Food Drying: Opportunities, Market Solutions, and Nutraceutical Properties of Chayote

Secado de Alimentos: Oportunidades, Soluciones de Mercado y Propiedades Nutracéuticas del Chayote

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ABSTRACT
Food drying is a practice that has brought several benefits to the food industry, facilitating transportation, increasing shelf life, and avoiding the need for special treatments or storage according to the product. Due to the benefits and great development in the field of drying in recent years, a review of the main drying techniques of *Sechium edule* (or chayote) has been developed. Bad practices, food waste, and poor nutrition are some of the problems that open up opportunities to work with the final producer to take advantage of food and extend its shelf life, especially foods with high humidity. In this sense, producing dehydrated products with high nutritional content is a feasible and necessary opportunity that would boost industries, promote better nutrition, and reduce waste. *S. edule* is an alternative with great growth opportunity due to its nutraceutical characteristics, with physiological benefits through seven of the nine essential amino acids. The latter include phenolic compounds that have shown diuretic, anti-inflammatory, and hypotensive effects, providing benefits to both the commercial sector and the producer by developing a product that facilitates consumption and production and takes advantage of the whole vegetable.
Keywords: Dehydration; Drying; Chayote; *Sechium Edule*; Nutrition.

RESUMEN
El secado de alimentos es una práctica que ha traído varios beneficios a la industria alimentaria, facilitando el transporte, aumentando la vida útil y evitando la necesidad de tratamientos especiales o almacenamiento según el producto. Debido a los beneficios y gran desarrollo en el campo del secado en los últimos años, se ha desarrollado una revisión de las principales técnicas de secado de S*echium edule* (o chayote). Los problemas de malas prácticas y desperdicio de alimentos, junto con la mala nutrición, abren oportunidades para trabajar con el producto final para aprovechar los alimentos y alargar su vida útil, especialmente alimentos con mucha humedad. En este sentido, producir productos deshidratados con alto contenido nutricional es una oportunidad factible y necesaria que dinamizaría las industrias, promovería una mejor nutrición y reduciría los desperdicios. *S. edule* es una alternativa con gran oportunidad de crecimiento por sus características nutracéuticas, con beneficios fisiológicos a través de siete de los nueve aminoácidos esenciales. Estos últimos incluyen compuestos fenólicos que han demostrado efectos diuréticos, antiinflamatorios e hipotensores, brindando beneficios tanto al sector comercial como al productor al desarrollar un producto que facilita el consumo, la producción y aprovecha la integridad de la hortaliza.

Palabras clave: Deshidratación; Secado; Chayote; *Sechium Edule*; Nutrición.

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1. INTRODUCTION

Drying has a long history in the food industry, which has brought benefits and opportunities in preservation, texturization, and transportation. Chayote (*Sechium edule*) has been widely accepted for consumption and recognized for its nutritional and biofunctional properties (Vieira et al., 2018). It is characterized as a tender, vine-like plant with a pale green to white, mild-flavoured, crunchy-textured vegetable with a single seed (Islam et al., 2018).

Chayote *(S. edule)* has been cultivated since pre-Columbian times in Mexico (Cadena-Iñiguez et al., 2007), offering multiple types of value, for example, in terms of the economy, culture, and health. *Edule* species play a key role in terms of cultural and social persistence in the areas where they are cultivated (Martínez-Bauer et al., 2021). According to Bermejo and León (1994) and Lim (2012), *S. edule* is popularly known as chayote (Mexico), christophene, mirliton vegetable pear, mirliton choko (Australia and New Zealand), starpreciantě, citrayota, citrayote (Ecuador and Colombia), chuchu (Brazil), machucha, caiota, pipinela (Portugal), chow chow (India), cho cho (Jamaica), Sayote (Philippines), güisquil (Guatemala, El Salvador), and calabaza pera or iskus (Nepal); where Mexico, Costa Rica, and Brazil stand out as the main producers.

Chayote has simple and conventional cooking methods as a boiled dish or used in stews and desserts (Saade, 1996), while the peel and leaves (residues) are usually little consumed but contain high diuretic or kidney stone dissolving properties (Loizzo et al., 2016). It is also known for its high fibre content and low lipid, protein, and calorie content, and for being a vital source of vitamins, minerals, and amino acids (Lira-Saade, 1996; Cadena-Iñiguez et al., 2006).

