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Ayrampo (Opuntia apurimancis) as a Natural Pigment in Lipsticks: Acceptance Evaluation and Analysis of Determinant Factors

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Abstract*– The need to use sustainable and non-toxic ingredients drives the use of ayrampo as a natural pigment. The study evaluates the use of Ayrampo within cosmetics as a pigment in lipsticks, measuring its impact on consumer acceptance. Logistic regression was used for data processing to identify the key factors that showed that the components related to pigments, fragrance, and texture are the most important. In this evaluation, Ayrampo (coefficient =0.18) showed an intermediate impact in sixth place, surpassed by pigment 600 (coefficient 0.59) and Orange Fragrance (coefficient =0.50). To indicate the results obtained, the correlation of ayrampo with other components was measured, explaining that the intermediate impact may be due to its interactions at the dependency level with high correlations (0.88) with other elements such as beeswax and coconut oil, which have a low impact (coefficients=0). To confirm the importance, machine learning techniques such as Random Forest were applied, which confirmed its intermediate influence, surpassed by pigments and fragrances. The findings reveal the importance and potential of Ayrampo as a sustainable natural pigment, but further research is needed with new formulations to ensure end consumers' acceptance.

Keywords—Ayrampo, Sustainable Cosmetics, Logistic Regression, Machine Learning.

I. Introduction

In recent decades, the use of cosmetic products has experienced exponential growth [1], driven by market changes and consumer perception. Their daily use sets new parameters for beauty, such as color, which plays a crucial role in highlighting the features and increasing the visual appeal of the face. In addition, the fragrance has a decorative function along with texture. Thus, among the wide range of products available, lip makeup stands out as the most popular [2] .

Among the many lipstick options available on the market, those of synthetic origin and organic origin stand out, which are distinguished mainly by their composition and ingredients. Synthetic lipsticks are made from chemical ingredients such as fragrances and pigments. For example, the pigment red 53, which was used in the cosmetics industry and the paint industry as a dye, was shown to cause cancer [3]. Furthermore, metalloids can cause health problems, which, although present below the standards of regulatory entities, can affect them in the long term. [4], [5]

In contrast, organic lipstick formulations contain natural ingredients, which guarantee the safety and efficiency of the product, standing out as a significant alternative within the industry. The original composition offers a wide range of textures, fragrances, and colors that align with consumers' environmental ideals [6] .

In this context, the ayrampo (Opuntia apurimancis), a plant native to the Andean areas of Peru, especially the Apurimac and Ayacucho regions, emerges as an outstanding natural alternative. Its fruits give off a pigment known as betalain, which gives it a purple-reddish coloration. Consequently, it is used in various areas such as textile dyeing, handicraft production, and the food industry [7], [8].

In a complementary way, the pigment of the ayrampo (Opuntia apurimancis) has functional properties, standing out as an alternative in the cosmetic industry. Studies conducted by [9], [10] Betalain has potent antioxidant activity, protecting the skin by neutralizing free radicals. Its anti-inflammatory effect is another outstanding property that can help reduce skin irritation and redness. In this way, the versatility of the ayrampo contributes to the personal care industry, such as in the production of moisturizers, serums, and sunscreens.

II. Theoretical Framework

A. Background

A classic synthetic lipstick is a product composed mainly of waxes (10 – 20%), oils (40 – 60%) and to a lesser extent of fatty pastes (5 – 10%), these components form the general structure of the lipstick, which directly influence the sensory characteristics of the lipstick, such as hardness, softness, and shine [11]. Likewise, the mineral waxes that compose them help considerably to improve the firmness of the lipstick, while helping to maintain oxidative stability; however, these products are a great risk to human health, because they contain small amounts of polycyclic aromatic hydrocarbons, which are classified as highly carcinogenic [12]. In the same way, synthetic waxes present a significant risk because they are primarily of petroleum origin.

In the research conducted by [13] The use of low molecular mass organogelators (LMOGs) as substitutes for part of waxes in lipstick formulations was evaluated, as they could provide the thermal, rheological, sensory, and performance properties for optimal results. DBS and 12-HSA were used to formulate four types of lipsticks, which were evaluated by sensory perception. This way, the potential use of LMOGs as a structuring agent was identified.

