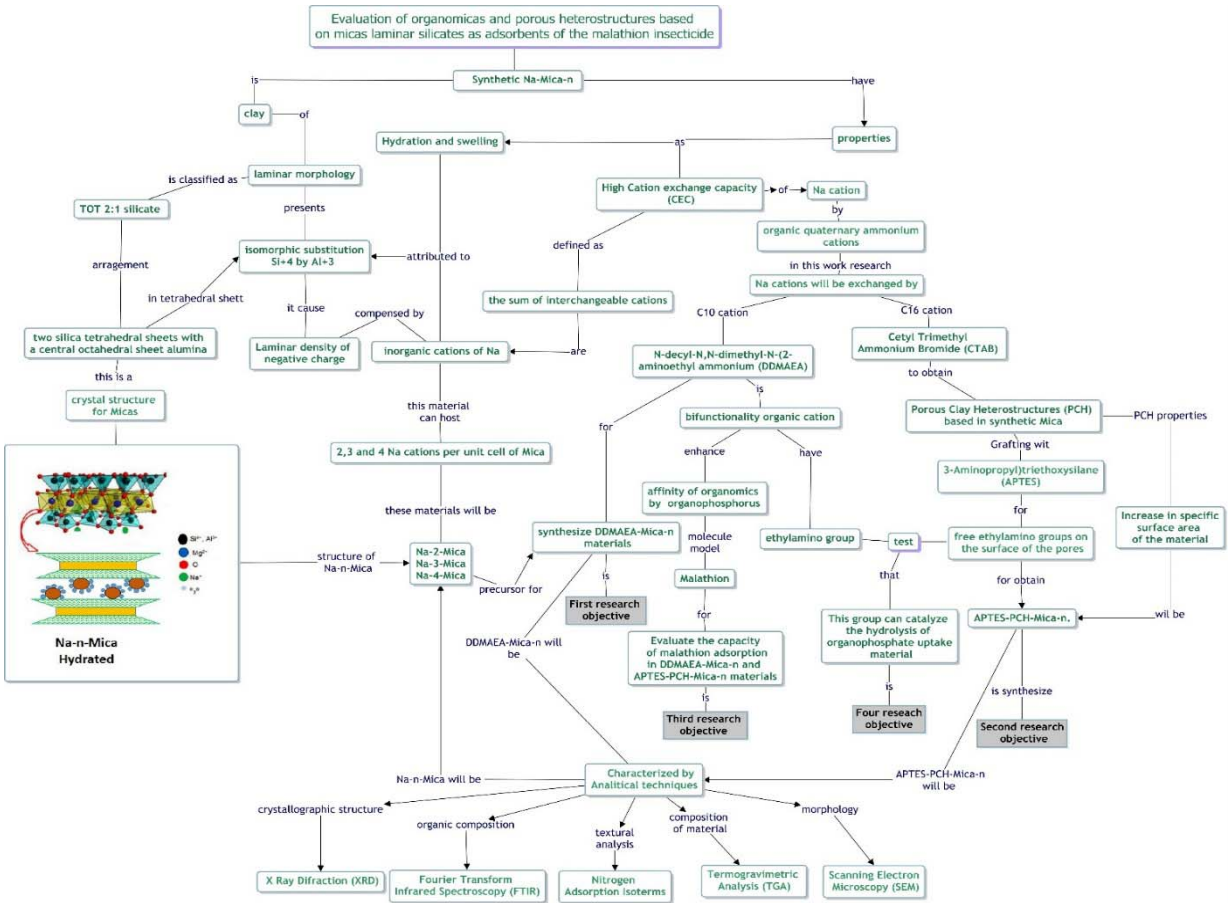

Figure 1. Concept map for the Evaluation of porous organomicas and heterostructures based on mica-type laminar silicates as adsorbents of Malathion insecticide.

2.2 Obtention Scaffolds of Polycaprolactone / Collagen / Microcapsule of TGFB3 for Skin Tissue regeneration

The first step for the construction of the concept map in figure 2 was to hierarchically graph the ideas and concepts based on existing knowledge about a specific area, such as the area of biomaterials, creating a coherent and orderly system making use of the construction of a concept map. In 1979, Stewart and colleagues defined the concept map as an instrument to represent the conceptual structure of a discipline or segment of a discipline in two dimensions (Stewart). This concept adequately describes the importance of the use of the concept map for the coherent structuring of thought and information that is held in the mind.

