Chemical Engineering & Processing: Process Intensification 181 (2022) 109161

Contents lists available at ScienceDirect

Chemical Engineering and Processing - Process Intensification

journal homepage: www.elsevier.com/locate/cep

Latin American women in chemical engineering: Challenges and opportunities on process intensification in academia/research

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ARTICLE INFO

Keywords:
Women researchers
STEM fields
Process intensification
Science
And gender equality

ABSTRACT

In the last years, different entities have developed programs to incentivize and involve women in Science, Technology, Engineering, and Mathematics (STEM) fields. In Europe, Asia, and Africa, only 30% of all professionals working on engineering research are women. In Latin American and the Caribbean countries, the panorama is more encouraging, nearly 50%. In this sense, this paper aims to analyze and highlight the woman's role in chemical and process engineering, especially in the process intensification area in the Latin American context. Initially, the document presents some historical data about relevant women. Then, statistic information is discussed on female researchers in the world, as well as in Latin American countries. The current work areas are also analyzed where there is a particular emphasis on intensified distillation configurations, biofuels and sustainable processes. Finally, some researchers that participated in the special issue solved a survey about their academic experiences. As noticed from the recovered answers, it is possible to claim that successful scientific women stimulate and inspire other women to exemplify transcendence. All academic family trees start with male mentors, but women have gained a relevant place in STEM fields; therefore, the structure will change and be more equitable in the future.

1. Introduction

Women's participation in science and research is in the international politics proposed by the United Nations General Assembly (UN-GA) through the Sustainable Development Goals (SDG's), specifically in the objective 5th "Achieve gender equality and empower all women and girls". In the last years, the academic community, governments, and institutions have developed different programs to incentivize, disseminate and involve women in STEM fields. Despite the numerous efforts to achieve gender equality, women are underrepresented in several labor areas. Currently, engineering is one of those areas. Despite efforts being made to increase the number of females doing research in STEM fields, nearly 30% of all professionals working in engineering research are women worldwide. In this context, international entities such as United Nations have promoted special programs to encourage complete and equal access to Technology, Science, and Innovation for women. This paper aims to analyze and highlight the woman's role in chemical and process engineering, especially in process intensification in Latin America. However, their role has been decisive in most study areas and is now irreplaceable. Their performance has allowed significant progress in gender equality achievement, which is vital for sustainable development. Encouraging and supporting women scientists to use their full potential is not only fair but necessary.

According to UNESCO, approximately 33% of researchers worldwide are women [1]. Nevertheless, at the doctoral training level, the balance leans towards men. This pattern also occurs in several Latin American countries. For this reason, the Organization for Economic Co-operation and Development (OECD) has established education policies for Latin America, based on STEM model for women [2]. These initiatives aim to allow gender equality and female empowerment. Similarly, educational

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https://doi.org/10.1016/j.cep.2022.109161
Received 10 May 2022; Received in revised form 29 September 2022; Accepted 1 October 2022
Available online 4 October 2022

institutions have chosen to transmit the model of successful scientific women in different study areas to stimulate and inspire other women.

Nowadays, women have access to the university to study engineering in a higher proportion than fifty years ago, being this field of high impact at international level. In the chemical engineering case, the women have had a relevant role with a significant presence, achieving important goals in the research and academy where skills such as innovation, dedication, and critical thinking have been key. Latin American countries have women researchers in training and with experience, working hard in biotechnology, processing, environmental engineering, energy, and materials science, focusing on process intensification. For this reason, this paper aims to show the women's process over the years in the STEM fields in the Latin American context, especially, in chemical engineering and processing-process intensification. Initially, some important historical data are presented, about the role of women in higher education, science, and engineering. Then, a current overview of the gained ground by women in favor of science and gender equality is shown, highlighting the main actions fields. Finally, the survey results on women's research experiences are analyzed, and some future perspectives are indicated.

2. The starting of women in the STEM fields

In the United States, since the 1800s, women have had a significant role as professors and administrators in higher education institutions, although in a low percentage [3]. Women's representation in occupational groups during the 1900s fluctuated considerably. In 1930, the women's representation achieved a 14%, in 1950 decreased to 10.8%, and in 1970 the female professional positions claimed the same percentage that in 1930 [3]. Their initial participation was in home economics, foreign languages, and literature. Some years later, careers such as social work, nursing, and elementary teaching were involved [3]. On the other hand, women's participation in STEM fields has been complicated and limited. The first woman who impacted history was Elizabeth Blackwell (1821–1910), the first doctor of medicine in America [4]. Another case is Katharine Burr Blodgett (1889–1979), the first female scientist, and expert in surface chemistry and engineering. She was also the first woman who earn a doctorate from Cambridge University [4].