The study conducted by [14] aimed to find an effective alternative solution to address health concerns associated with heavy metal contaminants in lipstick formulations. The lipstick

was made by the dispersion method with oils, incorporating the beet powder extract to provide the color; thus, later, studies were carried out to show the lipstick's stability, durability, irritability, solubility, etc., which turned out to be successful.

The study by [15] analyzed how light sources, lipstick colors, and gender affect consumer perception through surveys of 60 participants, who evaluated 15 lipsticks in 3 models under five types of light (CCT between 2500 K and 6500 K). Light influences color preference and purchase intent, while color affects sex appeal. Women were more sensitive to variations in light. No correlation was found between the evaluation of colors on lips and forearms, questioning this standard practice, and these results provide information for new marketing strategies for cosmetics.

The study by [16], part of a project on organic UV filters in personal care products (PCPs), collected data on the usage patterns of eight categories of PCPs that are not rinsed (including face cream, body lotion, lipstick, lip care, and sunscreen) in the German-speaking population of Switzerland. The study included children under 12 years of age. The study, through a survey showed that 99% of respondents used at least one personal care product that included lipsticks as a PCP, this result is vital to underscore the need to evaluate the exposures of specific components due to the cumulative exposure of the product and thus better understand consumption in different ages and nationalities.

Lip makeup contains a wide variety of colors for different skin tones. Research conducted by [17] Using hyperspectral imaging (SpectraFace), this study analyzed the different color varieties for different skin tones of African-American, Caucasian, and Hispanic women. This study took 410 participants and identified a continuous color space and great diversity, with 11 lip shades being defined. This result emphasizes (nude) shades close to the lips' natural color.

The trend of the new generations is to develop sustainable products through natural products free of chemical compounds. The study [18] evaluated whether Oryza sativa extract and Carissa carandas possessed antioxidant properties. Oryza sativa extract obtained better tyrosinase inhibition results (45.70%) compared to Carissa carandas (36.90%). This result was added to a formulation for a gel lipstick to evaluate some properties, such as color, odor, spreadability, and acceptability, using the sensory analysis of 20 women. The results indicated that Carissa carandas scored the best for dark shades and Oryza sativa for light colours. This result proves the ability of certain natural products to adapt them to lipsticks and reduce the impact of synthetic products.

Part of the composition of a lipstick is represented by waxes that provide structural properties. In the study by [19]Alkenones derived from marine microalgae replaced traditional waxes with synthetic lipsticks to provide a natural variant, generating stability and a pleasant texture. 384 lipsticks were formulated, and characteristics such as hardness, firmness, and friction were analyzed through sensory analysis based on 14 respondents, indicating that they did not irritate. Consumers preferred the L4 formulation as it confirmed the effectiveness of alkenones in improving lipstick. It is concluded that alkenones are an effective alternative to waxes of synthetic origin.

Beeswaxes fulfill structural properties, as demonstrated by the study by [20], which aimed to optimize the formulation of lipsticks' physical properties and then conduct sensory research on the influence of other main ingredients, such as beeswax and oils, on the properties of lipsticks. Antioxidant activity was assessed through spectrophotometry, and hardness was investigated with a texture analyzer. The results of the mixture with grapeseed and sea buckthorn oil reflect the highest antioxidant activity (70 +- 0.84%). According to the sensory analysis, the optimal composition was 57.67% oil mixture, 19.50% beeswax, and 22.75% cocoa butter. It is concluded that the formulation has good physical and sensory properties, which make it a candidate for sustainability in natural cosmetics.

B. Ayrampo

Ayrampo is a small plant, belonging to the cactus family, also scientifically called Opuntia apurimacensis or Opuntia soehrensii, native to the high Andean regions of Peru [7] . The pigment that is released from fruit and seeds is used as a dye of natural origin in gastronomy, coloring for natural ice cream, in the textile and ceramic industry, as well as in artisanal medicine [8]. This fruit is characterized by its antioxidant properties. The pigment it gives off is known as betalains, which are a group of natural pigments that contain nitrogen and also have the property of solubility. To date, around 60 types of betalains are known to share the chemical structure of betalamic acid [21].

