UNIVERSIDAD AUTÓNOMA CHAPINGO

DEPARTAMENTO DE FITOTECNIA
COORDINACION DE ESTUDIOS DE POSGRADO
DOCTORADO EN CIENCIAS EN HORTICULTURA

CULTIVO DE KIWI (*Actinidia chinensis* Lindl.) UNA ALTERNATIVA PARA LAS MONTAÑAS DEL ESTADO DE VERACRUZ-MÉXICO

TESIS

Que como requisito parcial
para obtener el grado de:

DOCTOR EN CIENCIAS EN HORTICULTURA

Presenta:

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Bajo la supervisión de

Dr. GUSTAVO ALMAGUER VARGAS

1854
COORDINACIÓN GENERAL DE ESTUDIOS DE POSGRADO
APROBADA

Chapingo, Estado México, diciembre del 2024

CULTIVO DE KIWI (*Actinidia chinensis* Lindl.) ALTERNATIVA PARA LAS MONTAÑAS DEL ESTADO DE VERACRUZ-MÉXICO.

Tesis realizada por Jhusua David Reina García bajo la supervisión del comité asesor indicado, aprobada por el mismo y aceptada como requisito parcial para obtener el grado de:

DOCTOR EN CIENCIAS EN HORTICULTURA.

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DEDICATORIA

Dedico con gran afecto esta tesis a mis padres Diddyer Reina Bonza y Gloria García Báquiro, ustedes han sido y serán mi motivación. Además, son mi ejemplo a seguir, sus luchas por la vida me han hecho esforzarme para ser cada día una mejor persona, sus sacrificios serán reflejados en mi vida.

Además, quiero agradecer enormemente a mi hermana Laura P. Reina G. y a Sergio H. Valenzuela M. por brindarme su apoyo en cada decisión que he tomado.

A mi abuela Lilia del Carmen Bonza, a mi familia Reina García, Díaz Reina, Calderón Reina y García Báquiro, a Sergio Parra y Camila Herrera sus apoyos emocionales, me ayudaron a persistir en la lucha de mi enfermedad y con voluntad y energía logre superarlo.

A Rogelio Deheza, Ana Robles y Verónica porque su trabajo también brindó la posibilidad de continuar con estos estudios.

También quiero resaltar la labor de personas especiales, que, con su ayuda, definitivamente logre cumplir mi meta y además estoy seguro de que puedo confiar en cada uno de ellos, con cariño y admiración a Francisca de los Ángeles Mejía B., Christian Camilo Castañeda C., Abigail Ortiz, Guillermina Hernández Rodríguez, Hilda Elín Pérez, Juana Pérez Martínez, Nancy Elena González, Alma Aurora Deanda, Ana Elizabeth Paredes, Nora Virginia Useche Carrillo, Ricardo Domínguez Puerto, Jessica Díaz Reina, Rommel Alvarado, Guadalupe Villafuerte, Guadalupe García, Dra. Irma Salgado, Anahí, Paola, Hypatia, Dr. Juan Martínez, Dr. Alejandro Barrientos.

Para todos ustedes, les agradezco con todo el corazón, sin su ayuda este logro no se hubiese podido realizar ¡Gracias!

AGRADECIMIENTOS

Por su trabajo y empeño, esta tesis se logró gracias al acompañamiento y seguimiento de múltiples personas e instituciones. Que por su saber, financiamiento y apoyo me ayudaron a orientar.

Al Consejo Nacional de Humanidades, Ciencia y Tecnología (CONAHCyT), por brindarme el apoyo económico brindado durante mi estancia en México y estudios de Doctorado.

A la Coordinación de Estudios de Posgrado de Horticultura del Departamento de Fitotecnia de la Universidad Autónoma Chapingo, por darme la oportunidad de seguir con mis estudios de posgrado en sus instalaciones y, además por facilitar la realización de mi experimento.

Al Dr. Gustavo Almaguer Vargas, por su liderazgo y acompañamiento durante el doctorado, sus conocimientos y experiencias, permitieron el desarrollo de esta investigación.

A la Dra. Diana Guerra Ramírez, por su acompañamiento, por su tiempo y estar pendiente del experimento, además de compartir su experiencia para el desarrollo del proyecto, se le agradece en lo más infinito.

Al Dr. Juan Guillermo Cruz Castillo, por el acompañamiento, sugerencias, observaciones y recomendaciones, para el escrito de la tesis, sin duda mejoraron esta investigación.

Al Dr. Álvaro Castañeda por su asesoramiento y disposición a favor del presente proyecto.

Igualmente quiero agradecer el apoyo recibido de mis profesores, colegas y amigos, durante mis estudios de doctorado y por los buenos momentos.

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RESUMEN GENERAL

CULTIVO DE KIWI (*Actinidia chinensis* Lindl.) UNA ALTERNATIVA PARA LAS MONTAÑAS DEL ESTADO DE VERACRUZ-MÉXICO

El kiwi hace parte de la familia Actinidiaceae y originario del suroeste de China, su fruto es reconocido por su pulpa dulce, ligeramente ácida y su alto valor nutricional. En México, la producción de kiwi es prácticamente inexistente, lo que obliga a depender de importaciones, y la información sobre su cultivo en condiciones de trópico de altura es limitada. Esta investigación generó conocimiento científico y técnico sobre el cultivo, incluyendo condiciones edafoclimáticas, germinación, perfil fitoquímico de fruto y hojas y una evaluación sensorial. Se llevaron a cabo diversos experimentos que permitieron estudiar su comportamiento en regiones subtropicales. Los resultados mostraron que, las vides brotan en condiciones de 443 horas frío y crecen en suelos volcánicos (0.81 t m^{-3}), con 12 % de materia orgánica, 34 ppm de N y pH de 5.3. La tasa de germinación se mejoró mediante la aplicación de una triple interacción de factores, obteniendo resultados favorables a 25 °C combinados con diferentes concentraciones de ácido giberélico (2000-6000 ppm). Se demostró que tanto los frutos como las hojas son una fuente rica en antioxidantes, incluyendo polifenoles, flavonoides y ácidos orgánicos. Además, una prueba sensorial destacó que las características de sabor ácido y dulce, junto con la pegajosidad y astringencia, eran comparables a las de los kiwis importados. Este estudio proporciona una base científica y técnica que podría apoyar el establecimiento del kiwi como una opción viable y nutritiva en el mercado nacional, contribuyendo a diversificar la producción agrícola y reducir la dependencia de importaciones.

Palabras clave: contenido fitoquímico, proceso de germinación, condición edafoclimática, análisis sensorial.

Tesis de Doctorado en Ciencias en Horticultura, Universidad Autónoma Chapingo
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GENERAL ABSTRACT

KIWIFRUIT CULTIVATION (*Actinidia chinensis* Lindl.) AN ALTERNATIVE FOR THE MOUNTAINS OF VERACRUZ, MÉXICO

Kiwifruit belongs to the Actinidiaceae family and is native to southwestern China. Its fruit is recognized for its sweet, slightly acidic pulp and high nutritional value. In Mexico, kiwifruit production is virtually nonexistent, necessitating reliance on imports, and information regarding its cultivation under high-altitude tropical conditions is limited. This research generated scientific and technical knowledge on kiwifruit cultivation, encompassing edaphoclimatic conditions, germination, phytochemical profiling of fruit and leaves, and a sensory evaluation. Various experiments were conducted to study its behavior in subtropical regions. The results indicated that the vines sprout under 443 chill hours and grow in volcanic soils (0.81 t m^{-3}), with 12 % organic matter, 34 ppm nitrogen, and a pH of 5.3. Germination rates improved through the application of a triple interaction of factors, yielding favorable outcomes at 25 °C combined with different concentrations of gibberellic acid (2000-6000 ppm). It was demonstrated that both the fruits and leaves are a rich source of antioxidants, including polyphenols, flavonoids, and organic acids. Additionally, a sensory test highlighted that the acidic and sweet flavor characteristics, along with stickiness and astringency, were comparable to those of imported kiwifruit. This study provides a scientific and technical foundation that could support the establishment of kiwifruit as a viable and nutritious option in the national market, contributing to the diversification of agricultural production and reducing dependence on imports.

Keywords*:* phytochemical content, germination process, edaphoclimatic conditions, sensory analysis.

Thesis of Doctor of Horticultural Science, Universidad Autónoma Chapingo
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1. INTRODUCCIÓN GENERAL

El kiwi (*Actinidia* sp.), perteneciente al género *Actinidia* Lindl*.* y originario del suroeste de China, comprende más de 50 especies, siendo altamente valorado en el mercado global por sus propiedades nutricionales y su elevado contenido de vitamina C (López-Sobaler et al., 2016). Las variedades comercialmente más relevantes son *Actinidia chinensis* var. deliciosa, con pulpa verde, y *Actinidia chinensis* var. chinensis, de pulpa amarilla (Cruz Castillo et al., 2022) que se distinguen por sus características organolépticas y composición nutricional (Ferguson & Ferguson, 2002). En la actualidad, la producción mundial de kiwi está liderada por China, Italia, Nueva Zelanda, Irán, Grecia y Chile, alcanzando una producción total de 4.54 millones de toneladas en 2022, cifra que refleja un crecimiento significativo desde principios del siglo XXI (Shahbandeh, 2024). Este incremento en la producción se atribuye a la creciente demanda internacional impulsada por el sabor y los beneficios nutricionales del kiwi.

En América Latina, Chile es el principal productor y exportador de kiwi, abasteciendo los mercados de Norteamérica y otros destinos internacionales, mientras que México depende de importaciones provenientes de Estados Unidos, Chile, Italia y Nueva Zelanda (Ma et al., 2017). Esta especie normalmente crece en condiciones agroclimáticas con una acumulación de 700-900 horas por debajo de 4 °C para estimular la floración (Wall et al., 2008). Asimismo, las vides crecen en humedades relativas entre 70-80 %, y sus suelos adecuados son profundos con pH entre 6-7, conductividad eléctrica 1.2 mS cm^{-1}, buena capacidad de drenaje, y elevada materia orgánica (García et al., 2015). Sin embargo, estudios preliminares sugieren que algunas regiones de México, como Huatusco en Veracruz, ofrecen condiciones edafoclimáticas adecuadas para el cultivo del kiwi. Esta zona, situada en el trópico de altura a 1900 m.s.n.m, presenta temperaturas promedio anuales de 16-26 °C y una precipitación entre 1100 y 1600 mm, aunque con una limitada acumulación de horas frío (180-300) que restringe la brotación de las yemas y, por ende, la producción (Sistema de Información Municipal, 2019). Estas características ambientales podrían aprovecharse para desarrollar variedades adaptadas a las condiciones tropicales de altura, lo cual contribuiría a reducir la dependencia de importaciones y a fortalecer la economía local.

Además del fruto, las hojas de kiwi han cobrado interés en investigaciones fitoquímicas, debido a que contienen compuestos nutraceúticos como antioxidantes, fenoles y flavonoides que podrían tener aplicaciones en el desarrollo de productos funcionales, como infusiones y suplementos (Kumar et al., 2020). Sin embargo, la mayoría de los estudios sobre las propiedades nutracéuticas de las hojas de kiwi se han centrado en especies nativas de China (He et al., 2019), dejando un área de oportunidad en el estudio de estas propiedades en cultivos de kiwi establecidos en México. La evaluación de compuestos nutraceúticos en las hojas podría abrir nuevas posibilidades en el mercado de productos naturales, extendiendo el uso de esta especie más allá de su fruto y brindando beneficios económicos y de salud a nivel local.

Un desafío importante en el cultivo del kiwi es la latencia de las semillas, que complica el proceso de germinación, lo cual es de importancia para la mejora genética. Debido a su relativamente corto tiempo de domesticación, las semillas de kiwi presentan una latencia que limita o impide su germinación bajo condiciones favorables, lo cual representa una barrera en la propagación de nuevas plantas. Esta latencia fisiológica restringe las condiciones en las que la semilla puede germinar, y su superación requiere técnicas especializadas (Windauer, et al., 2016). Para romper la latencia, la semilla debe ser sometida a condiciones de temperaturas controladas, alternancia de luz, o aplicaciones exógenas de hormonas como giberelinas, que han demostrado ser efectivas en el estímulo de la germinación de diversas especies vegetales (Tigabú & Odén, 2001). Las giberelinas inducen la ruptura de la dormancia tras la imbibición, reduciendo los requerimientos ambientales, como las horas de frío, necesarias para la germinación. Al contrarrestar los efectos inhibitorios de otras hormonas vegetales, como el ácido abscísico, las giberelinas facilitan la germinación y el crecimiento del embrión (Siobhan & McCourt, 2003).

Hasta la fecha, la germinación de las semillas de kiwi se ha abordado mediante tratamientos de reguladores de crecimientos con ácido giberélico (AG_3) a diferentes concentraciones, aplicados antes de la incubación (Bishwas et al., 2018; Celik et al., 2006; Kumar et al., 2020; Lawes & Anderson, 1980; Ozcan, 2000; Sekhukhune et al., 2018;). No obstante, este enfoque no siempre resulta rentable ni eficiente. El conocimiento profundo de los factores que influyen en la latencia y germinación de las semillas permitirá desarrollar herramientas que mejoren la propagación de plantas de kiwi, tanto a partir de semillas como de estacas.

El kiwi, al ser un fruto climatérico, experimenta cambios sensoriales significativos durante su proceso de maduración, lo cual afecta la calidad percibida por los consumidores y su satisfacción. Aunque en el mercado global ya se ha consolidado, su consumo en México aún es limitado y su aceptación está sujeta a factores económicos, culturales y políticos del contexto en el que se introduce (Nolasco-Matías et al., 2020). La evaluación sensorial es una herramienta en el proceso de posicionamiento del kiwi en el mercado, pues permite identificar las preferencias del consumidor y ajustar las características del producto para maximizar su aceptación (Ramírez-Navas, 2012).

La creciente popularidad del kiwi, junto con sus beneficios nutracéuticos y su potencial de adaptación a las condiciones agroclimáticas mexicanas, justifica la necesidad de profundizar en estudios científicos y técnicos sobre su cultivo, germinación, propagación y aprovechamiento en el país. Estos esfuerzos contribuirían a diversificar la economía local, avanzando hacia una mayor soberanía alimentaria mediante la reducción de importaciones y la creación de alternativas de ingreso para las familias en zonas de trópico de altura.

Con el propósito de analizar el potencial agronómico, nutracéutico y sensorial del cultivo de kiwi en la región del trópico de altura de México, específicamente en Huatusco, Veracruz. Se plantearon varios objetivos que se desarrollaron en capítulos específicos, integrando diferentes áreas de investigación, los cuales fueron:

Capítulo 1: Caracterización edafoclimática de la región de estudio:
En este capítulo, se analizaron las condiciones ambientales y del suelo que impactan la adaptación del kiwi. Variables como la temperatura, humedad relativa, acumulación de horas frío, porcentaje de brotación y propiedades fisicoquímicas del suelo fueron estudiadas para determinar su influencia en el desarrollo y productividad de esta especie.

Capítulo 2: Optimización del proceso de germinación:
La germinación de semillas de kiwi enfrenta desafíos relacionados con la latencia. Este capítulo abordó la implementación de técnicas como la estratificación y la aplicación de

ácido giberélico en diferentes concentraciones para superar estas barreras, mejorando así la emergencia de plántulas.

Capítulo 3: Evaluación de perfiles fitoquímicos:
Este apartado se centró en el análisis de los frutos del kiwi, evaluando compuestos nutracéuticos de interés, tales como antioxidantes, fenoles, flavonoides, contenido mineral y ácidos orgánicos. Este análisis busca resaltar el valor nutricional y funcional del cultivo en el contexto mexicano. Asimismo, se analizó las propiedades fitoquímicas de las hojas del kiwi y la influencia de los métodos de secado sobre estos.

Capítulo 4: Análisis sensorial del fruto:
La aceptabilidad del kiwi 'GoldenRouge' fue estudiada mediante pruebas sensoriales que incluyeron parámetros como sabor, textura, astringencia entre otros y comparada con el kiwi comercial 'Sungold', los resultados obtenidos permitieron identificar las preferencias del consumidor.

