The Implementation of Mixture Design and Design Thinking for the Development of a Bolivian Native Plants Based Liquor

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Abstract

Innovation is the engine for economic development. The need for new products represents opportunities for countries with unique characteristics, such as Bolivia. The country's location in South America combined with dramatic variations in topography and climate result in a range of ecosystems. As a consequence, there is a rich variety of underexplored resources, such as native plants. No studies have considered their use for the innovation of new products. Therefore, we developed the formulation of a new liquor based on native plants from Bolivia. For the development: (a) we made a literature review of Bolivian native plants; (b) we optimized the liquor's attributes through mixture design; (c) we used design thinking to understand consumers taste. The results suggest: (a) the combination of design thinking and mixture design allowed the successful development of a new liquor from 27 native plants; (b) the iterative nature of design thinking allowed the adaptation of liquor prototypes to consumer preferences; (c) market research found the prototype satisfied consumers. The development of this new liquor suggests that countries with rich and varied ecosystems offer new opportunities for innovative products. Combination of mixture design and design thinking offers new opportunities for new product development in combinatorial complexity.

Keywords
Design thinking, experimental design, product development, native plants, liquor.

1. Introduction

Bolivia is a landlocked country with a colorful history, interesting customs, abundant biodiversity, and a diverse landscape. Its ecosystems and habitats vary from high plateaus and snow-capped mountains as high as 6,500 meters (21,500 feet) to forests and low-lying wetlands. Such various ecosystems help make Bolivia one of the world's most biologically rich nations. Particularly, this biological richness has given Bolivia a wide variety of native plants with unique properties and potential. For example, known vegetal species in Bolivia represent around 19% of the total worldwide diversity (surrounding 40,000 higher-level plants). Many of these plants have been used by generations of native Bolivians for subsistence and are part of their culture.

To the best of our knowledge, there is still little scientific research about the use and applications of Bolivian native plants. For example, in the region, most of the available knowledge about native plants is attributed to the *Kallawaya* culture (Vidaurre 2006). Furthermore, few studies have gathered information about medicinal plants from the Andes and tropical regions from Bolivia (see Vidaurre 2006; Thomas and Vandebroek 2006). Available authors only make broad descriptions and applications of native plants. Moreover, their findings are limited to medicinal descriptions and anecdotal virtues without objectively analyzing their chemical properties or benefits. Further, their views and findings are limited only to ethnocultural use. Therefore, Bolivian native plants offer new academic and market opportunities for new product developments, that go beyond just its ethnocultural use.

Our study's main contribution is that we propose the combination of two widely used methodologies for new product development: design thinking and mixture design. Our methodology combines the main strengths of both methodologies to develop new products with market-accepted features with high complexity. Specifically, design thinking allows to know and iteratively improve a product with market-oriented features, but without considering its technical feasibility. On the other hand, mixture design allows to find the optimal and technically feasible formulation of a product with high combinatorial complexity, but without a market-oriented perspective. For example, for the formulation of liquor using 27 native plants we have 2^{27} (134.217.728) possible combinations, and without certainty that the product will be accepted by consumers.

1.1 Objective

Based on the arguments presented above, our main research objective is to develop a liquor formulation based on Bolivian native plants using design thinking and mixture design.

2. Literature review

The basic aim of the use of medicinal plants is to recognize plant-based bioactive compounds or their chemically active principles. These new compounds can be beneficial to people's health (Azmir et al. 2013). Moreover, bioactive compounds are related to specific organoleptic product characteristics, such as aroma, color, and flavor. Therefore, when they are added to beverages, they improve the consumption experience.

