IMPROVING KNOWLEDGE CAPITALIZATION IN PRODUCT FORMULATION: A COSMETIC INDUSTRY STUDY CASE

JULIANA SERNA
Universidad Nacional de Colombia Sede Bogotá/ Departamento de Ingeniería Química y Ambiental, Grupo de Procesos Químicos y Bioquímicos, Colombia

VINCENT BOLY
Université de Lorraine/Laboratoire ERPI (Equipe de Recherche des processus Innovatifs), France
Vincent.boly@univ-lorraine.fr

PAULO CESAR NARVAEZ RINCON
Universidad Nacional de Colombia Sede Bogotá/ Departamento de Ingeniería Química y Ambiental, Grupo de Procesos Químicos y Bioquímicos, Colombia

VERONIQUE FALK
Université de Lorraine/ Laboratoire LRGP (Laboratoire Réactions et Génie des Procédés), France

ABSTRACT

Cosmetic industry is looking for new methods and tools that enable the design of high added value products in order to respond better and faster to customer needs. In this sector, innovation represents a key success factor, although it is difficult to generate due to the time and cost it implies and the lack of a general product design methodology. Instead, cosmetic companies use their own methods for product formulation based on their know-how and staff experience.

A robust design methodology based on scientific knowledge can better help designers to face the intrinsic complexity of chemical product design, understand and translate customer needs into product specifications and explore the design space rapidly and broadly in order to find the best possible solution. With the aim to contribute to the topic chemical product design and cosmetics design, this research presents a comprehensive structure of a design methodology for cosmetic emulsions. The methodology enables the connection of design stages by integrating expert, scientific knowledge, and data bases. The methodology comprises a design workflow, containing three design stages: need analysis, product ideas generation, and product selection and an information structure containing two main data bases: emulsion data base and ingredients/processes data base, enabling designers to understand the form of the solution space and to take better design decisions. Innovation is then possible thanks to the proposed methodology by focusing on new needs, compounds or combination of properties. This methodology is directly applicable to the design of oil-in-water cosmetic emulsions. However, its structure can be extended to other type of emulsions and cosmetic product forms.

* Corresponding author

Key words: cosmetic product design, knowledge structure, design methodology, cosmetic industry

INTRODUCTION

The chemical industry, and particularly the cosmetic industry, is interested in the development of methods and tools that enables the design of high added value product in less time and with lower costs. This occurs as an answer to the increase of competitiveness in the chemical market, the growing demand for innovative products and the public concern about the environmental and safety issues (Charpentier, 2010). Nowadays, cosmetic companies develop their own methods of product formulation based on their know-how. Most of this knowledge remains tacit (Chandrasegaran et al., 2013). To avoid knowledge loss and improve the success rate, researches are more directed toward the formalization of cosmetic design processes and associated data bases, as can be seen by the high increase in the number of international publications containing the term “chemical product design” in the last ten years (SCOPUS, 2017).

Scientific production in chemical product design is significantly lower than the one in mechanical or digital design domains especially when considering cosmetic products specifically. However, cosmetic formulations still attests of some interesting characteristics that merit further research. Chemical products such as cosmetic emulsions are formed by multiple components interacting in multiple scales (Charpentier, 2009). They have to be designed in a manner that guarantees its technical feasibility, the satisfaction of customer needs and the fulfillment of sustainability requirements (Charpentier, 2009). The achievement of such a design is not straightforward, because components, structures, phenomena and processes that constitute the product are highly interrelated (Cisternas, 2006). Moreover, knowledge enabling chemical product design arises from various fields and has different forms, which requires and interdisciplinary work and an integration of scientific and empirical knowledge in order to take design decisions.

There are interesting existing approaches for chemical product design. Various design workflows have been proposed (Cussler and Moggridge, 2011; Hill, 2009; Mattei et al., 2014) and special emphasis has been placed in the development of methods based on Computer Aided Molecular Design (CAMD) (Conte et al., 2011a, 2011b; Mattei et al., 2014, 2013). Despite the above, there is not a robust chemical product design methodology, as the one used for process design or for product design in other fields.

With the aim to contribute to the generation of a robust design methodology, this research presents a comprehensive product design workflow connected to an information structure applicable for the design of oil-in-water cosmetic emulsions. The information structure considers the multi-scale nature of chemical products (Charpentier, 2009) by connecting product specifications (input) with emulsion characteristics (colloidal scale), production processes (process scale) and ingredients properties (molecular scale), and it enables the exploration of the solution space using the reverse design concept (Conte et al., 2011b), in which information is organized to go from product specifications (input) to product components and processing technologies and conditions (solution). This is done using two relational matrix filled with emulsion science principles and expert knowledge, and a data bases of cosmetic components and processing technologies. First, this article presents the main design stages: need analysis, product ideas generation and product idea selection. Second, the article shows the information structure of methods and data bases integrating the methodology. Finally, an example is presented.