Chayote has a high moisture content, ranging from 87-95% on a wet basis, which can cause a high rate of loss after harvesting due to microbial and chemical deterioration. Due to the interest in its properties, drying is studied as a method of conservation and to improve its life in processes such as distribution and storage (Lira-Saade, 1996; Pérez-Francisco et al., 2008; Villers, 2018).

Within naturopathic folk medicine, it is recognized as a versatile vegetable and used as a functional ingredient; however, there is still a long road ahead to prove its nutritional, phytochemical, and pharmacological properties. The present review examines and describes current findings on the investigation, including nutritional contents, ranging from carbohydrates and proteins to phenolic compounds, which give important and interesting points for review in the possible applications for this vegetable. Chayote has become an interesting ingredient in food product development due to its high fibre content, low carbohydrates, and the properties found in its flour, which make the latter suitable for products such as pasta or bread. In addition, an analysis has also been done on the utility of chayote at the industrial level in the food sector as a functional ingredient in the food, cosmetic, and pharmaceutical industries, as well as in nanotechnology and biotechnological processes.

Thus, the objective of the present study is to introduce an in-depth review of the last 6 years of research on chayote and its drying processes to become familiar with the panorama in the food industry, along with this vegetable's differences, advantages, disadvantages, and other characteristics. The main research objective is to have an overview on the food trade in this field and to review the nutraceutical properties, as well as the whole spectrum of characteristics to promote solutions to the problems within manufacturing.

2. MATERIALS AND METHODS

The information contained in this review article was obtained from scientific journals, official reports, and books no more than 6 years old. The criteria for the selection of the studies used in this paper included the use of the electronic websites e-book, Science Direct, Springer, Wiley Online Library, Scopus, and journal databases provided by Universidad de las Americas Puebla. On these sites, the keywords dehydration, drying, chayote, *Sechium edule* and nutrition were used to obtain a first glimpse of the abstract, which were reviewed to verify if the benefits and/or dehydration processes of the chayote were mentioned. It is important to mention that other main words involved in the search for these studies also included nutraceutical properties, as well as nutritional properties and physicochemical characteristics, along with their applications. If the abstracts were in line with the criteria, the studies proceeded to be read and, if they were published in the years between 2016 and 2021, they would be used in this paper as references. If they were outside of the pre-selected range of years, but contained information that is no longer studied, they would also be included as references.

The selection of references considered important for the present study, even outside of the six-year period, have been included: (i) to demonstrate the starting point of the studies on the benefits of chayote; (ii) to obtain specific data on the growth and impact of this vegetable since 1999; (iii) to develop an extensive analysis of the properties and varieties of chayote; (iv) to research pharmacological effects; and (v) to obtain articles that contained additional necessary and detailed information for the research of this paper. The references outside of the range of six years, prior to 2021, are: Cadena-Iniguez 2005, 2006, 2007 and 2010; Dire – 2003; Hernandez 2011; Karla 2003; Lewicki 2005; Lim 2012; Ordonez 2006; SIAP 2015; Bancomext 1999 - the chayote market in Mexico;

Bermejo 1994 - names of chayote in different regions; Jensen 1986 – health benefits of chayote; Lira-Saade 1996 - minerals and amino acids in chayotes; Salama 1986 and 1987, and Wu 1998 – pharmacological effects of the chayote.

3. RESULTS AND DISCUSION

3.1. State of the art of drying systems: available technologies

This section includes a review and selection of different drying processes used on chayote from 2016 to now. The operation processes were examined to draw conclusions on the advantages, disadvantages, and benefits of a correct dehydration technique, and it was determined that the fundamental variable in the drying process is whether air is used, which has a direct influence in terms of cost, energy production, and availability.

Food drying has long been prevalent in the fruit and vegetable sector due to their high humidity content. This has led to the development of diverse drying methods, where each method has different advantages and disadvantages, which dictate their administration depending on the final use of the food. In general terms, dehydration adds time to the shelf life of foods and nutrient conservation, reduces weight and volume, and allows for simple handling without special storage. It also bears mentioning that the process causes an increase in sugars, physical and sensorial changes, and a lack of the sensation of hydration (Lira-Saade, 1996).

