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Special Graduation Project
Elaboration of a Dehydrated Pineapple (*Ananas comosus*) Snack by
Osmo-convection

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Table of Contents

List of Tables	5
List of Figures	6
List of Appendices	7
Abstract.....	8
Resumen	9
Introduction	10
Materials and Methods.....	13
Experiment Location	13
Materials	13
Experimental Design	13
Elaboration Pineapple Snack.....	14
Physicochemical Analyses	16
Water Activity	16
Yield.....	16
Texture	16
Color	16
Dietary Fiber	17
Sensory Analysis.....	17
Acceptance Analysis.....	17
Preference Analysis.....	17
Statistical Analysis	17
Results and Discussion	18
Physicochemical Analysis	18
Texture Analysis	19

	4
Color Analysis.....	20
Sensory Analysis.....	22
Preference Test.....	23
Dietary Fiber Analysis	24
Nutritional Label	24
Conclusions	26
Recommendations	27
References	28
Appendices.....	31

List of Tables

Table 1 Water activity (a_w) and final weight of dehydrated pineapple snack	19
Table 2 Texture analysis of treatments of pineapple	20
Table 3 L, a, b, h, chrome color analysis of treatments of pineapple snack.....	22
Table 4 Color, texture, sourness, sweetness, and general acceptance sensory analysis of the four treatments of pineapple snack	23
Table 5 Kramer preference test	24

List of Figures

Figure 1 MD-2 pineapple shell color index (Source: MKADC Technical Research Group)	14
Figure 2 Flow process of Pineapple Snack elaboration	15
Figure 3 Theoretical nutritional label of pineapple snack with 6h of immersion	25

List of Appendices

Appendix A Sensory evaluation form.....	31
Appendix B Pineapple slices before dehydration.....	32
Appendix C Pineapple snack	33
Appendix D Nine point Hedonic scale.....	34
Appendix E Results of Color analysis a, b of Dehydrated Pineapple snack.....	35

Abstract

Dehydration is a crucial food preservation technique that enhances shelf life and nutritional quality of perishable products. This study explored the production of a pineapple snack using osmo-convective dehydration. In the context of increasing demand for healthier snacks, osmotic dehydration offers an alternative to preserve tropical fruits while maintaining their nutrient profile. The research applied various osmotic treatments with immersion times of 6, 12, and 24 hours in a honey-water-lime solution prior to drying which were compared to convective drying with no immersion (control). Physicochemical properties (water activity, texture, dietary fiber content, and yield) were analyzed alongside sensory evaluations to assess consumer acceptance and preference. Results showed that immersion significantly improved the texture, and nutritional profile of the dehydrated snack. Water activity of all treatments was below 0.60 and, as immersion times increased, water activity was reduced below 0.50, leading to shelf stable products with reduced risk of microbial growth. Yields increased (33-41%) when immersion was conducted while color hue and luminosity were reduced. Sensory evaluations indicated moderated positive consumer acceptance for all treatments, particularly for flavor and texture of the snacks. In terms of preference, panelists chose the dehydrated pineapple with six hours of immersion over the control and this treatment resulted in 2 grams of dietary fiber per portion (20 g) making it a source of this nutrient. These findings suggested that osmo-convective dehydration can effectively enhance the quality and shelf life of pineapple snacks, making them a promising alternative for promoting healthier dietary habits.

Keywords: Dehydration, immersion, osmosis, sensory evaluation, tropical fruit.

Resumen

La deshidratación es una técnica esencial para conservar alimentos perecederos, mejorando su vida útil y valor nutricional. Este estudio evaluó la producción de snacks de piña mediante deshidratación osmo-convectiva, en respuesta a la demanda de opciones más saludables. Se aplicaron tratamientos osmóticos con inmersiones de 6, 12 y 24 horas en una solución de miel, agua y limón, comparados con el secado convectivo sin inmersión (control). Las propiedades fisicoquímicas analizadas incluyeron actividad de agua, textura, contenido de fibra dietética y rendimiento, complementadas con evaluaciones sensoriales para medir aceptación y preferencia del consumidor. Los resultados mostraron que la inmersión mejoró significativamente la textura y el perfil nutricional. La actividad de agua fue inferior a 0.60 en todos los tratamientos, reduciéndose a menos de 0.50 con tiempos más prolongados, lo que minimizó el riesgo de crecimiento microbiano. Los rendimientos aumentaron entre un 33% y 41% con la inmersión, aunque el color y la luminosidad disminuyeron. En cuanto a las evaluaciones sensoriales, los consumidores mostraron una aceptación moderadamente positiva para todos los tratamientos, especialmente en sabor y textura. Los panelistas prefirieron la piña deshidratada con seis horas de inmersión, que proporcionó 2 gramos de fibra dietética por porción de 20 gramos, convirtiéndose en una fuente relevante de este nutriente. Estos hallazgos sugieren que la deshidratación osmo-convectiva es eficaz para mejorar la calidad y la vida útil de los snacks de piña, representando una alternativa saludable para el consumidor.

Palabras clave: deshidratación, evaluación sensorial, inmersión, piña, tratamiento osmótico.