A través de estos capítulos, el estudio establece una base científica y técnica que respalda la introducción y desarrollo del cultivo de kiwi en México, impulsando su aprovechamiento en la región del trópico de altura.

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Agro-Divulgación

Colegio de Postgraduados

2. Producción de kiwi (*Actinidia chinensis*) como contribución a la soberanía alimentaria frutícolade México

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2.1. Problema

El kiwi es un fruto cosechado de lianas caducifolias nativas de algunas zonas templadas de China. Es un fruto con alto contenido en antioxidantes, fibra y vitaminas, y muy apreciado en el mundo. En México, la producción comercial de kiwi es casi nula, satisfaciendo la demanda con frutos de importación procedentes de Chile, Estados Unidos de América, Italia, y Nueva Zelanda, y por esta razón es uno de los frutos más costosos en los mercados de México. El kilogramo de fruta alcanza un valor entre $60 y $130 pesos (USD $ 3.0 a 6.0), factor que limita su consumo. Las principales variedades de kiwi que México importa son el de tonalidad verde (*Actinidia chinensis* var. deliciosa) y la dorada (*Actinidia chinensis* var. chinensis). Producir kiwi en México es una aportación a la soberanía agroalimentaria de frutas al reducir su importación y con costos más accesibles al mercado mexicano. El kiwi necesita cumplir de 700 a 900 horas inferiores a los 4 °C para estimular la floración, por lo que se ha intentado cultivar en zonas templadas de Michoacán, Aguascalientes, Estado de México, y Jalisco. Sin embargo, no existen documentos indicando si el cultivo ha sido exitoso. La información científica sobre su cultivo en México es limitada.

Se han seleccionado varios individuos a partir de semilla que se han adaptado exitosamente a una zona de clima tropical de altura en Veracruz, estos kiwis son del tipo verde y amarillo en cuanto a su forma y color de pulpa, y presentan buen sabor en comparación con los kiwis importados. Su tamaño es ligeramente menor al kiwi proveniente de Nueva Zelanda. La producción de kiwi en México contribuiría diversificar la economía local y fortalecer la soberanía alimentaria al reducir su importación.

Cómo citar: Cruz-Castillo, J. G., Reina-García, J. D., Guerra-Ramírez, D., Almaguer-Vargas G., & Castañeda-Vildózola, A. (2022). Producción de kiwi (*Actinidia chinensis*) como contribución a la soberanía alimentaria frutícola de México. *Agro-Divulgación*, 2(4).

Editores académicos: Dra. Ma. de Lourdes C. Arévalo Galarza y Dr. Jorge Cadena Iñiguez.

Agro-Divulgación, 2(4). Julio-Agosto. 2022. pp: 59-61.

2.2. Solución planteada

En otros países, han sido seleccionados cultivares de kiwi generados a partir de semilla que se han adaptado a condiciones climáticas particulares. Por ejemplo, en Estados Unidos la variedad de *A. chinensis* var. deliciosa 'AU Fitzgerald', y en Italia la variedad de *A. chinensis* var. chinensis 'Soreli'. Usando esta metodología, se han seleccionado a partir de semillas de *Actinidia* spp. y se han adaptado a una zona tropical de altura en Veracruz a 1900 m. Algunas características de los frutos se aprecian en la Figura 1. La producción comercial de kiwi – diversificaría la producción frutícola de México y en un futuro poder reducir las importaciones de kiwi, así como propiciar su consumo a personas de bajos recursos económicos al ser cultivados en zonas tropicales de altura en países de Mesoamérica donde la producción de kiwi es inexistente.

En un estudio de evaluación sensorial llevado a cabo en México, la aceptabilidad global para el kiwi producido en el estado de Veracruz fue adecuada superando a la guayaba y a la carambola. En general, los sólidos solubles totales y su capacidad antioxidante son parecidos a los frutos importados. Históricamente en todas las regiones del mundo donde el cultivo del kiwi llega el contexto socioeconómico mejora. Parcelas de kiwi para pequeños productores o su cultivo en traspatio ayudarían en mucho a la economía y alimentación familiar. Los kiwis se encuentran establecidos en una zona tropical de altura a 1900 m de altura sobre suelos ácidos, en esta zona crecen otros frutales como la chirimoya, el durazno, la pera y el ciruelo. Plantas de estos individuos se encuentran a disposición en el Centro Regional Universitario Oriente de la Universidad Autónoma Chapingo en Huatusco, Veracruz.

2.3. Retribución social

Plantas de kiwi se encuentran a disposición para productores asociados en el Centro Regional Universitario Oriente de la Universidad Autónoma Chapingo en Huatusco, Veracruz, México.

Figura 1. Apariencia externa e interna de frutos de kiwi adaptados a las condiciones de Veracruz, México, realizando la selección a partir de semilla: a) Selección de kiwi verde similar al cultivar Hayward; b) Selección de kiwi verdoso, proveniente de planta femenina c) kiwi tonalidad amarilla procedente de plantas hermafroditas.

2.4. IMPACTOS E INDICADORES

Nivel de Innovación	Descripción	Transferido	Impacto		Indicador General de Políticas Públicas	Indicadores Específicos	Subindicador
			Sector	**Ámbito**			
Incremental	Busca mejorar los sistemas que ya existen haciéndolos mejores, más rápidos, más baratos, etc.	Asociaciones de Productores Gobierno de los Estados Productores independientes Comunidades Agrarias	Primario: Agricultura, Ganadería, Pesca, Explotación forestal, Minería Cuaternario: Procesos de Investigación, Desarrollo e Innovación (I+D+I)	Social Económico Ambiental Conocimiento	Ciencia y Tecnología Económico Responsabilidad Ambiental	Competitividad Comercio Generación de empleos Capacitación	Número de publicaciones Transferencias tecnológicas Desarrollo de productos y servicios para la sociedad Exportación incremento (%) Aplicación de técnicas y conocimientos tecnológicos para el desarrollo social y económico
Modelo de negocio	Creación o reinvención de un negocio						
Innovación sostenible	Desarrollo de productos y procesos que contribuyen al desarrollo sostenible						
Innovación frugal	Hacer más con menos. Idear estrategias de bajo costo para sortear las complejidades institucionales o limitaciones de recursos, conseguir innovar, desarrollar y entregar productos y servicios a los usuarios de bajos ingresos con poco poder adquisitivo						

3. Kiwifruit production in a tropical highland of Mexico-soil and climate

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3.1. Abstract

There is little information regarding kiwifruit production in the tropics. Green and yellow-fleshed kiwifruit (*Actinidia chinensis*) are deciduous climbing shrubs that grow well in temperate countries and blooming requires between 300-900 chilling hours (CH) below 4°C. In the tropical highlands during winter there are days with temperatures of about 28°C and selected kiwifruit vines originated from seeds attain 50% of natural bud burst, producing good quality fruit. The kiwifruit orchards are at 1848 m of altitude, and close to the kiwifruit orchards at 900–1300 m of altitude coffee beans (*Coffea arabica*) are produced. The objectives of this study were to show that kiwifruit would be produced in the tropics and that is an alternative to small producers with low income. c Most of the kiwifruit consumed in Mexico is imported and it is expensive for people with low economic input. The production of selected kiwifruit vines in tropical highland conditions of Mesoamerica could initiate new business for small farmers and currently is a new strategy for farmers to diversify their diet and economy. Kiwifruit growth information out of traditional areas of production is valuable due to the consequences of climate change.

Keywords: New production areas, new cultivars, rural development, small farmers

3.2. INTRODUCTION

Kiwifruit is a valuable food in the world market due to its good flavor and high content of antioxidants, fiber, and vitamins. In Mexico, kiwifruit production is almost nil, its demand is satisfied with fruits imported from Chile, Italy, New Zealand, and the United States of America, and for this reason, it is one of the most expensive fruits in the Mexican food markets (Cruz-Castillo et al., 2022). It had a good acceptance when it was sensorially compared with guava (*Psidium guajava*), feijoa (*Acca sellowiana*), and the starfruit (*Averrhoa carambola*) (Nolasco- Matías et al., 2020). The consumption competition for kiwifruit is strong with many other fruits that are produced in tropical, subtropical, and temperate zones of Mexico with accessible prices for all Mexicans.

The kiwifruit price fluctuates over the year, and the most expensive kiwifruit comes from New Zealand which shows the highest quality in comparison with the imported kiwifruit from other countries. In 2022, the price per kg ranged between 60 and 130 Mexican pesos or

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3.0 to 6.0 USA dollars. In contrast, the price of 1 kg of papaya (*Carica papaya*) or pineapple (*Ananas comosus*) is about 1.70 USA dollars or less. This indicates that their consumption is directly influenced by the per capita socioeconomic level, i.e., people with low incomes will have greater difficulty in accessing these products, thus decreasing their consumption. A similar situation occurs in Guatemala, Colombia, and other countries in Latin America where green and yellow kiwifruit is not produced.

Kiwifruit growth occurs in areas with agroclimatic conditions with an accumulation of 700-900 hours below 4°C to stimulate flowering (Wall et al., 2008). Likewise, the vines grow in relative humidity between 70-80%, and their adequate soils are deep and present pH between 6-7, with electrical conductivity 1.2 mS/cm, good drainage capacity, and high organic matter (Garcia, 2015). The establishment of ´Hayward´ kiwifruit orchards in Mexico has not been easy. Unsuccessful efforts have been made in the temperate zones of Michoacán, Aguascalientes, Estado de México, and Jalisco (Cruz-Castillo et al., 2022). It seems the main failure was the lack of satisfactory chilling hours for bud sprouting of the 'Hayward´ vines.

There is limited information on the success of this fruit crop in Mexico. Several years ago, individuals were selected from seeds that successfully adapted to a tropical highland in Veracruz, Mexico. These vines produce fruit of green, yellow, and green-yellow types. The size of the fruit is slightly smaller than those imported from New Zealand. However, its flavor and nutraceutical content are comparable (Guerra-Ramírez et al., 2021).

The studies on the adaptation of this species in tropical areas of the world have been few (Pichakum et al., 2018). The selection of kiwifruit varieties with low CH requirements has been the solution in these countries (Zhao et al., 2017), but these varieties have not been evaluated in Mexico. The kiwifruit production in Mexico could contribute to the diversification of the local economy and strengthen food sovereignty by reducing its importation (Cruz-Castillo et al., 2022).

Therefore, the purpose of this study was to show the adaptation of yellow-fleshed kiwifruit type to tropical highland conditions in Mexico considering edaphoclimatic variables.

3.3. MATERIALS AND METHOD

3.3.1. Characteristics of the study area

The study was conducted in the community of Elotepec in the municipality of Huatusco in the state of Veracruz, Mexico, which is located at an altitude of 1851 m, and at latitude 19° 11' 21 north and longitude 97°01' 59' west, during the period 2021-2023.

According to Köppen's climatic regime classification, the climate of the community is semi-warm A (c) (fm), with an annual average temperature of 18 to 20°C, where the temperature of the coldest month varies from -3 to 18°C. The minimum extreme temperature is 2 to -6°C and the maximum extreme temperature is 27 to 31°C, with an annual oscillation of 5 to 7°C.

The annual precipitation is 2000 to 2500 mm, distributed over more than 150 days a year. There are frosts in winter and the number of days they occur is 10 to 20, and the number of cloudy days per year is 150 to 200 (Gómez, 1993).

3.3.2. Plant material

The orchard has yellow-fleshed kiwifruit vines that are 3 to 5 years old and are harvested from August to October, with September being the month of the heaviest harvest. They originated from seeds of the yellow-fresh 'Jintao' kiwifruit (Cipriani and Testolin, 2007).

3.3.3. Temperature record

Daily day and night temperatures were recorded from November 2021 to March 2022. An Extech USB Datalogger sensor model RHT10 was used and located inside the vine at a height of 1.40 m with a recording frequency of every hour.

3.3.4. Quantification of chilling hours

With the recording of hourly temperatures, the quantification of chilling hours in the dormancy period was carried out through the use of the mathematical model of Da Mota (1957) cited by Rodríguez et al. (1983) and Elox et al. (1989). This model consists of the application of a simple linear regression equation that relates the chilling hours as a dependent variable, with the monthly average temperature values of the locality mentioned for November, December, January, and February separately, the accumulated chilling hours per year were obtained with the summation of those obtained for each of the previous months (Cervantes et al., 2004). The equation is referred as follows:

$$MCH = 485.1 - 28.52\ T$$

Where: MCH = Monthly chilling hours

- T = Monthly average temperature for November, December, January, and February.
- 485.1= intercept of the regression line with the Y's axis.
- -28.52 = slope of the regression line.

3.3.5. Budburst

Sprouting is understood as the process by which the plant breaks its rest and activates its metabolic processes, consequently, the swelling of the vegetative buds of the branches is observed, which later transform into a cluster of completely open leaves (open cluster) (Brundell, 1975).

This attribute was measured at three different times, on the fourteenth day of each month (February, march, and April) of 2023 on five randomly selected branches of approximately 1 m in length (Cruz-Castillo et al., 1997). The total number of buds per branch was evaluated and the % budburst was determined. A budburst classification by Brundell (1975) was considered: budburst, and advanced open cluster.

3.3.6. Soil chemical characterization

3.3.6.1. Soil sampling

Samples were taken in 5 different locations within the orchard, at a distance of 1.5 m from the kiwifruit plants at a depth of 0.3 m, with a superficial cleaning of the residues of plant debris. After the samples were taken, the analysis was carried out at Nutre Lab in Texcoco, State of Mexico, Mexico.

3.3.6.2. Soil analysis

The pH was determined with a soil-water ratio potentiometer 1:2. The organic matter (%O.M.) was by the Walkley and Black method (1934). The N, P, and K contents were extracted by the 1N potassium chloride method and determined by vapor entrainment by the Olsen (1965) method, and finally with 1N ammonium acetate, pH 7, ratio 1:20, and determined by flame emission spectrophotometry. The Ca and Mg contents were extracted with 1 N ammonium acetate, pH 7, ratio 1:20, and determined by atomic absorption spectrophotometry.

3.4. RESULTS AND DISCUSSION

3.4.1. Edaphoclimatic conditions in the tropical highland

The data obtained from the datalogger in the winter period of 2021 (November-December) and early 2022 (January-February) are shown in Table 1.

February was the coldest month, and according to the Papadakis climate classification (Esfandiari et al., 2017), the winter where the kiwifruit orchards are established was tropical. This is because the mean absolute minimum temperatures of the coldest month were higher than 7°C and lower than 15°C. In addition, based on the Köppen classification, the climate is a Cfa (humid subtropical-mid-latitude climate), given that during the rest of the year average temperatures between 15 and 18°C were recorded in the warmest months (March-September).

Table 1.Winter temperatures (°C) in the tropical highland of Huatusco, Veracruz, Mexico, in 2021–2022.

Year	Month	MT	AMT	AMMT	AMxMT	AMxT
2021	November	13.2	4.2	8.3	18.5	21.5
	December	14	5.2	8.4	21.2	27.9
2022	January	12.6	5.7	8.4	13.4	27
	February	12.6	4.4	7.7	18.8	28.1

MT: mean temperature; AMT: absolute minimum temperature; AMMT: absolute minimum mean temperature; AMxMT: absolute maximum mean temperature; AMxT: absolute maximum temperature.

3.4.2. Quantification of chilling hours

There was an accumulation of 443 CH with the mathematical model of Da Mota (1957) (Table 2). Other models consider negative CH with temperatures higher than 12°C in winter (Luedeling & Brown, 2011), and 15.6°C in summer (Richardson et al., 1974). Therefore, additional CH models could be tested.

Table 2. Quantification of cold hours with Da Mota's model using average temperatures for the months of November-February for the period 2021-2022.