The extraction of these compounds requires a transfer process, or the selective separation, from a solid mixture to a liquid phase (Azmir et al. 2013). Next, due to differences in concentration, the bioactive compound from the plant material is transferred to a solvent (Handa 2008). In our research context of liquor development, the solvent is ethanol (ethyl alcohol). Moreover, to efficiently and easily combine different botanical extracts to gather the best organoleptic product properties requires the use of the design of experiments. Particularly, among the different variations of experimental designs, the most adequate for our research purposes is mixture design (MD). It is the most adequate because this methodology is a special subset of response surface methodologies and it is used for the study of the components of a mixture (Thompson 1982). Moreover, an MD is an experiment in which the response only depends on the proportions of components or constituents present in the mixture (see equations below).

$$x_i \geq 0, \qquad i = 1, 2, \dots, q$$

$$\sum_{i=1}^{q} x_i = x_1 + x_2 + \cdots + x_q = 1$$

$$y = f(x_1 + x_2 + \cdots + x_q)$$

Additionally, this methodology assumes that the properties of interest are related to the composition of the product. This suggests that the modification of an ingredient's proportion changes the product properties (Cornell 1973; 2002). Consequently, independent variables, or controllable factors, are shown as the mixture's proportional quantities, are positive, and it must sum one.

MD allows obtaining a combination of native plant's compound extractions with the potential to be consumed. However, as different authors argue, consumption is far from only a utilitarian function that a product may or may not have (McGregor 1974). All products, no matter how mundane, always have a symbolic meaning (Levy 1959) and have a hedonic dimension (Hirschman and Holbrook 1982). Thus MD is limited on its scope because it only focuses on complexity reduction, and optimizing technical feasibility. Therefore, to solve MD market shortcomings, we chose to also use design thinking (DT) as a market-oriented tool. According to Lockwood (2010), DT is a human-centric innovation process that emphasizes observation, collaboration, rapid learning, visualization of ideas, rapid prototyping, and concurrent business analysis. In the last decade, there is a growing interest in DT, from pure innovation to firm applications (Brown 2008; Martin 2009). Academic journals and conferences identified the relevance and importance of DT as an innovation framework and business management tool (eg. Shafiee et al. 2018; Rusli et al. 2018). Moreover, Micheli et al. (2019) suggested the need for empirical research on the applicability and effectiveness of DT. In our research context, the available literature proposed some herbal liquors, however, none of them used the MD approach or applied DT (Petróvic et al. 2019). Therefore, our study is the first of its kind to propose the use of MD and DT for new product development.

Particularly, for our research context of liquor development, we selected the DT framework as suggested by Brenner et al. (2016). We selected this framework over other available DT frameworks because of its academic and experimental characteristics. Particularly, this framework proposes three components: as a way of thinking, as a process (micro and macro), and as a toolbox. Thus, this framework allows its integration with other design frameworks, such as MD.

3. Methods and results

As we mentioned above, we used the framework suggested by Brenner et al. (2016). Figure 1 shows the methodological approach used in our research. Particularly, each sequential process shown in Fig. 1 (macro-process) is followed by its respective micro-process (see Fig. 2). Moreover, Fig. 1 suggests the methodological approach should follow seven stages through the final design. Similarly, Fig. 2 suggests that the micro-process must comply with 5 tasks iteratively. Next, in the following section, we explain the implementation of each macro-process.