A notable example is Mae C. Jemison (1956-present), who earned a bachelor's degree in Chemical engineering and later studied doctor of medicine. She was the first Afro-descendent woman to travel into space in 1992 [4]. On the other hand, Sally Ride (1951–2012) was the first American woman in space in 1983. It occurred after two Soviet cosmonaut women, Valentina Tereshkova in 1963 and Svetlana Savitskaya in 1982, had already opened the way to the female space race [5]. In the Latin American context, Ellen Ochoa (1958-present) was the first woman of Hispanic origin to go to the space in 1993. She studied Physics at San Diego State University, and the Stanford University was the institution where she earned her master's in sciences and Doctorate degrees in Electric engineering [6].

In Colombia, Paulina Beregoff (1920–1970) was inscribed in history as the first woman to graduate from the School of Medicine and became a teacher of bacteriology and parasitology. It happened in 1925 at the University of Cartagena in the midst of a strongly conservative society [7]. Similarly, Rebeca Uribe Bone (1917–2017) is the first chemical engineer woman who graduated from the Universidad Pontificia Bolivariana and exercised her profession in the Bavaria beer company [8]. In Mexico, Concepción Mendizábal Mendoza (1893–1985) was the first woman graduated as Civil Engineer from the School of Engineering of Universidad Nacional in 1930 [9]. Likewise, Amparo Barba Cisneros (1918–2011) was part of the first generation of chemical engineers from the National School of Chemical Sciences and was also one of the first women with this degree. She served as head of Micro-analytic Department and worked at Syntex Research Laboratories [10].

In the last 30 years, despite women gaining ground in STEM fields, much work still needs to be done. Although, there is encouraging data in the United States that women earn more bachelor's and master's degrees than men. The main studied areas are social sciences, biological sciences, education, fine arts, and humanities [11]. In the engineering field, in 1996 the percentage of women that received PhD degrees was 12.3%; meanwhile, in 2012 this percentage increased until 22.6% [11]. For master's and bachelor's degrees, the increases were not considerable. In 1996 the percentage of women that received bachelor's degree was 17.9% and in 2012 was 19.2%. For master's degrees, the percentage passed from 17.7 to 22.9% [11]. These numbers and other reports were the starting point for promoting projects that incentivize women's participation in STEM fields in Latin America [12–14].

According to the United Nations Women, in 2021 several Latin American women were highlighted in science and technology. For example, Valentina Muñoz, a Chilean programmer, and activist. Idelisa Bonnelly, Dominican Marine Biologist, named "mother of marine conservation in the Caribbean." Africa Flores, Guatemalan agronomist, a research scientist, and winner of the Geospatial Women Champion of the Year award in 2020. Natasha Bloch, Colombian Evolutionary Biologist, and Genomic scientist. Kathrin Barboza Bolivian biologist, expert researcher on bats. Sandra López Verges, Panamanian microbiologist, and Ph.D. in Microbiology with emphasis in virology and Ana Inés Zambrana, Uruguayan Biochemist [15]. In the engineering field, Eileen Vélez-Vega and Diana Sierra are outstanding. Vélez-Vega is a Puerto Rican civil engineer specializing in Aviation, leading important projects in all of Puerto Rico's ten airports. Sierra is a Colombian industrial designer and co-founder of Be Girl (an entity that designs high-quality, re-usable, and affordable menstrual materials for destitute females) [16].

3. Current outlook of scientific and engineer women in Latin America

According to reported data by the UNESCO, during 2015–2018, women constituted 33% of researchers, 5% higher than five years before. Fig. 1 displays the distribution of female-male researchers in different world regions; as can be observed, Latin America and the Caribbean are two of the regions that favor gender parity in research (Fig. 1). Although this growth can seem slow, it can be considered a positive output. However, as discussed in such a report, it is very challenging to get conclusions since most countries do not collect complete data regularly, and their analysis suggested that country's wealth does not necessarily imply better results in achieving gender parity in this field [17]

Another index of women's participation in scientific research is the record of patent applications that includes at least one-woman inventor. Although most countries generally reported low participation of female researchers in patents related to engineering, there are some areas in life science, such as biotechnology, organic fine chemistry, pharmaceuticals, and food chemistry, wherein one can find a higher female representation

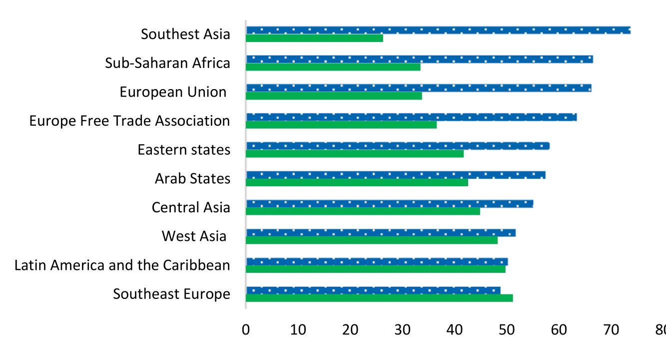

Fig. 1. Regional shares of female researchers 2018 (%). Adapted from [17].