Year	Month	Mean T (°C)	Da Mota (HF)
2021	November	13.2	109.2
	December	14	84.2
2022	January	12.6	125.6
	February	12.6	124.9
	∑	-	443

Wang et al. (2017) classified the different kiwifruit varieties into three categories based on their chilling requirements. *A. chinensis* (yellow flesh) varieties (‘Hort16A’ and ‘Hongyang’) integrated category 1 and are those that require the least amount of CH (<600h). The varieties of *A. deliciosa* (green flesh) (‘Jinkui’, ‘Jinfeng’, XX-128), conformed the category 3 and are those that demand a greater accumulation of cold (>713 h). Thus, the kiwifruit orchards studied are category 1 and also share the characteristic of yellow pulp color.

The budburst was 71% in February, and the advanced open cluster was 42% in April. Brundell (1975) recorded 55.5% (Figure 1) and Cruz-Castillo et al. (1997) 58% of budburst in New Zealand with green kiwifruit.

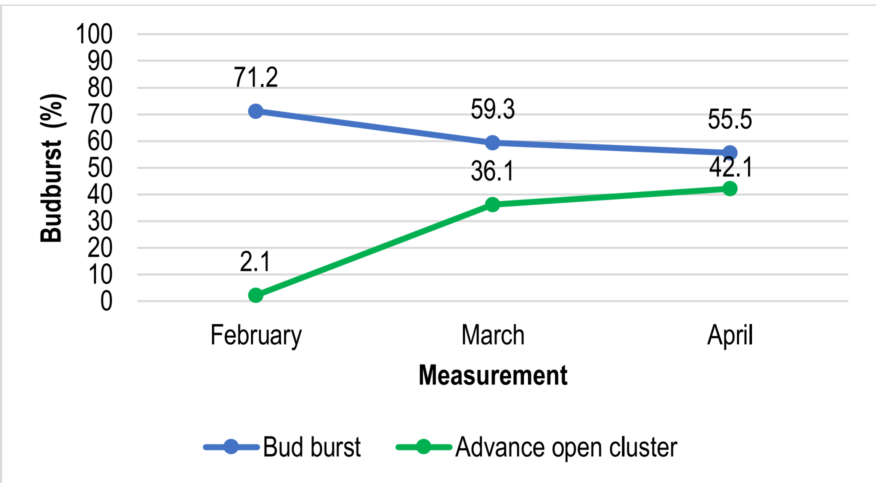

Figure 1. Figure 1. Budburst of A. chinensis plants in the period February-April of 2022 in Huatusco, Mexico.

It seems that the tropical highland area where the kiwifruit orchards are established has good conditions for the good bud development of this species. Risks of early and late frosts are reduced but hails sometimes occur. The summers are not very hot, with frequent rains to maintain a high relative humidity. Although this species can withstand extreme temperatures below 0°C (García et al., 2015), the absolute minimum temperature was 4°C in the winter period.

In winter, most of the leaves are dropped (Figure 2A), and budburst initiates in February (Figure 2A,B), and the development of the leaves is observed in April (Figure 2C).

Figure 2. Bud sprouting behavior of kiwifruit emerging from dormancy. A: plants emerging from dormancy after the winter period; B: budburst; C: bud in advanced open state

3.4.3. Soil properties

The chemical properties analyzed from the soil samples showed lower than expected values for phosphorus (3.4 ppm), potassium (82 ppm) and electrical conductivity (0.03 dS-m-1). Its bulk density (0.81 g cm^{-3}) determined that the soil is of volcanic origin with high levels of carbon and organic matter 6.95% and 12% respectively, and an optimum available nitrogen content (34.5 ppm) (Muñoz, 1978) (Table 3). Kiwifruit vines grow in moderately acid soils (pH= 5.3) typical of humid regions and a high cation exchange capacity (23 cmol (+) kg^{-1}). However, with applications of correctors or agricultural amendments, it is possible to obtain the ideal pH, which is between 6-7 (García et al., 2015).

Table 3.Physicochemical analysis of soil samples obtained from the orchard.

Samples	C.E. (dS m^{-1})	PH	(mg kg^{-1})					(t m^{-3})	Cmol(+) kg^{-1}	%CO	%MO
			N	P	K	Ca	Mg	DA	CIC		
Huerta-Elotepec	0.03	5.3	34.5	3.4	82	192.3	77	0.81	23.1	6.95	11.98

C.E: electrical conductivity; DA: Apparent density; CIC: Cation exchange capacity; CO: Organic carbon; MO: Organic matter

Despite the low content of some nutrients, this is not a limiting factor for kiwifruit production in this area. Each harvest has yielded fruits of moderate size, between 70 and 90 g, somewhat small compared to those imported from other countries, which can weigh between 150–170 g (Figure 3). In terms of phytochemical quality (Guerra-Ramírez et al., 2021), fruits from the Mexican tropical highlands have good results.

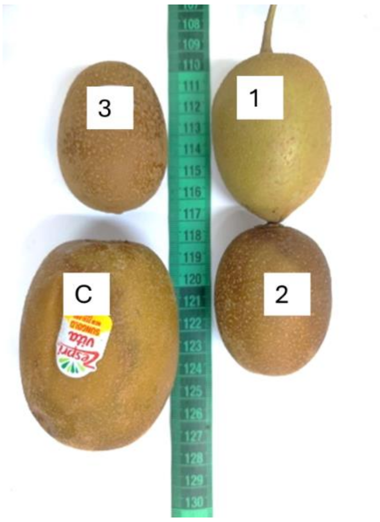

Figure 3. Size comparison of kiwifruit produced in a tropical highland in Mexico with respect to imported fruit. Fruits 1–3: kiwifruit from Mexico. C: imported fruit.

3.5. CONCLUSION

The edaphoclimatic conditions in Huatusco-Veracruz, Mexico, determined that yellow-fleshed kiwifruit production is possible in the tropical highlands. The low levels of some chemical properties of the soil found are not a limiting factor and can be corrected with soil amendments and pH correctors. The orchards had a climate with cool temperatures in summer, spring, and autumn without the risk of early and late frosts. Rainfall was frequent and the relative humidity was high. The kiwifruit vines do not attain a great accumulation of desirable cold hours but produce well. Kiwifruit production in Mexico will help smaller producers with low economic input. Climatic change makes our study relevant because it is possible to produce kiwifruit in areas that were not normally considered.

3.6. ACKNOWLEDGMENTS

We thank the National Council for the Humanities, Sciences, and Technologies (CONAHCyT) of Mexico for the Ph.D. scholarship of J.D. Reina-García, and the Autonomous University Chapingo for the project 23170-C-87.

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4. GIBBERELLIC ACID AND STRATIFICATION AS GERMINATION STIMULANTS FOR YELLOW KIWI SEEDS

ACIDO GIBERELICO Y ESTRATIFICACION COMO ESTIMULANTES DE LA GERMINACIÓN DE SEMILLAS DE KIWI AMARILLO

Jhusua David Reina-García[1*]; Juan Guillermo Cruz-Castillo[2]; Gustavo Almaguer-Vargas[3]; Diana Guerra-Ramírez[4]; Álvaro Castañeda-Vildozola[5]

4.1. ABSTRACT

The kiwi is a deciduous fruit tree of the Actinidiaceae family. Its industry is nascent in Mexico, and thus, it is necessary to introduce new kiwi cultivars with different colored and flavored pulp to the national market. To achieve this, a population of plants from seeds must be available; however, these exhibit dormancy and low germination rates. The objective of this study was to evaluate pre-germination treatments to stimulate germination. Treatments were established in a completely randomized design with a factorial arrangement, evaluating: one level of stratification (4 °C) for one month, 24-hour immersion in four concentrations of gibberellic acid (GA_3) [1000, 2000, 4000, and 6000 ppm] and one in water, as well as three levels of constant temperature (25, 30 and 35 °C) for 68 days. 50 seeds were assigned to each experimental unit, with three repetitions conducted simultaneously. The evaluated variables of germination percentage (GP), mean germination rate (MGR), mean germination time (MGT), and days to latency (DL) were subjected to an ANOVA and Tukey's mean comparison test ($P \leq 0.05$). Significant differences were found for all studied variables except the MGT treatment. The triple interaction of factors enhanced the germination capacity of kiwi seeds, yielding favorable results at 25 °C combined with any studied dose of GAs, as it shortened the days to latency (DL) and increased GP and MGR. Increasing the constant temperature (>30 °C) negatively affected these variables.

Keywords: deciduous, stimulation, latency, temperature

4.2. RESUMEN

El kiwi es un frutal caducifolio de la familia Actinidiaceae, su industria es incipiente en México y, por ende, se necesita introducir nuevos cultivares de kiwi con pulpa de diferentes colores y sabores al mercado nacional. Para lograrlo, se debe disponer de una población de plantas a partir de semillas, sin embargo, estas presentan latencia y una baja germinación. El objetivo del presente estudio fue evaluar tratamientos pre-germinativos para estimular su germinación. Se establecieron tratamientos dispuestos en un diseño completamente al azar con arreglo factorial donde se evaluaron: un nivel de estratificación (4 °C) durante un mes, inmersión de 24 h en cuatro concentraciones de ácido giberélico (AG_3) [1000, 2000, 4000 y 6000 ppm] y uno en agua, además tres niveles de temperatura constante (25, 30 y 35 °C) durante 68 días; 50 semillas se asignaron a cada unidad experimental, se repitieron tres veces en forma simultánea. Las variables evaluadas de porcentaje de germinación (PG), velocidad media de germinación (VMG), tiempo medio de germinación (TMG) y días a latencia (DL) fueron sometidas a un ANOVA y comparación de medias Tukey ($P \leq 0.05$). Se encontraron diferencias significativas para todas las variables en

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estudio a excepción del tratamiento TMG, la triple interacción de los factores potencializó la capacidad de germinación de las semillas de kiwi, obteniéndose resultados favorables a 25 °C combinado con cualquier dosis de AG_3 estudiada, ya que permitió acortar los días a latencia (DL) y aumentar la PG y VMG**.** El aumento de la temperatura constante (>30 °C), influyó negativamente sobre estas variables.

Palabras clave: caducifolio, estimulación, latencia, temperatura

4.3. INTRODUCTION

The kiwi (*Actinidia chinensis* var chinensis) of the Actinidiaceae family is a deciduous and perennial vine belonging to the genus Actinidia (Windauer et al. 2016). The industry for this fruit in Mexico is nascent, and therefore, it is necessary to introduce new cultivars with different colored and flavored pulp to the national market (Maghdouri et al. 2021). Its conventional or commercial propagation is through grafting, where the rootstock is obtained from plants grown from seeds. However, the presence of dormant embryos increases seed population losses and hinders the uniformity in seedling growth (Maghdouri et al. 2021).

The presence of dormant embryos results in a low germination rate; consequently, it is necessary to subject the seeds to favorable conditions such as alternating day and night temperatures and exogenous applications of chemicals to stimulate or improve the germination percentage of the seeds.

Applications of GAs (gibberellins) are key in controlling the promotion or induction of seed germination in various plant species (Tigabú and Odén 2001). Among other effects, they induce the breaking of dormancy after imbibition, help reduce the environmental requirements (chilling hours, light and/or temperature conditions, etc.) necessary for germination, and counteract the effects of other plant hormones like abscisic acid (ABA), thereby allowing the embryo to germinate and grow (Siobhan and McCourt 2003). Hormonal treatments applied to kiwi to break dormancy have consisted of using GA_3 at different concentrations, generally for 24 hours before incubation (Sekhukhune et al. 2016).

Bishwas et al. (2018) investigated the germination response of three kiwi varieties (Abbot, Allison, Bruno) that were pretreated with 2000, 4000, and 6000 ppm of GAs and observed a significantly higher germination percentage in Bruno (68.67%), followed by Allison (47.33%) pretreated with 6000 ppm of GAs. Bruno also had the fastest average germination rate (0.059 seeds day^-1) and time (17 days).

Seeds of two kiwi species (*A. arguta* and *A. chinensis*) were stratified at 4°C for 28 and 42 days and germinated using GAs (500, 1000, 1500, 2000, and 2500 ppm) (Sekhukhune et al. 2018).

Seeds stratified in cold for 28 days produced only 8% and 20% germination in A. arguta and A. chinensis, respectively. Cold stratification (28 days) followed by GAs treatments of A. arguta resulted in optimal germination (88%) in 23 days of optimal mean germination time at GAs concentrations of 1435 and 1610 ppm, respectively. The same combined treatment of *A. chinensis* seeds produced an optimal germination percentage of 80% and an optimal mean germination time of 25 days at GAs concentrations of 1565 and 2050 ppm, respectively (Kumar et al. 2020).

According to these antecedents, the objective of this work was to determine which pre-emergent treatment most effectively stimulates the germination process in kiwi (*Actinidia chinensis* var chinensis) seeds from the municipality of Huatusco-Veracruz. Different concentrations of 24-hour immersion in gibberellic acid [1000, 2000, 3000, and 4000 ppm] were evaluated, combined with constant temperatures (25, 30 and 35 °C) and a stratification period of 31 days at 4 °C.

4.4. MATERIALS AND METHODS

4.4.1. Study Area

The study was conducted in the seed laboratory of the Department of Phytotechnology at the Universidad Autónoma Chapingo, Mexico, located at 19°51᾽ N latitude and 98°88᾽ W longitude, and an altitude of 2377 meters above sea level (masl), during the winter of 2022-2023.

4.4.2. Seed Acquisition

Kiwi seeds (*A. chinensis* var chinensis) from ripe, yellow-fleshed fruits were used, obtained from the community of Elotepec in the municipality of Huatusco in the state of Veracruz, which is located at an altitude of 1851 meters above sea level and at 19°11'21" N latitude and 97°01'59" W longitude, in the fall of 2022.

The extraction process involved cutting the fruits in half (70 to 90 g each one) and extracting the seeds along with the pulp, which were then placed in plastic cups for three days for the fermentation process, which facilitated the removal of the pulp. Finally, the seeds were washed with distilled water, placed on napkins to dry in the shade, and stored in paper envelopes at room temperature (González-Puelles et al. 2018).

4.4.3. Experimental Design

The treatments were arranged in a completely randomized design with a factorial arrangement (1x4x3). 50 seeds were assigned to each experimental unit, and the experiments were repeated three times simultaneously. The methods evaluated for the germination process are indicated in Table 1.

Table 1.Description of pre-germination treatments for kiwi seeds

T	Cold Stratification (°C)	AGA [ppm]	Immersion Time (h)	Constant Temperature (°C)
1	4°C for 31 days	0	24	25±2
2				30±2
3				35±2
4		1000	24	25±2
5				30±2
6				35±2
7		2000	24	25±2
8				30±2
9				35±2

10			25±2
11	4000	24	30±2
12			35±2
13			25±2
14	6000	24	30±2
15			35±2

T: Treatments; AGA: Application of gibberellic acid

4.4.4. Stratification Method

Prior to the processes of scarification with gibberellic acid and disinfection, all seeds were stored in a cold room at 4 °C for 31 days.

4.4.5. Disinfection Process

After stratification at 4 °C for 31 days, the seeds were immersed in 70% ethanol for one minute, then in a 1% sodium hypochlorite solution for five minutes, and finally, they underwent four rinses with distilled water (Zhang et al. 2018).

4.4.6. Experimental Management

After the stratification and disinfection stage, the seeds were treated with gibberellic acid applications at different concentrations, then rinsed thoroughly with distilled water. Finally, 50 seeds were placed in each Petri dish (100 mm diameter) on moist filter paper and kept in darkness for five days in germination chambers (SEEDBURO brand) at constant temperatures of 25±2 °C, 30±2 °C, and 35±2 °C. They were moistened daily with distilled water (from three to 13 mL as the seeds germinated) throughout the experiment's duration.

4.4.7. Evaluated Variables

Seed germination was visually estimated every two days, up to 68 days after sowing, as no further seeds germinated after day 57. From this data, the following variables were determined:

-Germination Percentage (GP) = Number of germinated seeds / total number of seeds, expressed as (%) (Maghdouri et al., 2021).

$$PG= \frac{ni}{N} X\ 100\%$$

Where:

ni = Number of germinated seeds
N= Total number of seeds

-Mean Germination Rate (MGR) = Expressed as germinated seeds per day (seeds day-1) (Sharma et al. 2021).