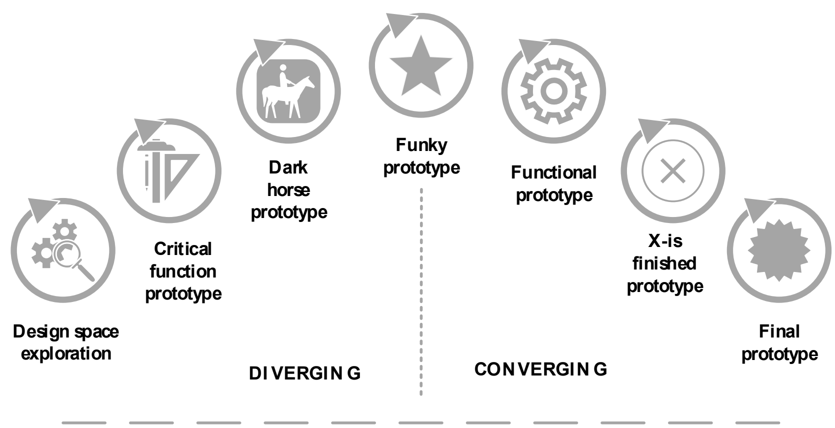

Figure 1. Macro-process of design thinking

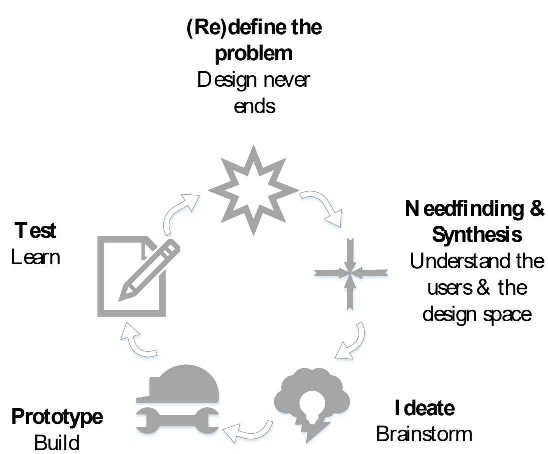

Figure 2. Micro-process of design thinking

3.1 Design space exploration

Initially, we implemented the design space exploration phase. In this phase, we analyzed different liquor design methodological problems. We also analyzed the conditions of the target market through the use of different DT tools:

(i) market description; (ii) stakeholder's map; (iii) empathy map; (iv) AEIOU method; and (v) persona method. Next, we present the main results of the implementation of each DT tool.

3.1.1 Market descriptive study

We selected a specific niche market to bound and structure our new product development. Specifically, we selected young people or the generation that is better known as millennials from Cochabamba, Bolivia. We developed a survey based on Roccas et al. (2002), Chrysochou et al. (2012), and Robin et al. (2017). Due to time constraints, we used non-probabilistic sampling. Following the recommendations proposed by Johanson and Brooks (2010), we surveyed 30 people. The sample had the following characteristics: (a) 53% were males; (b) 90% were 20-31 years old; (c) 96% were university students; (d) 78% had average to high income; (e) 86% consumed liquors in birthdays or anniversaries; (f) 73% consumed liquors at their friend's home; (g) 61% buy liquors at the liquor store; (h) 94% drink with their friends; (i) more than 45% drink mostly beer or fernet; (j) more than 60% consider quality and flavor the most important characteristics of a liquor; (k) 41% drink at least once a month; and (l) 75% drink on weekends.

3.1.2 Stakeholder's map

Ackermann and Eden (2011) suggest that the stakeholder's map should show the degree of interest and power of specific stakeholders. These authors classify them as subjects, players, crowd, and depending on the quadrant a context-bound. Therefore, following their recommendations we developed the stakeholder's map shown in Figure 3. In particular, Fig. 3 suggests that subjects (producers and developers) and context limiters (consumers and regulators) should increase their power and interest to go into the top right quadrant (players).