(>50%). However, for other areas such as engines, turbines, pumps, turbines, and control, women's participation as inventors fall below 30% [17]. Remarkably, even in these "hard" areas of engineering, women's participation in paten records has risen during the last 10 years 1(Fig. 2).

As mentioned above, even if in average women constituted 33% of researchers worldwide, Interestingly, highest proportion of women studying in science and engineering fields (almost achieving gender parity). Fig. 3 indicates the shares of women researchers by country in Latin America from 2009 to 2012 [13,14]. Among the Latin American countries that have had more significant achieves of gender parity (>50%) are Bolivia, Venezuela, Argentina, and Paraguay, followed by Uruguay, Brazil, Guatemala, and Costa Rica, ranging from 43 to 49% of female participation. Similar trends are observed for Caribbean countries such as Cuba and Trinidad and Tobago, with 47 and 44%, respectively. On the other hand, Chile, Honduras, and Mexico present a noteworthy disparity in women's representation, having the lowest score among countries, falling in the global mean, around 30% [17].

Among the areas wherein women researchers remain underrepresented, and have less visibility, are access to granted research projects, tenure tracks, lower publishing records in indexed scientific journals, and participation in science academies [13]. As reported by Inter-academy Partnership, only 10% of members in almost 30 countries' academies are women. Six of the top ten academies with more significant female representation (≥20%) are in Latin America and the Caribbean. Fig. 4 displays the distribution of members in Latin-American science academies. Remarkably, they also discussed that besides their low participation as academy members, women are better represented in the leading positions of some of these academies. [18].

4. Some examples of topics that Latin American women in PI have worked on

It has been suggested that chemical engineering is attractive to women because the environment, both in the workplace and in academia, tends to be more welcoming to women than disciplines largely dominated by men, such as mechanical or electrical engineering [19]. There is also evidence that women in chemical engineering not only expect economically attractive work, but also challenging activities and respect from others than their male counterparts. Brawner et al. (2011) reported that for all the women participating in the study, their reasons were multifaceted with various complementary influences [19]. For example, something relevant was that it influenced the feeling of

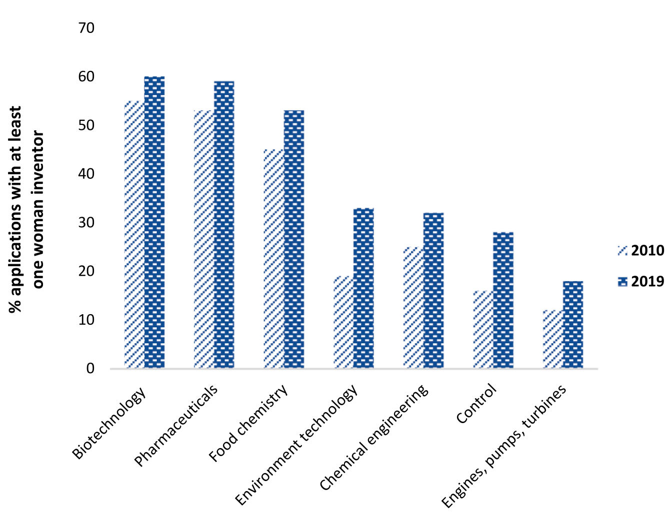

Fig. 2. Percentage of Patent applications with at least one female inventor in selected areas related to Chemical Engineering, 2010 and 2019. Adapted from [17].

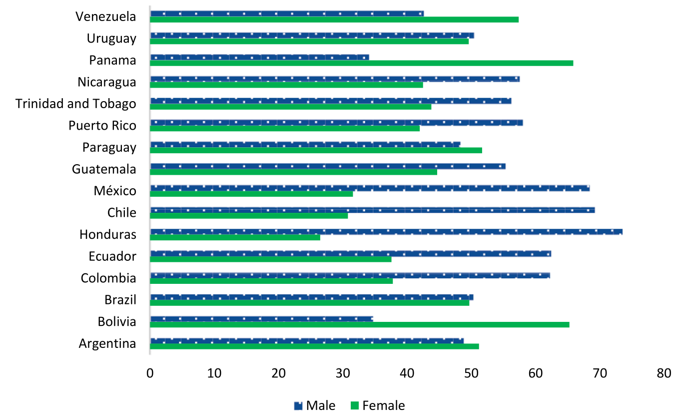

Fig. 3. Shares (%) of women researchers by country in Latin America. Adapted from [18].