The representation of the relationships between the concepts in figure 2, are arranged hierarchically, with the most inclusive (more general) concepts at the top of the map and the more specific (less general) concepts below, starting from the need to generate scaffolds for biomedical use, relating to the use of biomaterials, cells and growth factors for the regeneration of cutaneous tissue.

The present concept map was constructed based on the following focus question: " Will obtaining a construct from the mixture of a polyester (polycaprolactone) and a protein (collagen) as a scaffolding polymer matrix for electrospinning and adding the transforming growth factor β3 (TGF-β3) microencapsulated in spheres of alginate, serve as a scaffold for the adhesion, maintenance and differentiation of Wharton's mesenchymal cells (CEM-GW)?" To answer this question, knowledge is organized in the form of a concept map, in order to contextualize and highlight the relationships between concepts from different areas of knowledge. The crossed links present in figure 2 served to size the relationship between medicine, biology and chemistry that focused on a common good; the hierarchical structure also stimulated the ability to search and characterize new cross-links.

The main objective of the creation of this concept map is the use of this tool in the methodological development of the research, extending it and adapting it as the experimental phase is increased, possibly concluding with a complex knowledge model that links resources, results and experiments (Novak & Cañas, 2008).

The need to carry out an investigation from the area of Chemistry for a medical treatment arose from the following premise: poor wound healing after a burn, trauma or surgery, affects millions of people around the world every year, occurring as a consequence of poorly regulated events in the tissue repair response, generating a serious public health problem, since people who for various reasons are victims of burns, remain in a state of morbidity that prevents them from continuing with their daily lives.

The purpose of this research project was to elaborate a construct from polycaprolactone / collagen nanofibers as polymer matrix scaffolding to be added to the transforming growth factor TGF-β3 microcapsulated in sodium alginate spheres, which serves as a functional scaffold for the adhesion, maintenance and differentiation of mesenchymal stromal cells of Wharton gelatin (MSC-GW) (Wang et al., 2004), in order to obtain a construct that allows spatio-temporal control over the location and bioactivity of the growth factor and mesenchymal stem cells (MSC) after its placement in the body, thus achieving a greater therapeutic effect in the regeneration of skin tissue.

It is for all of the above mentioned that the elaboration of the concept map in figure 2 involved successive steps such as, identifying the concepts, ordering them in a hierarchical way, linking them, adding images, graphics, etc., not only to promote the extension and deepening of the content, but also to explore explicitly the relationships between propositions and concepts, in order to evidence significant similarities and differences and recognize inconsistencies during the development of the research (Costamagna, 2001). The development of this concept map or two-dimensional diagram was quite useful, both to find connections within the different disciplinary and interdisciplinary concepts (medicine, chemistry, biology), as well as to rediscover and enrich them when relating all the concepts, forming an integral scheme that reveals the importance of the study.