Drying or dehydrating food is a challenge in the industry, given that it can lead to important results for the user and seller when handled correctly, but the process must address several aspects to avoid losing nutrients or the sensorial experiences that can make products innutritious or even unpleasant for the consumer (Lewicki, 2005).

3.1.1. Types of drying

Table 1 describes several alternatives used to promote food drying processes. Vacuum, freezing, super evaporated vapor, air convection dehydration, refractive window, hot air and microwave, and fluidized bed drying are discussed below as alternatives that use these principles to promote food drying.

From Table 1, it can be seen that some drying techniques include:

1. Convective air drying: It must be mentioned that the convection drying process is not energetically efficient. Some examples of more efficient processes are (i) Vacuum drying, (ii) Freeze drying, and (iii) Fluid bed drying, while the hot pump and fluid bed drying processes use the same principle as convective air drying (Bourdoux et al., 2016).

2. Refractance window drying: This technique does not produce significant differences in the solubility from before and after the drying process and has major protein, water, oil, emulsifying activity index, emulsifying stability index, capacity, and foam stability resistance (Kumar et al., 2021).

3. Hot air and Microwave drying: This procedure retains the water, oil, and foam properties better than drying via hot air and microwave drying separately (Vargas et al., 2020).

4. Fluid bed drying: Most of the drying speed is given when the air velocity is sufficient to blow the grain in the recipient. The contact of the grains levitating in the middle increases the heat and mass transfer compared to conventional air drying (Bourdoux et al., 2016).

The four drying techniques mentioned above have several variables that must be considered. As this review considers chayote *(S. edule)*, we must analyse several factors, such as crop availability, carbohydrate, fat, and protein characteristics, and the variety, to correctly select the process that will best preserve the favourable characteristics of our product.

Table 1. Alternatives used to promote food drying: Drying by vacuum, Freezing, Super evaporated vapor and their drying techniques.

Drying process	Description	Temperature	Pressure	Reference
Vacuum drying	Used to dehydrate products that are sensitive to heat. Heat is controlled by conduction.	30°C	Changing pressure in intermittent in the drying chamber	Lewicki, 2005.
Freeze drying	Water is removed by sublimation. It is expensive, but the results are better than using atmospheric air.	Sublimation temperature	Changing pressure	Lewicki, 2005.
Super evaporated vapor drying	Water and heat are used in this process, where both are united in a cycle.	Evaporated temperature	Atmospheric pressure	Lewicki, 2005.

Convective air drying	A hot air flux passes over or through the material from which water is to be removed by vaporization, subsequently the saturation pressure of the material's vapor becomes lower than the pressure of the operation.	40°C to 80°C	Atmospheric pressure	Bourdoux et al., 2016.
Refractance window drying	Heat is transferred in three ways, using convection, radiation, and conduction.	70°C	Atmospheric pressure	Kumar et al., 2021.
Hot air and microwave drying	A microwave is adapted with air circulation, where drying occurs at temperatures of 40, 50, and 60 °C until a constant mass is obtained.	40°C	NA	Vargas et al., 2020.
Fluid bed drying	The procedure occurs with a gas flux that goes through a granular material bed.	60°C to 70°C	Changing pressure	Bourdoux et al., 2016.

3.1.2. Chayote (*S. edule*)

The present study considers chayote to be the best option for dehydration due to its nutritional benefits, as well as to take advantage of its production in Mexico. It is important to note that each food product behaves differently when dried, but nutrients such as carbohydrates, proteins, and lipids are preserved, continuing to provide energy and fibre (Quinceno et al., 2019).

Inspecting nutritious food that people consume has become a high priority, given that nowadays most edibles are fast food severely lacking in positive qualities. Vegetables or tubers can be used to conserve the requirements of a healthy diet, and the chayote is ideal to help fulfil this aspect. Figure 1 shows the percentage value of the carbohydrates in eleven raw vegetables and tubers comparable to chayote.