-Mean Germination Time (MGT) = The time elapsed in days from when the seeds are sown until 50% of the germinated seeds are reached (Sharma et al. 2021).

$$MGT = \frac{\sum ni * di}{N}$$

Where:

ni: Number of seeds germinated on day ddd.
di: Number of days since the start of the germination trial.
N: Total number of germinated seeds by the end of the trial.

-Days to Latency (DL): The number of days elapsed between sowing and the start of germination of the first seed (Bishwas et al. 2018).

4.4.8. Statistical Analysis

After evaluations, the germination percentage (GP), mean germination rate (MGR), mean germination time (MGT), and days to latency (DL) were calculated. The response variables PG and VMG were square root transformed due to non-normal distribution as per the Shapiro-Wilks test ($P \leq 0.05$). An ANOVA and Tukey's multiple comparison test were conducted with a 95% confidence level using the statistical software Infostat version 2020 (Di Rienzo et al. 2020).

4.5. RESULTS AND DISCUSSION

According to the mean comparisons, significant differences were found for all variables under study except for the TMG treatment, indicating differential responses of kiwi seeds to each constant temperature level (25, 30 and 35 °C) used in the incubation. Complete inhibition of germination was observed at 35 °C (Table 2).

Table 2. Comparison of means of germination percentage (GP), mean germination rate (MGR), mean germination time (MGT), and days to latency (DL) in kiwi seeds subjected to different temperatures.

Temperature (°C)	GP	MGR	DL (days)	MGT
25	5.96 A	0.54 A	7.2 A	42.5 A
30	4.52 B	0.30 B	12 B	39.5 A
HSD	0.65	0.11	2.34	4.6

Different letters between treatments denote significant differences (Tukey test, $P \leq 0.05$); HSD: honestly significant difference

It was demonstrated that seeds subjected to 25 °C for the 68 days of incubation achieved the highest GP and MGR (5.96 and 0.54 seeds germinated per day, respectively) and germinated in the shortest time (DL = 7.2 days). This duration is shorter than those reported by Sale (1985), Gao et al. (1984), Kim et al. (1988), and Celik et al. (2006).

When analyzing temperature as an independent factor, it is determined that once the seed tissues have rehydrated at constant temperatures of 25 °C, they better regulate the speed of biochemical reactions occurring inside the seed to trigger germination (Pérez 2003). Data presented by Celik et al. (2006) reported similar behaviors; as temperatures increase, germination percentage (GP) decreases. Temperatures above 30 °C and 35 °C have a negative effect on these variables.

On the other hand, various studies have demonstrated that the exogenous application of gibberellic acid in pre-germination treatments has positive effects on germination in kiwi seeds (Celik et al. 2006; Ahmad 2010; Zhang et al. 2018; Bishwas et al. 2018). However, although it is considered a stimulator in the germination process for this species and others, it was found that there were no significant differences among the evaluated variables subjected to different concentrations (Table 3). This indicates that the concentrations used in the study have the same capacity to effectively break seed dormancy in kiwi and significantly increase germination rates compared to the control, where the values obtained were zero.

Table 3. Comparison of means for the variables germination percentage (GP), mean germination rate (MGR), mean germination time (MGT), and days to latency (DL) in kiwi seeds subjected to different concentrations of gibberellic acid (GA).

Treatments with GA [ppm]	GP	MGR	DL (days)	MGT
1000	5.24 a	0.42 a	10.3 a	37.5 a
2000	6.63 a	0.50 a	8.7 a	39.2 a
4000	4.63 a	0.30 a	10.8 a	43.5 a
6000	5.45 a	0.45 a	8.8 a	43.8 a
HSD	1.25	0.2	4.47	8.7

Different letters between treatments denote significant differences (Tukey test, $P \leq 0.05$); HSD: honestly significant difference

Gibberellic acid produces a wide variety of responses in seed development and germination control, making it highly important for inducing dormancy breakage after seed imbibition (Tigabu and Odén 2001). Its effect on seeds is to reduce environmental requirements (chilling hours, light conditions, temperature, etc.) necessary for germination, counteracting the effects of other plant hormones such as abscisic acid (ABA), thus promoting embryo germination and growth (Siobhan and McCourt 2003).

Çelik et al. (2006) concluded that the influence of a single factor in germination studies is not satisfactory. However, when combined or interacting with other factors, germination percentage (GP) increases. Therefore, in the triple interaction of the studied factors, significant differences were observed for all variables except MGT (Table 4).

Table 4.Comparison of means for the variables germination percentage (GP), mean germination rate (MGR), mean germination time (MGT), and days to latency (DL) in kiwi seeds subjected to the triple interaction of the evaluated factors.

T	Descriptión	GP	MGR	DL (days)	MGT
4	4°C+1000 ppm+25°C	6.13 ab	0.62 ab	8.3 ab	38.8 a
5	4°C+1000 ppm+30°C	4.34 b	0.29 ab	12.3 ab	36.2 a
7	4°C+2000 ppm+25°C	6.14 ab	0.58 ab	7.3 ab	38.2 a
8	4°C+2000 ppm+30°C	5.12 ab	0.41 ab	10 ab	40.2 a
10	4°C+4000 ppm+25°C	5.21 ab	0.38 ab	7.6 ab	47.5 a
11	4°C+4000 ppm+30°C	4.06 b	0.22 b	14 b	39.5 a
13	4°C+6000 ppm+25°C	6.35 a	0.56 a	5.6 a	45.5 a
14	4°C+6000 ppm+30°C	4.54 ab	0.27 ab	12 ab	42.2 a

HSD	2.15	0.38	7.65	14.1
CV	14.5	16.44	28.01	12.85

Different letters between treatments denote significant differences (Tukey test, $P \leq 0.05$); HSD: honestly significant difference; CV: coefficient of variatión.

The results of treatments subjected to constant temperatures of 35 °C without gibberellic acid were not included in the tables because no satisfactory germination results were obtained (values were equal to zero). Although studies like Celik et al. (2006) achieved germination rates of 45.3%, 50%, 51.7%, and 48.2% at 35 °C combined with 0, 2000, 4000, and 6000 ppm of gibberellic acid, respectively, this research experienced complete inhibition of the seeds. This indicates that seeds of this kiwi species do not require high temperatures to activate their metabolism.

In contrast, the interaction of constant temperature at 25 °C with different concentrations of gibberellic acid broke dormancy and stimulated germination, increasing from 0% in the control (data not shown) to 40.6% in treatment 13. These findings align with those of Kim et al. (1988), who determined that for other kiwi species like *A. arguta* and *A. kolomikta*, the optimal constant temperature for germination is 20 °C and 25 °C, respectively.

Similarly, Celik et al. (2006) evaluated the interaction of three factors (temperature, growth medium, and GA concentration) on the germination process in Hayward kiwi seeds, observing germination responses across four temperature levels (20, 25, 30 and 35 °C), three types of growth media (peat, perlite + heater humus, and soil mix), and four concentrations of gibberellic acid [0, 2000, 4000 and 6000 ppm]. Seeds treated with 6000 ppm of GAs and sown in peat had the highest germination rate (79%), values much higher than those found in this research (40.6%).

4.6. CONCLUSION

The interaction between stratification methods (4 °C for 31 days), concentrations of gibberellic acid [1000, 2000, 4000, and 6000 ppm], and constant temperatures (25 and 30 °C) enhanced the germination process of kiwi seeds. Favorable results were obtained at 25 °C combined with any GA concentration, which shortened latency days and increased GP and MGR. Additionally, it was determined that temperatures above 30 °C negatively influence these variables.

Consequently, it is recommended to continue these studies evaluating temperatures below 25 °C combined with intermediate concentrations of gibberellic acid [2000 and 4000 ppm] to determine if the interaction of these factors, combined with the stratification method (4 °C for one month), has the potential to further enhance the germination process.

4.7. ACKNOWLEDGMENTS

We would like to express our gratitude to the National Council of Humanities, Science, and Technology (CONAHCyT), to technician Mateo Barrientos Reyes, and at Autonomous Chapingo University for their contributions and support during this experiment.

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5.INFLUENCE OF DRYING METHOD ON THE NUTRACEUTICAL POTENTIAL OF KIWI LEAVES

INFLUENCIA DEL MÉTODO DE SECADO SOBRE EL POTENCIAL NUTRACÉUTICO DE HOJAS DE KIWI

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5.1. ABSTRACT

The kiwi (*Actinidia chinensis*), native to China, is known for the nutritional benefits of its fruit; however, its leaves also provide notable properties for nutrition and are used as additives in food products and traditional Chinese medicine, though their study in Mexico has been limited. This study aimed to evaluate the nutraceutical potential of kiwi leaves collected in Huatusco, Veracruz, Mexico, for possible use in infusions by analyzing the impact of two drying methods (lyophilization and convective drying) on the concentration of phenolic compounds, flavonoids, and antioxidant capacity. Results indicated that both drying methods similarly preserved the antioxidant and nutraceutical properties of the leaves, with no significant differences in phenolic compound content or antioxidant capacity (as measured by FRAP and ABTS assays). However, variations were observed in flavonoid content. These findings suggest that both drying procedures are suitable for maintaining the nutraceutical quality of kiwi leaves, allowing their use in infusions and other nutraceutical products. The choice between lyophilization and convective drying may depend on factors such as cost and resource availability, as both methods effectively retain these compound concentrations.

Keywords: antioxidants capacity, phenols, flavonoids, lyophilization, convective drying

5.2. RESUMEN

El kiwi (*Actinidia chinensis*), originario de China, es conocido por los beneficios nutricionales de su fruto, aunque también se ha demostrado que sus hojas ofrecen propiedades relevantes para la alimentación y son utilizadas como aditivos en productos alimenticios y en la medicina tradicional china, sin embargo, su estudio en México no ha sido relevante. Este estudio tuvo como objetivo evaluar el potencial nutracéutico de las hojas de kiwi recolectadas en Huatusco, Veracruz, México, para su posible uso en infusiones, analizando el impacto de dos métodos de secado (liofilización y secado convectivo) en la concentración de compuestos fenólicos, flavonoides y en su capacidad antioxidante. Los resultados indicaron que ambos métodos de secado preservaron de manera similar las propiedades antioxidantes y nutracéuticas de las hojas, sin diferencias significativas en el contenido de compuestos fenólicos y en la capacidad antioxidante (mediante los ensayos de

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FRAP y ABTS). Sin embargo, se observaron variaciones en el contenido de flavonoides. Estos hallazgos sugieren que ambos procedimientos de secado son adecuados para conservar la calidad nutracéutica de las hojas de kiwi, permitiendo su uso en infusiones y otros productos nutracéuticos. La elección entre liofilización y secado convectivo podría depender de factores como el costo y la disponibilidad de recursos, dado que ambos métodos mantienen de forma efectiva la concentración de estos compuestos**.**

Palabras clave: capacidad antioxidante, fenoles, flavonoides, liofilización, secado por convección

5.3. INTRODUCTION

Kiwi fruit (*Actinidia chinensis*, Actinidiaceae), native to China, has seen a surge in global demand due to its high economic value, exceptional nutritional properties, and health benefits (D'Evoli et al. 2013; He et al. 2019). This fruit offers a combination of attributes that make it a commercially viable and highly productive option, standing out not only for its popularity among berries but also for its refreshing taste, pleasant aroma, and high nutritional and medicinal value. It is especially rich in vitamin C and vitamin K and is a good source of dietary fiber and essential minerals such as potassium, calcium, and phosphorus, while maintaining a low-calorie content (Amit et al. 2020). In Mexico, most kiwi consumed is imported from countries like California, Chile, and New Zealand. However, a kiwi cultivation project has been established in the municipality of Huatusco, Veracruz, aimed at enhancing the local economy of small farmers in this mountainous region (Guerra et al. 2021a). This initiative not only strengthens local production but also provides an opportunity to diversify agriculture and encourage the cultivation of species with high commercial and nutritional value.

To date, abundant information is available on the functional properties of kiwi fruit (Guerra et al. 2021a), but studies on the nutraceutical properties of kiwi leaves have been limited and have primarily focused on species native to China (Xie 1975). Kiwi leaves, however, also represent a potential source of nutraceutical compounds, particularly antioxidants, polyphenols, and flavonoids, which could have applications in the development of functional products, such as infusions and natural supplements. From this perspective, exploring the value of kiwi leaves cultivated in Mexico could open new opportunities in the natural products market, extending the use of this species beyond its fruit and providing economic and health benefits locally.

In this study, the potential of kiwi leaves, collected in Huatusco, Veracruz, Mexico, was determined as a source of nutraceutical compounds for infusion preparation. This was analyzed based on the impact of two drying methods—lyophilization and convective drying—on the total concentration of phenolic compounds, flavonoids, and antioxidant capacity.

5.4. MATERIALS AND METHODS

5.4.1. Study Area

Kiwi leaves (*Actinidia chinensis* var. *chinensis*) were randomly collected in May 2022 in the community of Elotepec in the municipality of Huatusco, Veracruz, Mexico (19°11'20.6'' N, 97°01'59.3'' W, at 1851 meters above sea level (masl)). The crop comes from a rainfed orchard that depends on rainfall patterns.

5.4.2. Plant Material

The kiwi plant (*Actinidia chinensis* var. *chinensis*) is a climbing vine with deciduous, heart-shaped leaves that have large, dentate laminae with serrated edges. The upper surface is dark green and nearly glabrous, while the underside is paler and densely tomentose, covered with very short hairs (Rubio et al. 2015).

The three-year-old kiwi vines were cultivated under similar soil and climate conditions and maintained as a rainfed crop with an average annual rainfall of 1800 mm.

5.4.3. Chemical Reagents and Instrumentation

The reagents used were phenol, sulfuric acid, glucose; DNS reagent (3,5-dinitrosalicylic acid); sodium potassium tartrate tetrahydrate ($C_4H_4KNaO_6 \cdot 4H_2O$); sodium carbonate (Na_2CO_3), Folin-Ciocalteu reagent, gallic acid; sodium nitrite ($NaNO_2$), catechin, aluminum chloride hexahydrate ($AlCl_3 \cdot 6H_2O$), sodium hydroxide (NaOH), TPTZ (2,4,6-tris(2-pyridyl)-s-triazine), iron (III) chloride hexahydrate ($FeCl_3 \cdot 6H_2O$), and 6-hydroxy-2,5,7,8-tetramethylchromane-2-carboxylic acid (Trolox). These were obtained from Sigma-Aldrich (St. Louis, Missouri, USA), except for aluminum chloride and potassium acetate, which were sourced from Fermont S.A. de C.V. and Meyer S.A. de C.V., Mexico, respectively.

The instruments used included a pH meter (Thermo Orion Model 420+); dehydrator (Sedona, model SD-P9000-F, with a digital temperature selector from 30°C to 68°C); freeze dryer (LABCONCO); vortex mixer (Synergy, WVR International); sonicator (8890, Cole-Parmer, Vernon Hills, USA); orbital shaking incubator (Prendo, INO-650M); centrifuge (OHAUS, FC5718R); and a Synergy 2 microplate spectrophotometer equipped with Gen5 data analysis software (Biotek Instruments Inc., Winooski, VT, USA).

5.4.4. Experimental Design

The kiwi leaves were washed with distilled water and dried with paper towels. Then, 100 g of fresh material was weighed on a scale and finally subjected to dehydration under the following conditions:

-Convective Drying (oven): Leaves were exposed to 45 ± 2 °C for 24 h in a dehydrator with forced airflow.

-Cold Drying (lyophilization): Frozen under liquid nitrogen immersion for 15 minutes, followed by lyophilization at 0.045 mBa and -53 °C for 24 h.