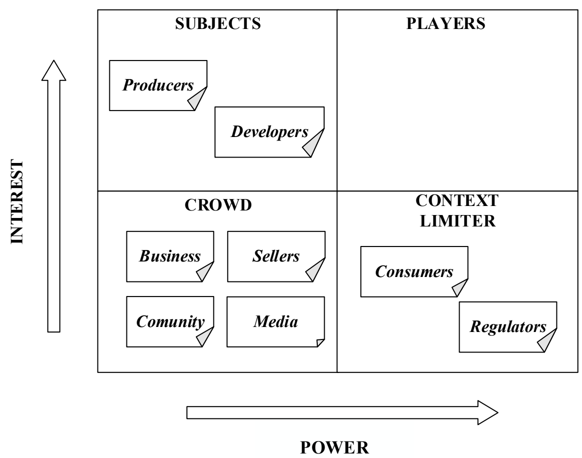

Figure 3. Stakeholder's map

3.1.3 Empathy map

An empathy map is a collaborative instrument that can be used by teams to gain a deeper insight into their customers. We implemented an empathy map and thus allowed us to obtain a comprehensive and empathetic understanding of the consumers. As Figure 4 shows, with the empathy map, we answered the following questions: what do consumers think and feel? what do they see? what do they say and do? what do they hear? and what are their problems and expectations? Specifically, we found that consumers: (a) *think and feel* that social life is predominant and are oriented to hedonism; (b) *say and do* put high relevance of aesthetics and appearance, being highly sociable, charismatic, outgoing, environmentally conscious, and gender-conscious; (c) looking to *hear* about different forms of recreation, achievements, and healthy lifestyles; (d) *see* social networks for social interaction and are characterized by disposable relations; (e) would like to *gain* economic success for ostentatious lifestyles and buying luxury items; and (f) causes them *pain* environments with high competition, are risk-averse and have fear of failure.

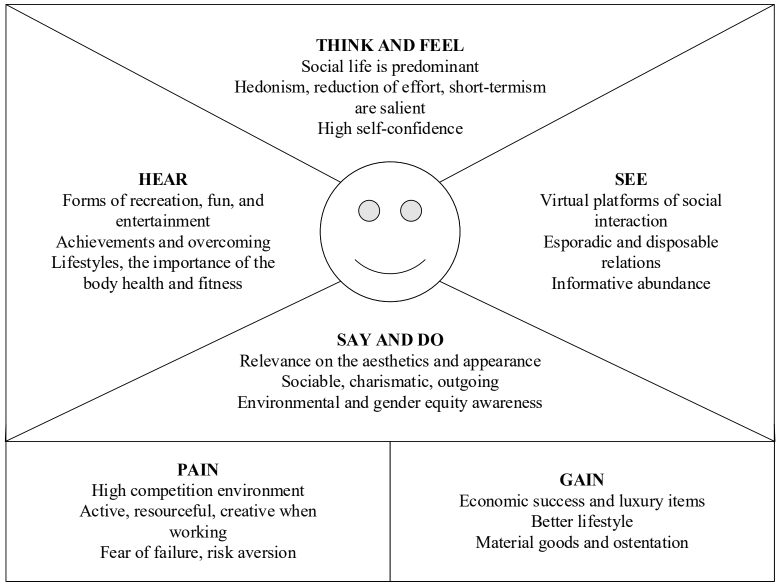

Figure 4. Empathy map of the Bolivian millennials

3.1.4 AEIOU method

We used the AEIOU method because is a tool that provides a structure for researchers to document and identify observations and information about activities, environment, interactions, objects, and users. Particularly, we followed the recommendations of Baskinger and Hanington (2011) (see Brenner et al. 2016). As a consequence, we had the following findings:

- *Activities.* Consumption of liquors was generally for birthdays or anniversaries (86%) and parties (65%). In other words, the purpose can be summarized as drinking for celebration.
- *Environments.* We found that essentially three environments are considered the places where drinking liquors are common: (a) friends' homes (73%), (b) discotheques (61%), and (c) their own homes (49%). The dynamics observed involved starting liquor consumption in a private home and continuing in a discotheque.
- *Interactions:* The people with whom interactions occurred most frequently were: (a) friends (94%), (b) family members (41%), and (c) coworkers (31%). Therefore, interactions were common with friends, being a typical trait of millennials.
- *Objects.* The surveyed millennials indicated that among the most frequently alcoholic drinks were: (a) beer (61%), (b) fernet (45%), (c) rum (41%), (d) wine (39%), and (e) singani (35%). These findings suggest that the target group prefers strong alcoholic drinks for binge consumption rather than so-called short and weak alcoholic drinks. This suggests that users tend to binge consumption in social events.
- *Users.* Users were defined as young people between the ages of 20 to 39 and born and between 1980 and 1999. These target users are better known as millennials, are mostly single, with medium to high income and most of them have university studies.

