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FOOD ENGINEERING

Uses, nutritional properties and sensory evaluation for amaranth, quinoa and grape and coffee by-products

INGENIERÍA DE ALIMENTOS

Usos, propiedades nutricionales y evaluación sensorial del amaranto, quinua y subproductos de uva y café

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Abstract

In a knowledgeable and demanding consumer environment, a tool such as sensory analysis, used to evaluate food products before they reach the market, plays a fundamental role in obtaining approval from the targeted audience and standardizing routes at the business level. Within the food and beverage sector, functional proposals and their derivatives are of great interest in the gastronomic context. Through this review, we aim to analyze sensory evaluation strategies, appropriate for four alternative raw materials: quinoa, amaranth, and by-products from grapes and coffee. In this study, the following are considered: type of test, type of judge and evaluation scale. On the other hand, the main nutritional properties and uses of targeted inputs are highlighted, including two agro-industrial residues. The use of these foods provides multiple benefits for humans, due to its high content of essential amino acids, fiber and antioxidants. These properties are based on the elaboration and consumption of derived products, with partial or total substitutions of matrices. The results of new developments are generally validated through the implementation of affective and preference tests, using semi-trained panelists and potential consumers.

Keywords: *by-products, food composition, nutrition, organoleptic analysis.*

Resumen

En un entorno de consumidores conocedores y exigentes, una herramienta como el análisis sensorial, utilizada para evaluar productos alimenticios antes de su llegada al mercado, juega un papel fundamental para conseguir la aprobación del público objetivo y estandarizar rutas a nivel empresarial. Dentro del rubro de alimentos y bebidas, las propuestas funcionales y sus derivados tienen gran interés en el contexto gastronómico. Por medio de esta revisión se pretende analizar estrategias de evaluación sensorial apropiadas para cuatro materias primas alternativas: quinua, amaranto y subproductos provenientes de uva y café. En este estudio se tienen en cuenta: tipo de prueba, tipo de juez

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y escala de evaluación. Por otra parte, se destacan las principales propiedades nutricionales y usos de los insumos focalizados, incluyendo dos residuos agroindustriales. La utilización de estos alimentos consigue aportar múltiples beneficios al ser humano, por su alto contenido de aminoácidos esenciales, fibra y antioxidantes. Estas propiedades se obtienen de la elaboración y el consumo de productos derivados, con sustituciones parciales o totales de dichas matrices. Los resultados de los nuevos desarrollos se validan, generalmente, por medio de la implementación de pruebas afectivas y de preferencia, utilizando panelistas semientrenados y consumidores potenciales.

Palabras clave: *análisis organoléptico, composición de alimentos, nutrición, subproductos.*

1. Introduction

In a society where it is essential to take care of health and to choose a healthy lifestyle, it is important to select foods that are functional. In its definition, this term refers to "any modified food or food ingredient that can provide a health benefit, more than is normally provided by the nutrients it contains in their natural form" [(1)]. Quinoa, for example, contains an ideal balance of all essential amino acids and a high percentage of high-quality protein [(2)]. Its average production for 2015, according to Jager [(3)], was around 3,000 kg in the Cauca department. On the other hand, amaranth, another andean pseudocereal, is considered rich in fiber and starches [(4)]. Its main producer is Mexico, with 51% of the supply worldwide [(5)]. Coffee is a product of high consumption in the world, with Colombia being the third global producer, with 9.4% of the world value. However, many by-products are associated with the grain, which are generally discarded despite their high value and biological potential [(6)].