Introduction

Pineapple (*Ananas comosus*) is a tropical fruit that is highly relished for its unique aroma and sweet taste. Based on the physicochemical composition and nutritional values, pineapple can be considered as one of the most useful fruits for manufacturing value-added compounds such as antioxidants, organic acids, bromelain, and phenolic compounds. (Barretto et al., 2013) extracted volatile compounds from the pineapple flesh to be utilized as aroma enhancing products as well as the production of natural essences. Pineapple primarily contains carbohydrates and water which are vital sources of dietary fiber, sugars, organic acids, vitamins (ascorbic acid, niacin, and thiamin), and minerals such as magnesium, manganese, and copper (Ancos et al., 2016) Through October 2019, Honduran pineapple exports totaled 56,207 metric tons, generating US\$ 26.5 million. The United States was the primary destination, capturing nearly all the market (USDA, 2019).

Based on research conducted by the Honduran Department of Agriculture and Livestock (Secretaría de Agricultura y Ganadería, SAG) in 2021, six of the eighteen departments of Honduras are main producers of pineapple: Ocotepeque, Copán, Cortés, Atlántida, La Paz, and Intibucá. Honduras has around 3,587 hectares (ha) including independent producers, with an average yield of 50.0 MT per hectare. Four varieties are: Azucarón, Cayenne Lisa, Champaka and MD2. Pineapple is a key economic driver for Honduras, with exports primarily to the United States generating substantial foreign exchange. While not all pineapples meet export standards, this presents a valuable opportunity. Dehydration can significantly extend the shelf life of these pineapples, allowing for year-round local sales. Moreover, dehydrated pineapple can be incorporated into a variety of products, from snacks to processed foods, creating new market opportunities, and reducing food waste. This value-added approach can strengthen the domestic economy and enhance food security.

However, there is little research on the effects of pineapple snacks on adult health. Sufficient intake of fruit and vegetables (F&V) has been related epidemiologically with reduced risk of many non-communicable diseases. Currently, much interest is focused on the vital role of antioxidants which

impart bright color to F&V and act as scavengers cleaning up free radicals before they cause detrimental health effect (Kour et al., 2021). Moreover, fibers found in F&V have been shown to reduce intestinal passage rates by forming a bulk, leading to a more gradual nutrient absorption (Pem & Rajesh, 2015).

Dietary fiber comes from the portion of plants that is not digested in the intestinal tract. Part of it, however, may be broken down by bacteria in the lower gut. Different types of plants vary in their amount and kind of fiber. Fiber includes pectin, gum, mucilage, cellulose, hemicellulose, and lignin (Pem & Rajesh, 2015). Fiber stimulates the liver to produce more bile, thus helping digestion. Insoluble fiber also causes digested food to pass through the intestines more quickly, thus contributing to “regularity” and reducing the length of time the gut lining is in contact with any potentially harmful substances contained in the digested food (Hong et al., 2016). Dietary fiber is the key nutrient for maintaining the diversity of gut microbiota. Low microbiota diversity is associated with many chronicles’ inflammatory diseases such as obesity, diabetes, and IBD. A low-fiber, high-fat, high-protein diet is a main contributing factor to the depletion of fiber-degrading microbes in populations in industrialized countries (Zhang, 2022). This study aims to elaborate a pineapple snack as an alternative for gastrointestinal development and prebiotic and probiotic health.

Postharvest management of fruit production is a necessity originating from the need to reduce the production losses that occur after the harvest. In practice, fruits must be harvested when they reach maturity and have optimal quality characteristics and need to be handled with care to avoid mechanical damage, cool quickly to remove heat accumulated in the field, stored in a modified atmosphere (if there are technologies suitable for the harvested species) and kept at acceptable temperatures during storage (Watkins & Nock, 2012). Food preservation refers to the measures taken to retain the desired qualities or characteristics of food over a certain period, ensuring it stays safe and enjoyable to eat. Here comes the food industry’s innovation to maintain these qualities and nutritional benefits.

Dehydration or drying of food is one of the preservation techniques that extend the shelf life of food by partially eliminating the water content (Valencia, 2020). Currently, there are different drying techniques, including solar or artificial and electric drying, this being the last one used in this study. Osmo-Convective Dehydration (OCD) is effective in preventing physicochemical and sensory changes, as well as reducing the loss of nutritional compounds (Tucker, 2016). This process involves the simultaneous flow of water and solutes, which is driven by the high osmotic pressure of the solution or the concentration gradient between the solution and the solid (Torres et al., 2013). (Kour et al., 2021) established that honey and sugar can act as osmotic agents for dehydrating foods. Honey is a natural substance produced by honeybees (*Apis mellifera*). They collect flower nectar, plant secretions or excretions of plant-sucking insects from plants and transform it into honey (Becerril et al., 2021) Antioxidant, anti-inflammatory, antibacterial, and antiviral properties have been linked to honey intake which has contributed to increasing the interest in this food (Ciulu et al.).

The objectives of this study were to develop an osmotically dehydrated snack by upcycled product, to evaluate physicochemical and sensory composition of the dehydrated pineapple snack and to analyze the dietary fiber content of osmotically dehydrated pineapple and compare it to fresh pineapple.