WORKFLOW OF PRODUCT DESIGN METHODOLOGY

Based on the proposal of Cussler and Moggridge (2011), but considering the design of product and process simultaneously (as suggested by many authors (Eden et al., 2003), (Bernardo and Saraiva, 2005), (Cheng et al., 2009)), a workflow for the design of cosmetic emulsions is presented in figure 1.

The stages of the methodology are following presented:

Stage 1 - need analysis: In this stage user needs are 1) identified, 2) analyzed according to their relative importance and 3) translated into product specifications. The input is information about customers and stakeholders, mostly expressed in common language and the output corresponds to product specifications, expressed in engineering terms. To develop this stage two methods are suggested: Kano model and Quality Functional Deployment.

Here, the concept of need is understood as a characteristic of a person or a group, which affects his/her/their activity and causes dependency (Rejeb et al., 2011). Needs are completely independent of any product, they are a lack in human experience and the reason for the design activity (Ulrich, 2005).

Stage 2 - product ideas generation: In this stage concepts of products accomplishing design specifications are generated. Due to the complexity of emulsion nature it is suggested to classify specifications into smaller design sub-problems and to solve each sub-problem separately. Solutions to sub-problems are ingredients, technologies and processing conditions. After solutions for all sub-problems are found, it is necessary to evaluate their compatibility and in some cases to make some trade-offs. Sets of compatible solutions that respond to all sub-problems are a design concept. To perform this stage an information structure comprising two data bases: emulsion data base and process and ingredients data base, is proposed. Emulsion data base comprises two relational matrixes with information of emulsion structure. Process and ingredients data base contents information of components and processing technologies properties.

Stage 3 - product idea selection: In this stage generated concepts are assessed and rated according to product specifications defined in stage 1 and a set of sustainability indicators. To perform this stage, a multi-criteria assessment method with performance indicators is proposed.

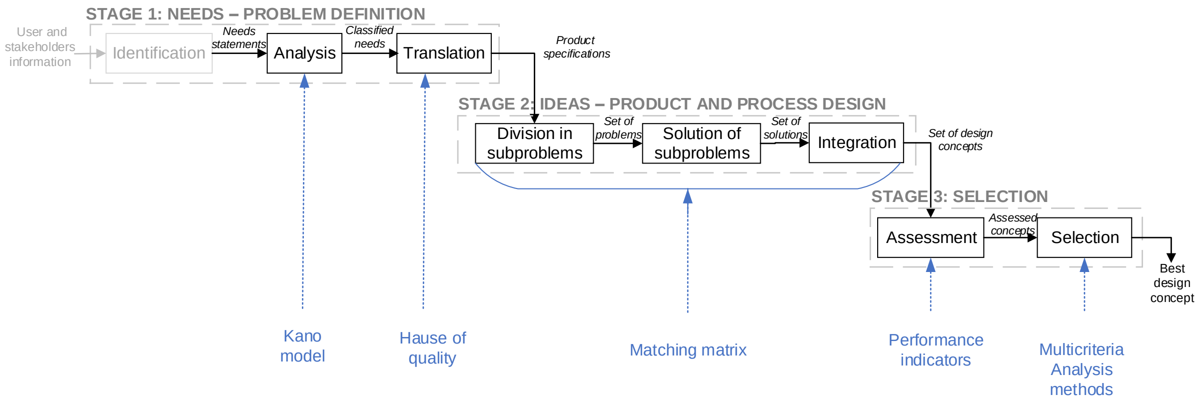


Figure 1 workflow of the methodology

Figure 1 presents the overview of the methodology. This article explain the information structure used to connect design stages.

INFORMATION EXTRUCTURE OF THE DESIGN METHODOLOGY

The proposed information structured is based on the concept of chemical product pyramid (Costa et al., 2006), in which the interrelations between chemical product, process, ingredients and usage (customer interactions and environmental parameters) are considered, and on the information structure for materials selection presented by Ashby (2005). According to the latter, information should be organized in a form adapted to information use. In this case, it should allow to go from customer needs to product specifications and from them to ingredients and process conditions. Figure 2 presents an outline of the structure.