3.1.5 Persona method

The persona method has the main objective to build and design all user types or profiles that make up the target audience of a product. Using this method, we created consumer profiles of our target segment (see Figure 5). Moreover, following Cooper (2004) and Brenner et al. (2016) we created artificial archetypes that show the behavioral characteristics and personality of consumer groups. As Figure 5 shows in detail, we created the consumer archetype for our new product in Valeria and Rodrigo. Both archetypes reconcile distinctive behaviors, attitudes, feelings, thinking, and aspirations of the target market.

Name: Valeria

Age: 23 years old

Adress: Luis Calvo Street #123, Cochabamba, Bolivia.

Likes: her favorite food is italian food. She is a fan of the film series *"Harry Potter"* and identifies others as *"muggles"*. Her favorite writer is Stephen King. She used to practice volleyball at school, now she likes spinning at the gym while listening to her favorite music. Once every two weeks she likes to go dancing with her friends.

Activities: she is a graphic desinger, working for 2 years in an advertising company.She is currently participating in the Biennial Poster of Bolivia "BiCeBé" and hopes to exhibit her own design one day. She has done work as a social media administrator and digital creative designer. She is passionate about photography. She has a Chihuahua at home. On her spare time she usually sips a coffee or a beer with friends, goes to the gym and enjoys series online.

Goals and expectations: she wants to travel southern Europe before getting the master's degree, become independent from her parents and finally start a family.

Name: Rodrigo

Age: 25 years old

Address: Los Robles Street #456, Cochabamba, Bolivia

Likes: his favorite food is a typical dish called "Pique Macho". He likes video games and his favorite TV show is "Game of Thrones", he also enjoyed very much "Breaking Bad" and "Money Heist". His favorite sport is soccer and favorite team the F.C. Barcelona. After playing or watching a match he always drink some beers with friends.

Activities: he is a commercial engineer, he works in his father's company, in the sales department. On the way to work he plays *"Clash of Clans"* on his cellphone.In his spare time, he enjoys playing *"FIFA"* or have barbecues with friends. As he lives alone he acquired the hobby of cooking and playing online games like *"Dota 2"*. Every two weeks he goes to his favorite bar with friends.

Goals and expectations: apply for a scholarship for an MBA, after that he would like to open a business with his friends.

Figure 5. Persona archetypes

3.2 Critical function prototype

To develop a technically feasible prototype, we used MD. Particularly, we used the sequential procedures suggested by Handa (2008) and 27 native plants were selected and extracted in the first stage. Regarding other technical requirements, we had to solve the combinatorial complexity due to the high number of components. We found that the combination of 3 components determined a manageable solution to the problem (see Figure 6). Thus, in the first stage, we obtained 9 sub-formulations, in the second stage 3 sub-formulations, and in the third stage, we found the critical function prototype. As a consequence, MD allowed data processing performance with reliability and robust results.