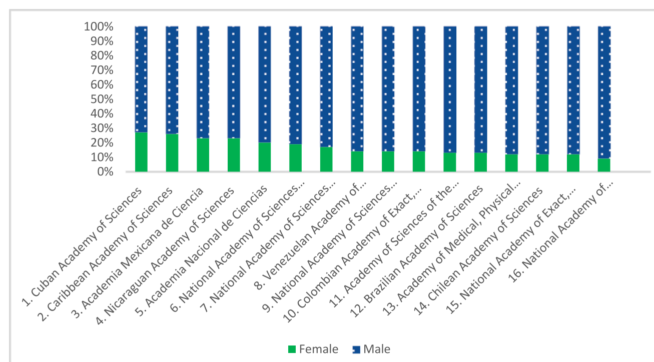

Fig. 4. Participation of women as members in Latin American science academies. Adapted from [18].

being welcome in the department or an advisor in the department was fundamental for the choice of becoming a chemical engineer. According to a study in year 2007, women who are qualified in math and science and who choose to study engineering elect the particular discipline through a seemingly random process: a) perceptions of career potential, b)influence of a nice professor, or c) even a process of elimination [20]. It has also been shown that female chemical engineering students tended to have higher academic achievement in performance metrics (high verbal and math scores, high school grade point average, among others) [21].

In the 21st century economy, chemical and process engineering must respond to new challenges and opportunities: i) meeting growing market requirements, ii) meeting specific end-use properties of the product, iii) societal and community needs, iv) raw materials, v) energy savings, and vi) the environmental impacts of the process. In the context of sustainability and globalization, it is shown that the intensification of processes is a way to meet these challenges. Process intensification leads to more or less complex technologies that replace large-volume, high-cost, and energy-consuming equipment with others that are less expensive, more compact, more efficient, and where in the environmental impact is minimized. Other important aspects include improving inherent security and enhancing the dynamic performance and the possibility of automation, or when multiple unitary operations are combined in the least amount of equipment [22]. The leading women in process intensification in Latin America have worked in recent years in solving problems of industrial impact on different topics of interest (sustainability, bioprocesses, and novel processes, among others), as can be seen in the following list of examples (the list that is not exhaustive).

4.1. Intensified distillation configurations

A Dividing Wall Column (DWC) is a distillation column that combines the operation of two conventional columns in one shell. It is a good example of intensified distillation columns. The separation of a three-component mixture in the individual components is made possible by installing a vertical wall in the middle of the column. One of the first works of the study of DWC (in Latin America) with non-equilibrium models was reported by Abad-Zarate et al. (2008) [23]. Data reported in the industrial literature are in agreement with results generated by the non-ideal model. In the same sense, Tamayo-Galván et al. (2008) studied the thermodynamic equivalence and the dynamic behavior of six equivalent configurations to the DWC [24]. Because the optimal design of DWC is a multivariable problem, a non-linear problem, and the objective function is generally non-convex with several local optimums, some relevant works have been reported. In a pioneering work, Gutiérrez-Antonio and Briones-Ramírez (2009) studied the design of dividing wall columns (ternary and quaternary mixtures) using a multi-objective genetic algorithm with restrictions and Aspen Plus for the evaluation of the model [25]. Ramírez-Corona et al. (2010) present an optimization strategy for DWC (ternary mixtures) [26]. The strategy uses a shortcut design method to model the configuration as a nonlinear programming problem.

The existence of snowball effects in steady-state conditions under the implementation of intensified distillation columns in reactor–separator–recycle systems is studied by Alpuche-Manrique et al. (2011) [27]. The effects of implementing thermally coupled distillation systems on snowball effects are compared to those generated by conventional distillation schemes in a process for ethylbenzene production.

López-Ramírez et al. (2016) reported the design, construction, and operation of a prototype of a reactive DWC column in Universidad de Guanajuato (México) [28]. The esterification between methanol and oleic acid was conducted in reactive intensified equipment. The temperature profile measured during the experimental run can be used for controlling the column.