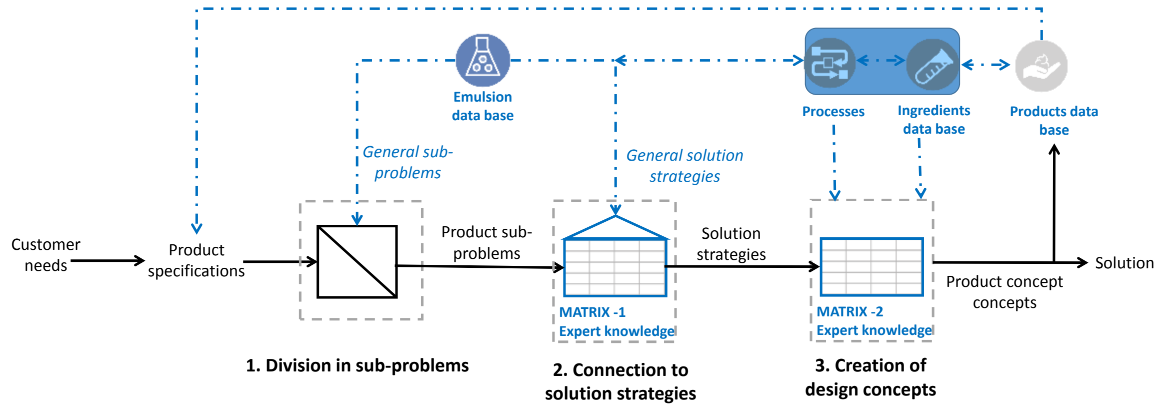


Figure 2 Information structure

The structure comprises two interrelated data bases one containing information of oil-in-water emulsion and the second containing information of ingredients and processes. The emulsion data base contains a list of general sub-problems and general solution strategies normally found in emulsion design problems. The lists are linked with expert knowledge, enabling the connection of product specifications of a specific design problem with possible solutions strategies applicable for emulsion design. Emulsion data base is in turn connected to ingredients and processes data base. This link enables to go from emulsion attributes to ingredients properties and processing conditions. In ingredients and process data base, ingredients are classified in functional cosmetic groups as emollients, surfactants and rheological modifiers, between others. They can be searched by their physical, chemical and performance properties. Figure 3 and 4 show an outline of emulsion and ingredients data base, respectively.