C. Betalains Properties and Pigment Extraction

Betalains are present in a variety of fruits and plants. This component has a great antioxidant capacity and a variety of colorful tones that provide a solution to chemical dyes [22]These are divided into betacyanins and betaxanthins, which give reddish and yellowish colors, respectively. Other notable properties are its stability at pH levels between 4 and 6, which reflects its ability to be used as a colorant in cosmetic lipsticks. These qualities also give the pigment a wide variety of applications in gastronomy, textiles, and personal care products, supporting sustainability.

The extraction of betalain from the Ayrampo fruit requires that stability and efficiency be ensured and supported by sustainable and ecological methods. Therefore, the maceration process through distilled water or phenolic components is the most commonly used method. The process is completed with centrifugation or freeze-drying of the product; in other unconventional methods, an ultrasound bath or microwave is used to increase efficiency and remove impurities within the process [23]. Similarly, it is recommended that the storage be in the necessary conditions that the product requires, avoiding changes in color, pH, and variations in temperature.

Recent research showed that the method with distilled water and centrifuging the solution achieved an extraction yield of 46%, using pulp and seeds as raw material [24].

D. Comparison with other natural pigments

Awareness of the production of natural products that help the sustainability of future generations leads us to search for new sources of organic raw material, such as natural dyes in lipsticks, as they are considered safer and healthier. This new way of thinking leads to the search for new sources of pigments in plants and fruits. An example of this in cacti is Opuntia stricta and Opuntia ficus-indica L., which were shown to be suitable as pigments for the cosmetic and textile industry, among the outstanding properties are the large amount of anthocyanins and bioactive components [25]. Other pigments come from fruits such as Capsicum annuum, Hylocereus polyrhizus, and esculentum, which contain antioxidant properties and help prevent some health problems [26], [27], [28].

In contrast to the pigment of Ayrampo, the pigment of Capsicum annuum and Capsicum esculentum possesses lipophilic qualities that contrast with the hydrophilic property of Ayrampo. However, this property does not prevent it from being used in cosmetics as a pigment. However, there are differences in color, pH, and stability, as some extractions are performed with alcohol or alkaline treatments, which adds to the treatment for dye stability [6], [21].

E. Comparison between organic and synthetic lipsticks

The cosmetics industry is facing a growing demand for novel and natural products that contain the properties offered by a synthetic one, but reflected in one of natural origin, which use ingredients such as vegetable waxes, essential oils, and natural pigments, whose effectiveness and acceptance are evaluated based on sensory analyses carried out by consumers [29], [30]. Although synthetic lipsticks have properties determined by chemical compounds such as heavy metals and petrochemical derivatives, their composition can generate, in the long term, problems in human health due to their accumulation [31]Therefore, Ayrampo can be used as a natural pigment that helps the industry achieve sustainability.

F. Ingredients and composition

The composition of organic lipsticks contains ingredients such as waxes, oils, butters, and pigments of natural origin, the latter, called betalain, for some fruits such as ayrampo, is extracted from plants or fruits. This composition makes it a renewable source of products, as well as an ecological and natural option, in contrast to the composition of a chemical-based lipstick. While it is true that most of them do not exceed the permitted levels of metalloids, in the long run, they can cause serious health problems [5]

G. Performance and stability

Performance and stability depend on the composition of lipstick, which is also a factor sought by the public. These parameters are susceptible to change due to other external factors such as temperature and humidity. Therefore, it is crucial to determine the conditions for adequate storage. In this sense, some studies carry out stability tests based on changes in shape, color, and smell, varying the temperature at which storage is conditioned [32], [33]. Therefore, some research improves the extraction and composition of some natural lipsticks by adding natural waxes and carnauba to enhance the thermal capacity of the lipstick [34].

H. Safety and toxicity

Lipstick, as a personal care product, generates concern about possible negative consequences for health due to the increase in its demand, especially in children and older adults, who may be more sensitive to these compounds. Although there is evidence to prove the presence of harmful chemicals, these are below the established limits [35]. For this reason, organic lipsticks, thanks to their natural composition, are safe and non-toxic for the population that uses them and help preserve the environment.

I. Color preference and adhesion

The existing diversity in the lips, face shapes, and skin color means creating new shades to complement the existing demand [17]Therefore, color is a determining factor for the attractiveness of the face. Another complementary factor is lighting, which brings out the color and consumers' perception. Among the preferred shades, red stands out based on the consumer's sensory analysis [15] .

