BEYOND AESTHETIC

SMART PACKAGING FOR THE BEAUTY INDUSTRY

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Beyond Aesthetic

Smart Packaging for the Beauty Industry

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INTRODUCTION

The technological advancements made by humans in the last decade have brought uncountable new problems and new solutions that require attentive research on what causes and consequences, often complex and intertwined, are for each development. In particular, the aftermath of overproduction caused by consumerism and an increasingly bigger world population contributed significantly to the escalation of environmental issues on a global scale.
Among the main problems, the most critical ones relate to the depletion of natural resources, the exponential increase in waste production and the consequent pollution of air, water and soil.

Furthermore, we can add phenomenon like climate change, unsustainable supply chains and planned obsolescence, which makes consumer goods less durable and pushes a continuous production-purchase-waste cycle.

However, scientific research led by academic centres, innovation labs and private institutes all around the world, has developed new strategies oriented towards more sustainable, ethical and functional production models. These solutions are mainly user-centred, as it is not only the final consumer, but also aware actor, an informed participant in a necessary change. Designing becomes a key tool to build products and systems respectful of the environment, yet still responsive of the people's needs

An increased attention has grown towards single-use plastic, ultimate symbol of an unsustainable consumer culture. Indeed, the packaging is not only a marginal container to the product anymore, but has become a central element, subject to critics, redesigns and experimentation. Designers, brands and institutions are called to rethink materials, functions, durability, disposal methods and life cycles of their packaging, trying to achieve a responsible consumerism.

This thesis aims to dive into the concepts of packaging in the beauty industry and whatever it may comprehend, through the analysis of various case studies in relation to the problems caused by bad design and the technology used to resolve them, followed by the development of a series of guide lines, and consequently a concept, to pursue when designing for a sustainable and environmentally responsible way of consuming and discarding.

PACKAGING IN THE BEAUTY INDUSTRY

Hygiene and personal care products represent, on a daily basis, a fundamental tool through which individuals can take care of their body. For many, these moments contribute to important occasions to slow down and reconnect with themselves; for other, actions like showering or washing their face are routine gestures, integrated into everyday life. In both cases, hygiene and cosmetic products take on a crucial role in the promotion of physical and mental health and the prevention of illnesses, through the construction of personal care rituals.

Regardless of the personal approach, from the start of the routine up to the final aim, it is possible to affirm that, design wise, the connection point between user and product is represented by packaging. It is through that same container that the user gets first in contact with the cosmetic product: an interaction full of expectations, informations and communication potential.

This moment represents a fundamental opportunity to inform the user on the contents of the product, on its use, its ingredients, the precautions and its expiry date.[1]

However, cosmetic packaging does not always address these expectations appropriately. During the last decades, the topic of packaging has been covering a central role in the beauty industry, not only as an aesthetic and identitarian tool for the brand's advertisement and marketing, but also as a functional element for what concerns conservation, distribution and communication of the product. This evolution transformed packaging from simple container into a multifunctional interface between product, user and environment. However, this growing complexity has seen the development of a series of structural problems, often underrated in many cases, which obstruct the sustainable and inclusive development of the sector.[2]

Several recent studies have underlined how, nowadays, cosmetic packaging is responsible for a significant part of the environmental and communicative impact of the product, generating criticalities which concern problems tied to environment, usability and customer fidelity.[3]

One of the problems emerging from these studies relates to ability of the product of ensuring the correct conservation of the cosmetic content. In fact, many containers do not guarantee adequate protection from contamination and oxygenation, especially when designed for refill systems or built with lightweight materials. These limitations compromise the integrity of the product, exposing it to chemical and physical alterations which endanger its stability and efficiency through time.[4]
Recent literature underlines how some biodegradable or recycled materials, often used to decrease environmental impact, show fewer performative values in terms of barrier as opposed to traditional plastics, with negative effects on the product's conservation.[5]

Another critical problem that resurfaced was the lack of transparency in the informations on the packaging, which leads too an increase of mistrust on the part of the consumer. The absence of clear tags, along with a diffused use of unregulated environmental claims, like "green" and "eco-friendly" often without the support of verifiable data, leads to a phenomenon known as greenwashing. Indeed, as stated by a study conducted by Università di Bologna in 2021, 59% of users prefer that clear environmental information about the product are directly stated in the product or primary packaging; however, the lack of a standardization in the sustainability information display and language creates confusion and uncertainties about the truthfulness of green statements, and compromises the readability and comparability between products.[6]
At the same time, absence of authentication and traceability systems – such as dynamic QR codes, NFC tags or blockchain technologies – increases the risk of counterfeit, especially in digital distribution, where the user can not directly verify the authenticity of the purchased product.[7]

Moreover, there is a strong need for easily discardable packaging, since mixed materials, reduced sizes and absence of clear instructions, place beauty packaging among the most difficult to recycle, especially in urban sites. The cosmetic packaging, often built with plastic combined with other materials like aluminium, glass or silicone, represents significant obstacles to the mechanical separation and correct treatment in the urban waste differentiation systems.

Only a tiny percentage is actually correctly discarded and recycled: according to the previously mentioned study, only 28,2% of beauty packaging has clear and specific recycling or discarding information, and only 6,5% of packaging is totally recyclable. In addition, 29% of consumers declared to be confused on the recycling instructions due to the previously mentioned criticalities, and 41% think that they would be more inclined to buy a product with clear, understandable and readable discarding information.[8] The Zero Waste Europe report underlines how beauty packaging represents a critical issue for circular economy, suggesting the

necessity of radically rethinking materials, formats and informative strategies.[9]

Last but not least, a growing topic in all industries, although often ignored, is that of accessibility: most of the cosmetic packaging does not provide reading systems for visually impaired people, neither do they implement any kind of specific opening mechanism for users with restricted mobility. There is a lack of tactile elements, such as embossments, braille texts or standardized markers, which allow people with visual impairments to identify and distinguish between products in autonomy. This excludes a big segment of consumers which meet many difficulties when it comes to identify or interact with the product or packaging. [10]

Also opening and closing systems are often perceived as unintuitive or difficult to activate for those with mobility impairments. According to the European Blind Union report, the cosmetic sector is among the less inclusive under the packaging design profile, contributing to the exclusion of beforementioned segment of consumers.[11]

These criticalities focus particularly in some certain types of packaging, where functional or market needs wind up against usability and sustainability objectives. These are just the situations in which packaging not only reflects, but also amplifies the tension between industrial requirements, consumer's expectations and sustainable constraints.

To better understand how these dynamics concretely manifest, an analysis of a representative case study is the most helpful tool: a packaging which answers all of the real necessities of the product.

and the target, however embodying one of the most critical points in terms of design and sustainability, making it the perfect ground of research for innovation and smart solutions.

CRITICAL FOCUS

In the vast landscape of cosmetics, the skincare sector represents one of the most dynamic and promising fields, in both terms of economic growth and design opportunities. Packaging is a strategic element in this industry, more and more attached to innovation. Market research reveals that the global value of skincare packaging stands between 17,3 and 17,9 billion USD in 2025, with a compound annual growth rate (CAGR) of 4.6%, and is estimated to grow up to 27.1 billion USD by 2035[12], in line with the expansion of the whole cosmetic industry, which reached about 55 billion USD in 2024 with a CAGR of 4,8%.[13]

Airless solutions are affirming as key element in this scenario. Valued to hit between 6,4 and 6,7 billion USD by 2025 and to surpass 9.9 billion by 2033, their growth is even more substantial, with a CAGR of circa 5%[14], particularly driven by the beauty sector which is estimated to represent 68% of the overall demand in 2025[15]. This trend is fuelled by a series of functional factors which make airless packaging a particularly suitable technology for high sensitivity products, like serums: it guarantees an increased hygiene, a better conservation of the active ingredient and an elevated precision dispensing – all characteristics which respond to growing demand by the consumers.

The modern context adds another complexity to the design process: the increasing request of sustainable measures. Airless packaging, typically realized with non-recyclable components, is at the centre of a transition towards more ecological versions: mono-materials, refillable or easily disassemblable, often integrated with intelligent technologies to monitor usage or guide the user to a correct disposal. This transformation is driven by a real market demand: 54% of American consumers state to prefer sustainable packaging [16], while 42% of European and 37% of Northamerican consumers actively avoid buying non-sustainable packaged goods [17].

In view of the gathered data, focusing on skincare serums in airless flasks means intercepting a critical point within the system: a type of product in quick growth, with concrete issues like content preservation or sustainable solutions compatibility, and a high technological and communicative innovation potential. It is in this area that design can make an actual difference by proposing solutions which not only address the issue of functionality and sustainability, but can also guide new usage behaviours, facilitate accessibility and improve the overall interaction with the product.

AIRLESS PUMP DISPENSER

In the cosmetic industry, products like serums and face cremes are particularly delicate, thanks to the active ingredients they often contain, sensible to oxygen, light and microbial contamination. Elements like vitamin C, retinol, peptides and exfoliating acids tend to rapidly degrade when in contact with air or when subject to thermal changes. For this reason, contamination and degradation protection is a priority for this particular sector of products.
The airless pump dispenser has established itself as a privileged solution, because it keeps air from entering the container while activating it, preserving its quality through time and improving the product's shelf life without adding aggressive preservatives.

Product characteristics

Airless pump dispensers are especially suited to host cosmetics with the need of elevated stability and hygiene during its utilisation. The most used ones are face serums with a high percentage of active antioxidant agents, cremes containing photo sensible ingredients, and natural or preservative-free formulas. These products are in fact highly sensible to oxidation and bacterial contamination if repeatedly exposed to air or in direct contact with hands.

Thanks to the sealed environment and controlled dispensing, the airless pump dispenser protects the formulas from air, light and contaminating agents, contributing to extend their shelf life and guaranteeing an improved efficiency of the active elements until the very last drop.

How does it work?