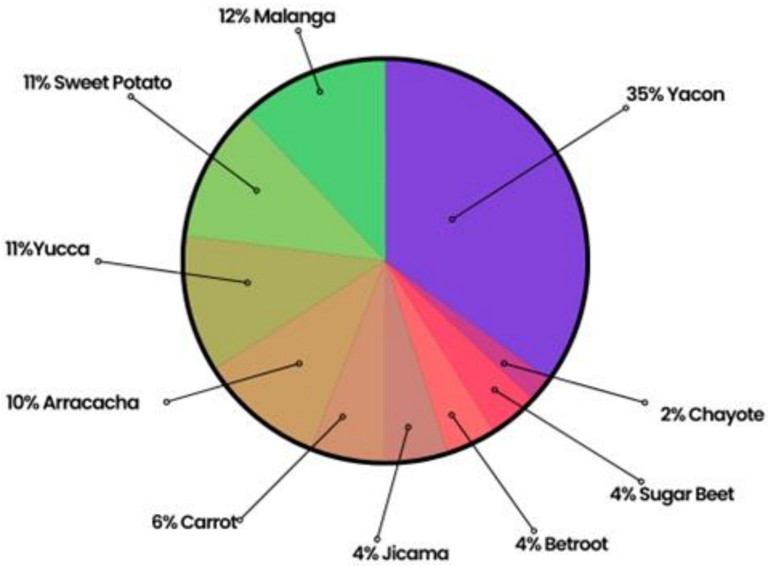

Figure. 1. Graphic of carbohydrates (divided by: carbohydrates, dietary fibre, and sugar) in selected raw vegetables and tubers.

3.1.2.1.The presence of chayote in Mexico and its relevance as a product

As mentioned above, chayote is a vegetable that has been produced and used in Mexico since pre-Columbian times and, since then, national production reached about 284,797 tons a year in 1999, generating around 46,802 jobs (Bancomext, 1999). Table 2 displays information on the chayote-producing states in Mexico.

Table 2. Chayote-producing states in Mexico. Taken from Cadena Iñiguez and Arévalo-Galarza, 2010.

Mexican States	Cultivated Area (ha)	Total Production (Ton)	Annual Jobs
Baja California	18	153	227
Chiapas	37	1739	466
Mexico State	69	2208	870
Guanajuato	37	-	466
Jalisco	847	27,527	10,676

Michoacán	112	180	1412
Nayarit	33	2970	416
San Luis Potosí	60	4020	756
Veracruz	2500	246,000	31,512
Total	**3713**	**284,797**	**46,802**

Mexico is the number one producer of chayote worldwide; however, Costa Rica is the first exporter of this vegetable. This has been attributed to limitations in national transportation capabilities regarding refrigeration and the variability of the characteristics of chayote (SIAP, 2015).

Chayote represents the fourth most important fruit and vegetable product imported from Mexico on the West Coast of the United States, estimated at an annual growth of 8%. The market for chayote is heterogeneous and has several attractive points, such as its high acquisitive power and competitiveness (Bancomext, 1999). The Asiatic and Hispanic populations have the highest interest towards this vegetable, with just the Latin market in the United States representing a purchasing power of 450 billion annual dollars, and the Latin food and beverages market representing about 4.3 billion dollars annually (Avendaño et al., 2010). Figure 2 shows some of the species of chayote grown in Mexico.

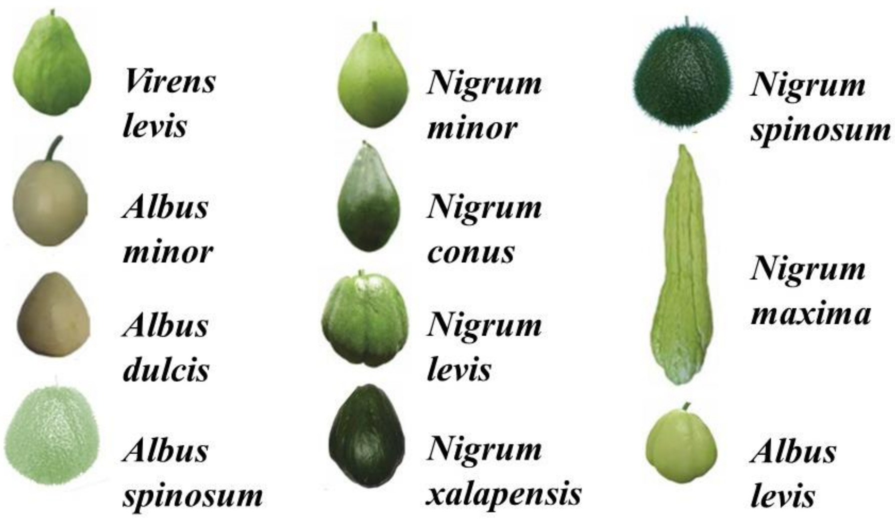

Figure 2. Varieties of chayote grown in Mexico.