Materials and Methods

Experiment Location

The research was conducted at the Escuela Agrícola Panamericana, Zamorano, Honduras. The dehydration processes osmotic and convective were made at the Fruit and vegetable processing plant. For the final product, physicochemical analyses were conducted at the Food Analysis Laboratory, as well as preference and acceptance sensory studies in the Sensory Analytical Laboratory. The preparation of the pineapple snack with the different times of immersions in the Osmo-convective solution was carried out at Zamorano's Fruit & Vegetable processing plant. All facilities are located at 30 km East of Tegucigalpa, on the highway to Danlí, Valle del Yeguaré, Municipality of San Antonio de Oriente, Francisco Morazán, Honduras.

Materials

The raw material used was fresh pineapple (*Ananas comosus*), which was harvested in a plantation near Zamorano. In addition, honey was acquired from the Zamorano Bee Plant and lime (*Citrus limon*) from Zamorano's fruit plantations. As well as napkins, disposable plastic plates, disposable plastic cups and soda crackers from the convenience store located at Zamorano.

Experimental Design

In this study, a Complete Randomized Design (CRD) was employed, evaluating four treatments and three replications per treatment. For this research, three treatments for osmotic dehydration of pineapple were compared to a convective drying process (Table 1). The first treatment wasn't immersed in any solution (control). The rest of the treatments were immersed in a solution of sugar, water and lime for 6, 12, and 24 hours, respectively.

Elaboration Pineapple Snack

For the osmotic solution honey of the Apiarian product processing facility of Zamorano was used. The solution was elaborated in the Fruit and Vegetable processing plant, following the procedure described. First, the honey was weighed, then the water and the lime solution. Thereafter, the three ingredients were mixed until there was a homogeneous mixture. To ensure quality, it reached a pH of 3 and °Brix in a range of 34 - 35, afterwards, the solution was refrigerated at 4 °C (FDA, 2023).

Pineapple of the variety MD2 with maturity of shell Color Index 5, Figure 1. The Pineapple snack was elaborated following the procedure described in Figure 2. First, pineapples were disinfected with a solution containing soap and water for an afterwards immersion in sodium hypochlorite at 50 ppm (Martinez Diaz, 2022). Afterwards, they were peeled and cut into slices and submerged in a honey & lime solution at a pH of 3 and °Brix in a range of 34-35, with different timing for each of the three immersion treatments (6, 12 and 24 hours) under refrigeration. Subsequently, they were dehydrated using the equipment (Dehydrator DY-110H Lassele) during 8 hours at 60 °C. The process was done at low relative humidity (less than 50%) and without sun exposition to avoid physical changes, this process was repeated on different days to elaborate snack for each treatment.

Figure 1

MD-2 pineapple shell color index (Source: MKADC Technical Research Group)

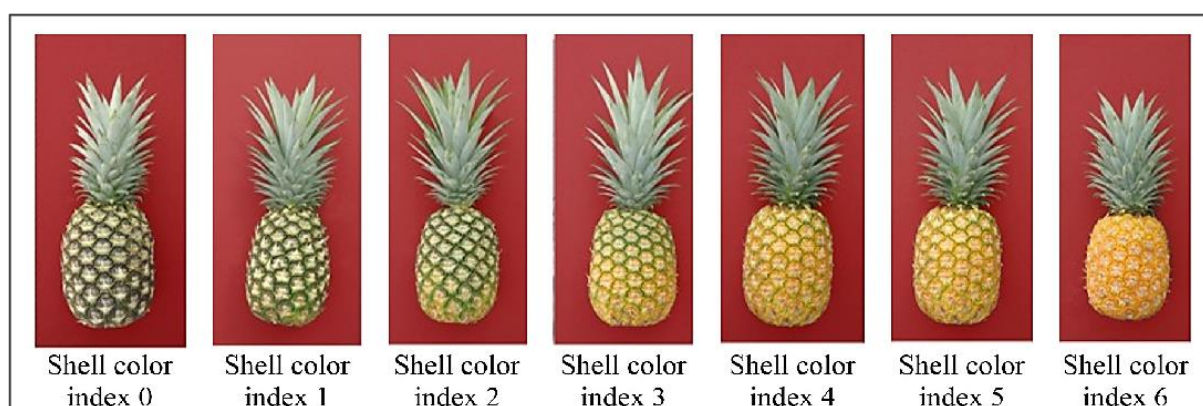
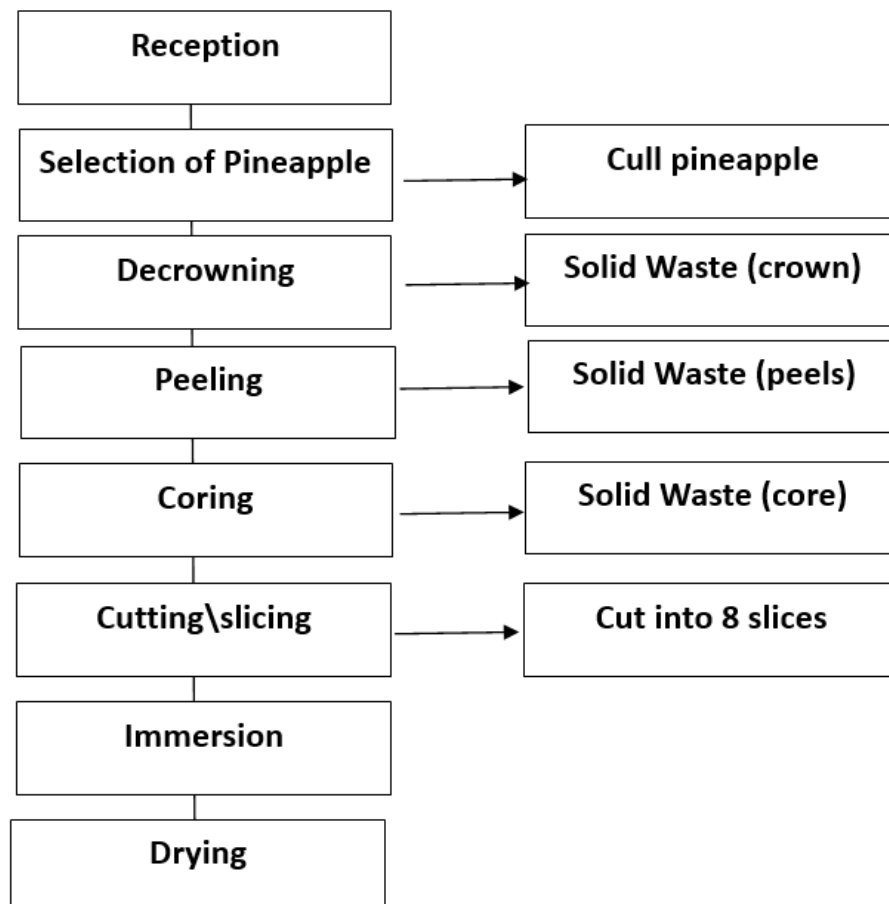