This technology is based on a mechanism which does not use air to push the product out of its container, but a rising piston or, in other cases, a system with an incorporated sachet or pouch. The structure is typically made by a hermetically closed cylindrical container which avoids the entrance of air even after using the product, a manual mechanical pump connected to a

compression chamber, activated by a finger's pressure, a mobile piston at the base of the tube that rises up every time the pump is activated and dispenses the product, and a unidirectional valve providing said dispensing and avoids air from entering and exiting the system. This mechanism guarantees a precise and hygienical distribution, a fundamental function for localized treatments like the ones serums are most used for.

Why focus on this format?

This choice was made based on a mix of functional, sustainable and market factors. First, their ability to protect sensible formulas makes them essential to brands promoting clean, natural or high-performative products. Furthermore, they offer a controlled and hygienic user experience, improving the quality perception of the consumer.

From the industrial point of view, the airless pump segment in just the beauty market is significantly growing: the global market was valued 5,9 billion USD in 2023 and is estimated to reach 9,2 billion USD by 2030, with a CAGR of 6,5%. This growth is led mainly by sectors concerning skin care and luxury cosmetics, which represent the prima application of airless packaging. Adding up, there is a substantial push from the consumer's demand for more hygienic, sustainable and easy to use packaging.[18]

Another research analysis confirms the strategic importance of this segment: it was underlined how airless packaging became a key technology to improve customer experience and reduce waste, thanks to the possibility of using over 95% of the product, as opposed to other kinds of packaging where much of the product can't be used. Moreover, increasing adoption of rechargeable and recyclable solutions by the brands is gradually aligning with emerging environmental regulations and with the growing consumers' requests, who are more and more sustainably aware and demand for safer and more ethical products and containers.[19]

Although airless flacons present a general high performance, they also represent a challenge for what concerns sustainability. The presence of mixed materials, like metal and plastic, is an obstacle to recycling and makes it difficult to integrate the use of these devices into recycling systems. However, the market is responding to these difficulties with innovations like mono-material and rechargeable solutions, which aim to conjugate functionality and environmental responsibility, lining up with circular economy principles.

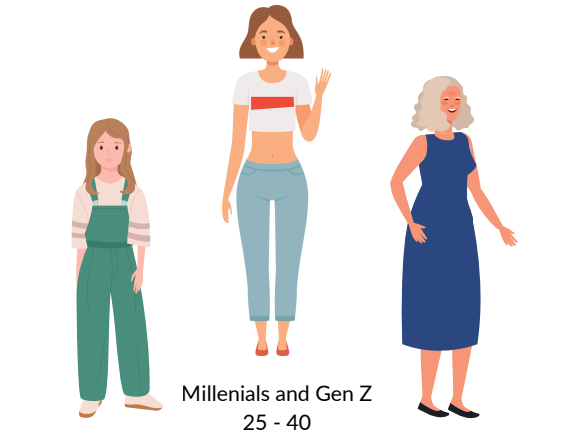
For these reasons, the analysis of airless pump dispensers becomes strategic when talking about cosmetic packaging: it is a technologically advanced container, compatible with modern formulas' requirements, suited to reach the users' expectations and in full evolution towards circular and smart models.

Target

The individuation of an ideal target for skincare products with advanced packaging requires an attentive analysis of demographic variables, in particular age and gender.

Age

Skincare preferences vary much based on the age of the user. Adolescents and young adults (age 13 – 24) tend to look for economic yet functional solutions against certain skin types or problems, with a large use of active ingredients. Millennials and Gen Z (age 25 – 40) represent a key range for adoption of more sophisticated packaging technologies: they look for multifunctional, anti-age, hydrating and sustainable products, and show a strong attention towards ingredient and sustainability transparency. More mature generations, like Gen X and Baby Boomers (age 41+), prefer advanced anti-aging formulas, with a major propension to buying high-end products.



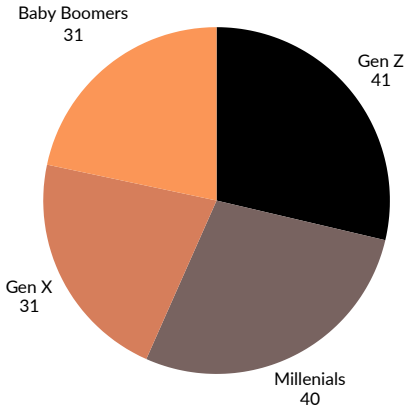
Gender

Women constitute the dominant segment in the skincare market, with interest shifting from sensible skin treatments to anti-aging or natural and biological ones. Men, however, have become a growing segment, with attention mainly to simplified routines and specific products for their skin type. There has also been a growing demand in unisex products by non-binary and gender-neutral consumers.

Market data

In the USA market, women between 25 and 44 buy about 38% of all beauty products. In particular, 64% of them buys advanced packaging skincare products, like airless pump dispensers, for reasons tied to hygiene, dosing precision and formula protection. Additionally, 40% of all skincare products is bought by women between the age of 18 and 41, with a predominance of Gen Z (41%) and Millennials (40%). [20,21]

What age group buys the most skin care products (%)?



These data clearly underline how the ideal target to take into consideration when designing for a skincare product is constituted by women between the age of 25 and 44. This demographic range not only represents the most active skincare market segment, but is also the more receptive when it comes to functional and sustainable innovations within the packaging domain. The combination between performance requirements (i.e. anti-age, precision), ethical values (i.e. sustainability, transparency), and aesthetic sensibility makes this group the most strategic to intercept to reach the outcome of commercial success, when working with advanced solutions like airless packaging. [22,23]

Conclusion

Although the current difficulties tied to sustainability, airless pump dispenser packaging represents a strategic opportunity for cosmetic companies' growth, thanks to its innovation potential. The recyclability limitations of many airless containers, caused by the use of mixed materials like plastic and metal springs, represent technical challenges to the integration into recycling systems. However, this gap between performance and sustainability has stimulated significant investments in research and development, accelerating the use of mono-material solutions, recycle-ready components and rechargeable models. A clear example are the innovations introduced by Aptar: in July 2025, the firm launched the nineth generation of Double Serum, with an airless dispenser integrated to a double chamber, able to gradually dose the product preventing waste, realized by 94% with recyclable materials; the product is also composed by 24% of recycled content, resulting in a more sustainable item.

These examples demonstrate how airless packaging, if well designed, can transform technical limitations into innovation levers: combining aesthetic differentiation, functional precision, waste reduction and progressive alignment to environmental norms. In a market where the innovation rapidity and personalization are fundamental factors, airless packaging stands not only ad a functional solution, but as a strategic vector in terms of branding, sustainability and fidelity.[24,25]

PACKAGING

Packaging has always played a fundamental role in design for both functional and communicative purposes. Primarily, it relates to enclosing and protecting the product for storage, transport, sale and use. Furthermore, it connects the product to the consumer and vice versa, by providing information and influencing the consumer's choices of purchase.[26] Indeed, a targeted design can make the difference when it comes to choosing a product or even interacting with it.

With different times come different needs: initially, the concept of packaging was merely a container built out of natural materials like wood, animal skin, leaves, etc.

Technological advancements have brought an increase in technical requirements concerning various aspects, first with the introduction of new materials, such as glass, metal, plastic and paper-based solutions, and consequently with the prelude of environmental issues that come from their production.[27,28] Today, the focus has shifted entirely towards sustainability, bringing companies to explore biodegradable, recyclable and reusable materials to minimise environmental impact. This shift is the evidence of consumer's awareness and national or international norms to reduce waste and carbon footprints.[29,30]

Besides its functionality, packaging serves the purpose of transmitting brand identity and displaying some sort of storytelling.

How a product is perceived is reliant upon its colours, typography, and design structure. A sleek and minimalistic box conveys sophistication, while a more vibrant and colourful packaging will capture the attention of a younger audience, whereas a more "vintage" and crafty approach to its aesthetic may appeal the older generation. It also depends on the kind of product: most beauty brands tend to keep their products neat and with a clean look, often by taking on a more minimalistic style. The psychology of packaging design has been deeply studied through time to lure emotions and deepen brand identity.[31]

In the end, packaging is much more than a protective layer: it is a dynamic aspect of the consumer's experience that fuses practical and artistic perception while adapting to the standards of a modern society.[32]

TYPES OF PACKAGING

When it comes to packaging, there is a first function-based distinction to be made between primary, secondary and tertiary packaging. This division is set by the Article 35 of Legislative Decree No.22 of February 5th 1997, and it aims to differentiate between the various kinds of containment that can be assumed by it: essentially, it's like a matryoshka game, with the tertiary packaging encompassing the second, which itself encloses the primary.

Primary packaging

A primary packaging is a single sales unit, and it comes in direct contact with the product. Therefore, it is also the packaging the consumer chooses at the moment of purchase, and it ensures the product's integrity until its final destination: the consumer's home. Its function, apart from the product's protection, is to communicate important information to the buyer, as well as identification and traceability codes that are mandatory by law and need to be displayed for the distribution process.[33]

Secondary packaging

The secondary packaging is what binds more units of primary packaging together. There is a certain standardized number of sales units for each product (e.g. a pack of six cans, ...) and they can be enclosed by various kinds of packaging, a paper carton, or a plastic band, or a shrink wrap. If the consumer chooses to, they can buy a whole cluster of sales units as well as just the single one, so its purpose is not only to facilitate stocking and organising, but also to eventually be sold as a final product; however, its removal shall not alter the products characteristics, as it does not represent the product itself: this is not possible with primary packaging.