Complementary to Figure 2 above, a compilation of a proximate analysis of fresh samples of chayote varieties was carried out on a wet basis. Table 3 assembles data such as Brix degrees, flavour, moisture percentages, ash, protein, crude fat, crude fibre, and carbohydrates.

Table 3 clearly shows that the composition of chayote ranges between 86-94% humidity, which occupies a large amount of volume. Therefore, dehydrating the chayote allows it to achieve low moisture percentages and acquire benefits with regards to long-term transport, storage, and conservation. Additionally, it is important to respect the composition of the nutraceutical properties of the chayote to obtain a greater nutritional benefit.

Table 3. Proximate analysis from fresh samples of chayote varieties (wet basis). Taken from Avendaño et al., 2010.

Characteristics	**Brix degrees (°Bx)**	**Flavour**	**Moisture [%][1]**	**Ash [%][1]**	**Protein [%][1]**	**Crude Fat [%][1]**	**Crude fibre [%][1]**	**Carbohydrate [%][1]**
Albus minor	7.66	Light Sweet	86.61	0.56	1.57	0.08	1.57	9.61
Albus dulcis	7.21	Medium Sweet	86.67	0.62	1.29	0.1	1.53	9.78
Albus levis	8.08	Light Sweet	94.2	0.42	0.68	0.04	0.85	3.74
Albus spinosum	-	-	90.65	0.52	1.04	0.07	1.23	6.48
Nigrum minor	-	Medium Sweet	88.14	0.49	1.46	0.09	1.28	8.53
Nigrum conus	7.2	Medium Sweet	91.51	0.39	1.21	0.08	0.89	5.89
Nigrum levis	5.47	Neutral	90.91	0.48	0.96	0.07	1.08	6.49

Nigrum xalapensis	4.93	-	94.76	0.38	0.8	0.03	0.61	3.43
Nigrum spinosum	6.43	Neutral/ Medium Sweet	87.75	0.5	1.2	0.08	1.96	8.49
Nigrum maxima	-	Neutral	93.51	0.44	0.74	0.04	0.83	4.43
Virens levis	5.14	Neutral	94	0.39	0.7	0.04	0.81	4.06

1 Data expressed in g of component by 100 g of sample (%).

3.2. Chemical composition of chayote and its nutraceutical properties

3.2.1. Chemical profile of chayote

Nutraceuticals are a portmanteau of nutrition and pharmaceutics, and include substances, foods, or the parts of them that provide medical or health benefits, including the prevention and treatment of diseases. In contrast to functional foods, nutraceutical compounds refer to specific substances in foods that achieve the above-mentioned objectives, such as antioxidants, peptides, carbohydrates, lipids, glucosinolates, and overall phenolic compounds. Bioactive compounds in foods are incredibly important in nutrition, as well as product development, and the research and development of foods and products containing these substances has been growing substantially (Kalra, 2003; Galanakis, 2017).

Phenolic compounds can be defined as natural bioactive compounds that present certain bioactivities such as antioxidant, antimicrobial, anti-inflammatory, and anti-proliferative, among others. Phenolic compounds are subject to bioavailability and efficient technologies for their extraction and refinement, as well as stability procedures, to take advantage of them fully. These compounds are being researched widely in technological and medicinal areas; their applications can provide new market opportunities, along with functionality for product development (Albuquerque et al., 2021; Cámara et al., 2020).