Lip health is a determining factor in evaluating the properties a cosmetic product should supply to the lips. According to surveys carried out by dermatologists and other related professionals, the characteristics and associated factors are dryness, softness, uniform tones, and lack of pigmentation in the lips [36].

J. Environmental impact

While it is true that consumers are the ones who must act in defining which products they should consume, awareness must also be raised about the processes to reach the final product [37]. Therefore, the new perspectives seek to mitigate the harmful environmental impact of extraction methods based on chemical compounds and synthetic dyes. This marks the search for new renovation strategies for use in industry, highlighting the extraction of new pigments, using plants [38] and fruits as research sources to develop environmentally friendly techniques, helping peasant communities and giving a particular sense to natural resources.

K. Sustainability in cosmetics

The ingredients in a lipstick are essential to determine the quality and sustainability of the product for consumers. In turn, the information on the packaging must be clear to achieve this purpose, as it has a positive impact on the perception of purchase [39]. Therefore, the use of advertising as a tool to inform and learn about ingredients gives a perspective to support consumer choice and long-term sustainability goals [40].

III. METHODOLOGY

A. Methodology

This research study is descriptive and cross-sectional since it focuses on the collection of data over a period of time to analyze it statistically to identify trends, relationships, and patterns among the variables examined [41]. The aim is to analyze the level of user acceptance of Ayrampo lipsticks. The

data collection was carried out from the second week of December 2024 to the first week of January 2025, which allowed us to identify the users' perceptions during that time interval.

B. Data collection

Data collection was carried out between December 2024 and January 2025 at the headquarters of the Universidad Nacional Mayor de San Marcos. Simple random sampling was used to select participants, ensuring that the selection of participants was equitable for all individuals [42]. This was done due to the limitations of collecting information, the main obstacle being the unwillingness of some people to participate. To calculate the sample size, the following variables were considered: probabilities of p and q = 0.5, with a confidence level of 90% (α=0.1) and maximum permissible error of 7.3%. With these parameters, a sample size of 127 was obtained, although data were finally collected from 130 people.

In addition, before applying the questionnaire, the necessary samples of the different lipstick formulations to be analyzed were prepared. Likewise, the users were informed of the objective of the research, having their consent for its development, and each one was given a sample of lipstick with the indicated formulation so that after using it for 1 week, they could complete the questionnaire.

The instrument used was the Random Forest model, which is composed of a powerful set of decision trees, in which each tree is built on a subset of the data series and a random subset of the characteristics, so that this variety of random trees increases its effectiveness in comparison with traditional decision trees [43], [44].

The questionnaire has three parts: in the first part, general information about the user, such as name, age, and gender, is collected; in the second part, the user is asked about their personal experience and preferences in using lipsticks; and finally, in the third part, information is collected about the user's perception of the lipstick sample delivered. The questionnaire is designed on an original Likert-type scale (1 to 5) for perspectives and binary questions for recommendations of the lipstick used.

C. Statistical analysis

The questionnaire was carried out using Google Forms based on information from Chemical Engineering specialists. Python with the mathplotlib and seaborn libraries was used as an information procedure for developing bar and stacked bar graphs for logistic regression, analyzing the standardized coefficients, and verifying the weight of the ayrampo in the acceptance of the lipstick using sklearn.linear_model and random forest to define the priorities of the ingredients with the library sklearn ensemble.

IV. Results

The figure shows the gender proportion of study participants, with the majority being women who agreed to participate.