To ensure transparency and traceability on the manufacturer's end, both primary and secondary packaging must display essential product information. This includes the Global Trade Item Number (GTIN), a standardized international identifier enabling perpetual tracking and identification of products across the entire supply and distribution chain.[34]

Tertiary packaging

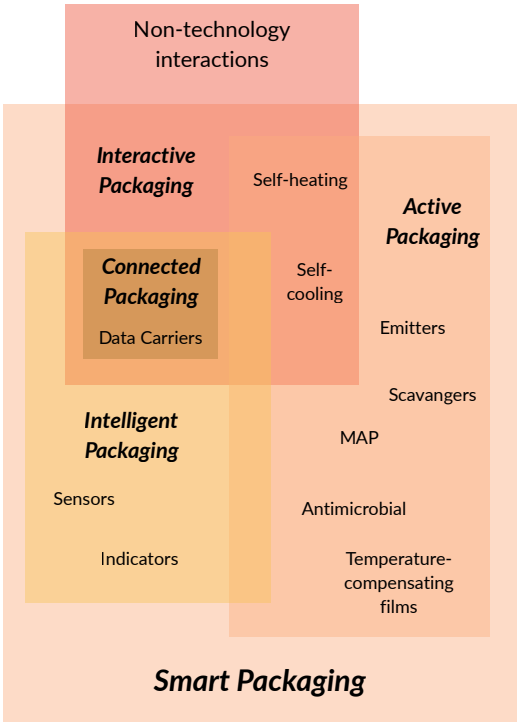
Tertiary packaging is solely designed to simplify the oversight and transport of large groups of sales units, and therefore serves as a container destined to shipment, following the product from the manufacturing facility to the salespoint's warehouse. It unifies and protects sets of secondary - and thus primary - packaging, often incorporating additional protective layers or other forms of reinforcement during handling and transport.[35]

SMART PACKAGING

In today's fast-paced, tech-driven society, the concept of packaging has embraced the new requirements dictated by both consumers and producers, including safety, quality, sustainability and transparency, growing beyond the simple task of containing. This evolution has resulted in the development of what is known as smart packaging, in which the container is designed not only to contain, but to interact, monitor and communicate with both the product and the consumer. This is achieved by integrating technological, mechanical, electronic, chemical and digital tools to enhance the packaging's functionality and the consumer's experience. The goal is to ensure the product's integrity, extend the shelf life and thus decrease unnecessary waste providing real-time information and engaging with the consumer.[36,37]

There are four main domains of smart packaging: active, intelligent, connected and interactive. In this chapter, we will be diving into the definitions and properties each of them, in order to understand their potential and how they can be effectively applied on new packaging solutions, with the objective of enhancing product preservation, improving user engagement and boosting supply chain efficiency.[38,39]

Relation between types of smart packaging:[40]



ACTIVE PACKAGING

Within the scope of smart packaging, active packaging represents a fundamental branch as it interacts with the product and its environment with the objective of extending shelf life and quality of its content. This is achieved with the introduction of functional elements integrated into the packaging or placed in sachets inside of it, which are able to absorb, scavenge, or release certain substances, preserving or preventing a series of microbiotic and chemical alterations. As a result, active packaging is widely used in the food and pharmaceutical industries, as these are the ones who handle fresh products with settled expiry dates.[41,42]

Oxygen scavanger

It contains iron powder that reacts with oxygen, removing it to prevent oxidation and aerobic microbial growth. It is widely used because of its effectiveness, but it is toxic if ingested and packaging may collapse without a replacement gas.[43]

Carbon dioxide scavanger or emitter

It suppresses microbial growth by increasing or decreasing carbon dioxide levels. It can be paired with an oxygen scavenger sachet or label for a dual action system.

To lower carbon dioxide levels, calcium hydroxide placed in sachets absorbs CO2; on the contrary, ferrous carbonate reacts with catalysts to emit CO2. Due to its cost and complexity, it is less common than oxygen scavengers alone; it is also made by toxic materials, and it can alter internal pressure, changing the packaging's appearance.[44]

Ethylene scavenger

It removes ethylene gas, which is a hormone that accelerates senescence, and slows down spoilage by containing potassium permanganate (KMnO4), an oxidizing agent, in a silica gel sachet (porous, stable and non-reactive). The reaction oxidizes into ethylene glycol, acetic acid, carbon dioxide and water, all harmless byproducts. Once the potassium permanganate reacts, it changes colour from purple (active) to brown (used up): this is used as a visual monitor of the scavenger's life. It is, however, toxic if put in direct contact with food, so it has to be contained into a sachet.[45]

Moisture absorber

It reduces humidity preventing microbial growth and flavour or texture degradation. It can be made either by silica gel sachets (most used), which entraps water into its pores, or calcium chloride, which reacts with water to form a brine, or clay, a naturally moisture absorbent. It can be placed in sachets, pads, sheets or even blankets for large scale storage. The material stops working after it has absorbed a certain amount of moisture and saturates, in some cases changing colour (visual monitor). It is non-toxic and non-corrosive, resulting in a safe solution for food packaging.[46]

Odour absorber and flavour emitter

Used to control the sensory experience of the product, odour absorbers trap and neutralize volatile organic compounds (VOCs) that might come from the product itself or even from the packaging through the use of antioxidants or activated carbon, cyclodextrins or other absorbent materials, while flavour releasers use microencapsulated flavour compounds or aromatic oils embedded in sachets or films, which are triggered by humidity, heat or just exposure to air. These solutions can not be used in food packaging as they are meant to mask spoilage and therefore can mislead the consumer; furthermore, Europe and USA have banned their employment in the food industry, while Japan still uses them for pharmaceutical products.[47]

Ethanol emitters

They emit ethanol haze to prevent microbial growth, killing bacteria, mould, yeast, etc. They come in sachets attached to packaging and are activated by moisture, reducing spoilage in food and pharmaceutical products. They are, however, toxic if ingested in abundance.[48]

Antimicrobial agents

They come in sachets, films or coatings that, when in contact with the product or its environment, release active and non-

toxic substances (silver zeolites, organic acids, essential oils) over time to prevent microbial growth. These substances disrupt the metabolism of the product, inhibiting microbes' reproduction, increasing safety and shelf life.[49]

Antioxidant agents

They prevent and lower oxidation in the product's environment, keeping it fresh and avoiding spoilage. They come in sachets, films or coatings applied inside the packaging, where they neutralise unstable molecules and either react with or absorb the oxygen inside the packaging.[50]

Self-heating and self-cooling packaging

Through a process of exothermic or endothermic reaction, the material releases or absorbs heat. In the exothermic process, a common combination is quicklime and water, which mixed together produce heat, whereas the endothermic process often involves ammonium nitrate or urea dissolved in water to withdraw heat from the environment. Despite their functionality, these solutions are single-use and only applied to niche products.[51,52]

MAP (Modified Atmosphere Packaging)

This system acts on the air inside the packaging, changing it to slow down the food spoilage process and extend the packaging is filled with a gas mix formed by oxygen, carbon dioxide and nitrogen, which respectively reduce oxidation, inhibit microbial growth and prevent collapse. The packaging is therefore vacuum sealed and closed with a special film able to control gas exchange.[53]

Temperature-compensating films

When exposed to temperature changes, these special kinds of films adjust their properties (permeability, adhesion, viscosity) to keep the quality of the product intact. What enables them to is a certain number of smart polymers with a built-in temperature switch that will tighten the film when exposed to cool temperatures to limit gas exchange, or contrarily make it permeable when in hot environments. Thanks to its properties, this solution is mostly used in packaging for fresh or raw produce.[54]

INTELLIGENT PACKAGING

When talking about intelligent packaging, we refer to a container able to monitor in real time the product's quality and general state, without necessarily interacting with it. They aim to enhance traceability, safety and communication for both user and producer, while unaltering the product's characteristics.[55]

Indicators

These devices provide visual signs in response to certain stimuli, such as temperature, time, or gas, usually changing colour or general appearance to permit an immediate control of the product's state.

- Time-temperature indicators (TTIs): they monitor the product's exposition to time and/or temperature, which is useful for logistics and transportation cases, especially when it comes to cold temperature maintenance in food and pharmaceutical fields; however, their cost is generally high, and their feedback can be inaccurate or inconsistent.

- Integrity indicators: these devices can track any evidence of tampering, damage signs or unauthorized breaches into the packaging, thus increasing security and preserving the product's integrity. However, they require specific infrastructures which can result in significant costs to implement.

- Gas indicators: they are able to detect the presence of gases, such as oxygen, carbon dioxide or harmful hazes, or the lack thereof, and are mostly employed in medical and pharmaceutical fields due to the ability to ensure sterility and security of the product. Conversely, their maintenance and calibration can require higher costs.

- Freshness indicators: these indicators can communicate the product's freshness, or contrarily the extent of its spoilage, by signalling the presence of volatile matter. While they improve the user experience and facilitate stocking management on the producer's side, they only work with perishable goods and may not always provide reliable information.

Sensors

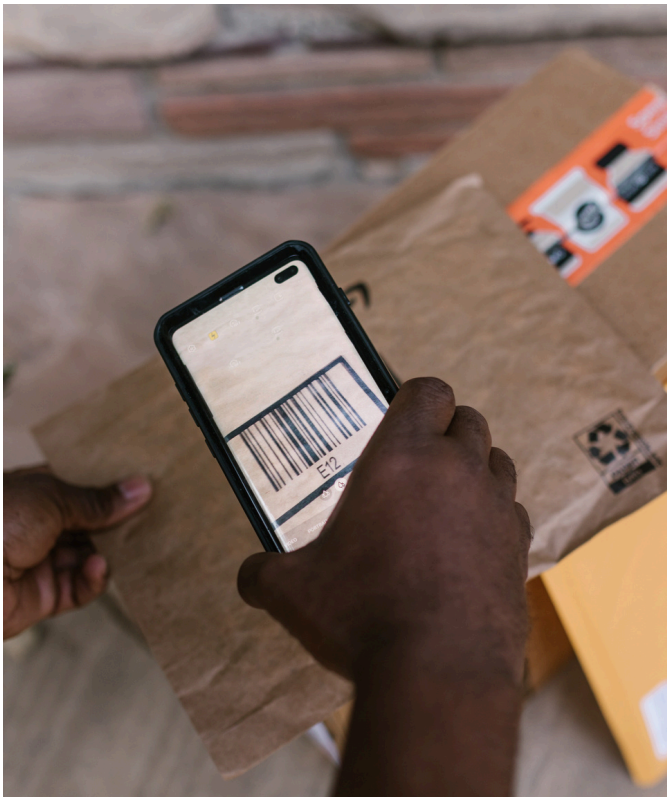
These devices are rather more sophisticated than indicators, as they not only detect certain parameters, but also file and transmit the information, making them ideal for real time monitoring and integration of IoT systems. The downsides to these solutions are the raise in production costs, the necessity of regular maintenance and calibration, and their disposal may not be environmentally safe.