According to the Agronegocios portal, in the latest data from the Asociación Hortifrutícola de Colombia (Asohofrucol), the largest grape production in Colombia is centered in Valle del Cauca, with some 19,513 tons in 2019 [(7)]. However, this raw material, used mainly by the wine industry, exhibits a production in the country around 24,000 t / year. In said tasks, a large amount of waste is produced, of which a small proportion is used as a by-product for the cosmetic industry. The remaining value is disposed of in the environment as waste [(8)]. The global waste of raw materials is a worrying factor, as one third of the food produced in the world is thrown away [(9)]. This problem can be mitigated by standardizing food development and manufacturing processes that use by-products from different chains in the generation of new, higher-value alternatives. For this, it is suggested to use evaluation and control tools through sensory analysis, which allow satisfying and maintaining the attributes of food. These strategies refer to the evaluation of organoleptic parameters by human panelists, thus being able to measure these characteristics and quantify the degree of acceptance of a product [(10)]. Sensory analysis is a process that humans carry out from their early years, through interaction with food. This evaluation method is variable according to the attribute to be studied; it is also defined according to the type of judge, the test applied and the scale on which it is measured. In addition, it is affected by multiple factors, such as the disposition of the jury, their environment, health status, among others [(11)].

There are three large groups, which classify the sensory analysis tests: the affective ones, which analyze the level of liking or disliking a food [(12)]; the discriminative ones, which compare and contrast two or more samples with each other [(13)]; the descriptive ones, whose purpose is to evaluate, categorize, measure and detail the attributes of the product [(14)]. Sensory studies allow feedback on transformation processes, giving place to the adjustment of manufacturing parameters, thus contributing to the final objective of standardization; in addition, research and development centers and departments are used to

study a perspective of how a certain food product will be received in the market [14].

The aim of this review was to analyze four alternative raw materials, with great use potential in the food industry: amaranth, quinoa, and grape and coffee by-products. A special emphasis was placed on the nutritional benefits of these inputs, considering the current needs in health and in the social development of human beings. In addition, some sensory evaluations implemented in the focused raw materials were reviewed, with a view to favoring, in the future, the manufacture and standardization of new products that incorporate these matrices of plant origin, either synergistically or independently.

2. Pseudocereals and by-products

2.1 Quinoa (*Chenopodium quinoa*)

Quinoa in Colombia is produced mainly in the department of Nariño; additionally, it is found in countries such as Ecuador, Peru, Bolivia, Chile and Argentina [15]. According to Romo et al. [16], this matrix has a high content of starch, iron (Fe) and vitamins B2, E and A; in addition, it contains 16 of the 24 essential amino acids. For Villacrés et al. [17] quinoa, called by the indigenous people "mother grain", can be compared to breast milk due to its nutritional properties. Table 1 shows the nutritional composition of the quinoa grain, according to different authors.

Moraes et al. [2], reported that quinoa is used in the diet, balancing it with other grains, for the preparation of soups, stews, chichas, sweets, breads, cookies, tortillas and desserts. According to Rojas et al. [15], to produce quinoa flour, it can be started from the raw or roasted matrix to achieve variations in its texture and flavor. As for its contributions to the area of medicine, this pseudocereal has anti-inflammatory, healing, analgesic and disinfectant properties. Quinoa is a rich source of low glycemic carbohydrates, which makes it beneficial for people with celiac disease or diabetes; in addition, it does not contain gluten [19, 20].

2.2 Amaranth (*Amaranthus* sp.)

Amaranth, like quinoa, is a pseudocereal; it is cultivated from Colombia to the north of Argentina, meaning, throughout the Andean zone [15].

According to Castel [21], this raw material has a considerable amount of iron (Fe), calcium (Ca), phosphorus (P), potassium (K), magnesium (Mg), zinc (Zn), copper (Cu), sodium (Na) and riboflavin; it has a higher protein content than wheat. Its ratio of essential amino acids is significantly better than most plant proteins, as it contains a good concentration of lysine, valine, methionine, phenylalanine, and threonine [21]. The high protein content of this matrix (Table 2) is comparable to that of casein in milk [15].

Amaranth is recognized by the National Aeronautics and Space Administration (NASA) as one of the best foods of plant origin for astronauts [15]; it is also considered by the Academy of Sciences of the United States of North America (NAS) and the Food and Agriculture Organization of the United Nations (FAO), as one of the crops worldwide, with high potential for economic and nutritional exploitation [23].