5.4.5. Preparation of polar extracts

To determine antioxidant properties, polar extracts were prepared as follows: 1 g of lyophilized and ground kiwi leaves was extracted according to Hernández-Rodríguez et al. (2016) using 80% methanol in a 1:25 (w/v) ratio, and the mixture was adjusted to pH 3 ± 0.3 with 1N HCl. Kiwi extracts were obtained by vortex mixing (1000 rpm, 3 min), sonication for 15 min, incubation, and agitation for 30 min at 180 rpm and 30 °C. Finally, the mixture was centrifuged at 4500 rpm for 15 min, and the supernatant was brought to a final volume of 10 mL with 80% methanol.

The extracts obtained were stored protected from light at 4 °C until analysis. Each sample was processed in triplicate, and from these extracts, total phenols, total flavonoids, and antioxidant capacity were quantified using the FRAP and ABTS assays.

5.4.6. Antioxidant Properties

The total phenolic content was determined using the Folin-Ciocalteu method adapted for microplates (Hernández-Rodríguez et al. 2016). In each well of a 96-well microplate, 25 µL of the sample, 125 µL of distilled water, 20 µL of Folin-Ciocalteu reagent (diluted 1:10 with distilled water), and 30 µL of 20% sodium carbonate (Na_2CO_3) were added. The reaction mixture was vortexed for 30 seconds and allowed to react for 30 minutes in the dark; absorbance against a blank was measured at a wavelength of 765 nm. A gallic acid calibration curve was prepared with a concentration range of 0.00125–0.01125 mg mL^{-1}. Results were expressed as milligrams of gallic acid equivalents per gram of dry sample (mg GAE g^{-1} dry weight (dw)).

Total flavonoids were determined using the colorimetric method described by Kubola and Siriamornpun (2011). The extract obtained (0.5 mL) was mixed with 2.5 mL of distilled water in a test tube protected from light, followed by the addition of 0.15 mL of 5% sodium nitrite ($NaNO_2$) solution. After 6 minutes, 0.3 mL of 10% aluminum chloride hexahydrate ($AlCl_3 \cdot 6H_2O$) solution was added and allowed to rest for another 5 minutes before adding 1 mL of 5% sodium hydroxide. The mixture was vortexed (3000 rpm, 3 minutes). In each well of a microplate, 0.2 mL of the reaction mixture was added, and absorbance was measured at a wavelength of 510 nm. The calibration curve was prepared with catechin over a concentration range of 0.000651–0.0325 mg CE mL^{-1}. Results were expressed as milligrams of catechin equivalents per gram of dry sample (mg CE g^{-1}dw).

The antioxidant capacity by the FRAP assay (Ferric Reducing Antioxidant Power) was determined according to the method described by Benzie and Strain (1996), adapted for microplates. The FRAP solution was prepared by mixing 10 mL of 300 mM acetate buffer solution at pH 3.6, followed by 1 mL of 10 mM TPTZ (2,4,6-tripyridyl-s-triazine) solution mixed with 1 mL of 20 mM iron (III) chloride hexahydrate ($FeCl_3 \cdot 6H_2O$) solution. In each well of the microplate, 20 µL of the sample extract, 180 µL of the FRAP mixture, and 60 µL of distilled water were added. The reaction was allowed to rest for 10 minutes, and absorbance was read at 595 nm. A blank was prepared with 260 µL of the FRAP mixture.
For the ABTS assay (2,2'-azino-bis-3-ethylbenzothiazoline-6-sulfonic acid), the method proposed by Re et al. (1999) was adapted for microplates. Prior to the assay, the ABTS•+ radical solution was prepared (10 mL of 7.4 mM ABTS reagent + 25 mL of 2.6 mM potassium persulfate solution). The ABTS•+ radical solution (180 µL), with absorbance adjusted to 0.9, was mixed with 20 µL of the sample extract, the reaction mixture was left to rest for 10 minutes, and absorbance was read at 734 nm. The ABTS•+ solution served as the control. The calibration curve for both antioxidant assays was prepared with Trolox (6-hydroxy-2,5,7,8-tetramethylchromane-2-carboxylic acid) in concentration intervals of 3.84 to 46.1 mg mL^{-1}. Results were expressed as micromoles of Trolox equivalents per gram of dry sample (µmol TE g^{-1} dw).

5.4.7. Statistical Analysis

The results were analyzed using Student's t-test ($P \leq 0.05$) for independent samples with the statistical software Infostat version 2020 (Di Rienzo, 2020). Data are presented as mean values with standard errors.

5.5. RESULTS AND DISCUSSION

Phenolic compounds are the most abundant secondary metabolites in plants and exhibit a range of biological activities, including antioxidant capacity (as measured by ABTS and FRAP assays) (Carlsen et al. 2010). For this reason, the total phenolic content, flavonoids, and antioxidant capacity in the analyzed extracts were measured, as summarized in Table 1.

Table 1.Average values (± standard error) of total phenols, flavonoids, and antioxidant capacity (ABTS and FRAP) in kiwi leaves subjected to two different drying methods. Values are based on dry weight.

Drying Method	**Total Phenols** mg GAE g_{dw}^{-1})	**Total Flavonoids** (mg CE g_{dw}^{-1}).	**Antioxidant Capacity (μmol TE g_{dw}^{-1})**	
			ABTS	**FRAP**
Convection	48.97±2.37 a	34.45±1.58 a	2381.01±120.95 a	182.05±5.3 a
Lyophilization	42.45±2.85 a	28.06±1.98 b	2734.67±159.33 a	194.61±7.3 a

Different lowercase letters within columns indicate statistically significant differences (Student's t-test, $P \leq 0.05$). dw: dry weight; fw: fresh weight; GAE: gallic acid equivalent; CE: catechin equivalent; TE: Trolox equivalent.

According to the data in Table 1, the total phenolic content and antioxidant capacity in kiwi leaves subjected to two drying conditions showed no statistically significant differences, except in flavonoid content. Drying treatments often affect the stability and sensitivity of phenolic compounds in plants (Lim and Murtijaya 2007). Oven drying at 45 °C demonstrated consistent levels of total phenols (TP). Furthermore, antioxidant capacity, as measured by ABTS and FRAP assays, remained constant regardless of the drying method used.

In *Cosmos caudatus* from the Asteraceae family, lyophilization with prior freezing at -20 °C better preserved total phenols compared to oven drying at 44.5 °C, which reduced the concentration (Mediani et al. 2014). Likewise, dehydrating feijoa fruit pulp in a standard convective air oven reduced its antioxidant capacity by more than 25% (Guerra-Ramírez et al. 2021b). Ortiz et al. (2019) reported that oven drying at 38 °C produced the highest total phenolic content compared to samples lyophilized at -80 °C in *Vicia faba* L. seeds.

These drying methods help preserve samples by removing water, although they may impact the stability and sensitivity of certain phytochemicals if conditions are unsuitable (Lim and Murtijaya 2007). Temperatures above 60 °C used in drying plant tissues can lead to oxidation or degradation of heat-sensitive compounds. In contrast, lyophilization forms ice crystals that break down the plant's cellular structure, enhancing compound accessibility and extraction (Asami et al. 2003). However, under certain conditions, dehydration can protect these compounds, provided temperatures remain below 60 °C to prevent quality loss (Mediani et al. 2014). Since no significant differences were observed, except in total flavonoid content, this indicates that dehydration and lyophilization drying methods in kiwi leaf tissue did not impact phenolic compound content.

The obtained results differ from other studies, possibly because a slightly higher forced-air oven drying temperature (45 °C) was used in this study than in studies with *Cosmos caudatus* leaves (44.5 °C) and broad bean seeds (38 °C). Furthermore, the collector temperature during lyophilization (-53 °C) was between the -20 °C used in the *C. caudatus* study and the -80 °C used for broad beans.

Regarding nutraceutical content, the values in Table 1 show that total phenols were lower than those found in leaves of 30 types of green and black tea from China, although they were similar in antioxidant capacity (FRAP and ABTS methods) (Cai-Ning et al. 2019). On the other hand, total phenolic and flavonoid values were higher than those reported by Alejandro et al. (2019) in infusions of *Vitis tiliifolia* (Humb. & Bonpl. ex Schult.) wild grape leaves collected in Atlahuilco, Cosautlán, Huatusco, and Ixtaczoquitlán, in the state of Veracruz, Mexico.

5.6. CONCLUSIONS

This study demonstrates that kiwi leaves (*Actinidia chinensis*), cultivated in Huatusco, Veracruz, represent a viable source of nutraceutical compounds, with significant concentrations of phenolic compounds, flavonoids, and antioxidant capacity (FRAP and ABTS), comparable to those in other widely used infusion leaves, such as green and black tea.

The drying methods evaluated, lyophilization and convective drying, showed no significant differences in preserving these compounds, except for flavonoid content, suggesting that both methods are suitable for maintaining the antioxidant and nutraceutical properties of the leaves. This finding highlights the feasibility of using kiwi leaves as a new source of natural antioxidants, providing an economical and healthy alternative that can benefit both consumers and local producers in Mexico, promoting the development of functional products and diversifying the infusions and nutraceuticals market.

5.7. ACKNOWLEDGMENTS

The contribution to the National Council of Humanities, Sciences and Technologies (CONAHCyT spanish acronym) and the Universidad Autónoma Chapingo for access to its facilities, laboratory equipment, and the support of its staff. Without their collaboration, this research would not have been possible.

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6.Nutritional Value of *Actinidia chinensis* var. chinensis and its potential as a promising crop in Mexico

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6.1. ABSTRACT

The kiwifruit (*Actinidia chinensis* var. chinensis) is one of the most nutritious berries, known for its dietary fiber, vitamins C and K, and essential minerals such as potassium, calcium, and phosphorus. However, studies evaluating its nutritional and nutraceutical quality under high-altitude subtropical conditions are limited. This study compared the physicochemical properties, antioxidant potential, and contents of titratable acidity, sugars, soluble solids, chlorophylls, carotenoids, organic acids, and minerals in polar pulp extracts from kiwifruits cultivated in Huatusco, Veracruz, Mexico, with those of kiwifruits imported from New Zealand. Statistical analysis was performed using the Student's t-test with three replicates per variable. Results showed that, although Mexican kiwifruits did not excel in morphological traits, they exhibited significantly higher levels of phenols (33%), flavonoids (57%), antioxidant capacity (35.8% in FRAP and 25% in ABTS), minerals such as nitrogen, calcium, sulfur, zinc, boron, nickel, and molybdenum, as well as organic acids like ascorbic and tartaric acids, enhancing their nutraceutical value. These findings suggest that kiwifruits produced in high-altitude regions of Mexico possess remarkable nutritional and antioxidant properties, representing a valuable agricultural development opportunity. In conclusion, cultivation in tropical highlands could provide significant health benefits for local consumers and be an accessible option in the national market.

Keywords: antioxidant capacity, flavonoids, phenols, minerals, organic acids, promising crop

6.2. INTRODUCTION

Kiwi (*Actinidia chinensis* var. chinensis) is a shrubby, woody, deciduous, and dioecious plant from the Actinidiaceae family (He et al., 2019). Currently, more than 50 species and over 100 taxa of the *Actinidia* genus have been reported; they can be found from cold temperate forests at 50° N latitude to tropical regions near the equator (Ferguson, 1990). However, the cultivation of this crop predominantly occurs in countries with well-defined seasons, such as New Zealand, the United States, Greece, Italy, and Chile, among others (Ma et al., 2017).

The consumption of kiwi fruit has grown internationally due to its refreshing taste and pleasant aroma, as well as its outstanding nutritional and nutraceutical properties (Amit et al., 2020). For example, kiwi contains proteins (1.2%), lipids (0.15%), carbohydrates (14.23%), β-carotene (43 μg/100 g), vitamins such as ascorbic acid (105 mg 100 g^{-1}), and minerals like calcium, potassium, and phosphorus, with values of 20, 316, and 29 mg 100 g^{-1}, respectively (Satpal et al., 2021). Moreover, it has been documented that kiwi contains catechin, quercetin, esculin, esculetin, and anthocyanidins, phenolic compounds with antioxidant properties that combat reactive oxygen species, thereby slowing the aging process, strengthening the immune system, and helping prevent cardiovascular and ocular diseases (Xia et al., 2020). According to reports, consuming 90 g of green kiwi or 50 g of SunGold kiwi exceeds the daily recommended intake of ascorbic acid (Vitamin C) by the European Union (80 mg 100 g^{-1}), surpassing strawberries, oranges, and pineapples by threefold (Mai et al., 2022).

As with all biological tissues, the concentrations of various bioactive compounds in a fruit may vary due to multiple factors, including horticultural practices, environmental conditions of the geographical area, soil type, plant training system, and genotype. Additionally, post-harvest conditions, especially fruit maturity, should be considered for quality (Drummond, 2013).

According to Mexico’s National Market Information and Integration System (SNIIM spanish acronym), kiwi is among the most expensive fruits in Mexican markets, with a kilogram costing between $60 and $130 MXN (SNIIM, 2024). This high price is due to limited domestic production, which drives imports from countries such as Chile, the United States, Italy, and New Zealand, where the main varieties marketed are green (*Actinidia chinensis* var. *deliciosa*) and golden (*Actinidia chinensis* var. *chinensis*) (Cruz-Castillo et al., 2022).

The cultivation of kiwi in Mexico, specifically in the mountainous area of Veracruz, could become a strategy to generate higher income for small producers in these mountainous regions, thereby improving nutrition and reducing soil erosion impacts (Guerra-Ramírez et al., 2021). To date, studies have been conducted on the phytochemical composition of the pulp of *A. chinensis* var. *chinensis*, including polyphenols, carotenoids, polysaccharides, organic acids, and microelements under temperate conditions (Twidle et al., 2018). However, no studies are available that describe the nutritional quality of kiwi grown in high-altitude tropical climates in Mexico. This research aimed to analyze *Actinidia chinensis* fruits cultivated in the high-altitude tropical region of Huatusco, Veracruz, Mexico, focusing on their physicochemical, mineral, and nutraceutical properties.

6.3. MATERIALS AND METHODS

6.3.1. Plant Material

Thirty kiwi fruits (Actinidia chinensis var. chinensis) were randomly collected from three-year-old plants in the community of Elotepec, Huatusco municipality, Veracruz, Mexico (19°11'20.6" N, 97°01'59.3" W, at 1851 masl), with an average weight of 65 g. This crop is low-input, relying solely on rainfall without fertilization systems or intensive agronomic management. Conversely, commercial fruits imported from New Zealand were purchased from a supermarket in the summer of 2022. Both types of fruits exhibit an ovoid shape, a light brown epidermis without hair, a prominent protrusion at the floral end, and yellow pulp (Rubio et al., 2015).

6.3.2. Chemical Reagents and Instrumentation

The reagents used were phenol, sulfuric acid, glucose; DNS reagent (3,5-dinitrosalicylic acid); sodium potassium tartrate tetrahydrate ($C_4H_4KNaO_6 \cdot 4H_2O$); sodium carbonate (Na_2CO_3), Folin-Ciocalteu reagent, gallic acid; sodium nitrite ($NaNO_2$), catechin, aluminum chloride hexahydrate ($AlCl_3 \cdot 6H_2O$), sodium hydroxide (NaOH), β-carotene, sodium acetate trihydrate ($C_2H_3NaO_2 \cdot 3H_2O$); TPTZ (2,4,6-tris(2-pyridyl)-s-triazine), iron (III) chloride hexahydrate ($FeCl_3 \cdot 6H_2O$), and 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox). These were obtained from Sigma-Aldrich (St. Louis, Missouri, USA), except for aluminum chloride and potassium acetate, which were sourced from Fermont S.A. de C.V. and Meyer S.A. de C.V., Mexico, respectively.

The instrumentation included a portable digital refractometer (ATAGO PAL-3 (±0.01%)); potentiometer (Thermo Orion Model 420+); vortex mixer (Synergy, VWR International); sonicator (8890, Cole-Parmer, Vernon Hills, USA); orbital shaker incubator (Prendo, INO-650M); centrifuge (OHAUS, FC5718R); microplate reader spectrophotometer Synergy 2, equipped with Gen5 data analysis software (Biotek Instruments Inc., Winooski, VT, USA), and a spectrophotometer (Thermo Fisher Scientific model Genesys® 10S UV-VIS).