- Gas sensors: they measure gas composition inside the packaging and reveal when irregular leaks, decay or fermentation occur through the use of oxygen, CO2, ethanol or other VOCs sensors.

- Biosensors: they determine whether biological reactions caused by bacteria, enzymes, microorganisms or viruses occur. They are mostly used for fresh-cut produce because of their ability to increase consumer's sanitary safety and to intervene in case of microbiological contamination (propagation of bacterial pathogens like salmonella, E. coli, etc).

- Chemical sensors: they detect the presence of specific chemical substances or eventual contaminants through the absorption and desorption of targeted molecules, which generates a chemical interaction triggering a measurable signal, then converted into information about the packaging's environment. These indicators are usually implemented in food and pharmaceutical packaging as a result of the accuracy and the consequent safety they provide.

- Humidity sensors: they monitor the humidity level inside the packaging to maintain the right atmosphere in order to avoid mold, deterioration or spoilage. This parameter is very helpful when speaking of electronic, pharmaceutical or moisture-sensitive products.



CONNECTED PACKAGING

These types of packaging are considered part of both intelligent and interactive packaging, and are commonly known as data carriers: differently to indicators and sensors, these systems memorize and transmit information related to the product's logistic details, dates of expiry or general conservation, and usage information. Their employment facilitates many aspects from both the supply and consumer side, as they guarantee traceability, help contrast counterfeiting and optimize inventory and shipment management. They can also be matched with indicators and sensors to deliver a full interactive experience.

Barcodes (1D)

They are a simple and economic way to communicate the packing's informations, broadly used to monitor stock levels and track products throughout the supply chain. Their information capacity is, however, limited and does not provide real time monitoring.

QR codes (2D)

Their data acquisition and storage are increased by the presence of dots and spaces arranged to form an image than

can be scanned by simply pointing a phone camera at it, but they are also easy to replicate which decreases their security level.

RFID (Radio Frequency Identification)

These chipped labels transmit, receive and change information via radio waves, allowing to collect data in real time without contact and transferring it into a users' information system. They ensure traceability, safety, quality, and supply chain monitoring

NFC tags

They are similar to RFIDs, but short range; therefore, they are used for direct interactions between smartphones and packaging, and useful for digital experiences and authenticity verifications. However, they can be subject to security threats, including data interception.

Digital watermarks

These are invisible codes embedded in digital files or images, in order to verify the product's authenticity and integrity. However, the visible versions of this mechanism can be easily removed.

AR/Web AR

Augmented Realtity is able to overlay digital contents and physical reality thanks to the use of a smartphone, which increases interactiveness and consumer engagement, requiring a good connection to the internet and updated devices.

VR codes

Virtual Reality codes permit an immersive and interactive virtual experience, offering engaging opportunities to the consumer; they are used mainly in digital marketing also because of their high cost and technological requirements.

INTERACTIVE PACKAGING

Interactive packaging is designed, aside from containing and protecting the product, to actively engage with the consumer, creating an emotional and memorable experience between the user and the brand through physical, visible, cognitive or sensorial interactions.[56]

There are different kinds of interaction that can be included into a packaging.

Inclusivity

In this case, the packaging is designed with the aim to reach not only the typical target audience, but also to accommodate peolple with disabilities. For example, a label which includes a translated braille version of the text is interactive for visually impaired individuals, who can access the product's information through touch.

Augmented reality

As already mentioned before, with the introduction of AR, which overlays digital content onto the real world with the use of smartphones or other compatible devices, the packaging transforms into a platform that can be used to display further informations about the product, or even for interactive games.

Narrative packaging

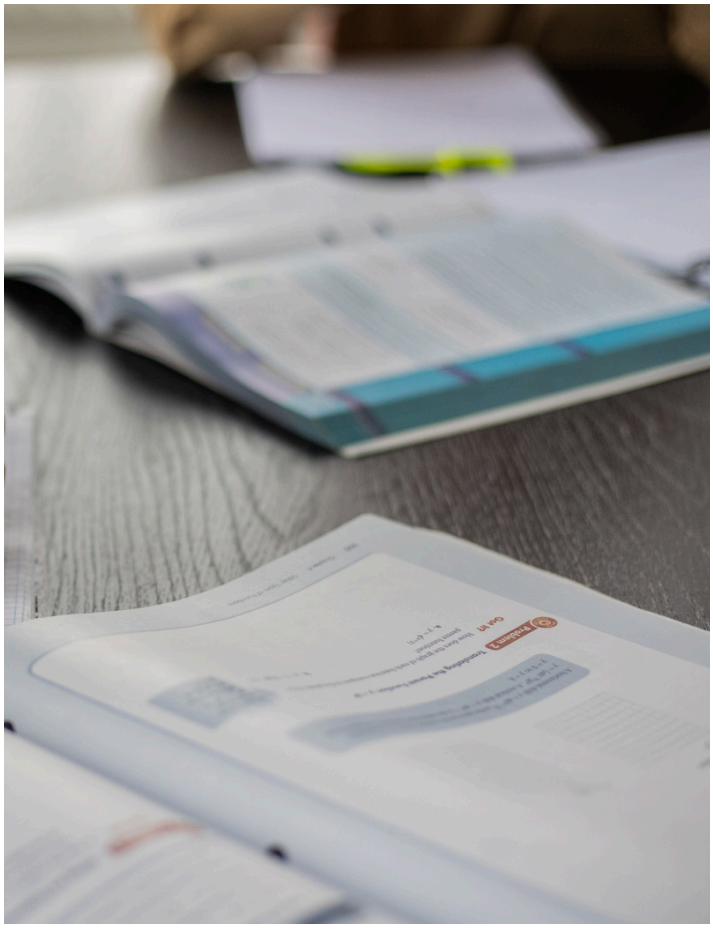
This packaging becomes a way to narrate a story, whether the product's or the brand's, through either an explicit approach (texts or images) or o more indirect way, with the use of visual elements, materials, shapes, colours or digital tools. This packaging works with the impression that the consumer has of the product, because its storytelling creates a lasting connection and makes the product appear more human and authentic.

Multisensoriality

It stimulates more senses simultaneously (sight, touch, smell and hearing) to engage in a deep and personal level with the user and create an immersive, rich and memorable experience. This is made possible by reaching multiple brain areas to increase the user's emotional involvement and to communicate the brand's – or the product's – values.

Reusable packaging

In this case, the packaging is purposely designed to be reclosed after its initial opening, preserving the content's integrity and extending the usage time.[57]



CASE STUDY ANALYSIS

This research aims to find a set of guide lines which are able to ensure a design that is both functional for its purpose and sustainable, thanks to the integration of smart technologies and solutions to various problems. To do so, I have collected a series of case studies with different answers to similar problems to those that can emerge when it comes to beauty packaging. Consequently, I have analysed the case studies to find what key solutions to these issues have been implemented, to then finally reach the point of having a set of strategies and design approaches that will define the backbone of an eventual concept for an ethical, sustainable and functional beauty packaging.

I have decided to divide the macro-arguments of my analysis - funcitonal on the product and user sides, sustainable on the social and environmental sides, and communication - and to find two cases per argument. This will enrich the final guide lines that will come from the analysis of these cases, without leaving any aspect of design out.

FUNCTIONAL - PRODUCT

CASE STUDY AIRLESS PAK

Brand/producer: Bottless

Country: Republic of Korea

Year: 2025

Description

The Airless Pak system combines an internal rechargeable pouch with an advanced airless dispenser. It reduces up to 90-95% of plastic use as opposed to traditional airless packaging. The internal pouch functions as piston: pushing it, the product is dispensed without getting in contact with air, preserving sensible formulas.[58]

Particularity

Optimizing environmental sustainability and keeping the product fresh; strong accent on usability, transparency and sustainability.

FUNCTIONAL - PRODUCT

CASE STUDY AIRLESS-ONE

Brand/producer: Fusion PKG

Country: USA

Year: 2024

Description

The Airless-One™ is a single-material airless dispensing system designed to ensure complete product protection, avoiding contact with air and minimizing waste. Both the bottle and pump are made entirely of polyolefin, with the option of using 100% recycled polypropylene (PP) resin. This design allows for up to 100% product evacuation, preserving the integrity of the formula and enhancing the consumer experience.[59]

Particularity

Keeps formula's integrity by uniting usability and sustainability thank to recycled materials; transparent on functional and ecological advantages.

ANALYSIS CRITERIA

	Airless Pak	*Airless - One*
Functional - product		
product protection	◆	◆
product preservation	◇	◆
transport sustainability	◆	◇
easy storage	◇	◇
material resistance	◆	◇
Functional - user		
grip comfort	◇	◇
easy opening/closing	◇	◇
controlled dispensing	◆	◆
user-friendly	◆	◆
disposal facilitation	◇	◆
Sustainability - social		
inclusiveness	◇	◇
transparency	◆	◇
safety/hygienicy	◆	◆
local	◇	◇
ethical	◆	◇
Sustainability - environmental		
recycled/recyclable materials	◆	◆
lightweight/volume optimisation	◆	◆
disassemblable/end fo life optimisation	◆	◆
reusable/compostable	◆	◆
extended life cycle	◆	◆
Communicative		
clear product info	◆	◆
usage guidance	◆	◆
shelf appeal	◆	◆
brand storytelling	◆	◇
brand/product category identification	◆	◆

FUNCTIONAL_USER

CASE STUDY CAPSULE AIRLESS PUMP

Brand/producer: HCT by kdc/one

Country: USA

Year: 2025

Description

The Capsule Airless Pump is an innovative dispensing system that integrates the cap as both an actuator and a container. Made of 95% monomaterial polypropylene (PP), the airless design eliminates contact with air, reducing waste and contamination. The structure is fully recyclable and can be reused with new internal components.[60]

Particularity

Combines premium aesthetic and functionality, with an accent on product protection and reduced environmental impact.