A database search was done to find an article about the nutraceutical compounds of *S. edule*, analysing its phenolic acid and flavonoid constituents. Given the recent research on this tuber, only one accessible article meeting the requirements was found. The process implemented to obtain the compounds in the paper was liquid chromatography coupled with the mass spectrometry (LCMS) method. The predominant results were vanillic acid with 4080.82 µg/g, protocatechuic acid with 1736.59 µg/g, and syringic acid with 1676.97 µg/g for the phenolic acids and catechin with 75.83 µg/g for the flavonoids (Jain et al., 2021). The profile of the chayote is presented as a basic means to recognize the potential for both the vegetable and its flour in the food industry. Recognizing the properties of the vegetable will impact the segment or niche market to be taken for product development; this, for example, is shown in the fact that the protein intake of this vegetable is low, but it stands out against other vegetables in other aspects, such as fibre content.

Table 4 shows an analysis of the composition (protein, carbohydrates, fibre, and fat) of several varieties of chayote, highlighting the diversity of states analysed.

Table 4. Proximal analysis from examples of chayote varieties.

Chayote Variety	Status	Composition					Reference
		Protein [%][1]	Carbohydrates [%][1]	Fibre [%][1]	Fat [%][1]	Ash [%][1]	
Albus minor	Raw	1.57	9.61	1.57	0.1	0.56	Avendaño et al., 2010.
	Flour	11.41	69.83	11.4	0.6	4.06	
Albus dulcis	Raw	1.29	9.78	1.53	0.1	0.62	
	Flour	9.47	71.44	11.2	0.7	4.53	
Albus levis	Raw	0.68	3.74	0.85	0	0.42	
	Flour	11.25	62.15	14.16	0.7	6.04	
Albus spinosum	Raw	1.04	6.48	1.23	0.1	0.52	
	Flour	10.76	67.41	12.85	0.7	5.42	
Nigrum minor	Raw	1.46	8.53	1.28	0.1	0.49	
	Flour	12.04	70.55	10.64	0.8	4.06	
Nigrum conus	Raw	1.21	5.89	0.89	0.1	0.39	
	Flour	14.11	67.77	10.29	0.9	4.6	
Nigrum levis	Raw	0.96	6.49	1.08	0.1	0.48	
	Flour	10.26	69.52	11.61	0.7	5.21	

Nigrum xalapensis	Raw	0.8	3.43	0.61	0	0.38	
	Flour	14.45	62.05	11.03	0.5	6.9	
Nigrum spinosum	Raw	1.2	8.49	1.96	0.1	0.5	
	Flour	9.56	67.32	15.58	0.7	3.98	
Nigrum maxima	Raw	0.74	4.43	0.83	0	0.44	
	Flour	11	65.98	12.42	0.7	6.55	
Virens levis	Raw	0.7	4.06	0.81	0	0.39	
	Flour	11.16	64.33	12.79	0.7	6.15	
Sechium edule buds	Raw Microwave Steamed	30.27	36.6	19.18	1.5	12.5	Chang et. al., 2021.
Sechium edule	Raw Pectin	3.61	-	-	-	3.19	Ke et. al., 2020.

1 In g of component by 100 g of sample.

Chayote consumption is recommended in low calorie diets because it has up to 10 times less fat compared to other raw vegetables and possesses a large amount of fibre, which reduces the risk of gastrointestinal disease, cancer, diabetes, obesity, and hypertension. This is also why chayote is highly recommended in hospital diets, in addition to the fact that chayote contains seven of the nine essential amino-acids (lysine, leucine, methionine, phenylalanine, valine, isoleucine, and histidine) (Pérez-Francisco et al., 2008). It is important to note that fibre has been proven to be unaffected by any kind of thermal or dehydration treatments.

Table 5 shows the benefits of the *S. edule* variety, which is the most produced variety in Mexico and a good starting point for the analysis of other types of chayotes.

Table 5. Pharmacological effects of the *S. edule* variety of chayote.

Type of extract	Effects	Reference
Methanolic extract	Anti-inflammatory cardiotonic	Salama et. al., 1986.
β-sitosterol-β-D- glucopyranoside stigmasterol-β-D- glucopyranoside	Anti-inflammatory agent	Salama et. al., 1987.
Protein "sechiumina" from aqueous seed extract	Ribosomal inactivation Chemotherapeutic agent	Wu et al., 1998.
Aqueous and methanolic extracts	Antioxidant	Ordoñez et. al., 2006.
Raw extracts of eight biological types	Antiproliferative L-929 and p-388*	Cadena-Iñiguez, 2005; Cadena-Iñiguez et al., 2007.