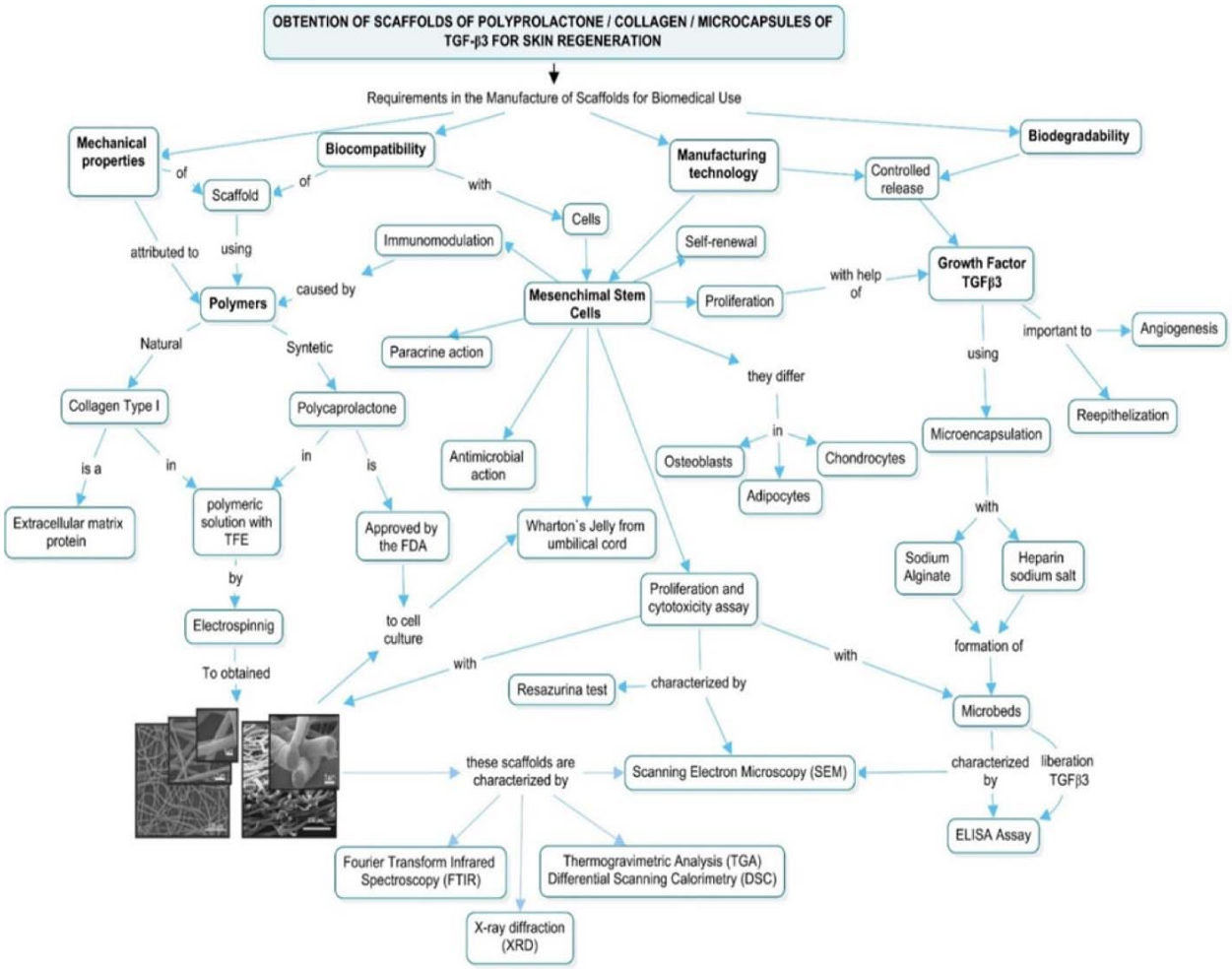

Figure 2. Concept map for the "Obtention of Polycaprolactone / collagen / microcapsules scaffolds of TGFβ3 for regeneration of cutaneous tissue"

2.3 Study of the Formation of Advanced Glycation End Products (AGEs) in Quinoa Flours (chenopodium quinoa)

The study starts from the need to investigate the Maillard Reaction, since it is of high importance in the food industry. Many widely used products are derived from this, such as dyes and syrups among others, and also consumer products, such as flavors. As such, this reaction is a constant presence in the kitchen when we prepare roasted, fried, baked or toasted foods, since the products of this reaction are evident in the "burned" or toasted part of the prepared foods.

The AGEs hypothesis was introduced in the mid 80's and was a great impulse for understanding the meaning of the Maillard reaction in aging and in other pathological processes, focusing attention on the formation reactions of AGEs and in the accumulation of these in tissues. More recent studies show that with age, AGEs accumulate in tissue proteins with a long half-life, such as crystalline, collagen, elastin and myelin, and that this process is accelerated by both hyperglycemia and increase in glycation that exists in diabetes mellitus (Brownlee, Vlassara, Kooney, Ulrich, & Cerami, 1986). The majority of these investigations refer to two AGEs that have been chemically and structurally characterized: pentosidine and NΣ-carboxymethyllysine (CML). However, antibodies have also been found against proteins incubated in vitro with glucose for long periods of time. These antibodies have been used in immunoassay (ELISA) to measure and quantify AGEs that have not been characterized in serum and tissue. The formation of AGEs can cause pathological changes through three general mechanisms; a) by altering the structure and function of proteins b) varying the level of soluble signals, such as cytokines, hormones and free

radicals interacting with specific cellular receptors for AGEs; and c) the formation process of AGEs results in the formation of reactive oxygen as an intermediate product (Baynes & Thorpe, 1999).