FUNCTIONAL_USER

CASE STUDY TUBEAIRLESS

Brand/producer: Induplast Packaging Group

Country: France

Year: 2024

Description

Tubairless® is an innovative packaging system that combines the convenience of a traditional tube with the advanced performance of airless packaging. Inside the tube is a soft plastic bag that acts as a one-way piston: when pressure is applied to the tube, the bag pushes the product toward the outlet, preventing air from entering and preserving the formula. This design is particularly suitable for rich, dense, and delicate creams.[61]

Particularity

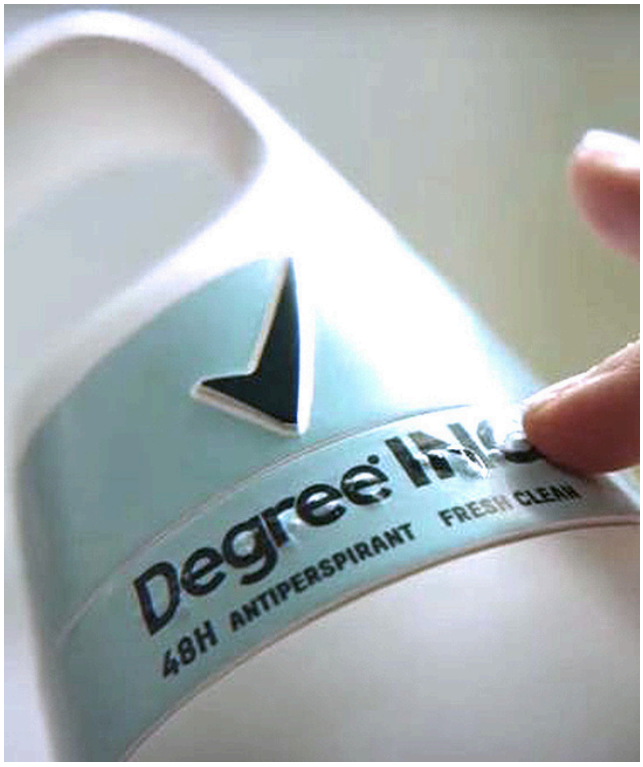
Tube format which assures protection, conservation and easy usage, with simple disposal instructions, without renouncing to performance.

ANALYSIS CRITERIA

	Capsule Airless Pump	*Tubeairless*
Functional - product		
product protection	◆	◆
product preservation	◆	◆
transport sustainability	◇	◇
easy storage	◇	◇
material resistance	◇	◇
Functional - user		
grip comfort	◇	◇
easy opening/closing	◇	◇
controlled dispensing	◆	◆
user-friendly	◆	◆
disposal facilitation	◆	◆
Sustainability - social		
inclusiveness	◇	◇
transparency	◇	◇
safety/hygienicy	◆	◆
local	◇	◇
ethical	◇	◇
Sustainability - environmental		
recycled/recyclable materials	◆	◆
lightweight/volume optimisation	◆	◆
disassemblable/end fo life optimisation	◆	◆
reusable/compostable	◆	◇
extended life cycle	◆	◆
Communicative		
clear product info	◆	◆
usage guidance	◆	◇
shelf appeal	◆	◆
brand storytelling	◇	◇
brand/product category identification	◆	◆

SUSTAINABILITY_SOCIAL

CASE STUDY DEGREE INCLUSIVE



Brand/producer: Unilever

Country: USA

Year: 2021

Description

Degree Inclusive is a roll-on deodorant developped to make the application easier for people with physical disabilities. It has an ergonomic shape with a hook for single hand use, a magnetic closure that is easy to open and close, a broad applicator to cover more skin surface, and instructions written in braille. The flacon is both rechargeable and sustainable, and was created with the collaboration of people with disabilities to ensure autonomy and inclusivity.[62]

Particularity

Social sustainability and inclusivness are a top priority, efficient and empathetic communication, advanced user experience.

SUSTAINABILITY_SOCIAL

CASE STUDY TACTILE BOTTLE

Brand/producer: Herbal Essence, P&G

Country: USA

Year: 2019

Description

Herbal Essence introduced a tactile marker system on their shampoo and conditioner bottles to support blind and viasually impaired people. Developed in collaboration with experts and tested directly by people with visual disabilities, this system uses distinctive tactile embossments to the products apart. This solution serves the purpose of giving visually impaired people autonomy.[63]

Particularity

Good balance between social and environmental sustainability, accessible packaging and clear, ethical, and green informations.

ANALYSIS CRITERIA

	Degree Inclusive	*Tactile Bottle*
Functional - product		
product protection	◆	◆
product preservation	◆	◇
transport sustainability	◇	◇
easy storage	◇	◆
material resistance	◆	◇
Functional - user		
grip comfort	◆	◇
easy opening/closing	◆	◇
controlled dispensing	◆	◇
user-friendly	◆	◆
disposal facilitation	◇	◆
Sustainability - social		
inclusiveness	◆	◆
transparency	◆	◆
safety/hygienicy	◆	◆
local	◇	◇
ethical	◆	◆
Sustainability - environmental		
recycled/recyclable materials	◇	◆
lightweight/volume optimisation	◇	◇
disassemblable/end fo life optimisation	◇	◆
reusable/compostable	◇	◇
extended life cycle	◇	◇
Communicative		
clear product info	◆	◆
usage guidance	◆	◆
shelf appeal	◇	◆
brand storytelling	◆	◇
brand/product category identification	◆	◆

SUSTAINABILITY_ENVIRONMENTAL

CASE STUDY PAPER POINT NECK AIRLESS

Brand/producer: Yonwoo Co. Ltd, PKG Group

Country: South Korea

Year: 2022

Description

Yonwoo's airless pump dispenser is designed to reduce waste and enhance the product's conservation, avoiding contact with air and external contaminants. From the point of view of sustainability, this system allows the use of all the the product, and its airless structure contribuites to limit the use of chemical preservatives, thanks to the protection of the formula, and can be realized in lightweight and recyclable materials.[64]

Particularity

The aim is to reduce plastic use and engage with more eco-compatible materials, keeping high performance and usability.

SUSTAINABILITY_ENVIRONMENTAL

CASE STUDY AIRLESS REFILLABLE SYSTEM

Brand/producer: APC Packaging

Country: USA

Year: 2023

Description

The Airless Refillable System by APC Packaging is designed to combine functionality and sustainability, offering a reusable solution which drastically reduces waste. Thanks to the rechargeable design, the consumer can substitute the internal cartridge keeping the external flacon, reducing environmental impact and plastic use. The airless technology assures that the product is dispensed until the last drop, avoiding formula waste and guaranteeing a usage otpimisation without the use of preservatives.[65]

Particularity

Optimizes environmental sustainability with the use of recycled materials and a refillable system thanks to the cartridge; practical thanks to ergonomy and inserting system.

ANALYSIS CRITERIA

	Paper Point Neck Airless	*Airless Refillable System*
Functional - product		
product protection	◆	◆
product preservation	◆	◇
transport sustainability	◆	◆
easy storage	◇	◇
material resistance	◇	◇
Functional - user		
grip comfort	◆	◇
easy opening/closing	◇	◇
controlled dispensing	◆	◇
user-friendly	◆	◆
disposal facilitation	◆	◆
Sustainability - social		
inclusiveness	◇	◇
transparency	◇	◆
safety/hygienicy	◆	◆
local	◇	◆
ethical	◇	◆
Sustainability - environmental		
recycled/recyclable materials	◆	◆
lightweight/volume optimisation	◆	◆
disassemblable/end fo life optimisation	◆	◆
reusable/compostable	◆	◆
extended life cycle	◆	◇
Communicative		
clear product info	◆	◆
usage guidance	◆	◇
shelf appeal	◆	◆
brand storytelling	◇	◆
brand/product category identification	◆	◆

COMMUNICATION

CASE STUDY THE ORDINARY

Brand/producer: DECIEM

Country: Canada

Year: 2016

Description

The Ordinary emerges among other brands for its minimalistic and scientific approach to skincare. Their products have a clean and pharmaceutical aesthetic, with essential tags which clearly report the ingredients, their concentration and their function. The brand uses a clear yet technical language, making the comprehension of complicated formulas accessible to anyone.[66]

Particularity

Excellent functionality and user experience thanks to clear, transparent and accessible comunication.

COMMUNICATION

CASE STUDY
MY SKIN
UV TRACK

Brand/producer: La Roche Posay & L'Oréal

Country: USA

Year: 2019

Description

This tiny wearable sensor without battery measures the exposition to UV lights of the person's skin. Connected to an app, it suggests which products are suited best to protect the skin. The integration of packaging and user experience offers a constant education to the consumer. It is a perfect example on how the beauty industry con expand beyond the physical product.[67]

Particularity

Innovative UX with empowerment of the user through technology; focus on brand fidelity and customisation.