Figure 2

Flow process of Pineapple Snack elaboration



Physicochemical Analyses

Water Activity

To carry out the water activity analysis, the procedures established by the AOAC 978.18 method were followed using the AquaLab Series 3 (LAA-1210-27). During the process, a Decagon standard with a value of 0.984 was used to calibrate the water activity result of the equipment, performing this validation for each of the treatments.

Yield

Snack slices were individually weighted before the immersion and dehydration process. Afterwards, dehydrated slices of each treatment were individually weighted in order to see the final mass of the pineapple slices. The results were expressed in grams (g) of the dehydrated pineapple slices.

Texture

Pineapple snacks were evaluated using the equipment Brookfield CT3/Instron by the method ASTM E83 using the probe TA7 with a velocity of 3 mm/s and activation charge of 0.067 N. For the physical analysis the sample's dimensions were approximately 30 x 29 x 0.30 mm. Hardness of the normal pineapple dehydrated snack were measured, repeating this process nine times each treatment for an accurate average. The results were expressed in N (Newton).

Color

Color the method used in this study was CIELAB (Commission Internationale de l'Eclairage L*, a* y b*), evaluating L* (lightness), a*(red component), b*(yellow component), C*_{ab} (Chroma), and h*_{ab}(hue angle) that were determine by photographs, controlling parameters such as illumination and angle in order to reduce the error in this evaluation, wich gave data in RGB that subsequently were transformed into L, a, b hue angle and chrome data for the analysis.

Diestary Fiber

Pineapple snack from Treatment 1 was evaluated, with AOAC 985.29 method which involves enzymatic digestion to remove digestible components like starch and protein, followed by ethanol precipitation to isolate the soluble fiber. The sample is then filtered, dried, and weighed to measure the remaining insoluble and soluble fibers. To ensure accuracy, corrections for ash and protein are made, with the final dietary fiber content calculated as a percentage of the sample weight. This method provides a reliable measure of total dietary fiber in a wide range of food products.

Sensory Analysis***Acceptance Analysis***

A sensory evaluation of the affective type was conducted using an acceptance test to assess aspects such as appearance, color, odor, taste, sweetness, and acidity of the fruit subjected to different treatments. During the sensory analysis, a nine-point hedonic scale (Appendix H) was used to quantify these qualitative characteristics, allowing panelists to indicate their level of acceptance for each of the aforementioned attributes.

Preference Analysis

A survey was conducted among the panelists, where they were asked to rank their preferences using a scoring system from 1 to 4 (with 1 being the highest preference and 4 the lowest). This information was complemented with a preference analysis using the Basker and Kramer table, a recognized tool for evaluating the statistical significance of preferences. The critical value established was 46.9, providing an additional level of rigor to the analysis.

Statistical Analysis

The collected data were subjected to an analysis of variance, and mean separation using the Tukey test to detect significant differences among treatments, with a significance level set at 95%. These statistical analyses were conducted using SAS® online (Statistical Analysis Software).

Results and Discussion

Physicochemical Analysis

Water activity is a key metric in the food industry, it is defined as the ratio of the partial vapor pressure of water in equilibrium with the food to the partial vapor pressure of pure water at the same temperature (Tapia, 2020). This factor is essential to determining shelf life, as it directly affects the availability of water for microbial growth, as well as chemical and enzymatic activities. The scale ranges from 0 to 1, with lower values indicating minimal water availability and higher values indicating greater water availability.