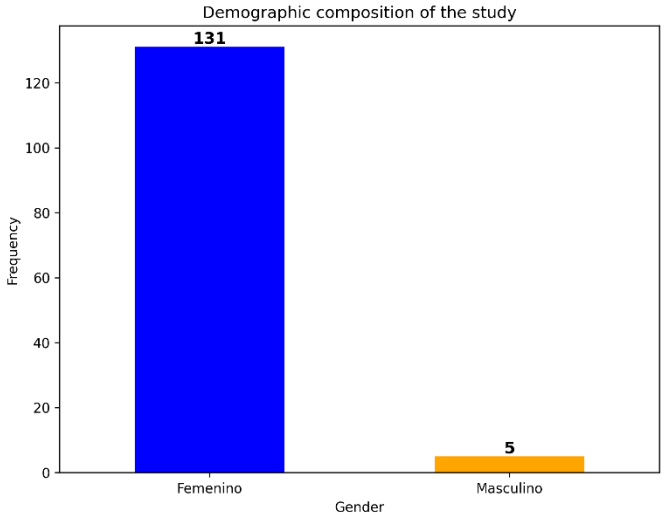

Fig. 1 Demographic composition of the study

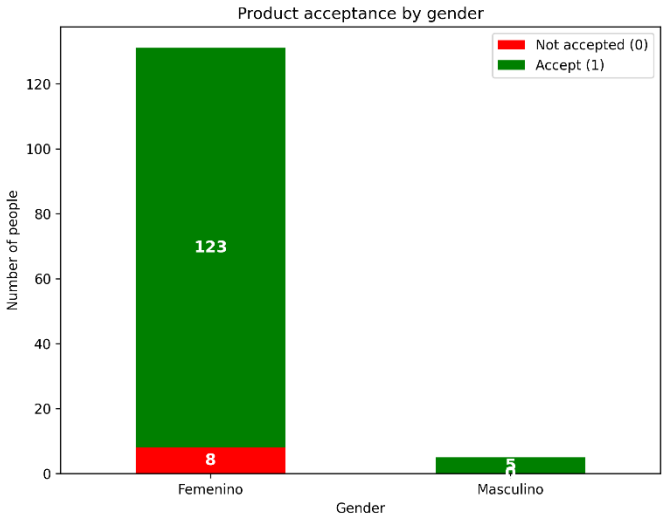

Fig. 2 Acceptance of Ayrampo-based labial

The production of the ayrampo-based lipstick samples was carried out using formulations with different ingredient compositions, which were used to obtain a formulation that was accepted by the customers. Table 1 shows a cross-table measuring the acceptance of each formulation.

TABLE 1
NUMBER OF FORMULATIONS AND RESULTS

Formulation	Recommends (1)	No Recommend (0)	Total
34	6	0	6
35	7	0	7
36	10	0	10
37	3	1	4
38	12	0	12
39	9	4	13
40	5	1	6

41	10	1	11
42	6	0	6
43	7	0	7
44	5	0	5
45	7	0	7
46	9	1	10
47	5	0	5
48	11	0	11
49	2	0	2
50	4	0	4
51	4	0	4
All	122	8	130

Own elaboration

For a clearer visualization of the acceptance of the formulation, a nested bar chart is presented.

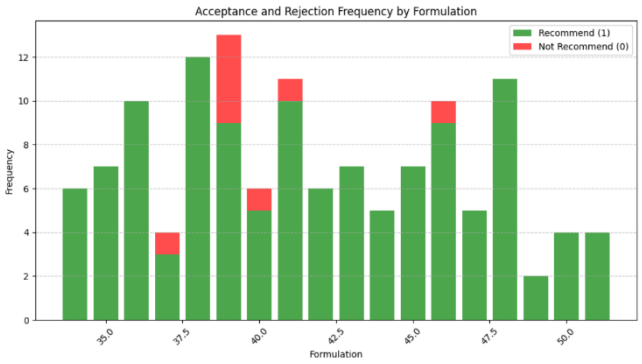

Fig. 3 Nested bars formulation and acceptance

With categorical and binary data as dependent variables (1/0) where 1 is the acceptance, and 0 is the non-acceptance. As independent variables, the different components of the lipstick for each formulation, table No. 2 presents the results of the logistic regression and its significance. A model accuracy of 92.85% was obtained for the calculation, and the formulation coefficients have the following results.

TABLE 2

Material	Coefficient
red lipstick pigment 600	0,59
orange fragrance	0,50
Vitamin E	0,45
Candy Sweet Fragrance	0,30
red lipstick pigment 400	0,30
Strawberry Essence	0,25
hibiscus	0,24
Ayrampo	0,18
Love Fragrance	0,10
Soy Lecithin	0,10
Preservative	0,07
Shea Butter	0,04
Jojoba Oil	0,04
Carnauba Wax	0,02
Rice silk	0,01
Magnesium stearate	0,01
Cocoa Butter	0,01
Argan Oil	0,00
Coconut Oil	0,00
Beeswax	0,00
Orange fragrance (nua)	-0,42
red lipstick pigment 700	-0,49
Coconut fragrance	-0,57
pearl red pigment	-0,57

Own elaboration

The components with the most significant impact on acceptance, i.e., the probability of the event, are red lipstick pigment 600, orange fragrance, vitamin E, candy sweet fragrance, and so on, with Ayrampo at number 8 in terms of impact on lipstick acceptance.