ANALYSIS CRITERIA

	The Ordinary	*My Skin Uv Track*
Functional - product		
product protection	◆	◇
product preservation	◆	◇
transport sustainability	◆	◆
easy storage	◇	◇
material resistance	◇	◇
Functional - user		
grip comfort	◇	◇
easy opening/closing	◇	◇
controlled dispensing	◆	◇
user-friendly	◆	◆
disposal facilitation	◆	◆
Sustainability - social		
inclusiveness	◇	◇
transparency	◆	◆
safety/hygienicy	◆	◇
local	◇	◇
ethical	◆	◆
Sustainability - environmental		
recycled/recyclable materials	◆	◆
lightweight/volume optimisation	◆	◇
disassemblable/end fo life optimisation	◆	◆
reusable/compostable	◇	◆
extended life cycle	◇	◇
Communicative		
clear product info	◆	◆
usage guidance	◇	◆
shelf appeal	◇	◇
brand storytelling	◆	◆
brand/product category identification	◆	◆

Conclusions

From the analysis of these case studies emerge a variety of packaging solutions, aiming to the resolution of functional, social, environmental and communicative challenges tied to cosmetic products.

From the point of view of product functionality, the common objective is to preserve the formulas' integrity and quality, preventing contamination and oxidation thorugh airless piston or pouch systems which minimize contact with air. From the user functionality side, the designs priviledge ergonomy, dosing facilitation and accessability, including refillable systems easy to use for any kind of user. Talking about social sustainability, there is a growing interest for inclusivity, transparency and ethical practices , with brands promoting accessible packaging and collaborating directly with the users. When it comes to environmental sustainability, the most diffused strategies include the use of recycled and recyclable materials, packaging volume and weight reduction, and rechargeable systems - or reusable ones - to minimize waste and unnecessary secondary packaging. Finally, communication is confirmed to be a key element to educate and involve users, building loyalty and exploiting ethical and innovative brand values.

The solutions adopted by these case studies show a broad range of approaches: from totally recyclable or based on innovative materials like post consumer recycled carton packaging, to refillable systems and functional features for the removal of the inner cartridge, up to technological skin monitoring devices.

The most effective airless system for the protection and conservation of the product adopt internal pistons and vacuum mechanisms which reduce final product waste to the minimum, offering also a precise and controlled dosing, a crucial aspect when handling sensible products and cosmetic treatments.

The user-experience centered solutions aim to simplify everyday use of the product, including ergonomic, and accessible elements and facilitating overall maintenance.

Social sustainability is best portrayed through inclusive packaging as well as transparent and active brand policies, while environmental sustainablity priviledges recycled materials and circular design.

Best Practice

Airless Pak by Bottless distinguishes as the best practice between all of the other case studies for its combination between functional, social, environamental, and communicative features. Its innovation resides in a design that eliminates the external bottle, thus significantly reducing material use, and in the adoption of a high percentage of recycled materials, adding the value of disassemblable components and simplifying recycling. As to the functional point of view, it guarantees maximal protection from contamination and oxidation thanks to an advanced airless mechanism which maintains the product fresh until the last drop, eliminating unnecessary waste.

GUIDE LINES

The analysis of the case studies has brought to the conclusion that the success of an airless packaging for cosmetics depends form the efficient integration of multiple criteria which vary from technical functionality to simple usability. To design an airless pump dispenser which answers these requirements, I enlisted the following guidelines to reflect the best solutions adopted by the case studies I previously analysed.

01 TOTAL PROTECTION

Use **airless piston** or **sealed pouch** mechanisms that prevent any contact with air or other contaminants, assuring the integrity and freshness of the product. Choose **compatible materials** to avoid formula alterations and keep the packaging **structure stable and resistant** to not compromise its functionality during transport.

02 USER FRIENDLY

Choose simple and intuitive paths when designing, assuring a good and **comfortable grip**, **dimensions** that fit **any kind of hand**, and a fluid and **metered dispensing** mechanism. Use **easy opening and closing** systems, and refills with **simply inserted cartridges**, with **clear informations** for the user. The aim is to make the design as universally appreciated as possible.

03 ACCESSIBILITY AND ERGONOMY

Design an ergonomic and simple to use packaging, with precise and dosable dispensing, and intuitive opening and closing. Include accessibility enhancing elements like a **magnetic snap**, **tactile or non-slip surfaces** for users with disabilities or limited mobility. Make the **substituition or recharge quick** and effective to ensure a fluid and satifying user experience.

04 CIRCULAR DESIGN

Priviledge **recycled plastic materials**, such as **PP PCR**, and innovative solutions like **recycled carton**. Design the packaging to be **completely disassemblable**, favouring recycling and end-of-life waste reduction. Integrate **refillable and substituible systems** which enhance the packaging efficiency without the need to buy more products each time.

05 ACTIVE COMMUNICATION

Each element of the packaging must be linked to **clear and detailed informations** on product, sustainability, correct use and recycling. Use **graphic and written elements**, which must be readable and accessible, to inform the consumer and catch his attention, turning the packaging into an efficient brand and product communication tool.

INTEGRATION OF SMART TECHNOLOGIES

The evolution of cosmetic packaging doesn't only apply to form, materials and technical functionalities, but it also extends to the employment of digital and interactive technologies. Smart packaging represents a fundamental lever to translate the previously mentioned guidlines into practice. This perspective allows to see smart packaging as a powerful tool able to reinforce their efficiency and permitting to open up to new interaction possibilities between product, user and brand.

Total protection

If the airless system stands as an efficient barrier to air and contaminants, smart technologies allow to go further the passive protection. Through the use of **intelligent tags** or **TTIs**, the packaging can comunicate eventual risks for the formula, increasing transparency and brand fidelity. The freshness of the product is not only preserved, but also monitored and brought to the attention of the user.

User friendly

The integration of smart packaging allows to enhance the intuitivity: **visual** or just **bright indicators** can signal the correct dispensing or closing, while **interactive digital systems** can guide the user when refilling the product o changing the cartridge. This way, the usage is not only simple and accessible, but also enhanced by a technological support which reduces waste and improves general satisfaction.

Accessibility and ergonomy

Inclusivity doesn't stop with the physical design of the dispnser, but can be extended thanks to digital solutions. The access through **QR codes** or **NFC tags** to instrucitions and audio-visual tutorials gives the opportunity of an autonomous interaction to people with impaired mobility and sight. Even the employmentt of a **tactile** or **audible feedback** at the moment of dispensing becomes an added value which makes the experience more intuitive. This way, smart packaging turns ergonomy into a concept that unifies both physical and digital dimensions.

Circular design

The adoption of recycled materials and refillable solutions can be boosted by intelligent system which guide and educate towards sustainable behaviours. **QR codes** or **digital tags** can provide clear instructions on the correct disposal of the components of the packaging, reducing frequent input errors. At the same time, **chips** or **sensors** can monitor the refilling cycle and reward the user with prizes, enforcing circular and reuse culture.

Active communication

Finally, smart packaging can lead to a communication which overcomes the limits of paper tags. Technologies like **AR** or dynamic contents accessible via **NFC tags**, transform the dispenser into a storytelling interactive device, able to involvingly communicate the brand's history, the product's sustainability and the optimal usage instructions. This way, communication is more than just static and definitive, but can update through time and offer a personalized experience.

The integration of smart technologies into the guidelines for the design of an airless pump dispenser grants the transformation of these principles into interactive, verifiable and concrete experiences. Each criteria finds an expansion in smart packaging which amplifies its range and keeps it true to contemporary transparency, sustainability and inclusivity requirements. In this perspective, packaging is more than just a functional container: it becomes an intelligent platform, able to mediate between user, product and brand, contruibing to redefining the future of the cosmetic industry.

CONCEPT

The analysis of the case studies and on the different approaches adopted by the market has brought to the identification of a number of fundamental guidelines to the design of an airless pump dispenser driven by innovation and sustainability. These guidelines desfine a broad vision which doesn't only apply to the technical functions of the container, but also embraces ergonomic, social, environmental and communicative aspects.

In particular, it has emerged how the total protection of the product represents an essential requirement: the packaging must ensure integrity, freshness and safety of the formula during all its life cycle.

The criteria of user friendliness concentrates on everyday semplicity, assuring an intuitive, comfortable and immediate system and reducing errors and struggles from the user's side.

In parallel, accessibility and ergonomy aim to make the user experience fluid and inclusive, permitting an easy interaction to a wide range of users.

As to the principle of circular design, it underlines the importance of recycled materials, disassemblable structures and refill systems, possibly enhanced by the interaction with technologies which guide the user to the correct dismissal of the packaging.

At last, active communication transforms packaging from simple container to a dialog tool for the consumer: through interactive element, augmented reality and dynamic digital systems, the dispenser becomes a narrative and informative vessel which enhances the relation between brand and user.

This recap shows how an airless packaging can become a strategic multifunctional tool, a device capable to connect protection, inclusivity, sustainability and storytelling in one coeherent experience.

Concept definition

In view of the previous analysis of the case studies and the criteria, the design concept can be defined as follows:

> ***A smart and sustainable airless pump dispenser packaging, designed to guarantee maximal protection of the product, a simple and universal user experience, circular processes based on refill systems and recycled materials, and digital interactive communication that elevates the packaging not only to its functional purposes, but also narrative, transparent and distinctive.***

Concept elements

There is a set of features that this concept, along with the guidelines, expects from an eventual project.

Airless pump system

- An internal piston dispenser to ensure hygiencity and product conservation
- A fluid mechanism that allows precise dosing without waste

Main body in recycled/recyclable materials

- PCR plastic, or certified bio-polymers
- Surface treatment to ensure collision resistance

Internal refillable or interchangeable cartridge

- Easily removable and substituible module
- Compatibility with pre-dosed refill pods
- Lightweight and recyclable materials like monomaterial PET or PP

Intuitive opening/closing system

- A snapping or twist-lock cap avoiding accidental opening
- Visual or tactile signals indicating the correct closing

Ergonomic shape

- Slightly curved body to ensure firm grip
- Adaptable/universal dimensions
- Anti-slip surface with rubber or bumped areas

Usage and consumption indicators

- Transparent window or graduated line to monitor product level
- Cromatic or symbolic signals to indicate the right time to refill

Universal accessibility components

- Wide and pressure sensible dispensing button
- Cromatic contrasts
- Embossed tactile symbols

Modular stucture

- End-of-life disassembling of parts (pump, body, cartridge)
- Absence of permanent glue (only mechanical or thread fixtures

Smart integrations

- Printed QR code or NFC tag for informations on the product, traceability or brand storytelling
- Connection possibility to an app to monitor expiry dates, dosing and usage guidance.