Treatments with more hours of immersion demonstrated a greater reduction in a_w of samples compared to other treatments, according to (Van Boekel, 2023). Basic components of honey are water, glucose, and fructose, but its composition is very complex and contains many other components in minor quantities: disaccharides like sucrose and maltose, salts, organic acids. The combination of these components may have interacted efficiently with water in pineapple cells due to natural osmosis. Also, the organic acids in honey acidified the osmotic solution, which also contributed to lower the a_w (Rios et al., 2005).

The results presented showed significant differences ($p \leq 0.05$). As immersion increased over 6 hours, water activity was reduced (Table 2). Water activity is a parameter that determines the start or end of the growth of many microorganisms. Most pathogens require a water activity (a_w) above 0.96 to multiply (Arevalo, 2017). Pathogenic bacteria cannot grow below 0.85 a_w ; yeast and molds are more tolerant to a reduced a_w , but usually no growth exists below 0.62 a_w (Barbosa et al., 2020).

Pineapple industry is big in Honduras, having considerable exports, but there is some fruit that doesn't qualify for exportation, being dehydration one solution to this problem in order to avoid having to discard this fruit. As observed in Table 2, immersion treatments, regardless of their duration, significantly increase the final weight compared to the control. This increase in yield is related to the absorption and retention of water and solutes during immersion, resulting in a final product with

greater weight and possibly better sensory quality. The 33-41% increase in final weight in the immersion-treated products highlights the benefit of this method in optimizing yield during the pineapple dehydration process.

Table 1

Water activity (aw) and final weight of dehydrated pineapple snack

Immersion time (h)	Water activity Media \pm S.D ⁴	Final Weight (g) Media \pm S.D
0	0.55 \pm 0.02 ^{a3}	1.30 \pm 0.47 ^b
6	0.53 \pm 0.04 ^a	1.84 \pm 0.61 ^a
12	0.46 \pm 0.01 ^b	1.83 \pm 0.60 ^a
24	0.48 \pm 0.02 ^b	1.73 \pm 0.49 ^a
p ¹	0.6206	0.0004
%CV ²	4.94	32.54

Note. ¹(P<0.5) indicates statistical difference. ² Coefficient of variation. ³Small case letters from (a-b) show differences between treatments of each column (P<0.05). ⁴Standard deviation.

Texture Analysis

Food texture plays an important role in consumer's preference. Texture is one of the attributes used by consumers to assess food quality (Day & Golding). The osmotic dehydration process significantly impacted the texture of pineapple as a function of immersion time in a honey, water, and lime solution, with clear differences observed in the first cycle of hardness, deformation, and second cycle of hardness. For the first cycle in (Table 3), the control sample (0 hrs) had the lowest hardness (0.96 \pm 0.99 N), while the 12-hour sample showed the highest (4.23 \pm 4.71 N), indicating that increased immersion time enhanced firmness. Interestingly, the 24-hour treatment had slightly lower hardness than the 12-hour treatment, suggesting a potential tissue breakdown or stabilization after prolonged exposure. Deformation remained relatively stable across treatments, with only a slight increase after 6 hours of immersion as observed in (Table 3). This suggests that osmotic treatment primarily affects hardness rather than elasticity. In the second cycle of hardness, the control (1.37 \pm 1.87 N) and 6-hour (3.39 \pm 6.04 N) treatments showed significant increases, with the 12-hour treatment again reaching the highest hardness (6.28 \pm 8.75 N). However, the second cycle values dropped for the 24-hour

sample (3.92 ± 9.59 N), mirroring the trend seen in the first cycle. These results align with existing literature on osmotic dehydration, where immersion time is a critical factor in enhancing firmness (P. Fito, Chiralt, Betoret, Gras, Cháfer, Martínez-Monzó, et al., 2001). While deformation remained stable, hardness was most affected by immersion, especially at the 12-hour mark, confirming the potential for osmotic dehydration to produce firmer, texturally desirable dried fruit (Corzo et al., 2007).

Table 2

Texture analysis of treatments of pineapple

Immersion time (h)	First Cycle of Hardness (N) Media \pm S.D ⁴	Deformation (mm) Media \pm S.D	Second Cycle of Hardness (N) Media \pm S.D
0	$0.96 \pm 0.99^{\text{c}3}$	$1.34 \pm 0.19^{\text{b}}$	$1.37 \pm 1.87^{\text{c}}$
6	$1.79 \pm 2.36^{\text{b}}$	$1.51 \pm 0.12^{\text{a}}$	$3.39 \pm 6.04^{\text{b}}$
12	$4.23 \pm 4.71^{\text{a}}$	$1.48 \pm 0.12^{\text{a}}$	$6.28 \pm 8.75^{\text{a}}$
24	$4.14 \pm 9.82^{\text{a}}$	$1.47 \pm 0.13^{\text{a}}$	$3.92 \pm 9.59^{\text{b}}$
p ¹	0.0008	0.0671	0.4805
%CV ²	12.35	9.45	46.43

Note: ¹($P < 0.5$) indicates statistical difference. ² Coefficient of variation. ³ Small case letters from (a-b) show differences between treatments of each column ($P < 0.05$). ⁴ Standard deviation.