4.2. Biofuels

Several hybrid configurations for the purification of a typical mixture of ethanol/water obtained from the fermentation of biomass have been proposed by Avilés-Martínez et al. (2012) [29]. This study proposes alternative intensified systems using liquid-liquid extraction and extractive distillation to obtain bioethanol for use as fuel. The proposed systems are analyzed in terms of energy consumption and total annual cost. The hybrid scheme presents both lower total energy consumption and lower total annual cost as compared to the conventional purification scheme. In the same line, Vázquez-Ojeda et al. (2013) present the design and optimization of a dehydration process for bioethanol (fuel grade), using two separation configurations: a conventional and a hybrid scheme based on liquid-liquid extraction [30]. Three extraction solvents were evaluated: octanol, octanoic acid, and ethyl hexanol. The results show savings in total annual cost for the hybrid systems, for a feed stream with 22 wt% of bioethanol.

With the intention of modeling and simulating a complete plant for biojet fuel production, a lot of efforts are being carried out. Gutiérrez-Antonio et al. (2018a, 2018b), in novel works, presented the modeling of conventional and intensified hydrotreating processes to produce biojet fuel [31,32]. In this proposal, they evaluate two distillation methods: conventional and intensified schemes. Microalgae oils and *Jatropha curcas* are considered renewable raw materials. In the results, authors show that total annual costs of all hydrotreating processes are similar. However, the carbon dioxide emissions of the conventional purification structure are 34% higher than the ones reported for an intensified alternative separation process. Thus, the intensified proposal allows producing biojet fuel with a competitive price and minimum environmental impact.

Romero-Izquierdo et al. (2020) presented the immediate application of intensification techniques [33]. In this work the modeling and intensification of ATJ conventional process is presented (raw material is lignocellulosic wastes). Moreno-Gómez presented the modeling, simulation, and intensification of the hydroprocessing of chicken fat to produce renewable aviation fuel [34]. Conventional hydrotreating processes are modeled and used to define the intensified ones. All processes are compared in terms of economic and environmental indicators. Their results show that intensified schemes comprise the best scenario regarding environmental and economic indicators.

To date, Gutiérrez-Antonio et al. (2020) have prepared a complete book about Biojet fuel production, considering an in-depth review of process intensification and energy integration strategies [35]. Process intensification is shown as one of the most viable strategies for designing economically profitable and under sustainability criteria for the large-scale production of biojet-fuel from various biomass.

4.3. Analysis of (bio) sustainable intensified processes

Process intensification in the area of bioprocesses has been worked by Lutze et al. (2012). They are developing novel methodologies for this kind of processes: systematic computer-aided model-based synthesis and design methodology incorporating PI [36]. The methodology employs a decomposition-based solution approach, generating a set of process options until optimal is found.

Medina-Herrera, et al. (2014) studied the application of risk measurements as part of the design of conventional and intensified purification structures [37]. Quantitative risk analysis and economic criteria are used to design two kinds of distillation schemes: conventional and multi-effect distillation. As case studies, two types of mixtures that address different safety implications are used.

Considering the biorefinery concept in the Colombian context, an environmental and techno-economic study for producing bioethanol, biodiesel, biobutanol, hydrogen, and electricity as main products and acetone as by-product from oil palm was studied, by Aristizábal-Marulanda et al. (2016) [38]. Their results show a positive economic margin of 77 and 20% is showed for biodiesel and hydrogen, respectively. The stages involved in the biodiesel production have a lesser extent of potential environmental impact in the process due to the minimum waste streams obtained, from the environmental point of view.

Ortiz-Espinoza et al. (2017) present a strategy for including an inherent safety index that can be used to compare different intensified arrangements at the design stage [39]. The basis for a safety metric is obtained by combining two indices: one that rates the process routes and a second one that rates the process streams. Results from simulations of process flowsheets can be used to obtain the data needed to apply the safety indices.

A framework to integrate the economic, social, and environmental aspects in a bioprocess intensified design is shown in the paper by Monsiváis-Alonso et al. (2020). In this work, the authors have also established strategies for life cycle analysis in that kind of process [40]. Experiments in an intensified biorefinery based on Coffee Cut-Stems to produce ethanol, furfural, and electricity is presented by Aristizábal – Marulanda and Cardona (2021) [41]. Experimental and simulation results are compared in terms of productivity and conversions. Recently, Romero-García et al. (2022) evaluated the environmental impact of coupling an optimized CO_2 capture intensified scheme (based on reactive absorption with amines) to an electric power generation plan [42]. This work considered the use of four different fuels in the power plant: coal, biogas, non-associated, and associated natural gas. Two operating scenarios were studied: i) the same fuel flow was considered for all the plants, and ii) the same energy demand was specified. Results show that the efficiency of the capture processes is directly related to the CO_2 concentration in the combustion gas and the absorbent flow for carbon dioxide capture.