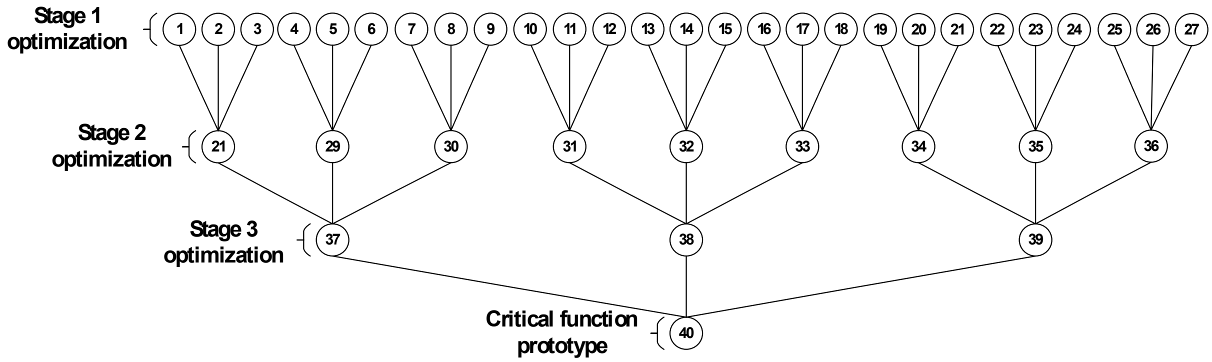

Figure 6. Combination structure for the MD

Then, the next methodological problem to be solved was related to the need for high sensitivity when measuring differences between extracts and their combinations. To solve the problem, we selected color as the sensitive response variable to be measured. Particularly, the Beer-Lambert law suggests a relationship between light attenuation and material properties. Moreover, the Munsell color system allows a better and intuitive understanding of the measurement (see Figure 7). Specifically, the electromagnetic energy content that constitutes the visual stimulus (color) encodes the chromatic information (*chroma*, i.e. vividness of color) and the luminance (value). Thus, the color content shows the spectral composition of the image. Moreover, the luminance information provides the overall amount of electromagnetic energy present in the object under analysis (Lloreda 2001).

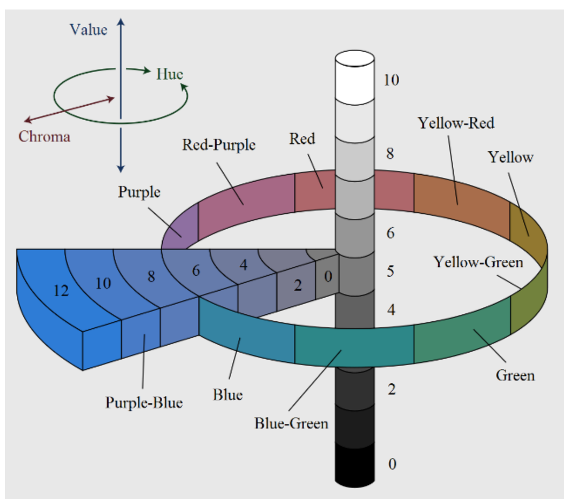

Figure 7. Munsell's color system

According to Lloreda (2001), black and white images contain a single type of chroma with luminance variations. In other words, the transformation of an image to a grayscale allows the artificial extraction of the luminance content and color information including the structure of color images. Therefore, using the algorithm suggested by Saravanan (2010), we transformed the color components information held in the RGB scale to a grayscale. Moreover, this color transformation followed the guidelines from the International Commission on Illumination. Due to the high-resolution image performance and compatibility with mobile applications for components on the RGB scale detection, to detect colors we used a mobile cellphone.

Table 1 shows the results for the color optimizations in extractions. The design shows three components with six points in the simplex-lattice space with 2 averaged replications. We followed the structure and sequence presented above in Figure 3. Due to space constraints, the results we show in Table 1 are only for stage 3. Particularly, these are the results (R) for the sub-formulation clarity (SC) measurements and their combinations. It is worth mentioning that we obtained similar results in stages 1 and 2, and thus obtained 13 formulations.

Table 1. MD results of the SC optimization stage 3

R	X1	X2	X3	SC
1	*100%*	*0%*	*0%*	21,166
1	*0%*	*100%*	*0%*	22,885
1	*0%*	*0%*	*100%*	21,082
1	*50%*	*50%*	*0%*	21,90
1	*50%*	*0%*	*50%*	20,938
1	*0%*	*50%*	*50%*	21,739
2	*100%*	*0%*	*0%*	21,850
2	*0%*	*100%*	*0%*	22,987
2	*0%*	*0%*	*100%*	20,856
2	*50%*	*50%*	*0%*	21,792
2	*50%*	*0%*	*50%*	20,695
2	*0%*	*50%*	*50%*	21,569

Next, using ANOVA we analyzed differences in measures of color in mixtures. We found statistically significant differences ($F = 21.87$; $p < 0.001$), and thus the proportions mixed were related to color. Moreover, we also found that the quadratic model had the best fit for our data. Specifically, as Table 2 shows, we found statistically significant results ($p < 0.001$) with a coefficient of determination of 0.999 and thus higher predictive capabilities.