Color Analysis

The osmotic dehydration process affected each CIELAB color parameter of pineapple differently as immersion time increased. For lightness (L), the control sample (0 hours) had a moderate value of 62.94 ± 12.01 . After 6 and 12 hours of immersion, lightness significantly increased to 70.37 ± 11.80 and 72.11 ± 7.95 , respectively, indicating that the pineapple became brighter. However, by 24 hours, lightness decreased to 54.52 ± 14.04 , suggesting potential darkening or browning due to prolonged immersion. This is consistent with findings that lightness initially increases due to water removal but decreases over extended time due to browning reactions during dehydration (Boun & Huxsoll, 1991). In a (red-green axis) parameter, the control sample had a value of 4.40 ± 6.55 , indicating a slight red hue. Immersion for 6 and 12 hours reduced this redness, with values of 3.22 ± 6.43 and 1.05 ± 5.23 , respectively, suggesting a shift towards a greener hue. However, after 24 hours, the "a" value sharply

increased to 12.69 ± 5.46 , indicating a reintensification of the red hue, possibly due to pigment concentration or oxidative reactions during extended dehydration. Similar color shifts towards red have been reported in fruits undergoing oxidative stress in extended osmotic dehydration (Santos & Silva, 2008).

For the b (yellow-blue axis) parameter, the control sample showed a strong yellow hue (63.31 ± 9.30), which further intensified after 6 and 12 hours of immersion, reaching 69.28 ± 8.20 and 70.59 ± 4.81 , respectively. However, after 24 hours, the yellow hue diminished to 55.68 ± 10.74 , likely due to pigment degradation or moisture loss over time. This decrease in yellowness aligns with previous findings showing that prolonged dehydration can lead to a breakdown of carotenoids and other yellow pigments (Hammond & Renzi, 2013).

The hue parameter, which measures the overall color tone, showed an increase from 85.56 ± 6.56 at 0 hours to 88.99 ± 4.28 at 12 hours, indicating a shift towards greener tones. However, at 24 hours, hue decreased significantly to 76.34 ± 6.99 , suggesting a shift towards more reddish hues, possibly due to chemical changes occurring with longer immersion times. This trend is consistent with previous studies showing that hue changes in fruits are common during osmotic dehydration as a result of pigment concentration and degradation (Maskan, 2001).

Finally, as it can be observed in Table 4, the chroma parameter, representing color intensity, increased from 63.87 ± 8.77 at 0 hours to 70.78 ± 4.71 after 12 hours of immersion, showing greater color saturation. After 24 hours, chroma decreased to 57.51 ± 9.89 , indicating a reduction in color intensity, likely due to the breakdown of pigments. Previous studies have shown that color intensity in osmotically dehydrated fruits can increase initially but declines as pigment degradation and browning reactions set in (García et al., 2014).

Table 3*L, a, b, h, chrome color analysis of treatments of pineapple snack*

Immersion time (h)	L ⁵	a	b	hue	Chrome
	Media ± S.D ⁴	Media ± S.D	Media ± S.D	Media ± S.D	Media ± S.D
0	62.94 ± 12.01 ^{b3}	4.40 ± 6.55 ^b	63.31 ± 9.30 ^b	85.56 ± 6.56 ^b	63.87 ± 8.77 ^b
6	70.37 ± 11.80 ^a	3.22 ± 6.43 ^b	69.28 ± 8.20 ^a	86.80 ± 6.11 ^b	69.71 ± 7.68 ^a
12	72.11 ± 7.95 ^a	1.05 ± 5.23 ^c	70.59 ± 4.81 ^a	88.99 ± 4.28 ^a	70.78 ± 4.71 ^a
24	54.52 ± 14.04 ^c	12.69 ± 5.46 ^a	55.68 ± 10.74 ^c	76.34 ± 6.99 ^c	57.51 ± 9.89 ^c
p ¹	0.5641	0.7535	0.8910	0.6732	0.9067
% CV ²	17.28	4.60	4.35	6.78	11.56

Note. ¹(P<0.05) indicates statistical difference. ² Coefficient of variation. ³Small case letters from (a-b) show differences between treatments of each column (P<0.05). ⁴Standard deviation. ⁵Luminosity, a: (red, green), b: (yellow- blue), h: hue angle, chrome.

Sensory Analysis

The sensory evaluation of osmotically dehydrated pineapple revealed significant variations in color, texture, sourness, sweetness, and general acceptance based on the immersion time. In fruits and vegetables, color is associated with maturity and quality identification (Talens, 2016). For color, in (Table 5) the control (0 h) had a score of 6.20 ± 1.88 , similar to the scores for 6 and 24 hours of immersion (6.21 ± 1.90 and 6.16 ± 1.91 , respectively), while the 12-hour immersion led to a significantly lower score (5.34 ± 1.75). This suggests that prolonged immersion times can either preserve or degrade color depending on the duration, consistent with findings that color degradation can occur due to pigment oxidation in prolonged exposure to osmotic treatments (Amami et al., 2017). For texture, in (Table 5) the control sample had a value of 6.43 ± 1.92 , and the best texture score was observed after 24 hours (6.58 ± 1.72), while shorter immersion times of 6 and 12 hours resulted in lower texture scores (5.76 ± 2.12 and 5.93 ± 1.89 , respectively). The decline in texture quality at shorter immersion times may be due to insufficient dehydration, which aligns with research showing that textural improvements often require longer treatment times (P Fito, Chiralt, Betoret, Gras, Cháfer, & Martínez, 2001).