*HeLa P-388 and L-929 cancer cell lines.

S. edule contains a diversity of nutraceutical compounds, making it ideal for any kind of diet, with the physiological benefits and nutrimental functions that reduce the risk of certain diseases. Some of its proven effects include diuretics, anti-inflammatory, and hypotensive, and it is even known to be an adjuvant in the elimination of kidney stones (Jensen and Lai, 1986). Furthermore, *S. edule* is used as a complement in the treatment of atherosclerosis and hypertension, as it relieves intestinal and skin inflammation, in addition to favouring the cauterization of ulcers (Diré et al., 2003).

3.2.2. Implications and effects of drying processes on food products and chayote

It is estimated that around 25% of harvested chayote is lost due to bad practices and improper handling, which represents major losses if we consider the total annual production (Álvarez and Luna, 2018). In accordance with previous studies, the rehydration of chayote comes to values of 53 to 98%, which indicates that, under certain circumstances and temperatures, this product can be used as a commercial additive or even in products such as instant soups (Álvarez and Luna, 2018).

By dehydrating chayote and passing it through a mill to obtain flour, interesting results were found about its properties, highlighting the water and oil absorption, along with the foam capacity, which makes this flour an ideal additive for bakery (Vargas et al., 2020). Table 6 displays these properties indicating the differences between HAD (Hot Air Drying) and HAD-MW (Hot Air Drying – Microwave) treatment.

Table 6. Techno-functional properties of chayote flour. Taken from Vargas et al., 2020.

Techno-functional properties	**Treatment HAD**	**Treatment HAD-MW**
Water absorption capacity (WAC) (g water/g flour)	6.80±0.28	6.80±0.28
Oil retention capacity (ORC) (g oil/g flour)	0.15±0.07	0.10±0.00
Water retention capacity (WRC) (g water/g flour)	1.85±0.21	2.50±0.71
Swelling capacity (SC) (mL water/g flour)	-	-
Foam capacity (FC) (%)	66.60±0.00	33.30±0.00

Oil absorption capacity is a desired trait in foods for scent preservation, as well as to increase the intensity and average life of pleasant tastes in baked products. The low absorption level of chayote oil, although it cannot contribute to the previously mentioned benefits, can support the production of foods with low fat contents, which has become a trend in food and bakery (Vargas et al., 2020).

It should be noted that most, if not all, of the studies referenced here dried their chayote using hot air at temperatures between 40 and 80 ºC, with the low loss of properties and sensorial characteristics attributed to the low temperatures but increasing the drying time to almost double (Avendaño et al., 2010; Chang et al., 2021; Ke et al., 2020; Vieira et al., 2018).

3.3. Chayote flour assessment and its possibilities

3.3.1. Technologically viable alternatives

By analysing some of the different product options based on chayote, namely chips, flour, and the simple dried vegetable, we find that the applications between these alternatives can vary in ways that make a significant difference as to utility, as in the case of flour and its possible uses for bakery or nutrimental additives as a fibre or juice source (Saade, 1996), while the greatest economic advantage is to be had in the production of simply dried chayote. This is because the requirement of a specific crunchy consistency for the chips and the flour delays the drying process and makes it more complicated, which in turn makes it more expensive (Saade, 1996).

In the production of these foods, exploitation is obtained in its totality when considering that the solid and liquid components of a chayote can be used for different processes. One example would be the production of juice. Although juice production is not proposed here, it does bear mentioning that its waste products can be included or used to make animal feed or fertilizer through a grinding process like the one used to make flour. Figure 3 visually expresses the processes needed for the elaboration of chips, flour, and juice, along with the possible interconnection that can be obtained in the latter two by grinding certain sub-products (Saade, 1996).

Other research studies, which demonstrate some technological alternatives that can be made from chayote, show that this tuber is a great source of starch, which is also morphologically, physicochemically, and molecularly comparable to potato starch (Hernandez- Uribe et al. 2011). In this way, chayote starch is a great substitute for wheat flour, which can appeal to special nutritional requirements, such as those demanded by Coeliac disease (Hernandez-Uribe et al., 2014).