4.4. Special issue "Challenges and opportunities in process intensification for Latin American women"

Recently the journal "Chemical Engineering and Processing: Process Intensification" has published a special issue called "Challenges and Opportunities in Process Intensification for Latin American Women". Some examples of papers published in this special issue are:

Producing pristine chitosan nanofibrous mats is challenging because some of these traits restrict its solubility in most common solvents, thus limiting its electrospun processability. Pérez-Nava et al. (2022) present the intensified production of pristine chitosan electrospun nanofibers using the 1,1,1,3,3,3-Hexafluoro-2-propanol/acetic acid binary mixture as solvent [43]. This binary solvent improves pristine chitosan spinnability and facilitates the one-step fabrication of highly stable nanofiber mats insoluble in water and aqueous media without the need for crosslinking and neutralization, which implies no need for further washing steps, no waste production, less energy consumption, reagents saving and a significant impact on reducing total processing time compared with previously reported methodologies.

Munguía-López et al. (2022) propose a mathematical model for optimal solid waste management, proposing a circular value chain where all types of waste are treated in an intensified industrial park [44]. The model selects the processing technologies and their production capacity. The problem was formulated as a mixed-integer linear programming problem to maximize profits, and the waste processed, minimizing environmental impact.

Coffee husks are abundant lignocellulosic materials that can be used to produce fermentable sugars. In the study by Sabogal-Otalora (2022), sugars are produced from coffee husks through intensified biological pretreatments using the white-rot fungi *Pleurotus ostreatus* (PL) combined with steam explosion. This work demonstrated that combined treatment increased coffee husk sugar production [45].

The research by Diniz da Silva et al. (2022) aimed to model and simulate water transfer during lipases production by solid-state cultivation of the fungus *Metarhizium anisopliae* using babassu coconut bagasse as substrate in a pilot-scale tray bioreactor. A material balance was applied for water, and individual equations for drying processes were adapted for both solid and gas phases. The model proposed is a powerful tool for guiding the intensified bioreactors scale-up [46].

Understanding how the type of biomass t and parameters of the pyrolysis process influence the characteristics of the biochar obtained, including its calorific value and potential as solid fuel, is important in generating alternative energy sources. In this context, de Almeida et al. (2022) assessed intensified biochar production by pyrolysis of parent biomass, straw, and treated biomass. The approach followed in this work was to contribute to a more in-depth understanding of the valorization of subproducts of the sugarcane industry through pyrolysis to produce biochar that can be used as an energy vector or material for different environmental applications, contributing to the goals of a circular bioeconomy [47].

5. Survey on woman experiences

Aiming to make visible the female researcher's journey in their professional development in process intensification, we prepared and sent a survey to the invited authors of this special issue. Although the participants' universe is small, and its attributes may bias the survey responses, the main objective of this article, as well as of the special issue, is to expose women's contributions, recognizing their valuable efforts and the challenges they have faced along their careers. The survey contains 10 open questions (**Supplementary material**). Five out of these ten questions were adapted from Murphy et al. (2018); the remaining questions were prepared to identify additional information that allows us to figure out the role of female mentors in their professional development [48]. This section intends to share experiences, not to generalize or make conclusions about these experiences, but to recognize them, looking to inspire the new generation of women researchers.

To analyze the received answers, a relational content analysis (RCA), based on qualitative research methods, was performed by an expert in Social Psychology, aiming to understand together how women experience Latin American Chemical Engineering. This RCA allows us to analyze the data directly from their told experience by transforming it into categories that help us re-narrate a group experience by exposing transversal factors. It is important to say that women will be characterized as S1, S2, S3… to remain anonymous and account for their answers and experiences.

Participants recognized that some of the factors that helped them decide to study chemical engineering were related to their skills (they recognized them as good at it) (S1, S2, S3). Other reasons were that the engineering school was an affordable option in terms of proximity to their homes, tuition fees, or access to scholarships (S1-C1). Also, S1, S2, and S3 reported it was related to their favorite academic subjects. For all of them, there were important figures, predominantly masculine figures (according to their professional family trees), that supported the idea, as their dads and advisors.

Regarding the main motivation for pursuing postgraduate studies, collected answers reflect similar reasons: i) they like challenges, ii) because they are good at it, iii) because they got a mentor who supports and motivate them to continue. They mention three different inputs: first, their interest: "important field, innovation, challenge, passion"; Second, their skills that support this interest. The external recognition of their abilities and interest "Many professors with Ph.D. motivate me to continue" (S4-E2).