In terms of sourness, sour taste perception builds on both chemical and physiological foundations and serves for detecting unripe fruits and spoiled foods (Mao et al., 2021). Table 5 demonstrates scores

ranged from 6.38 ± 1.86 for 6 hours to 6.98 ± 1.96 after 24 hours, though no statistically significant differences were observed. This suggests that the immersion process did not drastically affect the perception of sourness, aligning with studies indicating that osmotic dehydration preserves flavor attributes, particularly acidity (Santos & Silva, 2008).

For sweetness, scores increased slightly with immersion time, as observed in Table 5, with the control at 6.90 ± 1.31 and the highest sweetness at 24 hours (7.22 ± 1.89). Although not statistically significant, this trend is consistent with osmotic dehydration's role in concentrating sugars, enhancing the perceived sweetness of fruits (Shi & Le Maguer, 2002).

Finally, general acceptance followed a similar trend, with the control (6.98 ± 1.51) and 24-hour immersion (7.02 ± 1.89) receiving the highest scores, while the 12-hour immersion was rated the lowest (6.42 ± 1.80). This reflects the overall improvement in sensory attributes such as sweetness and texture with longer immersion, which generally leads to higher consumer acceptance (Rodriguez et al., 2010).

Table 4

Color, texture, sourness, sweetness, and general acceptance sensory analysis of the four treatments of pineapple snack

Time of immersion (h)	Color ⁵ Media \pm S.D ⁴	Texture Media \pm S.D	Sourness Media \pm S.D	Sweetness Media \pm S.D	General Acceptance Media \pm S.D
0	6.20 ± 1.88^{a3}	6.43 ± 1.92^{ab}	6.66 ± 1.73^{ab}	6.90 ± 1.31^{ab}	6.98 ± 1.51^a
6	6.21 ± 1.90^a	5.76 ± 2.12^b	6.38 ± 1.86^b	6.79 ± 1.90^b	6.82 ± 1.72^a
12	5.34 ± 1.75^b	5.93 ± 1.89^b	6.40 ± 1.98^b	6.72 ± 2.07^b	6.42 ± 1.80^b
24	6.16 ± 1.91^a	6.58 ± 1.72^a	6.98 ± 1.96^a	7.22 ± 1.89^a	7.02 ± 1.89^a
P ¹	0.0015	0.0062	0.0760	0.2184	0.0601
%CV ²	31.12	31.04	28.31	26.27	25.50

Note. ¹(P<0.5) indicates statistical difference.² Coefficient of variation.³Small case letters from (a-b) show differences between treatments of each column (P<0.05).⁴Standard deviation.⁵An hedonic scale of nine points was use.

Preference Test

This test of the four treatments was conducted with a panel of 100 non-expert participants, who evaluated four products made whit dehydrated pineapple. These results guide the research to

determine that, overall, the participants chose the fruit treated with 6 hours of immersion. By using the Basker and Kramer table, tests that are useful to understand which product overall evaluated is preferred by different panelist used as nonparametric test a critical value of 46.9 was identified, and by comparing this critical value with the data recorded in Table 6, it was determined that the treatment one (T1) presented statistically significant difference ($P \leq 0.05$) among the other treatments.

Table 5

Kramer preference test

Treatments	Trt Control	Trt 6h	Trt 12h	Trt 24 h	
Sum of cathegories	279	217	267	238	
Control	279	0	62	12	41
T1 6 h	217	62	0	50	-21
T2 12h	267	-12	50	0	29
T3 24h	238	-41	21	-29	0

Note. The critical value used was of 46.9 according to Basker and Kramer table.

Dietary Fiber Analysis

Dietary fibers are plant-derived carbohydrates and associated components, that are not digested within the human upper intestinal tract/gut. Traditionally they are classified based on their solubility in water i.e., soluble dietary fiber (SDF) and insoluble dietary fiber (IDF) (Khorasaniha et al., 2023). Dietary fiber analysis of the samples of treatment one (T1) yielded highly consistent results, with an average fiber content of 6.10%. Honey creates a coating effect in pineapple slices which helps to preserve the snack's structure during dehydration. The mention above might occur by hydrogen bonding, where the hydroxyl (-OH) groups in honey sugar form hydrogen bonds with the (-OH) groups on the fiber (Santagata et al., 2018).

Nutritional Label

When comparing the dietary fiber content of dehydrated pineapple sample of 6 hours (T1) to fresh pineapple, several key differences arise as observed in Figure 3. Fresh pineapple typically contains about 1.4-2.3% dietary fiber by weight, depending on the variety and ripeness (FoodData

Central: Pineapple, raw., 2023). In contrast, T1 dehydrated sample has 6.10% fiber, and the nutritional label reports 10% fiber per serving (2g per 20g serving). Dehydration significantly concentrates the nutrients and fiber because water, which makes up around 86% of fresh pineapple, is removed during the process, leading to a higher percentage of fiber in the dried product (Polidori et al., 2009). The use of honey for the elaboration of this snack creates a coating that preserves the pineapple’s structure during dehydration, potentially through hydrogen bonding between hydroxyl groups in the honey sugars and the fiber, enhancing the texture without significantly altering the fiber content (Santagata et al., 2018). Therefore, while fresh pineapple provides valuable dietary fiber, osmotically dehydrated pineapple offers a more concentrated source due to the dehydration process.