The elements enlisted above are not optionals, but represent projectual priorities to follow with the goal of reaching a new idea of packaging, able to conjugate tecnical efficiency, environmental respect and intuitive use.

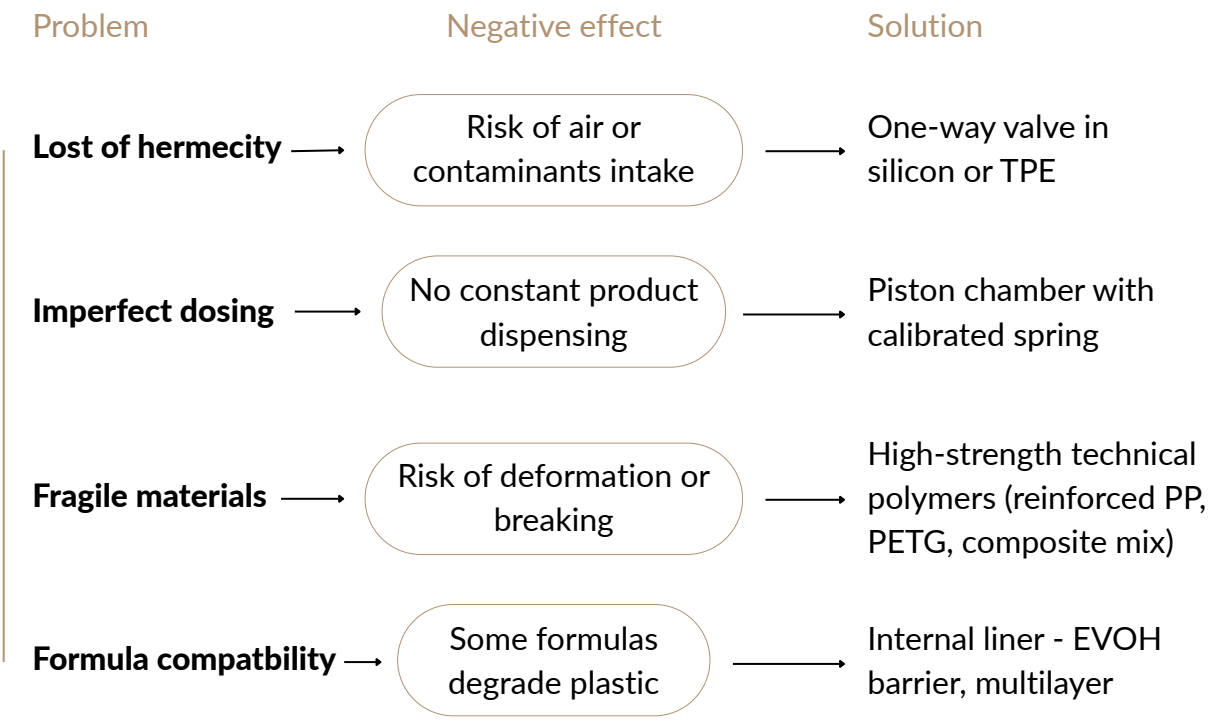
Their integration permits to transform a passive packaging into an interactive and active system, capable of resolving concrete problems tied to conservation, accessibility and communication with the consumer. In this sense, the forementioned concept stands as an open platform, adaptable to many sectors and markets, but stable in its essence: a universal packaging, both smart and sustainable, which accompanies the user with semplicity, and ensures the product quality as well as the relation with the brand.

PRACTICAL PROBLEMS

The research conducted in the last chapter has underlined how designing an airless pump dispenser is not only limited to its dispensing function, but also faces a series of concrete criticalities tied to technical functionality, user experience, social and environmental sustainability, and communication.

The analysis of the problems and solutions, based on the case studies and the conclusions drawn subsequently from their review, allows the definition of not only the main challanges to overcome, but also the most efficient technical interventions to do so. In this chapter, I will be enlisting and explaining the principal practical problems that emerged, and what the best way to respond to such issues.

Functional - product

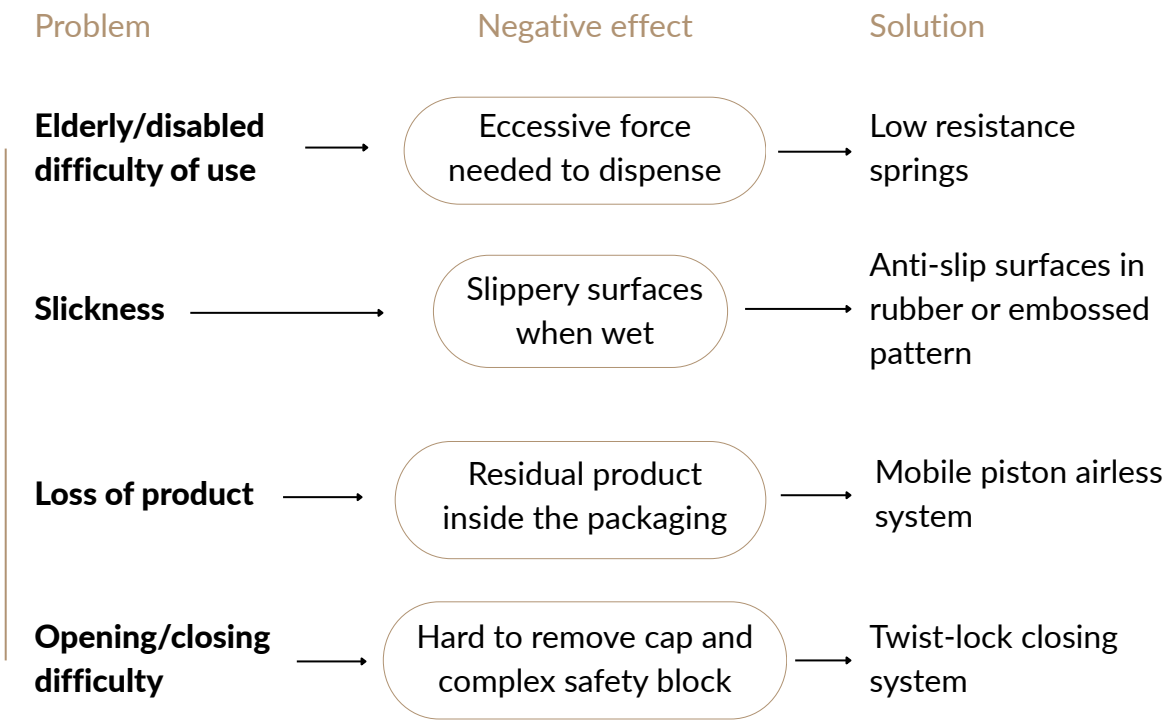


One of the main technical obstacles concerns the loss of hermecity, which will compromise the airless functionality. The entrance of air or contaminants reduces the duration of the formula and increases hygienical risks. The most efficient solutions is the use of one-way valves made out of silicone or thermoplastic elastomer (TPE), which seal the system.

Other common problems are the diffuclity to guarantee a constant and stable dispensing of the product, and material fragility. These aspects can be resolved by implementing a piston chamber with calibrated springs, which keep the dispensing regular, and the use of highly resistant polymers, like reinforced PP or PETG, which are very durable and not easily defomrable.

Some cosmetic formulas can also degrade plastics, so there has to be an internal ethylene vinyl alcohol barrier that isolates the content and preserves the formula's properties.

Functional - user



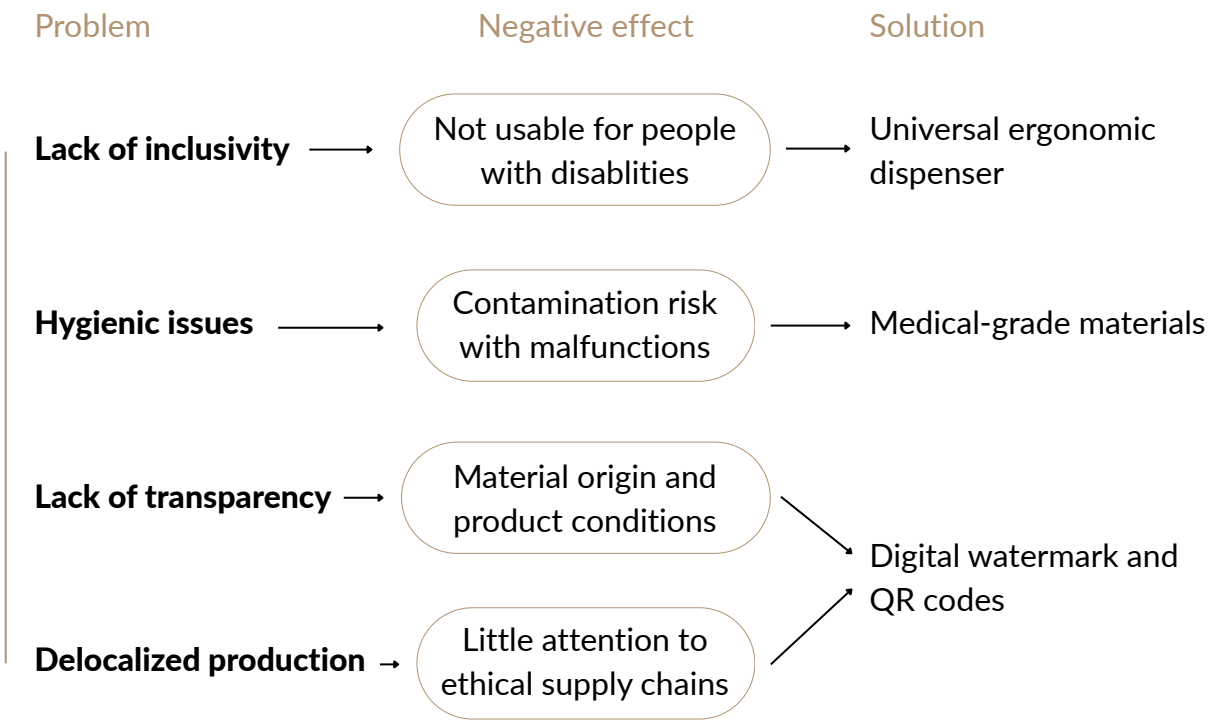
From the users' side, the main problems regard ergonomy and accessibility. Elderly or people with less manual strength can find it difficult to use dispensers which require eccessive pressure. The solutions include low-resistance springs and soft-touch systems which require less strength to be used.