Regarding their current position, women in our survey report to be in research and academic positions from Senior Research to Research Group Head, Full-time, and Researcher Professor (Fig. 5a). Their current areas of interest in process intensification reported different fields and interests, as shown in Fig. 5b, being in large size those recurrent. In reply to their participation in projects financed by a public or private entity, one can observe that these women are in different stages in their careers (Fig. 5c), from leading: […] at least 20 projects (S3-D8), to "not lead any financed projects (S4-D8)".

As commented above, our participants' universe mainly comprises women in academia in Latin American universities. Exploring how they became interested in such an academic position was interesting in this context. Some of them commented that it is the primary option in their countries for Ph.D.'s (S2-C4), since they can apply their skills and knowledge by belonging to a research group. Some other women emphasize their interest in teaching in two different ways: as giving and as receiving, "I like to support the next generation" (S1), "I love teaching, so I decided to move to university (leaving research center)" (S3-D4). One of them explicitly said: I was particularly interested in working in my home country to contribute to its development and motivate others to pursue similar careers (S4-E4). In all cases, they move or remain in academia or research to practice their skills/develop abilities and knowledge, inspire and motivate others (as retribution) to pursue their careers, and even contribute to their countries' development.

An obligated topic in the context of this paper regards the barriers related to their identity/gender expression during their life as researchers. Two of the six women expressed that they had not faced these barriers. One of them says that although she has no evidence, she believes barriers exist (S3-B6), while S2 and S4 expressed they have experimented with this once or more "Several […]" (S1-B6) and "Yes, I found […]" (S3-D6). When we ask them specifically about the experience of discrimination, in this case, related to gender identity/ gender expression, they mostly replied by describing sexism and discrimination by their peers or coworkers. Some of the experiences of discrimination women perceive could be categorized as indirect discrimination or prejudice. Prejudice "implies the rejection of others, more specifically a negative attitude or a predisposition to adopt negative behavior towards the members of a group, which rests on an erroneous and rigid