Figure 3

Theoretical nutritional label of pineapple snack with 6h of immersion

Nutrition Facts	
Datos de Nutrición	
5 servings servings per container 5 porciones Raciones por Envase	
Serving size	1/4 cup (20g)
Tamaño por Ración	1/4 taza (20g)
Amount per serving / Cantidad por ración	
Calories / Calorías	60
<small>% Daily Value* / % Valor Diario*</small>	
Total Fat / Grasa Total 0g	0%
Saturated Fat / Grasa Saturada 0g	0%
Trans Fat / Grasa Trans 0g	
Cholesterol / Colesterol 0mg	0%
Sodium / Sodio 0mg	0%
Total Carbohydrate / Carbohidrato Total 17g	6%
Dietary Fiber / Fibra Dietética 2g	7%
Total Sugars / Azúcares Totales 15g	
Includes 15g Added Sugars / Incluye 15g Azúcares Añadidos	30%
Protein / Proteínas 1g	
Vitamin D / Vitamina D 0mcg	0%
Calcium / Calcio 20mg	2%
Iron / Hierro 0.2mg	2%
Potassium / Potasio 160mg	4%
<small>*The % Daily Value tells you how much a nutrient in a serving of food contributes to a daily diet. 2,000 calories a day is used for general nutrition advice. *El % Valor Diario le indica cuánto un nutriente en una porción de alimentos contribuye a una dieta diaria. 2,000 calorías al día se utiliza para asesoramiento de nutrición general.</small>	

Conclusions

Osmotic dehydration using honey, water, and lime solution effectively transformed underutilized pineapple into a shelf-stable snack with improved texture, sweetness, and sensory appeal. This method supports sustainability by upcycling fruit and reducing food waste.

The physicochemical and sensory evaluation of osmotically dehydrated pineapple snacks demonstrated significant improvements in texture, firmness, sweetness, and reduced water activity, enhancing shelf life. The process increased yield over 30% through immersion treatments. While initial lightness improved, it later declined due to browning, with color parameters shifting based on immersion time. These findings underscore that osmotic dehydration is an effective method for producing high-quality, shelf-stable pineapple snacks.

The osmotically dehydrated pineapple (6h) contained significantly more fiber (6.10%) than fresh pineapple (1.4-2.3%) due to dehydration, which concentrates nutrients. The dehydrated pineapple snack was considered a source of fiber compared to fresh pineapple.

Recommendations

Future studies should explore the long-term storage stability of the dehydrated pineapple snack and its nutritional retention over time.

Conduct market studies to assess consumer preferences for various flavor profiles and packaging options to enhance marketability.

Additional research on the health impacts of regular consumption of the dehydrated pineapple snack should be conducted to establish its role in a balanced diet. Assess non-caloric carbohydrates in order to reduce sugar intake.

Evaluate the viability of adding ingredients that provide fiber to snacks like the one presented above.

Conduct a thorough characterization of the dehydrated pineapple snack, focusing on its nutritional profile. Additionally, link findings to public health research to highlight its role in promoting healthy eating.

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Appendices

Appendix A

Sensory evaluation form

Boleta de evaluación sensorial

Prueba de aceptación y preferencia de un snack de piña deshidratada

Nombre: _____ Fecha: _____

Instrucciones: Se le presentarán 4 muestras de piña deshidratada, proceda a evaluar cada muestra de izquierda a derecha. Antes y después de probar cada muestra debe tomar un sorbo de agua y comer un trozo de galleta para limpiar su paladar. Posteriormente, evalúe según el grado de gusto o disgusto que cada muestra le generó según la escala del Cuadro No. 1 y anotando sus resultados (solo los números) en el Cuadro No. 2.

Cuadro No. 1

1	2	3	4	5	6	7	8	9
Me disgusta mucho	Me disgusta moderadamente	Me disgusta	Me disgusta poco	Ni me gusta ni disgusta	Me gusta poco	Me gusta	Me gusta moderadamente	Me gusta mucho

Cuadro No. 2

Muestra	Color	Textura	Acidez (percepción del limón)	Dulzura (percepción de la miel)	Aceptación general

Comentarios: _____

En el Cuadro No. 3, ordene las muestras según su preferencia, siendo 1 la más preferida y 4 la menos preferida. No se puede asignar el mismo valor a varias muestras.

Cuadro No. 3

Número de muestra	Orden de preferencia
	1. Más preferida
	4. Menos preferida

Justifique su preferencia: _____

Appendix B

Pineapple slices before dehydration



Appendix C

Pineapple snack



Appendix D*Nine point Hedonic scale*

1	2	3	4	5	6	7	8	9
I dislike it extremely	I dislike a lot	I moderate dislike it	I slightly dislike it	Neither like nor dislike	I slightly like it	I moderately like it	I like it a lot	I like it extremely

Appendix E

Results of Color analysis a, b of Dehydrated Pineapple snack