Table 2. Model fitting of the SC optimization stage 3

Predicted model	R^2
$\mathbf{SC = (21,508)X_1^{**} + (22,936)X_2^{**} + (20,969)X_3^{**} + (-1,504)X_1X_2 + (-1,688)X_1X_3 + (-1,195)X_2X_3}$	0,999

Note. $^*p < 0,01$; $^{**}p < 0,001$

Subsequently, using the model in Table 2 we calculated the response surface and response contour (see Figure 8). Our results show a function slightly concave upwards without finding a local optimum. In other words, component 2 was the one that contributed the most to the final product formulation.

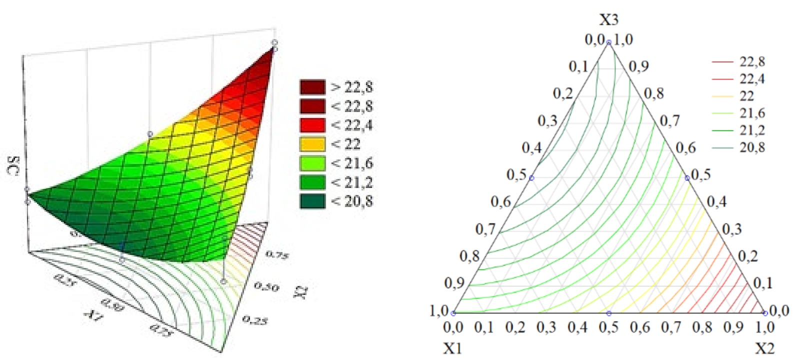

Figure 8. Response surface and contour of the SC optimization stage 3

3.3 Darkhorse prototype

The darkhorse prototype name comes from horseracing: it is the horse that nobody bets on and ends up winning. Using this framework, we improved previously disregarded product characteristics in our prototype. For our research context, we optimized the sugar content (Brix degree) using a refractometer. Specifically, we prepared a combination of 3 types of sugar. The prototype obtained consisted of a 750 mL bottle, of which 150 mL was optimized caramel. These proportions left the liquor with an alcohol content of 30°.

Afterward, we gathered sensory evaluation data regarding the intensity and taste of our prototype. Moreover, using a 20-point scale, a trained panel evaluated the bitterness intensity, acidity, pungency, and astringency. Also, using a 9-point hedonic scale, we measured taste attributes, such as odor, sweetness, and overall acceptability (Stone and Sidel 2004; Taylor and Organ 2009). Specifically, the results were divided into intensity and flavor attributes. The intensity attribute with the lowest score was spiciness (5,08 out of 20 points), and the highest was astringency (9,17 out of 20 points). The rating for bitterness was related to the decrease in alcohol content and the adding of sweetness. The 9-point hedonic scale on taste, sweetness, and overall odor received high scores (7-7,42). Moreover, the color attribute received the lowest score (5,92).

3.4 Funky prototype

In the funky prototype, we enhanced the combination and selection of the most relevant product characteristics. Particularly, we took a close-up from the divergent phase (ideas generation and proposals) towards a convergent context (synthesis and feedback). Our prototype is a convergence prototype that unified all the generated ideas and suggestions. Thus, we modified the sugar proportions with our model, equivalent to the one from Table 2, and found a sugar content of 14.1° Brix.

3.5 Functional prototype

In this stage, we established the liquor presentation characteristics in a functional prototype. Specifically, we defined packaging shape, colors, packaging type, attributes, volume, name, presentation, and aesthetic qualities. The concepts we considered were related to the liquor's herbal essence, national representativeness, and status consumption. In this stage, we had to balance the product's technical feasibility (MD) with the consumer needs and desires (DT).