According to Bressani [24], the most common way of processing amaranth is by expansion, exposing it to high temperatures for short periods of time. However, this matrix is also used in the form of flour; it is recommended to roast the grain, to grind it more easily. Amaranth flour is popular for making drinks, chicha and breakfast cereals, as well as bakery and pastry products. It is usually used in some fortified foods and in milk substitutes [15]. From the health perspective, Suárez et al. [25] reported the main therapeutic effects attributed to the consumption of amaranth: decrease in plasma cholesterol, protection against oxidative stress and inflammation, retardation of tumor growth, and decrease in mean arterial pressure.

Table 1. *Nutritional composition of Junín white quinoa (Chenopodium quinoa Wild) (g/100g).*

Nutrient	Concentration (%)	Reference
Moisture	11.2	Fries and Tapia [18]
Proteins	14 – 18	Romo et al. [16]
	11.8	Fries and Tapia [18]
Carbohydrates	50 – 60	Romo et al. [16]
	68.0	Fries and Tapia [18]
Fiber	5.2	
Soluble Fiber	5.31	
Insoluble Fiber	2.49	Romo et al. [16]
Dietary Fiber	7.80	
Fat	6.3	Fries and Tapia [18]
Ashes	2.8	

Source: own elaboration

Table 2. *Nutritional composition of Amaranth (Amaranthus sp.) (g/100g).*

Nutrient	Concentration (%)	Nutrient	Concentration (%)
Moisture	11.4	Magnesium	0.24
Protein	18.7	Potassium	0.60
Raw Fiber	9.8	Calcium	0.16
Fat	4.6	Phosphorous	0.61
Ashes	4.6	Manganese (ppm)	24.0
Iron (ppm)	90.0	Zinc (ppm)	42.0
Copper (ppm)	9.0	Energy (cal)	366 - 459

Source: Adapted from Díaz [22].

2.3 Grape by-products (*Vitis vinifera*)

Grape contains 80% water and 18% sugars; it is an excellent power source for athletes and children. This matrix contains other antioxidant substances, such as resveratrol (present in all the components of the fruit), which is effective in preventing aging, Alzheimer's, cancer and cardiovascular diseases [26]. It is a food rich in antioxidant compounds, such as polyphenols, highlighting some groups of flavonols, phenolic acids and antianidins [27].

Each year, the global wine industry produces around seven million tons of grape by-products; part of these elements are used in the manufacture of distilled alcoholic beverages. However, more than 60% of the seeds, husks and stems are still discarded. The uses that can be given to these residues in other fields are different: the shells are used in the production of concentrates for animals, thanks to their high protein content; while the seeds are reprocessed for the extraction of oils [28].

Grape by-products are rich in antioxidant compounds: phenolic acids, quercetins, flavonoids, phytoalexins, stilbenes, and resveratrol, which are capable of counteracting the effects of saturated fats, reducing the risk of cardiovascular disease [29]. The antioxidant content stimulates the production of collagen and elastin [30].

Grape seeds are mainly composed of ashes and protein, as shown in Table 3. On the other hand, they have a high fiber content, as can be seen in Table 4. According to Hidalgo et al. [26], the

medicinal properties of grape seeds include: protective effect against deterioration caused by tobacco smoke; reinforcement of the walls of blood vessels; prevention of heart problems, various types of cancer and lung diseases; increased defenses and improvement of the immune system. In addition, they have a good amount of unsaturated oils (omega 3 and 6), a low amount of linolenic acid and a concentration of antioxidants higher than that of wine; they also contain vitamin C, E and beta-carotene.

Table 3. *Nutritional composition of grape seeds (Vitis vinifera).*

Nutrient	Concentration (%)
Moisture	17
Proteins	8
Oligosaccharides	8
Fiber	52
Fat	10
Omega 3	16 - 22 (lipid content)
Omega 6	63 - 71 (lipid content)
Ashes	3

Source: Hidalgo et al. [26].

Table 4. *Fiber profile of grape seeds (Vitis vinifera).*

	Nutrient	Concentration (%)
Fiber	Pectins	0.25
	Hemicellulose	18
	Cellulose	37
	Lignin	64

Source: Hidalgo et al. [26].