6.3.3. Morphological characteristics and physicochemical properties

The variables of fresh weight, polar and equatorial diameter were measured using an analytical balance (Pionner OHAUS) and a digital caliper (MITUTOYO, precision ±0.001 mm), respectively. Dry matter content was determined by dehydrating the fruits with forced air flow (Sedona SD-P9000-F, Tribest, Anaheim, USA) at 45 ± 2 °C for 48 hours until no apparent moisture was present. Additionally, the number of seeds was quantified by weighing 100 seeds per fruit, using a total of 10 fruits from each species.

The pH of the fruit juice was measured using a previously calibrated potentiometer, and total acidity was determined by potentiometric titration with a 0.1 N sodium hydroxide (NaOH) solution until reaching a pH between 8.1 and 8.3 (AOAC, 2012). The concentration of total soluble solids in the fruit juice was measured with a portable digital refractometer and the results were reported in °Brix.

Total sugar content was determined using the phenol-sulfuric acid colorimetric method (Yue et al., 2022). Freeze-dried and ground pulp (1 g) was mixed with 10 mL of distilled water, vortexed (2 min at 3000 rpm), incubated at 30 °C for 10 min, and centrifuged for 15 min at 4000 rpm. The supernatants were recovered and diluted to 10 mL with water. For the test, 0.3 mL of extract, 0.3 mL of 5% phenol, and 1.5 mL of 98% sulfuric acid were added in a test tube. The reaction mixture was allowed to cool to room temperature, and absorbance was measured at a wavelength of 490 nm. The glucose calibration curve was prepared in a concentration range of 0.010 to 0.05 mg mL^{-1}, and results were expressed in milligrams of glucose per kilogram on a dry weight (mg Kg^{-1}dw).

Total reducing sugars were quantified according to Miller's method (1959). A sample of freeze-dried pulp (0.2 g) was mixed with 10 mL of distilled water, vortexed (2 min at 3000 rpm), incubated (10 min at 30 °C), and centrifuged (4000 rpm for 15 min). The supernatants were recovered and diluted to 10 mL. Then, 0.5 mL of extract was mixed with 0.5 mL of a DNS solution and diluted to 50 mL with distilled water. Absorbance was read at a wavelength of 540 nm. The calibration curve was prepared in a concentration range of 0.1 to 0.5 mg mL^{-1}, and results were expressed in milligrams of glucose per kilogram of sample on a dry weight (mg Kg^{-1}dw).

Chlorophyll content was determined according to Salgado-Escobar et al. (2020). For this, 1 g of freeze-dried kiwi pulp was mixed with 90% methanol in a 1:10 (w/v) ratio. The mixture was vortexed (10 min at 3000 rpm), sonicated (15 min), and centrifuged (10 min at 1300 g). Supernatants were recovered and diluted to 10 mL with the same solvent used for extraction. Absorbances were measured at 665 and 652 nm using a microplate reader. Determinations were performed in triplicate, with results expressed in milligrams of chlorophyll per 100 g of fresh weight (mg 100g_bf^{-1}) and calculated using the following equation.

$$\text{l}Ct = \frac{(0.28(A665) + 27.64\,(A652)) \times V}{m} \text{x}100$$

Where:

- **A** = absorbance at 665 and 652 nm
- **V** = volume in liters of 90% methanol
- **m** = mass in grams of the sample on a fresh weight basis

The content of macronutrients (P, K, Ca, Mg, S, and Na) and micronutrients (Fe, Zn, Mn, Cu, B, Ni, and Mo) was determined according to the AOAC 2006.03 method, based on acid digestion assisted by microwave (Webb et al., 2014), while nitrogen was quantified using the DUMAS technique. Results were expressed in parts per million (ppm) and percentage (%) on a dry weight, respectively.

The concentrations of organic acids (acetic, tartaric, citric, ascorbic, malic, lactic, succinic, and oxalic) were determined in the freeze-dried and ground kiwi pulp. For this purpose, the sample extract was injected into a high-performance liquid chromatograph (HPLC) Aquity Class H model, WATERS brand. A solution of 20 mM sodium phosphate and HPLC-grade acetonitrile in a 99:1 (v/v) ratio was used as the mobile phase, with a flow rate of 0.5 mL/min. A Zorbax Aq C18 column at 20 ºC and a UV detector at 210 nm were employed. The samples were analyzed in triplicate, and the results were expressed in milligrams per gram of sample on a dry weight (mg g^{-1}dw).

6.3.4. Antioxidant Properties

To determine antioxidant properties, polar extracts were prepared as follows: 1 g of kiwi pulp, previously freeze-dried and ground, was extracted according to the method of Hernández-Rodríguez et al. (2016), using 80% methanol in a 1:10 (w/v) ratio. The mixture was adjusted to a pH of 3 ± 0.3 with 1N HCl. Kiwi extracts were obtained through vortex agitation (1000 rpm, 3 min) (Vortex Synergy, WVR International), sonication for 15 min (sonicator 8890, Cole-Parmer, Vernon Hills, USA), and incubation with agitation at 180 rpm and 30 °C for 30 min (orbital incubator Prendo, model INO-650M). Finally, the mixture was centrifuged (OHAUS, model FC5718R) at 4500 rpm for 15 min, and the recovered supernatant was adjusted to a final volume of 10 mL with 80% methanol. The extracts obtained were stored protected from light at 4 °C until analysis. Each sample was processed in triplicate, and from these extracts, total phenol and flavonoid contents were quantified, as well as antioxidant capacity using FRAP and ABTS assays.

Total phenol content was determined using the Folin-Ciocalteu method adapted to microplates (Hernández-Rodríguez et al., 2016). In each well of a 96-well microplate, 25 µL of the sample, 125 µL of distilled water, 20 µL of Folin-Ciocalteu reagent (diluted 1:10 with distilled water), and 30 µL of sodium bicarbonate (Na_2CO_3) at 20% were added. The reaction mixture was vortexed for 30 seconds and left to react in darkness for 30 min; absorbance against the blank was measured at a wavelength of 765 nm. A gallic acid calibration curve was prepared within a concentration range of 0.0013 to 0.0113 mg mL^{-1}. Results were expressed in milligrams of gallic acid equivalents per gram of dry weight (mg GAE g^{-1}dw).

The total flavonoid content was determined using the colorimetric method proposed by Cañarejo-Antamba et al. (2021). The obtained extract (0.5 mL) was mixed with 2.5 mL of distilled water in a light-protected test tube, followed by the addition of 0.15 mL of a 5% sodium nitrite ($NaNO_2$) solution. After 6 minutes, 0.3 mL of a 10% aluminum chloride hexahydrate ($AlCl_3 \cdot 6H_2O$) solution was added, and the mixture was left to stand for another 5 minutes before adding 1 mL of 5% sodium hydroxide. The mixture was vortexed (3000 rpm, 3 min). In each well of a microplate, 0.2 mL of the reaction mixture was added, and absorbance was measured at a wavelength of 510 nm. The calibration curve was prepared with catechin at concentrations ranging from 0.00103 to 0.0516 mg EC mL^{-1}, and the results were expressed as milligrams of catechin equivalents per gram of sample on a dry weight (mg CE g^{-1}dw).

The total carotenoid content was determined according to the method by Parrado Muñoz et al. (2024). A 2 g sample of freeze-dried and ground kiwi pulp was mixed with 10 mL of a hexane-acetone solution (3:2 v/v). The mixture was vortexed (2 min at 3000 rpm), incubated (10 min at 30 °C), and then centrifuged at 1280 rpm for 15 min. The supernatants were collected and adjusted to 10 mL with the same solvent used for extraction. Absorbance was measured at 450 nm using a Thermo Fisher Scientific Genesys® 10S UV-VIS spectrophotometer. The β-carotene calibration curve was prepared in a concentration range of 0.048 to 0.375 µg mL^{-1}, and results were expressed as mg β-carotene equivalents per gram of sample on a dry weight (mg βCE g^{-1}dw).

The antioxidant capacity by the FRAP assay (Ferric Reducing Antioxidant Power) was determined according to the method proposed by Cañarejo-Antamba et al. (2021), adapted to microplates. The FRAP solution was prepared by mixing 10 mL of a 300 mM acetate buffer solution at pH 3.6, 1 mL of TPTZ (2,4,6-tri(2-pyridyl)-s-triazine) 10 mM, and 1 mL of a 20 mM ferric chloride ($FeCl_3 \cdot 6H_2O$) solution. In each well of the microplate, 20 µL of the sample extract, 180 µL of the FRAP mixture, and 60 µL of distilled water were added. The mixture was left to stand for 10 minutes, and absorbance was read at 595 nm. As a blank, 260 µL of the FRAP mixture was used.

For the ABTS (2,2'-azino-bis-3-ethylbenzothiazoline-6-sulfonic acid) assay, the method proposed by Cañarejo-Antamba et al. (2021), adapted for microplates was used. Prior to the assay, the ABTS•+ radical solution was prepared by mixing 10 mL of 7.4 mM ABTS reagent with 25 mL of 2.6 mM potassium persulfate solution. The ABTS•+ solution (180 µL), with an adjusted absorbance of 1.1, was mixed with 20 µL of the sample extract. The reaction mixture was allowed to rest for 10 minutes, and its absorbance was measured at a wavelength of 734 nm. The ABTS• solution was used as a control. The calibration curve for both antioxidant assays was prepared with Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid) at concentrations ranging from 3.84 to 46.1 mg mL^{-1}. Results were expressed in micromoles of Trolox equivalents per gram of sample on dry weight (µmol TE g^{-1}dw).

The data obtained were analyzed using Student's t-tests ($P \leq 0.05$) for independent samples with the statistical software Infostat, version 2020. The properties of fruits from Huatusco were compared to those from New Zealand.

6.4. RESULTS AND DISCUSSION

The global fruit market, especially for kiwi, is increasingly demanding. In particular, larger fruits are preferred, with weights ranging between 80 and 120 g (Ontivero et al., 2012). Table 1 compares the physical characteristics of *A. chinensis* kiwi from different origins.

The fruits from New Zealand displayed greater size and number of seeds compared to those from Huatusco. However, fresh weight did not influence the dry matter content, as no statistical differences were observed. Nonetheless, both exceeded cultivars Gold, Bruno, Allison, and Hayward, which have an average dry matter content of 17% (Satpal et al., 2021) (Table 1).

A Pearson correlation determined a moderate positive relationship (0.44) between size and total number of seeds per fruit. This indicates that fruit size is influenced by seed number, which in turn depends on the number of pollen grains fertilizing the ovules (Rubio et al., 2015). Therefore, kiwi flowers need to receive large amounts of pollen to produce well-sized fruits (Rubio et al., 2015). Consequently, the fruits produced in Veracruz were smaller than those from New Zealand, possibly due to multiple factors such as pollination issues, scarcity of pollinators, fruit thinning, exposure of the crop to unfavorable conditions, or low agricultural technology (minimal agronomic management) (Famiani et al., 2012).

Additionally, compared to cv HORT16A, characterized by fruits between 95 and 100 g, the fruits from Huatusco were smaller in weight. On the other hand, cv 'Jintao' shows values similar to commercial varieties, with fruits ranging between 90 and 160 g (González Puelles De, 2019).

Kiwi fruits are renowned for their health benefits and contributions to human health. Nutritionally, they are a rich source of carbohydrates, carotenoids, vitamins (especially vitamin C), minerals, polyphenols, and antioxidants, all which aid in the prevention of various health conditions (Drummond, 2013). Table 2 compares the chemical properties, antioxidant capacity, mineral content, and organic acids of kiwi fruits from Huatusco, Veracruz, with those from New Zealand.

No significant differences were observed in pH, titratable acidity, total soluble solids content or reducing and total sugars between kiwi fruits from different origins. The concentration of total reducing sugars was higher than those reported by He et al. (2019) and Satpal et al. (2021). Regarding pH and °Brix, both types of fruit exhibited higher values (17.5 °Brix), with less acidic and sweeter pulp (pH 4.47 and 14.6 g 100 g fw^{-1} of total sugars) compared to the six *A. chinensis* cultivars evaluated by Liang et al. (2021), which showed values of 12–17 °Brix, pH 3.2–3.5, and 8–13 g 100 g^{-1}fw.

Lipophilic pigments like carotenoids and chlorophylls contribute to the color and visual appeal of kiwi fruits. During the ripening of golden kiwis, chloroplasts are converted into chromoplasts with a loss of chlorophyll. Thus, the color difference between green and golden kiwis is due to the absence of chlorophyll, revealing the golden hue of carotenoids (Montefiori et al., 2009). Statistically significant differences in carotenoid concentrations were observed between the fruits evaluated, with those from Huatusco showing a higher concentration. The β-carotene content in the samples analyzed (0.0954 mg β-carotene 100 g^{-1}fw) was similar to that of the Gold variety (0.066–0.09 mg 100 g^{-1}fw) as determined by McGhie (2013) but lower than that of the Hort16A variety, which showed 0.147 mg 100 g^{-1}fw by HPLC and 0.62 mg 100 g^{-1}fw (Taylor et al., 2004) .

Through chemical analyses, it was determined that the mineral composition of kiwi pulp (Table 2) from Huatusco showed statistically higher levels of N, Ca, S, Zn, B, Ni, and Mo; lower levels of Mn and Cu; and similar levels of P, K, Mg, and Fe compared to other studies.

The volcanic soil where kiwi is cultivated may explain the elevated nitrogen, calcium, sulfur, zinc, and boron levels in the pulp tissue. The recorded values fall within an optimal range and, in some cases, exceed those reported in previous studies, such as Zhang et al. (2022), who evaluated five yellow-fleshed kiwi cultivars (*Huayoa*, *Sungold*, *Jinyah*, *Jintao*, *Puyu*) out of a total of 15.

During ripening, organic acids contribute significantly to the sensory profile of fruits. In kiwi, predominant acids include malic, citric, and ascorbic acids, although their concentrations vary across species and cultivars. In the fruits analyzed, significant differences were observed in the levels of citric, ascorbic, tartaric, and acetic acids. Notably, ascorbic acid content was approximately 30% higher in the fruits from Huatusco, a value comparable to the 7.21 mg g^{-1} dry weight reported by Mai et al. (2022) using ultrasound-assisted extraction and solvent methods.

Additionally, Ma et al. (2017) reported vitamin C concentrations in 11 kiwi cultivars, ranging from 54.86 to 159.08 mg per 100 g fresh weight. Li et al. (2018) analyzed 14 kiwi varieties, with concentrations ranging from 51.32 to 390.68 mg per 100 g fresh weight. Similarly, Satpal et al. (2020) reported 105.4 mg per 100 g fresh weight, and Zhang et al. (2020) observed variability in five yellow-fleshed cultivars, with values ranging from 73 to 233 mg per 100 g fresh weight. Differences in ascorbic acid levels among cultivars and species may be attributed to genetic and environmental variations.

Citric acid, recognized as a highly versatile carboxylic acid, is widely used in the food, pharmaceutical, and cosmetic industries, among others (Muñoz-Villa, 2014). In this study, it was found that the concentration of this acid in the analyzed samples was higher than that reported by Taylor et al. (2004) for the Gold variety, which recorded values of 460 mg100 g^{-1} fw.

In contrast to citric acid, oxalic acid can pose a health risk when consumed in large amounts, as it is associated with the formation of calcium oxalate kidney stones in 70% to 80% of cases. For some patients, it is recommended to limit intake of this compound to less than 50 mg day^{-1}. In the samples of this study, the oxalic acid concentration was less than 0.002 mg g^{-1}dw, compared to values of 18 to 45 mg100 g^{-1} fw observed in the Gold variety (Rassam and Laing, 2005), suggesting that consumption of these fruits would not contribute to kidney stone formation.