These properties make chayote appropriate for hospital diets, as well as a variety of food products such as sauces, jams, juices, pasta, and even baby foods (Siciliano et al., 2004; Loizzo et al., 2016; Shiga et al., 2015).

Figure 3. Process for the elaboration of different chayote products. Modified from Saade, 1996.

3.3.2. Economically viable alternatives

Having introduced and analysed the potential of chayote and especially its dried products in the market, we can confidently present the chayote as a proposition for the development of a dried product. We find it to be an excellent opportunity for exploitation due to its high percentage of losses caused by poor practices and high humidity content, which produce a short shelf life. The idea of taking advantage of this vegetable in a dry product has great economic benefits that would also present a healthy food alternative for the population (Álvarez and Luna, 2018).

The production of chayote chips is extremely easy, except for controlling the humidity and the drying time needed to obtain different textures in the final product, since this is a highly fibrous food (Álvarez and Luna, 2018; Hernández et al., 2011). In the case of making a dehydrated product to include in "instant" products, the chayote has been proven to contain promising properties, rehydrating to between 53 and 98%, depending on the water temperature used for rehydration. These products not only end in a simpler procedure, without the necessity for grinding or seasoning, but also imply a faster drying process, as they do not require a crunchy texture (Álvarez and Luna, 2018).

4. CONCLUSIONS

This paper presents an in-depth review of the last 6 years of research on chayote and its drying processes, to have an overview on the food trade in this field and to review the vegetable's nutraceutical properties, as well as its applications in the food industry. The main conclusions are as follow:

Chayote has been used around the world, but mostly in countries in Central America as a cuisine dish, where varieties are abundant, but their beneficial properties have not been well exploited. This paper proposes to use a drying method to make the chayote more appealing and to use drying techniques to make it into innovative applications such as a juice, flour, or even chips, taking advantage of its nutritional value and nutraceutical properties.

Demonstrating the chayote as a first-choice dehydration vegetable, the following conclusions of the present research tables have been obtained:

- As this tuber has a high socio-economic impact in Mexico, as seen in Table 2, by itself it generates over 46,000 jobs annually, in the state of Veracruz.

- As seen in Table 3, its humidity composition ranges between 86-94%, making it a perfect tuber to dehydrate and still hold its beneficial properties in long-term transport, storage, and conservation.

- As demonstrated in Table 4, all the different varieties of chayote contain a high protein, carbohydrate, fibre, and fat content. The importance of taking advantage of chayote comes from its already high annual production of 284,000 tons and its overall potential both economically through exports and its nutritional value.

- As seen in Table 5, anti-inflammatory, antioxidant and antiproliferative properties are just some of the pharmacological effects associated with this food, adding to its potential as a nutraceutical.

- Table 6 reviewed the ability to maintain high water and oil absorption, as well as the foam capacity, of the dehydration processes that can be used to obtain chayote flour. This makes chayote's presentation as flour ideal for bakery.

The drying methods presented in this paper have similar qualities that differ in the specifications of the final product. The method of drying should be selected depending on the final product required. To acquire a crunchy texture, a complex procedure such as a reactance window should be used. On the contrary, for a final texture functioning as flour, it would not matter if the product breaks or if its shape is not as specific, therefore the drying process may not be as demanding, so a simpler one such as convective air drying would be sufficient.

It is highly encouraged to conduct further research and experimentation around chayote drying and its use in the food industry. Its versatility, as showcased by the properties of the dried products, offers many innovation opportunities that would bring growth-triggering benefits in having better health in the population.

In the case of nutraceutical compounds, there is still a lot of work to be done. Very few papers contain broken-down information on the phenolic compounds of chayote, and a thorough comprehension and knowledge of these compounds is essential for the development of more functional and nutritious foods. Scientific articles on the topic tend to study other parts of the chayote but are lacking research surrounding its nutraceuticals and how they are affected by diverse types of treatments.

Most of the reviewed papers focused only on obtaining the phenolic compound profile of raw chayote; further investigation and much more complete profiles are encouraged in this line of investigation when developing flours, dried products, and any other applications that treat chayote to observe the behaviour of these nutrients when subjected to different treatments. The investigation and obtention of a complete profile regarding this would lead to a more integrated and complete route of action to where chayote can be applied and how its characteristics and benefits can be exploited to the highest degree.

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