Salinas [31] experimented with the frozen grape bagasse to make a functional flour. It was found that the best drying option for the bagasse was the operation at 60 ° C, for a time of 9 h, until achieving a moisture lower than 8%. The optimization of the antioxidant capacity of the matrix and the profitability of the process according to time were taken into account. Wong and Mey [32] did tests with powdered grape peel, to make partial substitutions of preparations containing wheat flour. The authors proposed, as the best treatment, to dry the pomace at 60 ° C for 24 h, to subsequently achieve a milling of 150 µm.

2.4 Coffee by-products (*Coffea arabica*)

Ocampo López and Álvarez Herrera [6], state that around 600,000 million cups of coffee are produced in the world per year and that this activity represents one of the pillars of the Colombian economy. According to data from the National Federation of Coffee Growers of Colombia [33], the production for 2019 closed with 14.8 million bags (60 kg each), showing an increase of 9% compared to the previous year.

According to Bonilla [34], coffee beans contain more than 2,000 different substances, among which are: 1.2% caffeine, 4.2% minerals, 16% lipids, 1.0% trigonellines, 11.5% amino acids and proteins, 1.4% aliphatic acids, 0.2 % glycosides and 58% carbohydrates.

The pulp is the main by-product of coffee, representing around 29% of the weight of the fruit; when it is dehydrated, it contains 10% crude protein, 21% fiber, 8% ash and 4% nitrogen-free extract [35]. There are also biocomponents, such as polyphenols, alkaloids, phenolic and caffeic acids, which are variable according to the species and the place of cultivation [36].

Another by-product of coffee is mucilage: this hydrogel, adhered to the husk of the grain, contains 84.2% water, 8.9% protein, 0.91% peptic acid, 4.1% sugars and 0.7% ash [35]. It can be used as animal feed, to make coffee honey or in body care products [37]. On the other hand, the husk serves as animal feed, as fuel in the fruit drying process [35], as a source of energy biomass [38] and as a substitute for fats, in bakery and pastry preparations [39].

From the solid waste of coffee, it is possible to produce some edible and medicinal mushrooms: *Pleurotus ostreatus*, *Pleurotus pulmonarius*, *Pleurotus sajorcaju*, *Lentinula edodes* and *Ganoderma* [37].

Table 5. *Quality control in focused raw materials, through sensory analysis: systematization of cases*

Raw material	Description and details of the study	Reference
Quinoa	For a beer made with quinoa, acceptance tests were applied with a panel of 24 users, 10 trained and 14 untrained. It was concluded that the replacement of 1% of the formulation by quinoa flour presented better acceptance, in addition to a good degree of foam stability.	Martínez and Tuano [42]
	In an effective sensory analysis of a Haden mango jam with quinoa to evaluate the level of consumer acceptance, taking into account: flavor, color and consistency. It was found that the inclusion of quinoa in the preparation changed the product in color, viscosity, pH and protein concentration. In addition, the costs of the product increased and the caloric content decreased, having a great acceptance for this food.	Iza and Elva [43]
	Acceptance tests were carried out to measure the acceptance or not of a healthy snack made with quinoa and corn, in one (70% and 30%, respectively). A 9-point hedonic scale was used, where color, smell, taste and general taste were taken into account. The test was carried out in duplicate, differentiating between the same snack with a sweet coating and with an icing sugar coating. The color of the sample without the cover was found to be more attractive to potential consumers; in turn, the analysis for the taste between the two did not vary significantly.	Repo-Carrasco, Pilco and Encina-Zelada [44]
	For a fermented milk formulated with quinoa, it was established that the best percentage of flour addition of the pseudocereal was 3%. The instrument used was an acceptance test, evaluated with a 9-point hedonic scale, where the level of satisfaction was rated for color, taste, smell and general appearance.	Mera et al. [45]
	Using quinoa as a meat extender for sausages, the product was sensorily analyzed by a group of 100 people, satisfaction and preference tests were applied, rated by a 7-point hedonic scale. The diners evaluated flavor, color, smell and texture. It was determined that the most accepted treatment corresponded to a 100% replacement of the synthetic extender (additive) by quinoa flour.	Zapata et al. [46]
Amaranth	Corn tortillas were made with a partial replacement of corn flour with amaranth flour and other matrices. The product was sensorily analyzed by a panel of 32 judges, evaluating its characteristics using a hedonic scale. Subsequently, a group of 18 semi-trained panelists rated the tortillas with a multiple comparison test. It was concluded that amaranth, bean and cactus flour have more acceptance for this particular food.	Vázquez [47]
	In noodles, the partial substitution of wheat semolina for amaranth flour was evaluated. Affective acceptance tests were made, with a 9-point hedonic scale. In this process, there was a panel of 25 untrained judges for 3 repetitions, where smell, color, flavor, texture and general level of liking were taken into account.	Vedia et al. [48]
	Sensory attributes of a drink, made with amaranth and muicle, were evaluated. For this, a panel of 50 untrained volunteer judges were counted on to rate taste, smell and texture, in an acceptance test with a 5-point hedonic scale.	Hernández et al. [49]