On the other hand, kiwi fruits also contain nutraceutical compounds with beneficial effects, among them polyphenolic compounds, which are primarily associated with the antioxidant activity of foods. These compounds have various mechanisms of action against reactive oxygen species (ROS). In this context, kiwi fruits from Huatusco showed significantly higher levels of phenols, flavonoids, carotenoids, and chlorophylls compared to commercial kiwis (Table 2), in addition to higher values in the FRAP and ABTS assays, highlighting their antioxidant potential and health benefits.

The total phenol and flavonoid values found in this research (8.67 mg GAE g^{-1} dry weight and 1.33 mg CE g^{-1} dry weight, respectively) are comparable to those reported by Jiao et al. (2019) in the SunGold variety. However, these values exceed those obtained by Zhang et al. (2020) in their analysis of 15 kiwi cultivars, including five yellow-fleshed varieties (*Huayoa*, *Sungold*, *Jinyan*, *Jintao*, and *Puyu*), with ranges of 74-160 mg GAE and 14-20 mg CE per 100 g fresh weight for phenols and flavonoids, respectively.

Additional studies report variations in the total phenol content across different kiwi cultivars. Cömert et al. (2020) reported 211 mg GAE mg100 g^{-1} fw in 11 varieties; Liang et al. (2021) observed a range of 75.4 to 206.1 mg GAE mg100 g^{-1} fw in 15 cultivars; Zhang et al. (2020) recorded values of 78 to 133.9 mg GAE mg100 g^{-1} fw in five cultivars; and Alim et al. (2019) detected 9.5 mg GAE g^{-1} dw in the pulp.

These results are comparable to those obtained in the present study. Regarding antioxidant capacity, the ABTS assay values obtained in this research were higher than those reported by Mai et al. (2022), who achieved 70.38 and 59.39 µM Trolox g^{-1}dw through ultrasound-assisted and solvent extraction, respectively. Zhang et al. (2020) evaluated FRAP activity in five yellow-fleshed kiwi cultivars, obtaining a range of 6 to 19 µM Trolox g^{-1} dw.

The observed differences can be attributed to the influence of geographic environment, stress induced by abiotic factors (such as high temperatures and prolonged periods without irrigation), and genetic variations among kiwi species and cultivars. Even within the same species, these variations can be accentuated when cultivation occurs under contrasting climatic conditions (Xie et al., 2019).

For this study, an Extech USB Datalogger sensor (RHT10) was positioned inside the vineyard at a height of 1.40 m, recording daytime and nighttime temperatures every hour from November 2021 to September 2022. Based on the data collected, it was determined that the kiwi crop in Huatusco grows under rainfed conditions and a climate classified as Cwa (temperate with dry winters) according to the Köppen classification. In this climate, maximum temperatures can reach up to 28°C during the coldest months and up to 32°C during the hottest months. These conditions may trigger the synthesis and/or accumulation of non-enzymatic antioxidant components (polyphenols and flavonoids), which serve as complex detoxification mechanisms in response to reactive oxygen species generated by water stress and high temperatures in the area. This response helps maintain redox homeostasis, given the reducing power of ROS (Qasim et al., 2017).

Prior to the phytochemical and nutritional analysis, a soil sample was collected and analyzed for its physicochemical properties at the *A. chinensis* cultivation site in Huatusco, Veracruz, Mexico. Based on its bulk density and proximity to the Orizaba volcano, the analysis revealed that the soil is of volcanic origin, rich in carbon (6.95%) and organic matter (12%), with an optimal level of available nitrogen (34 ppm) and a pH of 5.3, these characteristics could influence its mineral content.

The kiwi crop's exposure to the environment promotes natural pollination; however, factors such as the low level of mechanization and the lack of irrigation systems result in fruits with different characteristics than those produced in New Zealand, where advanced agronomic management and protection from abiotic factors enhance quality and uniformity. New Zealand, a leader in kiwi production, has achieved a high level of mechanization and developed improved varieties such as 'Hort16A' or Zespri Gold, globally recognized for their quality. Through innovative agronomic practices and protective strategies, the country has established itself as an exporter of high-quality kiwis. Additionally, New Zealand promotes advanced research in the mechanization of cultivation processes, pollination, harvesting, and classification, positioning itself as a benchmark in kiwi industrialization and in the advancement of precision agriculture (Mu et al., 2018).

6.5. CONCLUSION

The *A. chinensis* fruits cultivated in Huatusco-Veracruz, Mexico, are smaller than imported commercial kiwis; however, they stand out due to their high content of organic acids, minerals, phenols, and flavonoids, as well as their strong antioxidant capacity, attributable to their concentration of phenolic compounds and vitamin C. These characteristics suggest that kiwi cultivation in high-altitude tropical zones of Mexico and Mesoamerica could offer significant health benefits for local consumers and provide an economically accessible alternative in the domestic market. To enhance the competitiveness of these fruits compared to imported products, it is recommended that future studies explore increasing their size through entomophilous pollination techniques**.**

6.6. ACKNOWLEDGEMENTS

The collaboration and contribution of the National Council of Humanities, Science, and Technology (CONAHCyT spanish acronym), the Universidad Autonoma Chapingo, and Lic. Itzel Nayelli Silvestre González are appreciated.

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Table 1. Comparison of morphological characteristics in *A. chinensis* fruits from New Zealand and those cultivated in Huatusco, Veracruz, Mexico.

Variables	**Fruit origin**		**p-value**
	Huatusco	**New Zealand**	**(*p* ≤0.05)**
Fresh weight (g)	74.7± 0.94 b	159.75±7.95 a	0.0002
Equatorial diameter (mm)	44.89± 0.23 b	60.41±3.53 a	0.0031
Polar diameter (mm)	61.35±0.23 b	76.38± 2.12 a	0.0008
Dry matter (%)	21.27±0.61 a	20.69 ± 0.47 a	0.1825
Total sedes	285 ± 31.31 b	418± 28.61 a	0.0198

Means with identical letters in the same row do not show statistically significant differences (Student's t-test, P ≤ 0.05). Data are expressed as means ± standard deviation.

Table 2. Comparison of chemical properties, mineral content, and antioxidants in the pulp of *A. chinensis* fruits from New Zealand and those cultivated in Huatusco, Veracruz, Mexico.

Parameters (unit of measurement)		**Fruit origin**		***p-value***
		Huatusco	**New Zealand**	
pH		4.47 ± 0.24 a	4.34± 0.55 a	0.66
Titratable acidity	%	0.51 ± 0.07 a	0.65± 0.25 a	0.33
°Brix		17.57± 0.6 a	17.1 ± 0.47 a	0.2605
Total sugars	(mg GE Kg^{-1}_{dw})	240±28.44 a	239.29 ±25.5 a	0.97
Total reducing sugars	(mg GE Kg^{-1}_{dw})	1.93 ± 0.20 a	1.98 ± 0.23 a	0.79
Total chlorophylls	(mg 100 g^{-1}_{fw})	47.66 ± 0.01 a	33.09 ± 0.01 b	0.0001
nitrógen (N)	%	1.04 ± 0.05 a	0.9 ± 0.05 b	0.0233
phosphorus (P)	%	0.17 ± 0.03 a	0.14 ± 0.01 a	0.1605
potassium (K)	%	1.41 ± 0.15 a	1.52 ± 0.07 a	0.2788
calcium (Ca)	%	0.14 ± 0.02 a	0.08± 0.003 b	0.0428
magnesium (Mg)	%	0.06 ± 0.01 a	0.06±0.003 a	0.9195

sulfur (S)	%	0.10 ± 0.01 a	0.06±0.01 b	0.0036
sodium (Na)	mg g^{-1}_{dw}	68.00 ± 2.00 b	294.00±1.00 a	<0.0001
iron (Fe)	mg g^{-1}_{dw}	14.70 ± 0.10 a	12.90±0.10 a	0.0878
zinc (Zn)	mg g^{-1}_{dw}	5.63 ± 0.25 a	4.50±0.10 b	0.0019
manganese (Mn)	mg g^{-1}_{dw}	0.95 ± 0.02 b	1.03±0.03 a	0.0154
copper (Cu)	mg g^{-1}_{dw}	9.40 ± 0.26 b	9.94±0.03 a	0.0746
boron (B)	mg g^{-1}_{dw}	13.60 ±0.20 a	10.30±0.10 b	<0.0001
níckel (Ni)	mg g^{-1}_{dw}	2.00 ± 0.02 a	1.69±0.03 b	0.0001
molybdenum (Mo)	mg g^{-1}_{dw}	1.94 ± 0.18 a	1.64±0.03 b	0.0424
acetic acid	mg g^{-1}_{dw}	15.26 ± 9.1 a	15.8±0.46 a	0.43
tartaric acid	mg g^{-1}_{dw}	11.08 ± 5.7 a	9.63±9.72 a	0.09
citric acid	mg g^{-1}_{dw}	51.59 ± 9.4 b	59.92±5.02 a	0.0002
ascorbic acid	mg g^{-1}_{dw}	6.76 ± 0.30 a	4.73±0.91 b	<0.0001
malic acid	mg g^{-1}_{dw}	<0.002	<0.002	-
láctic acid	mg g^{-1}_{dw}	<0.002	<0.002	-
succínic acid	mg g^{-1}_{dw}	<0.002	<0.002	-
oxálic acid	mg g^{-1}_{dw}	<0.002	<0.002	-
total phenols	mg GAE g^{-1}_{dw}	8.67±0.23 a	5.77±0.47 b	0.0006
flavonoids	mg CE g^{-1}_{dw}	1.33±0.23 a	0.57±0.2 b	0.0118
total carotenoids	µg βCE g^{-1}_{dw}	8.97 a	7.24 b	0.017
FRAP	µmol TE g^{-1}_{dw}	46.96±1.32 a	30.13± 1.93 b	0.0002
ABTS	µmol TE g^{-1}_{dw}	452.95± 13.67 a	339.71± 25.84 b	0.0026

Average values (± standard error); means with the same letters in the same row are not statistically different (Student's t-test, P ≤ 0.05); dw: dry weight; fw: fresh weight; GE: glucose equivalent; GAE: gallic acid equivalent; CE: catechin equivalent; TE: Trolox equivalent; βCE: beta-carotene equivalent.

7. Evaluación sensorial preliminar de ‘GoldenRouge’ una selección de frutos de *Actinidia chinensis* Lindl. de México

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7.1. ABSTRACT

The kiwifruit, known for its high content of vitamin C and antioxidants, is mostly imported in Mexico, with local production limited and concentrated in a high-altitude tropical region in Veracruz. However, the sensory quality of locally produced kiwifruit compared to imported fruit is unknown. This study compared the sensory quality of Mexican ‘GoldenRouge’ with the imported ‘SunGold’ from New Zealand. Attributes of acidity, sweetness, residual taste, stickiness, astringency, freshness, texture, and pulp homogeneity were evaluated using global acceptability methods and principal component analysis (PCA). The results showed that ‘SunGold’ had higher overall acceptability (7.47) and excelled in freshness (7.18), residual taste (6.37), texture (7.20), and pulp homogeneity (7.33). The PCA indicated that pulp homogeneity and texture, along with freshness and sweetness, were key to consumer preference. These findings guide improvements in local varieties and agricultural management.

Keywords: acceptability, tangible attributes, subtropical fruit, new fruit

7.2. RESUMEN

El kiwi, reconocido por su alto contenido de vitamina C y antioxidantes, es mayormente importado en México, y su producción local es limitada y concentrada en una región de altitud tropical en Veracruz. Sin embargo, se desconoce la calidad sensorial del kiwi producido localmente frente al importado. Este estudio comparó la calidad sensorial del ‘GoldenRouge’ mexicano con el ‘SunGold’ importado de Nueva Zelanda. Se evaluaron atributos de acidez, dulzor, sabor residual, pegajosidad, astringencia, frescura, textura y homogeneidad de pulpa mediante métodos de aceptabilidad global y análisis de componentes principales (PCA). Los resultados mostraron que ‘SunGold’ tuvo mayor aceptabilidad general (7.47) y se destacó en frescura (7.18), sabor residual (6.37), textura (7.20) y homogeneidad de pulpa (7.33). El PCA señaló que la homogeneidad de pulpa y la textura, junto con frescura y dulzor, fueron clave en la preferencia del consumidor. Estos hallazgos guían mejoras en variedades locales y manejo agrícola.

Palabras clave: Aceptabilidad, atributos tangibles, fruta subtropical, nueva fruta

7.3. INTRODUCCIÓN

El kiwi (*Actinidia sp.*) es un arbusto trepador vigoroso, que produce una baya valorada internacionalmente por su pulpa dulce y ligeramente ácida, así como por su alto contenido nutricional, que incluye vitaminas, fibras dietéticas, minerales como calcio y hierro, y varios fitoquímicos (Wei & Guohua, 2015). En México, se ha ganado la popularidad, debido a su alto contenido nutracéutico y demanda en el mercado, lo que lo convierte en una de las frutas importadas más caras (Cruz-Castillo et al., 2022).
El principal kiwi consumido en México es ‘Hayward’ (*Actinidia chinensis* var. deliciosa) (pulpa verde) y no se produce en el país. ‘SunGold’ (*Actinidia chinensis* var. chinensis

‘Zesy002’), desarrollado por Zespri® (pulpa amarilla), se vende en algunos supermercados y es muy apreciado por su baja acidez, alta dulzura y grandes beneficios digestivos para la salud (Eady et al., 2020). Esta variedad es muy productiva, y su temporada de cosecha es similar a la de ‘Hayward’ (García et al., 2015).

El kiwi es una fruta de clima templado o subtropical (Mueller et al., 2015), pero en el estado de Veracruz, México, las plantas de kiwi seleccionadas como ‘GoldenRouge’ se han adaptado exitosamente al clima tropical de altura, produciendo frutos con buen sabor, aunque de menor tamaño que los kiwis importados de Nueva Zelanda (Cruz-Castillo et al., 2022; Guerra-Ramírez et al., 2021). Aunque se ha estudiado la composición nutricional y capacidad antioxidante del kiwi verde mexicano (Guerra-Ramírez et al., 2021), la investigación sobre la percepción y aceptación del consumidor de kiwi cultivado en México es limitada (Nolasco-Matías et al., 2020).

El kiwi es una fruta climatérica que experimenta cambios durante su proceso de maduración, lo cual puede afectar su calidad sensorial y, en consecuencia, la satisfacción del consumidor (Ceroli et al., 2022; Cozzolino et al., 2020). La evaluación sensorial es crucial para determinar la aceptación y percepción del producto, ya que permite identificar atributos que podrían mejorarse para aumentar su competitividad en el mercado (Jaeger et al., 2019) y para su mejora genética (Cozzolino et al., 2020). Este estudio se determinó la percepción del consumidor a partir de la evaluación de las características sensoriales del kiwi ‘GoldenRouge’ en comparación con el kiwi importado ‘SunGold’ de Zespri®, con el propósito de analizar a futuro su aceptación y viabilidad para su introducción en el mercado mexicano.

7.4. MATERIALES Y METODOS

7.4.1. Área de estudio

La evaluación sensorial se realizó en la Universidad Autónoma Chapingo, en el Departamento de Fitotecnia, del municipio de Texcoco de Mora, Estado de México; a una latitud 19°51' norte y longitud 98°88' oeste y una altitud de 2377 msnm, en septiembre del 2023.

7.4.2. Material vegetal

Veinte frutos fueron seleccionados al azar de tres vides de ‘GoldenRouge’, una selección de kiwi que produce fruta con pulpa amarilla en Huatusco, Veracruz, México. Las vides estaban ubicadas en una zona tropical de altura a 1851 m de altitud (19°11'20.6" N y 97°01'59.3" W) y se plantaron a 3 x 3 m. Estas vides no tenían riego, poda ni aclareo de frutos. ‘GoldenRouge’ tiene una forma ovoide, con una epidermis marrón claro sin tricomas y una protuberancia en el extremo floral (A). La pulpa amarilla presentó un diámetro polar promedio de 6.1 cm y un diámetro ecuatorial promedio de 4.3 cm, con un peso fresco promedio de 68 g y un índice de 15-16 ºBrix al consumo (figura 1). Simultáneamente, se compraron 20 frutos de ‘SunGold’. Estos frutos también presentaban color de pulpa amarilla, pero eran más grandes, con un diámetro polar de 7.7 cm, un diámetro ecuatorial de 5.5 cm y un peso fresco promedio de 146 g (B) (figura 1). También alcanzaron un índice de 16-17 ºBrix al consumo.