Said reaction has different routes such as Glycolysis, the formation of Acrylamides, and the formation of AGEs by means of protein degradation due to the succession of several reactions: a) Schiff Bases Formation reaction by direct reaction of a non-sugar reducer with a protein (Phase 1. Initiation); b) Protein Glycation (Phase 2. Propagation); and c) Formation of AGEs derivatives (Phase 3. Completion).

From the nutritional and dietary point of view, quinoa is the natural source of economic vegetable protein and high nutritional value due to the combination of a higher proportion of essential amino acids. The caloric value is higher than other cereals, both in grain and in flour reaches 350 Cal / 100 g, which characterizes it as an appropriate food for cold areas and seasons. The protein of Quinoa helps the development and growth of the organism, conserves the heat of the organism, conserves the heat and energy of the body, is easy to digest, forms a complete and balanced diet (Tapia, 1979). Another factor that corrects the biological quality of proteins is digestibility. The digestibility of egg, milk and meat proteins is close to 100%. Cereals and legumes due to their fiber content have a lower digestibility. It is estimated that the digestibility of quinoa is a better concentration of amino acids and with limiting amino acids virtually disappearing. The processes that use dry heat, such as roasting, can notably decrease the availability of lysine, which is thermolabile and can also react with other components of the grain (Maillard reaction, for example), decreasing its bioavailability.

Taking into account that AGEs are fluorescent molecules, the proposal is to validate an analysis methodology by means of reverse phase HPLC, using fluorescence and refractive index detectors to be able to monitor the initial degradation of sugars and the formation of the compounds of interest. Additionally, a complete proximal analysis of the different Quinoa samples is carried out, in order to know their composition and also to show how much degradation their nutritional content can suffer when the Maillard reaction takes place during the production of bread products.

The development of the concept map is a very useful tool, since it allowed to differentiate the importance of the reaction cycles and the different reactions involved in the AGE formation process, in order to focus the analysis on target molecules (specific amino acids) and in turn, allowed for planning a follow-up of the compounds of interest, without diverting the analyzes towards secondary reactions that do not end in the formation of AGEs. The concept map made it possible to design the analysis matrix with greater clarity, since it demonstrates the use of a single instrumental technique for monitoring the reaction of interest, which optimizes the use of reagents and the project development time.