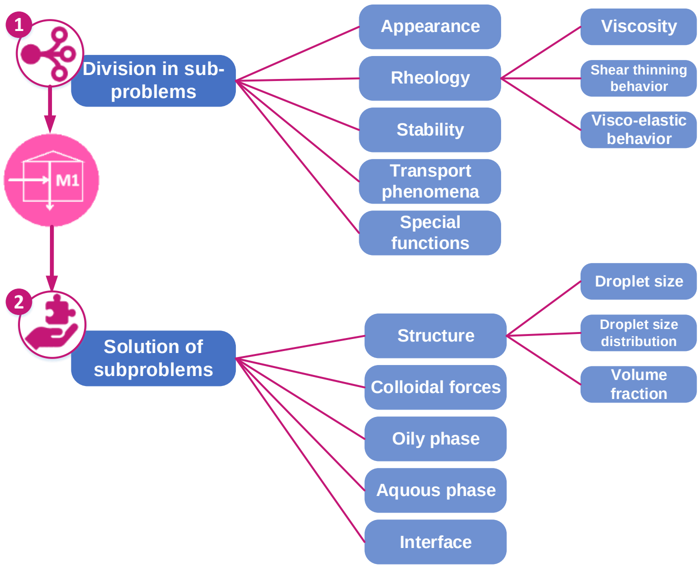


Figure 3 Information structure –emulsion data base

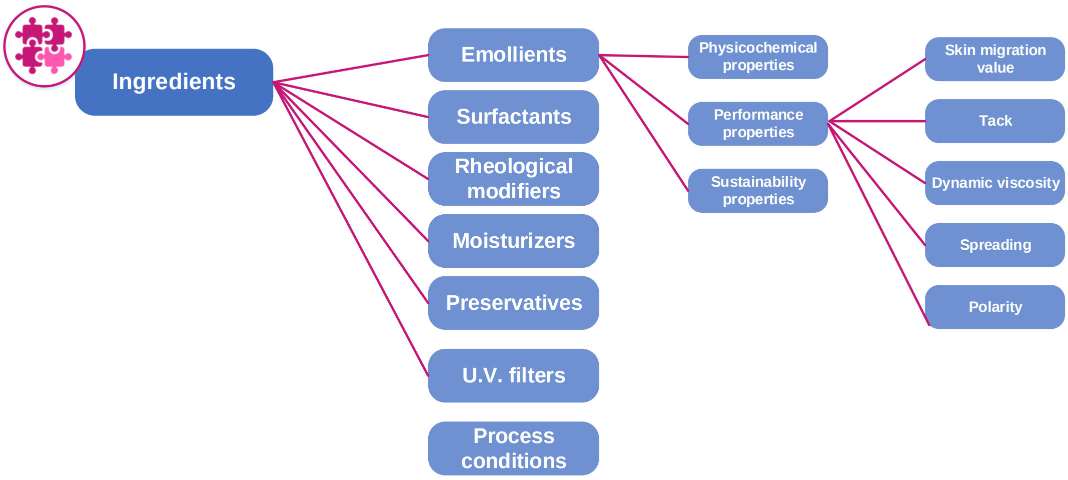
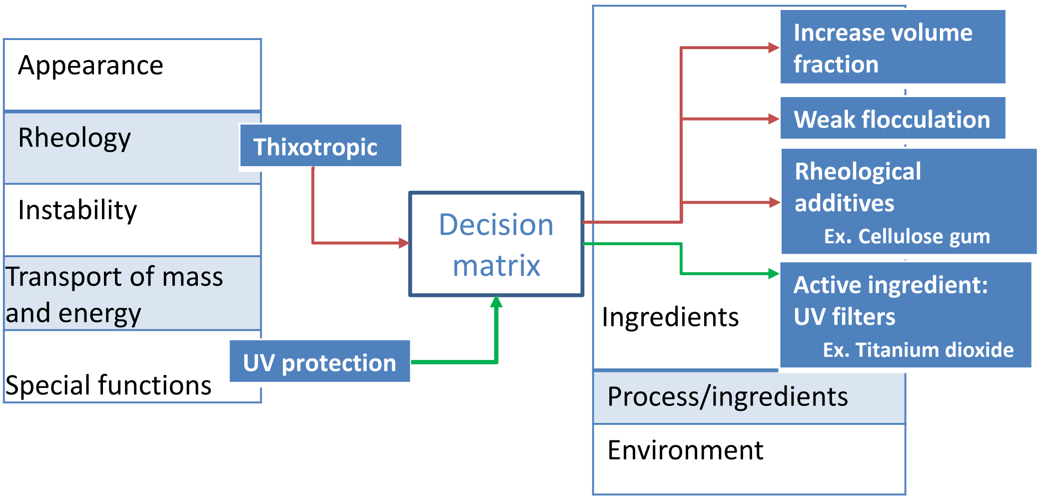


Figure 4 Information structure –ingredients data base

APPLICATION EXAMPLE

For the design of a sunscreen, the main specification corresponds to the Solar Protection Factor (SPF) that indicates the protection given by the product. It should be minimum of 15 to give a real protection. SPF is normally generated by the presence of molecules that either block or absorb the UVA and UVB light (Cussler & Moggridge 2011). This function depends on the presence of active ingredients (U.V. filters) and therefore it is classified as a special function using the emulsion data base. Additionally it was found that the SPF factor augments when the product forms an uniform coating on user skin, protecting the entire exposed area (Gaspar & Campos 2003). Uniform coatings can be enhanced with some degree of rheological thixotropic behavior (Gaspar & Campos 2003), (Laba 1993). A thixotropic fluid is one in which viscosity decrease with an applied shear and remains low for a period until the material recovers its original viscosity (Tadros 2010). Therefore, SPF specification is related to two general sub-problems of the emulsion data base: 1) Special functions - Active ingredient for UV protection and 2) Rheology - thixotropic behavior.



The first data base founds four possible solutions for the sub-problem. An active UV filter has to be used and thixotropic behavior can be enhanced by increasing volume fraction, enhancing weak flocculation or adding rheological modifiers.

The second data base enables to select an U.V. filter or a mixture according to the PFD factor it gives. From a list of 22 filters, a large number of mixtures given a SPF of 15 is possible. All those mixtures are design possibilities that have to be screened out according to additional criteria as safety and sensorial properties of the final product

CONCLUSIONS

The design of cosmetic emulsions such as shampoos, moisturizing creams and sunscreens, needs a systematic approach to address the design requirements and generate feasible product designs that fulfill them. This is not an easy task because emulsion chemical products are complex systems whose elements are highly interrelated. Traditional structure information goes from ingredients identity and product concepts to products attributes, requiring the designers to know the ingredients and products to be used in order to find their properties and accommodate them to customer needs (technology based design). This article shows an information structure that enables to go from product specifications defined based on customer needs to ingredients and process technologies, giving interesting tools to the designers for new products and innovation.

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