3.6 X-is finished prototype

The purpose of this prototype was to detect a crucial function (X). In addition to continuous improvement, we tried to find the functionality that would mark the product's competitive advantage. The crucial functionality of our product had to account for several considerations around millennial consumers without neglecting effective marketing of product information. Thus, we decided that the X functionality should be included in a quick response code (QR code). This inclusion allowed to consider millennial consumer preferences and purchasing attitudes (Lancaster and Stillman 2003; Olsen et al. 2007 and Chrysochou et al. 2012).

3.7 Final prototype

The final prototype synthesized all the functionalities, characteristics, and needs, achievable and suitable for consumption. For this prototype, the degree of detail was the highest and was tested with the consumer. Particularly, consumers provided feedback and perceptions for final product improvements. In Figure 9 we show our liquor final design, packaging, and its website. Product presentation is fundamental for the diffusion of our innovation.

4. Discussion and conclusions

The results presented above show the successful combination of two methodologies for new product development: design thinking and mixture design. Particularly, we first defined product requirements and market characteristics. Specifically, we defined millennials as the target market. This market is characterized by (a) being single, (b) have middle-income consumers, (c) have university studies. Furthermore, they are characterized as self-reliant with high self-confidence and drinking occasionally during social gatherings in intimate environments. Our results were consistent with the studies made by Qenani-Petrela et al. (2007) and Chrysochou et al. (2012).

Note. To see the website, go to https://aukkaliquor.wixsite.com/mysite

Figure 9. Final prototype design

Next, we used MD to reduce design complexity and obtain a satisfactory product based on color optimization (27 native plants). Due to space constraints, we only presented stage 3 optimization for the critical function prototype. Moreover, we made 26 optimizations for the final product. Further, as Figure 10 shows, we selected clarity optimizations due to the target requirements and other practical implications (see Reinoso et al. 2017; 2019). Additionally, we used a colorimetric measurement method transforming RGB scales to grayscale. In this way, we transformed components' color information (luminance and chroma), into a single value (Saravanan 2010). This outcome opens new space and study opportunities for further colorimetric applications.

Finally, our methodology opens new avenues for new product development. Specifically, the combination of the strengths of the two methodologies allows the development of new products for different industries. As Buchanan (1992) suggested, the design's object has a potentially universal scope. In other words, using MD in different DT prototypes generates synergies that can be used in any area of human experience. We were able to achieve our objective to develop a liquor formulation based on Bolivian native plants using DT and MD.

Figure 10. Color optimizations' final results

5. Limitations and recommendations

Every study has weaknesses, and ours is no exception. Among the limitations, is the limited sample size. Subsequent studies should consider larger sizes to obtain more accurate conclusions and inferences about consumer behavior. However, the minimum sample size used for the survey suggests that the results are generalizable to a larger population. We neglected a sizeable sample approach due to the prioritization of formulation under combinatorial complexity. Although DT does not require expensive testing, the container's shape and material labels were underexplored characteristics. Future studies could seek to reproduce our study with better equipment and more controlled conditions. Moreover, future research should try more precise colorimetric measurements. In our study, due to economic constraints, we adopted a cheaper measurement technique. However, according to the literature, our method should not greatly differ from more complex measurement methodologies. Finally, future studies should investigate the chemical characterization of the final product bioactive profile. They should consider stability features, storage conditions, and preservation. Changes in physical properties are related to the secondary metabolites' decomposition by enzymes and parameter changes should be controlled. Future studies should assess color, taste, odor, specific gravity, solid residue, viscosity, microbial content, chromatographic, and spectral characteristics of our final product.

As our combined methodology and successful new product development have shown: "*Innovation is taking two things that exist and putting them together in a new way*" (Tom Freston, Co-founder of MTV).

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