	A beer made with amaranth, blonde ale type, was evaluated by comparing it with another one of the same type, made without the pseudocereal. The test consisted of a discriminative test between the two beers. The panel of judges used was made up of 16 people (between men and women), habitual beer consumers. The attributes of the product evaluated were color, foam, aroma and flavor; these were rated according to a 5-point hedonic scale.	Ramírez et al. (50)
	For cereal snacks, made with amaranth, a "difference test with a control" was performed. The sensory panel was made up of 38 untrained judges, in order to identify the temperature and the most suitable drying time for the products.	Batlle et al. (51)
Grape by-products	Different tests were made, replacing 8%, 10%, 12%, 15%, 20%, 22%, and 25% of wheat flour for the preparation of bread, by grape bagasse flour. First, a profile test was applied to 12 trained judges. Then, with a panel made up of 50 regular consumers, the product was evaluated on a 7-point hedonic scale. Greater approval of bread was obtained with the replacement of 12% and 20% of wheat flour with grape bagasse flour.	Ehrenfeld (52)
	The characteristics of a functional paste were studied, with the addition of grape bagasse flour. For this, a panel of 41 people between 18 and 65 years old was used, who were given a survey with a 7-point hedonic scale. The level of general liking for the product was measured by an acceptance test.	Navarrete (53)
	For this study, cookie type cookies were made, replacing 35% and 40% of the wheat flour in the formulation with grape pomace flour. Affective tests were applied to the product, measured by a hedonic scale. Semi-trained judges were used, who established that the best result was given with the partial replacement of 40% of wheat flour with grape pomace flour.	Sainz et al. (54)
	To evaluate the characteristics of a cheese enriched with grape skin powder, a group of 13 men and 8 women, aged between 24 and 70 years, chosen from among the tasters of the Italian National Association of Cheese Tasters (ONAF) was used. To evaluate the product, a free profile test was performed. This was done in 2 parts: the first consisted of developing a vocabulary of sensory characteristics of the prototypes, asking the judges to rate the product using their own list of terms. They took into account appearance, smell, taste and texture. The second stage consisted of delivering numbered samples back to the panel and in a different order. Subsequently, the tasters were asked to rate them, on a scale of 1 to 9, the intensity of attributes defined in consensus.	Torri et al. (55)
	A petitsuisse cheese, made with organic Bordeaux grape juice, skin and seed extract, was evaluated to make it rich in phenolic compounds. A sample with lyophilized grape seed extract and another without said extract were analyzed by means of an acceptance test for sensory attributes: degree of taste, odor, flavor, consistency, appearance and global acceptance. The rating was made using a 9-point hedonic scale.	Deolindo et al. (56)
Coffee by-products	A coffee oil was made from by-products of the grain. The product was tasted by expert tasters from Cenicafé, Colombia. The aroma of the oil incorporated in a beverage was analyzed, using a scale from 1 to 9, according to the rejection or excellence of the odoriferous qualities of the product.	López-Fontal and Castaño-Castrillón (57)