To review the impact of Ayrampo and how it relates to the other components of the formula. It is shown in table No. 3

TABLA 3
CORRELATION WITH AYRAMPO

Component	Correlation
Beeswax	0,881
Coconut Oil	0,881
Argan Oil	0,881

Cocoa Butter	0,881
Preservative	0,880
Magnesium stearate	0,879
Rice silk	0,879
Carnauba Wax	0,879
Soy Lecithin	0,877
Jojoba Oil	0,874
Shea Butter	0,873
pearlized red pigment	0,482
red lipstick pigment 600	0,419
red lipstick pigment 700	0,409
red lipstick pigment 400	0,346
Candy Sweet Fragrance	0,238
Vitamin E	0,231
orange fragrance	0,218
Orange fragrance (nua)	0,202
hibiscus	0,202
Coconut fragrance	0,119
Strawberry Essence	0,016
Love Fragrance	0,015

The objective of the correlations is to understand which component was also increasing in the formulation with an increase in ayrampo, having more impact with the components beeswax, coconut oil, and argan oil.

To know the impact without assuming that they are linear models, as in the case of linear regression, a random forest was carried out using a combination of the other ingredients. Figure No. 4 shows the results of the random forest.

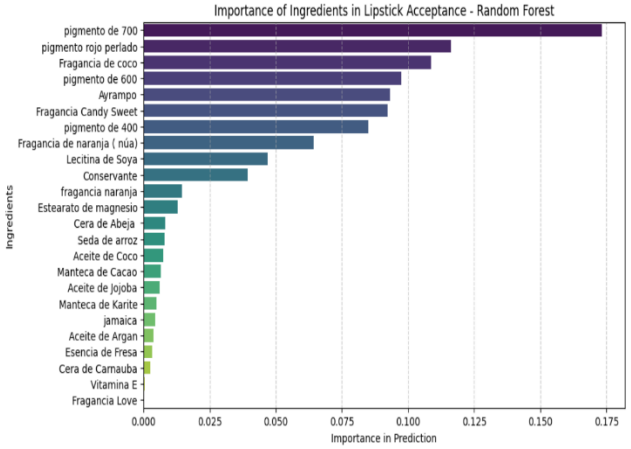

Figure 4. Random Forest Results

The results presented by Random Forest show that Ayrampo is sixth in importance, which means that it has an intermediate influence on the product's acceptance. It is displaced in importance by magnesium stearate and coconut oil.

IV. Discussion

Evidence shows that Ayrampo is a component with lower toxicity than synthetic ones. It is a source of betalains.

The study and the formulations evidenced an intermediate impact, with the highest impact being red lipstick pigment 600, orange fragrance, and vitamin E, and the lowest impact being red lipstick pigment 700, coconut fragrance, and red pearl pigment.

The correlations show a strong relationship with coconut wax, coconut oil, and argan oil, which suggests that the importance of ayrampo may not necessarily be due to the component but also to the other ingredients.

In the random forest procedure, the average importance of Ayrampo was evidenced, with the most significant impact being on red lipstick pigment 700, pearl red pigment, and coconut fragrance.

V. Conclusion

Ayrampo is a viable natural pigment alternative. However, its impact is intermediate; it is not an influential ingredient in consumer acceptance. The results show an intermediate importance.

The results of the factors obtained show that pigments and fragrances are essential for consumers' decisions. Formulations could continue to improve the acceptance of Ayrampo due to its properties that mitigate the toxicity of synthetic components.

Related machine learning models, such as Random Forest, confirm the intermediate importance of the Ayrampo component.

To avoid health damage due to the use of lipsticks with synthetic chemical components and the environmental impacts generated in their production process, it is necessary to switch to natural products, as Ayrampo becomes one of the essential components to achieving the beauty parameters women require.

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