Figura 1. Frutos ‘GoldRouge’ (izquierda) y ‘SunGold’

7.4.3. Evaluación sensorial

Para los dos tipos de kiwis, se consideraron ocho atributos para diferenciar los frutos: sabor ácido, sabor dulce, pegajosidad, astringencia, frescura, sabor residual, textura de pulpa y homogeneidad de pulpa (Nolasco-Matías et al., 2020). Se realizó una prueba de aceptabilidad global (López-Ortiz, 2015) con la participación de 100 consumidores de entre 18 y 23 años. El análisis sensorial incluyó panelistas de 23 estados mexicanos, con mayor representación del Estado de México (21 %), Oaxaca (19 %), Puebla (10 %) y Veracruz (7 %), mientras que el 43 % restante provino de otros estados. El 54 % eran hombres y el 46 % mujeres, de los cuales el 94 % eran estudiantes.

Se utilizó una escala hedónica de nueve puntos (Hernández-Montes, 2007): 1 = Me desagrada extremadamente, 2 = Me desagrada mucho, 3 = Me desagrada moderadamente, 4 = Me desagrada ligeramente, 5 = Me gusta ligeramente, 6 = Ni me gusta ni me disgusta, 7 = Me gusta moderadamente, 8 = Me gusta mucho, 9 = Me gusta extremadamente. Ambos tipos de kiwis muestreados fueron codificados con números aleatorios de tres dígitos y presentados en platos de unicel.

7.4.4. Análisis estadístico

Los datos fueron evaluados mediante la prueba no paramétrica de Wilcoxon, utilizada para identificar diferencias significativas entre las dos variedades analizadas. Esta técnica, considerada el equivalente no paramétrico de la prueba t para muestras independientes (McCall, 1996), permitió un análisis detallado de las variaciones. Adicionalmente, se aplicó un análisis de componentes principales (PCA) para analizar el desempeño de los panelistas, proporcionando una visión integral de los patrones y relaciones en los datos. Todo el procesamiento de la información se realizó utilizando el software XLSTAT, versión 2023.1.1.

7.5. RESULTADOS Y DISCUSIÓN

7.5.1. Aceptabilidad global

'SunGold' destacó en frescura, sabor residual, textura de pulpa y homogeneidad de pulpa (Cuadro 1), y tuvo una mayor aceptabilidad global, lo cual permilte determinar la calidad sensorial percibida por los consumidores (Civille & Oftedal, 2012). La superioridad de 'SunGold', uno de los mejores cultivares de kiwi en el mundo (Vlasiuk et al., 2024), podría atribuirse a sus propias características de calidad y a la optimización en el manejo de las vides (MacLeod et al., 2016; Thorp et al., 2017; Mu et al., 2018), los atributos sensoriales de 'GoldenRouge' podrían mejorarse con un manejo del huerto que incluya polinización, aclareo y nutrición; ya que como menciona Chai et al. (2023) estás condiciones influyen en el número y tamaño de las semillas y el dulzor que afectan la calidad sensorial de la textura de la pulpa, el aroma y el sabor, lo cual podría haber influido en las calificaciones más bajas obtenidas por ‘GoldenRouge’, donde esta especie contiene entre 200 a 300 semillas por cada fruto de 60 g, mientras que ‘Sundgold’ supera en valor a la anterior variedad, con 400 a 600 semillas por cada fruto de 120 g.

Cuadro 1. Comparación de medias por atributos para las muestras de kiwi.

Atributo	**Kiwi A (A) ‘GoldenRouge’**	**Kiwi B(B) ‘SunGold’**
Aceptabilidad global	6.73±1.70[z] a	7.47±1.34 b
Sabor ácido	5.13±2.29 a	5.70±2.36 a
Sabor dulce	6.49±1.97 a	6.72±1.95 a
Pegajosidad	5.30±2.20 a	5.56±2.41 a
Astringencia	4.88±2.09 a	5.39±2.27 a
Frescura	6.55±1.79 b	7.18±1.60 a
Sabor residual	5.45±2.24 b	6.37±2.12 a
Textura de la pulpa	6.08±2.23 b	7.20±1.75 a
Homogeneidad pulpa	6.37±2.02 b	7.33±1.70 a

[z] Error estándar. Letras diferentes dentro de las filas indican una diferencia significativa ($P < 0.05$) Rango mínimo = 1; rango máximo = 9.

La puntuación asignada para cada atributo (Cuadro 1) por los consumidores muestra la preferencia de consumo y sugiere las áreas de mejora para el kiwi ‘GoldenRouge’, lo cual puede promover estrategias para optimizar su calidad sensorial y mejorar su competitividad en el mercado. El kiwi ‘SunGold’ recibió la puntuación más alta de aceptabilidad global, con un promedio de 7.47, con una diferencia significativa en comparación con ‘GoldenRouge’, que registró un promedio de 6.73 (Cuadro 1). Estos resultados indicaron que ‘SunGold’ fue preferido por los panelistas.

7.5.2. Análisis de componentes principales

Los dos primeros factores tuvieron una capacidad explicativa del 65.9 % de las relaciones entre los atributos sensoriales evaluados y su impacto en la percepción general de los consumidores (Cuadro 2). El factor F1 solo presentó valores positivos, lo que indicó que no había oposición entre los atributos evaluados, revelando una tendencia uniforme en su percepción. El factor F2 mostró tanto valores positivos como negativos, reflejando una oposición entre ciertos atributos y sugiriendo una diferenciación más marcada en la evaluación sensorial de las muestras (Cuadro 3). Esta dualidad en F2 permitió la identificación de contrastes específicos en las características de las muestras de kiwi, que proporcionó una perspectiva más detallada sobre las preferencias y diferencias percibidas por el consumidor.

Cuadro 2. Vectores propios de ocho componentes principales obtenidos de una evaluación sensorial utilizando ocho atributos de kiwi por 100 panelistas. También se muestran los valores propios de la matriz de correlación y el porcentaje de varianza.

	F1	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	**F8**
Valor propio	3.954	1.324	0.664	0.616	0.482	0.426	0.331	0.203
Variabilidad (%)	49.428	16.545	8.299	7.700	6.019	5.326	4.142	2.542
Acumulado (%)	49.428	65.973	74.272	81.972	87.991	93.316	97.458	100.0

Cuadro 3. Puntuaciones de los dos primeros componentes principales de la evaluación sensorial realizada por 100 panelistas que evaluaron ocho atributos de los kiwis ‘GoldenRouge’ y ‘SunGold®’.

	F1	**F2**
Aceptabilidad global	0.331	-0.362
Sabor ácido	0.338	0.023
Sabor dulce	0.344	-0.348
Pegajosidad	0.355	-0.429
Astringencia	0.369	0.252
Frescura	0.375	-0.145

Sabor residual	0.377	0.455
Textura de la pulpa	0.335	0.521

La Figura 1 muestra la relación entre las variables sensoriales evaluadas: sabores ácido, dulce y residual, pegajosidad, astringencia, frescura, textura de pulpa y homogeneidad de pulpa en ambos tipos de kiwi evaluados. Independientemente del origen, la ubicación de los cuadrantes en la gráfica nos explica la relación de los atributos de cada muestra de ‘A’ y ‘B’. Los valores positivos mayores en la gráfica son considerados puntuaciones altas, los valores positivos menores son considerados puntuaciones promedio y los valores negativos en la gráfica son para las puntuaciones bajas. Estos hallazgos reflejaron cómo los consumidores percibieron y valoraron los diferentes atributos de las muestras analizadas.

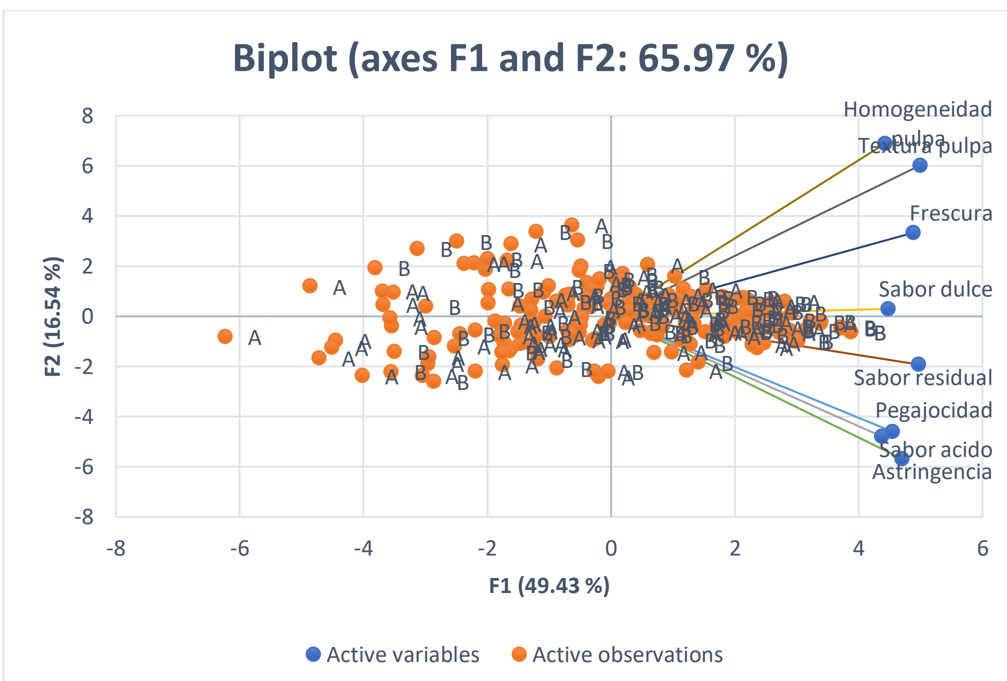

Figura 1. Análisis de componentes principales de los atributos del kiwi evaluado y agrupamiento de los atributos. A: ‘GoldenRouge’, B: ‘SunGold’**.**

Los atributos evaluados en el análisis sensorial representan cada una de las muestras de kiwi estudiadas. Esta representación gráfica permitió una visualización clara de las diferencias y similitudes en la percepción del consumidor respecto a los atributos sensoriales de las muestras A y B.

La evaluación sensorial puede estar influenciada por factores subjetivos, como las preferencias personales y las experiencias previas de los evaluadores (Wang et al., 2022). Además, en frutas climatéricas como el kiwi, que maduran rápidamente, existe el riesgo de deterioro de la calidad antes de las evaluaciones sensoriales (Jaeger et al., 2003), lo cual podría afectar ligeramente la percepción y los resultados obtenidos. Este factor se controló con ayuda de una cava de unicel rellena de hielo, para mantener la fruta fresca.

El establecimiento de huertos de kiwi 'GoldenRouge' en algunas áreas de México no solo aumentaría el consumo de kiwi local en los mercados regionales, sino que también contribuiría a diversificar la oferta agrícola del país, reduciendo la dependencia de las importaciones. Además, esta variedad podría posicionarse como una alternativa económica y accesible para los consumidores, al mismo tiempo que impulsaría la economía de las comunidades productoras al generar empleo y promover prácticas agrícolas sostenibles en las regiones donde se cultive. La producción local también fomentaría el desarrollo de cadenas de valor más cortas, beneficiando tanto a productores como a consumidores finales.

7.6. CONCLUSIÓN

Al ser la primera prueba sensorial realizada con el kiwi 'GoldenRouge', estos resultados proporcionan una base inicial para entender su percepción por parte del consumidor. Aunque el kiwi 'SunGold' destacó en frescura, sabor residual, textura y homogeneidad de pulpa, el 'GoldenRouge' mostró características competitivas, como su equilibrado sabor ácido y dulce, junto con atributos de pegajosidad y astringencia comparables. Estos hallazgos indican que el 'GoldenRouge' tiene potencial para ser una alternativa agrícola para la región considerando en mejorar las labores agronómicas.

7.7. AGRADECIMIENTOS

Agradecemos al Consejo Nacional de Humanidades, Ciencia y Tecnología (CONAHCyT), a la Universidad Autónoma Chapingo, y a los colaboradores (Francisca de los Ángeles

Mejía Betancourt, Christian Camilo Castañeda Cardona, María Guadalupe Villa Fuerte, Paola Díaz Barrios, Laura Hypatia Sánchez Hernández, Abigail Ortiz, Dra. Irma Salgado).

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8. CONCLUSIÓN GENERAL

La investigación sobre el cultivo de kiwi en el trópico de altura de México brindó una visión integral de los factores clave para su producción y aprovechamiento. En particular, las condiciones edafoclimáticas de Huatusco, Veracruz, se caracterizan por un clima húmedo semicálido, con temperaturas promedio de 12 a 14 °C y una humedad relativa que oscila entre el 75 % y el 95 % durante los meses más fríos. Además, se observó que las yemas de las vides alcanzaron una brotación cercana al 50 % bajo condiciones de 443 horas frío, creciendo de manera favorable en suelos volcánicos con una densidad aparente de 0.81 t m^{-3}, 12 % de materia orgánica, 34 ppm de nitrógeno y un pH ligeramente ácido de 5.3. Estos resultados destacan el potencial de esta región para el cultivo exitoso de kiwi.

En relación con la germinación, se comprobó que la aplicación de técnicas específicas, como el uso de ácido giberélico en concentraciones de 1000 a 6000 ppm, combinadas con temperaturas constantes de 25 y 30 °C, mejora significativamente la tasa de germinación al superar la latencia de las semillas, pasando de 0 % en el testigo a casi un 50% de germinación. Estos resultados demuestran la efectividad de estas estrategias para optimizar el proceso germinativo y favorecer el establecimiento del cultivo

El análisis fitoquímico de los frutos de kiwi cultivados en Huatusco, Veracruz, México, reveló que, aunque presentan un tamaño menor en comparación con los kiwis comerciales importados, destacan por su elevado contenido de ácidos orgánicos (a. ascórbico), minerales (N, Ca, Zn, Ni y Mo), fenoles y flavonoides. Asimismo, su notable capacidad antioxidante, atribuida a la alta concentración de compuestos fenólicos y vitamina C, resalta el potencial nutracéutico de estos frutos, posicionándolos como una alternativa valiosa en términos de calidad y beneficios para la salud.

En cuanto al perfil fitoquímico de las hojas y la influencia del método de secado, este estudio confirma que las hojas de kiwi (*Actinidia chinensis*) cultivadas en Huatusco, Veracruz, son una fuente viable y prometedora de compuestos nutracéuticos, con concentraciones significativas de compuestos fenólicos, flavonoides y alta capacidad antioxidante (FRAP y ABTS), comparables a las de hojas tradicionales como el té verde y negro. Asimismo, los métodos de secado evaluados, liofilización y secado convectivo, resultaron igualmente efectivos para preservar la mayoría de los compuestos bioactivos, salvo pequeñas diferencias en el contenido de flavonoides.

Finalmente, el análisis sensorial comparativo entre el kiwi 'GoldenRouge' y 'SundGold' mostró que, aunque la variedad 'SundGold' presentó una mayor aceptación global y se destacó en atributos como frescura, textura y homogeneidad de la pulpa, la variedad 'GoldenRouge' mostró características competitivas, como su equilibrado sabor ácido y dulce, junto con atributos de pegajosidad y astringencia comparables.

En conclusión, el cultivo de kiwi en zonas de trópico de altura en México posee un potencial significativo tanto para la diversificación agrícola como para el desarrollo de productos con alto valor nutracéutico. La mejora en prácticas de manejo agronómico, estrategias de germinación y un enfoque en la calidad sensorial podrían fortalecer la competitividad y aceptación de estas variedades en el mercado nacional.