Other obstacles are tied to the surfaces' slickness, which can make the hand grip unstable, especially when wet. For the resolution of this problem, it is fundamental to introduce anti-slip surfaces or a rubber insert to create friction.

There is also a frequency of problems regarding the opening and closing of the packaging, often not very intuitive: in this case, a twist-lock system can guarantee both safety and ease of use.

Another critical point concerns the total recovery of the product: without an adequate mechanism, important residue of the formula or serum remain untouched and will be thrown away. The adoption of mobile pistons that follow the product's level allows to use all of the formula, without wasting it.

Sustainability - social

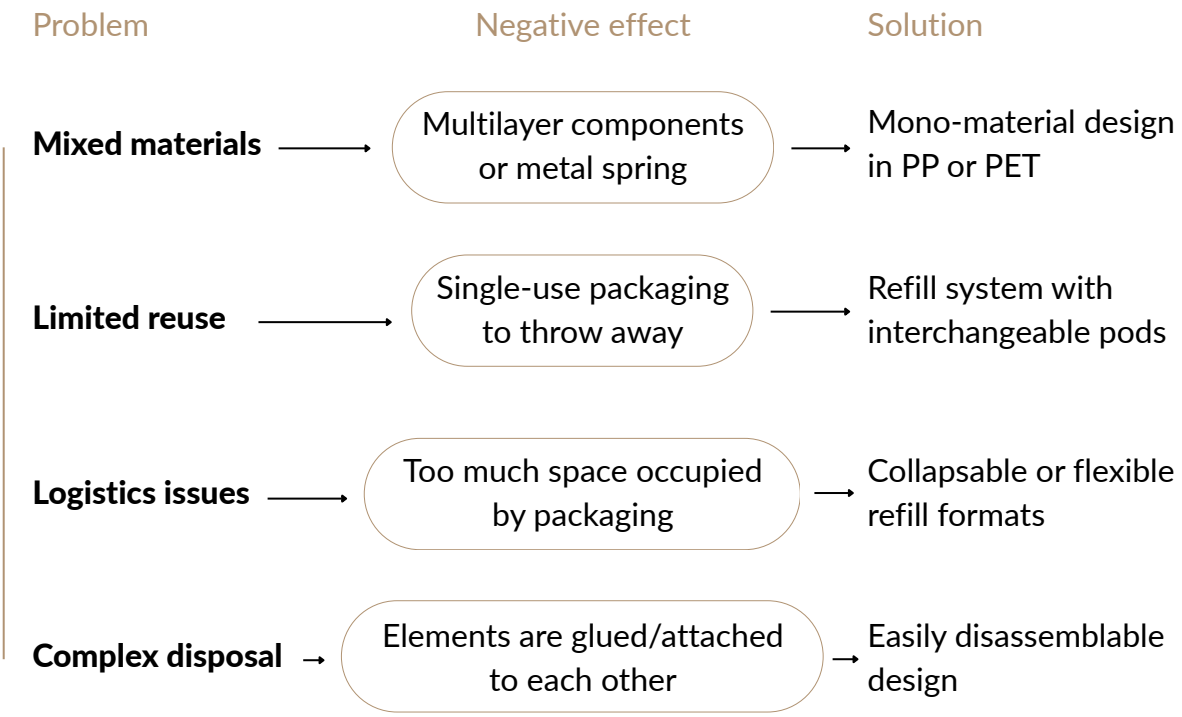


In the case of social sustainability, there are several problems concerning inclusivity and scarce transparency on the brand's end. Often dispensers, and more generally cosmetic products, are not designed for users with mobility disabilities, excluding a portion of consumers. The response to this is the development of universally ergonomic devices that can be designed also with the help of people with disabilities.

The production delocalization and absence of ethical informations pose further criticalities: this is where tools like digital watermarks and QR codes come in use, communicating the material's origin and the compliance with responsible manufacturing standards.

Lastly, the use of medical-grade materials represents a good solution to reduce hygienic risks and guarantee more product fidelity.

Sustainability - environmental



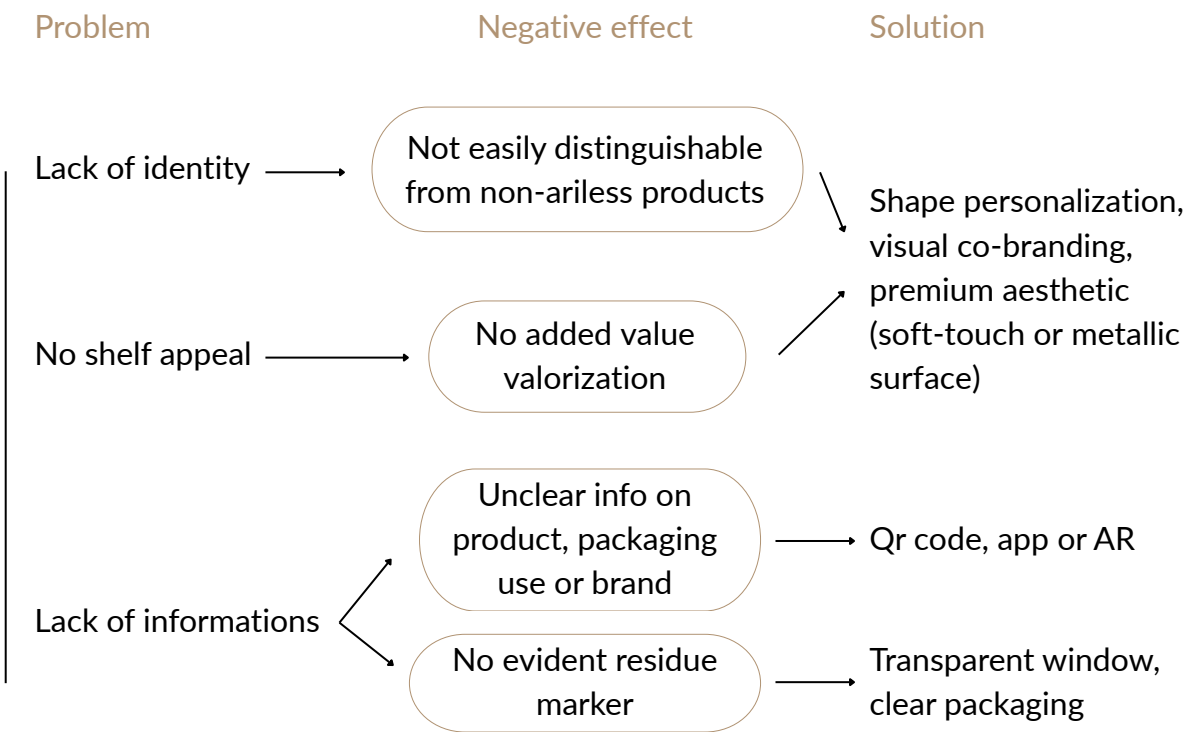
From the sustainable point of view, the primary problem is the difficulty to recycle the packaging, caused by multimaterial or glued together elements. The technical solutions to this consists in a recyclable mono-material, for example in PP or PET, or easily disassemblable design.

Moreover, scarse reuse possibility is also an issue: many dispensers are meant to be single-use. The introduction of refill systems with interchangeable cartridges represents a concrete response to this recurrent problem.

Logistics also poses space occupancy issues, as this affects product transportation. Collapsable or flexible formats allow volume reduction and optimize the distribuition.

At last, the eccessive use of secondary packaging contruibutes to waste production: more lightweight and modular solutions can decrease the complessive enviromental footprint.

Communication



Communication is often a weakness for airless pump dispensers. One of the main problems is the lack of visual identity: in fact, they look like any other dispenser and rarely transmit their added value. The solutions to this lies in shape, texture and surface characterization thorugh soft-touch or metallized parts, or with dynamic or premium aesthetics, to create a distinctive identity.

Another criticality regards information readability: reduced surfaces and curves limit the clarity of tags. The use of QR codes, which can connect the user to an informative app or AR contents, can help improve the user's education on the product, brand and ingredients.

As for the product level, which is often hidden inside the bottle, the implementation of a seethrough window surely helps identifying how much of the formula is left, and when the right time to change the inner cartridge actually is.

CONCLUSION

The analysis of the problems and consequent technical solutions shows how desinging an airless pump dispenser is a complex process, which requires a multidimensional and integrated approach. It is not only about assuring the correct dispensing of the product, but it also includes resolving questions tied to ergonomy, safety, social transparency, environmental sustainability and communication.

The technical improvemnts that came out of the analysis represent solutions to practical problems, but also an innovation opportunity to rethink the role of packaging in the beauty industry.

In conclusion, the future of airless packaging can be found in a device which embodies functionality, inclusiveness, sustainabilty and communication, able to integrate advanced technologies and ethical values. Its evolution is not only a technical question, where the container is no more just a simple support to the product, but becomes a protagonist in the relations between brand and consumer.

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