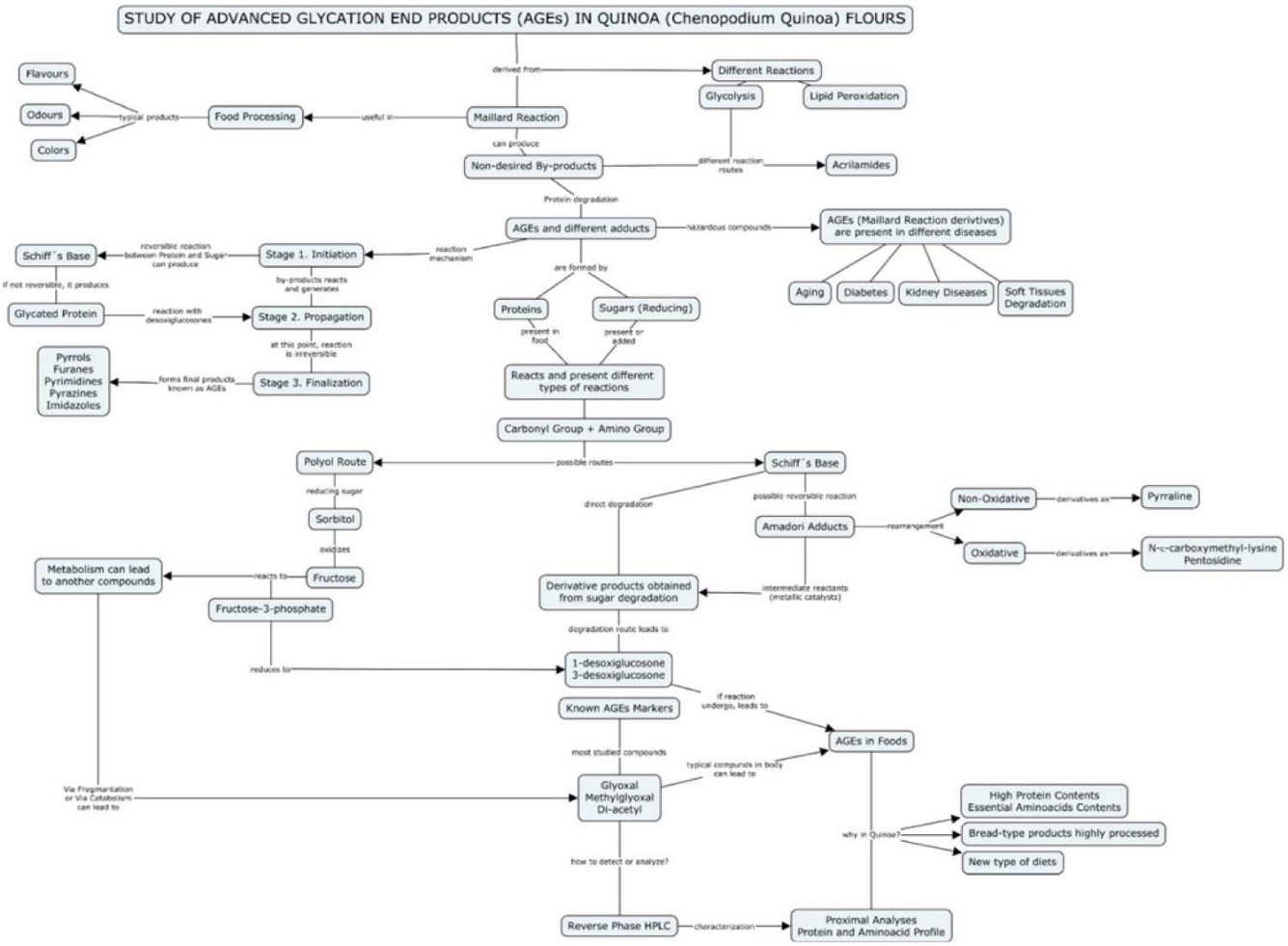

Figura 3. Study of advanced glycation end products (AGEs) in Quinoa flours (Chenopodium Quinoa)

3 Conclusions

The application of the concept map in the research entitled "Evaluation of porous organomicas and heterostructures based on mica-type laminar silicates as adsorbents of the Malathion insecticide", has made it possible to find the most efficient application for the materials proposed in said project. The approach and constant updating of state-of-the-art information on the subject related to synthetic clays and the use of their properties for the benefit of science, as well as recovery of areas degraded by emerging pollutants such as Malathion, were key points that allowed to establish the research route obtained. A remarkable feature of this concept map is the level of interconnectivity that it presents, which reflects the great importance that the generation of links between ideas had in order to improve the research. Finally, the development of this research, through the approach and constant improvement of the concept map, improved the researcher's performance and optimized the development and finalization of the project.

Through the elaboration of a concept map, for the research study entitled "Obtaining scaffolds of Polycaprolactone / collagen / microcapsules of TGFβ3 for skin tissue regeneration" it was possible to express the hierarchy of the concepts, navigating through the most general concepts, starting from the theory of previous studies and available information, reaching the most specific concepts, such as materials for the development of nanofibers. In addition to this, through the use of cross-links it was possible to relate different hierarchical branches of different disciplines to each other, establishing connections or links that give an account of what type of relationship exists between the concepts involved, creating important nuclear sentences to size the scope and representativeness that different areas of knowledge have, in addition to the contribution from the area of Chemistry to that of Regenerative Medicine.

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