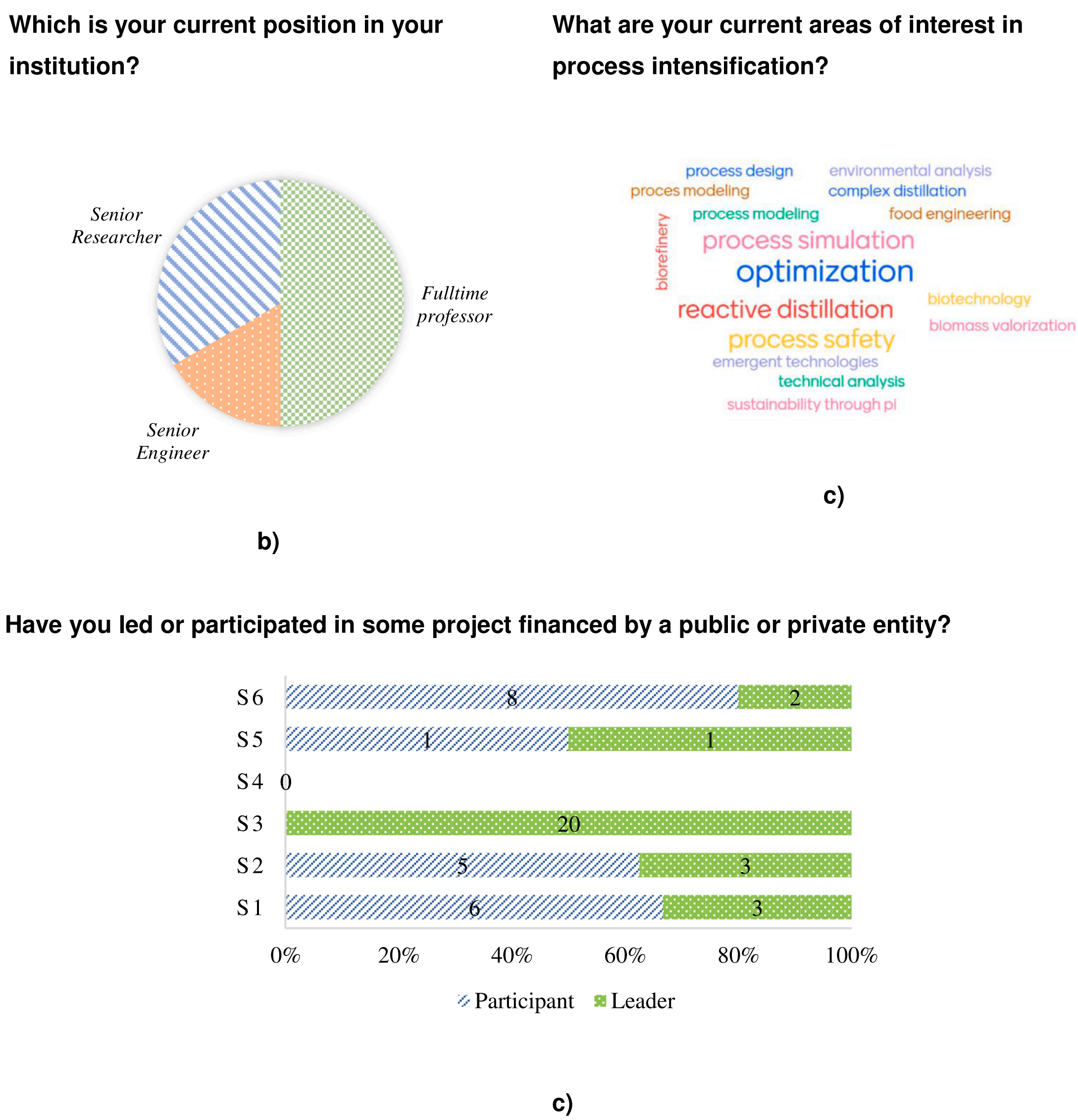

Fig. 5. Responses to selected survey questions related to current academic positions and research interests.

generalization without taking into account the individual differences that exist within the group" [49]. When prejudice (idea) becomes an act based on this idea, it becomes discrimination. For instance, S2 (-C7) and S3 (-D7) report discrimination that could be categorized as sexism: "Firstly, when I was looking for a position in academia, I do believe some colleagues found jobs easier than me even with a curriculum less strong than mine" (S2-C7). This phenome called: "Indirect discrimination (and) may occur when apparently neutral rules and practices have negative effects on a disproportionate number of members of a particular group irrespective of whether or not they meet the requirements of the job" (ILE, Global Report,2003)" [50]. It is important to remark that even with different experiences of discrimination, the confidence in what they know and their potential as researchers remain, showing a solid formation and the consciousness of all the hard work they have done over time.

Furthermore, all the women in our survey directly expressed the critical role that their mentors have in their career, with phases as: "has a huge role in my professional and personal life" (S2-C9), " … always believe on my potential, and support all my activities" (S3-D9), "He was one of the professors who encouraged me to pursue graduate studies, and he always has supported my development." (S3-C9). From the role of mentors in their personal life, we can see here the importance of respectful/healthy, long, and motivational relations between students and mentors, and the impact these relations can have in real life's. This relationship can help women avoid any backlash and contribute to their full potential. When they talk of the women who inspire them, the figures they present move from project partners and researchers they work with to figures from other epochs. We can say that women inspired by other women mainly came from their daily relations, in which they value the roles of other women who join them in their career path.

Finally, authors were requested to draw an "academic family tree" (**Supplementary material**) wherein they captured the essence of their working groups. In most of these trees, one can recognize: 1) The Ph.D. advisors of all authors who responded to the survey were male; 2) Most of them recognized female fellow researchers as a minority in their former working groups as graduate students; 3) There is an increase in female participation in their current research teams; 4) There is a clear contribution in training a new generation of female researchers.

6. Final remarks

In the last 20 years, the presence of women in higher education institutions has increased considerably, especially in programs such as social sciences, biological sciences, education, fine arts, and humanities. In engineering disciplines, the women earn undergraduate degrees but, in a lower proportion. The preference is towards industrial, chemical, and materials engineering. The opposite case occurs in electrical, aerospace, and mechanical engineering, where men's presence predominates. In several institutions, administrative directives have opted for transmitting the model of successful scientific women in different study areas to stimulate and inspire other women.

In summary, successful scientific women in different study areas inspire other women to exemplify transcendence. The respectful/healthy, long, and motivational relations between students and mentors promote a better performance and can significantly impact daily life. Most of the students who earn a Masters and/or Doctoral degree remain in academia or research to practice their skills/develop abilities and knowledge, inspire and motivate others (as retribution) to pursue their careers, and even contribute to the country's development. In this work, most participants invited to answer the survey are in academia, so further work focused on women's participation in the industrial ambit help complete this picture.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors express their gratitude to the project research called "Aprovechamiento y valorización sostenible de residuos sólidos orgánicos y su posible aplicación en biorrefinerías y tecnologías de residuos a energía en el departamento de Sucre" with BPIN code 2020000100189, funded by the Sistema General de Regalías - SGR.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.cep.2022.109161.

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