A drink was made from coffee husks. 30 semi-trained university students, who had taken the "illycoffe" course, were used. The test was affective, of acceptance, to measure the level of liking the product, on a hedonic scale of 9 points.	Umanzor [58]
In this study, attributes of beers made with coffee of the robusta variety were evaluated, using roasted beans by the microwave method. 8 judges were selected, among students and laboratory personnel. They were then trained to recognize individual flavor and aroma determinants, according to ISO 5496: 1992. Finally, the flavor intensities in the coffee were evaluated by means of a descriptive test (profile), with a scale of 1 to 10.	Nebesny and Budryn [59]
A hedonic sensory analysis and a descriptive one was implemented, with a total of 10 judges, for instant and fresh coffee. In addition, a group of expert panelists was used to prepare a list of the vocabulary related to coffee, to make a profile of free choice. The tasters were asked to rate the intensity on a linear scale from 0 to 10, evaluating a total of 13 samples.	Stokes et al. [60]

Source: own elaboration

3. Sensory studies, for evaluation of the materials of interest

Sensory quality refers to the preservation of the physical characteristics of a food, which help its acceptance or rejection [40]. The fundamental role played by the senses and perception, together with the attributes of a product, determine factors of its demand, since it is directly related to preferences, complacency and the creation of emotional ties that generate the diner's experience [41].

Foods of plant origin cannot be oblivious to the organoleptic satisfaction demanded by the consumer. It is a diner who demands freshness, new aromas, striking colors and appearances, pleasant textures, as well as innovative preparations and uses. [40].

Table 5 presents different experiences that applied sensory analysis tools to evaluate the quality of plant products made from focused raw materials. In the selected studies, the following were analyzed: level of like or dislike, preference and acceptance by the consumer, description of organoleptic attributes in food, among others.

According to research, it can be noted that affective, preference and acceptance tests are the most common in the validation of new foods, made from targeted raw materials. They are followed, in order, by descriptive tests with an organoleptic profile, and discriminative tests; these are used specially to choose the proportions of ingredients and the ideal formulations of the products [50, 52, 60].

The most valued attributes, in the foods that used inputs of vegetable origin, were smell, color, texture and general appearance. This fact corresponds to that proposed by Cordero-Bueso [12].

The use of untrained judges or potential consumers requires a lower level of training; it allows knowing the perception of traditional, non-technical diners who make the decision to purchase a product, based on their own tastes, perceptions, and history [61]. It should be considered that this strategy entails lower costs in the research and development process implemented by companies [62]. Additionally, the implementation of sensory evaluations allows obtaining information on the quality of food or determines specific attributes that lead to it; some of these aspects to improve products cannot be identified by means of other techniques [63].

4. Conclusions

Quinoa is a pseudocereal with great attributes, which contribute to the objective of a balanced diet. It has a high content of protein of high biological value, essential amino acids, and fiber important for human nutrition. In addition, this raw material has multiple uses within the kitchen, which give rise to endless textures, flavors, and preparations.

Amaranth has a higher content of calcium, iron, and essential amino acids than most proteins of plant origin. This raw material is suitable for making multiple preparations, partially replacing the formulation of other flours from cereals such as wheat.

The grape by-products, as peel and seeds, supply an important amount of antioxidants, which offer a great number of benefits for the prevention and treatment of diseases. On the other hand, the pulp, mucilage, and coffee husk, have a natural energizing and antioxidant effect.

The use of quinoa, amaranth or by-products of grapes and coffee in the gastronomic sector, has the potential to generate products of great value, suitable for the feeding of children and adults. Its composition could be supplemented, to create a balanced and functional food.

According to various studies, the trend in the application of sensory evaluation methods for targeted raw materials is directly related to the development of novel and innovative products that create value and experiences for consumers. To evaluate the acceptance of products made from quinoa, amaranth, and grape and coffee by-products, the most used are affective tests, measured by means of hedonic scales.

From the gastronomic perspective, the relevance and opportunity of studies that delve into the organoleptic evaluation of pseudocereals and by-products is clear. In this framework, it is recommended to favor the application of sensory profiles or discriminative tests, since research is still focused on affective and preference tests.

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