# FRITURA AL VACÍO DE NUEVA VARIEDAD DE PAPA DIPLOIDE: SNACK CON POTENCIALES PROPIEDADES ANTIOXIDANTES

# VACUUM FRYING OF NEW VARIETY OF DIPLOID POTATO: SNACK WITH POTENTIAL ANTIOXIDANT PROPERTIES

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# RESUMEN GENERAL

La papa representa un cultivo de gran importancia a nivel mundial, debido a su aporte de nutrientes es esencial para la alimentación humana y su consumo en el mundo tiene una buena participación después del arroz y el trigo; así es considerado el principal alimento de origen no cereal y su cultivo alcanza más de la mitad de la cosecha mundial. La Universidad Nacional de Colombia ha tenido un avance significativo desde el punto agronómico con el desarrollo de nuevas variedades de papa diploide: Paola, Primavera, Paysandú, Violeta y Milagros, con el fin de aprovechar estas grandes ventajas y llevarlas consumidor final, ofreciéndole un valor agregado en el producto transformado y de practicidad al momento del consumo, se planificó en el desarrollo de snacks de papa variedad Primavera, freídos al vacío, de manera que se conserven la mayor cantidad de sus compuestos antioxidantes.

Por tal motivo, el objetivo de la investigación fue estandarizar el proceso tecnológico de fritura al vacío para la obtención de "*snacks*" de papa (*Solanum phureja* cv Primavera) con potenciales propiedades antioxidantes.

Se utilizó papa variedad Primavera (*Solanum phureja*), la cual se caracterizó en estado fresco durante su almacenamiento (0,7,14,21,30 días poscosecha), siendo su tiempo de procesamiento hasta el día 21. La papa fresca presentó las siguiente propiedades: textura (fuerza máxima: 12.2 ± 1.8 N; distancia: 2.7 ± 0.3 mm), humedad (80.8 ± 1.2 %), actividad de agua ($a_w$) (0.980 ± 0.003), capacidad antioxidante: DPPH (2.3 ± 0.1 mg trolox/g), ABTS (2.7 ± 0.2 mg trolox/g), fenoles totales (6.1±0.1 mg GAE/g), color zona interna ($L_{in}$*: 37.6 ± 6.0; $a_{in}$*:18.1 ± 2.5; $b_{in}$*: 6.1 ± 3.7).

Se optimizó experimentalmente el proceso de fritura al vacío de la papa diploide variedad Primavera, utilizando la metodología de superficie de respuesta y un diseño central compuesto en función de las variables independientes: ΔT ($T_{aceite}$-$T_{ebullición\ agua}$) (°C) (45-65 °C), presión de vacío (25-70 kPa) y tiempo de freído (240-420 s), y las variables dependientes: $a_w$, humedad, color zona interna y externa ($L_{in}$*, $a_{in}$*, $b_{in}$*, $L_{out}$*, $a_{out}$* $b_{out}$*), textura (fuerza máxima), capacidad antioxidante (ABTS y DPPH), índice de peróxidos y contenido de grasa. Se utilizó el análisis de varianza (ANOVA) con un nivel de significancia del 5%, siendo las condiciones óptimas de proceso: $T_{aceite}$: 136 °C, tiempo de freído: 420 s y presión de vacío: 59,4 kPa, y los valores de las variables dependientes: fuerza máxima: 5.8 ± 1.1 N, distancia: 1.4 ± 0.3 mm), $L_{in}$* (34.0 ± 5.2), $a_{in}$*(14.5 ± 2.2), $b_{in}$* (7.3 ± 2.7), $L_{out}$* (34.8 ± 6.1), $a_{out}$*(13.6 ± 1.8), $b_{out}$* (7.4 ± 2.8), humedad (3.4 ± 0.1 %), $a_w$ (0.390 ± 0.020), IP (4.4 ± 0.6 meq $H_2O_2$/kg), DPPH (0.5 ± 0.0 mg trolox/g), ABTS (0.6 ± 0.0 mg trolox /g), contenido grasa (26.7 ± 1.8 %).

Finalmente, se evaluaron las cinéticas de reacción de los compuestos antioxidantes y productos de la oxidación lipídica de la papa variedad Primavera freída al vacío durante su almacenamiento: temperatura (15, 25,35 °C), atmósfera de envasado ($N_2$, aire) y tiempo (0, 30, 60, 90, 120 y 150 días), determinándose el orden de reacción y la energía de activación para DPPH, ABTS, fenoles totales, índice de peróxidos y acidez. Se encontró que la temperatura y la atmósfera de empaque afectaron significativamente los atributos de calidad, a mayores temperaturas y atmósfera de aire, se presentó mayor degradación del color y la textura; mientras que, los compuestos antioxidantes presentaton una retención del 50% en envasado a 15 °C y $N_2$ durante los 150 días de almacenamiento.

**ABTRACT**

The potato represents a crop of great importance worldwide, due to its contribution of nutrients is essential for human and its consumption in the world has a good participation after rice and wheat; thus it is considered the main food of non-cereal origin and its cultivation reaches more than half of the world's harvest. The National University of Colombia has had a significant advance from the agronomic point with the development of new varieties of diploid potatoes: Paola, Primavera, Paysandú, Violeta and Milagros, in order to take advantage of these great advantages and bring them to the final consumer, offering a value added in the processed product and practicality at the time of consumption, was planned in the development of potato snacks variety Primavera, fried in vacuum, so that they retain the greatest number of their antioxidant compounds.

For this reason, the aim of the research was to standardize the technological process of vacuum frying in order to obtain potato "snacks" (*Solanum phureja* cv Primavera) with potential antioxidant properties.

The potato variety Primavera (*Solanum phureja*) was used, which was characterized in its raw state during storage (0,7,14,21,30 days post-harvest), being its processing time until day 21. The raw potato presented the following properties: texture (maximum strength: 12.2 ± 1.8 N, distance: 2.7 ± 0.3 mm), humidity (80.8 ± 1.2%), water activity (aw) (0.980 ± 0.003), antioxidant capacity: DPPH (2.3 ± 0.1 mg trolox) / g), ABTS (2.7 ± 0.2 mg trolox / g), total phenols (6.1 ± 0.1 mg GAE / g), internal zone color (Lin *: 37.6 ± 6.0, ain *: 18.1 ± 2.5, bin *: 6.1 ± 3.7).

The process of vacuum frying of the spring variety diploid potato was optimized experimentally, using the response surface methodology and a central composite design based on the independent variables: $\Delta T$ ($T_{oil}$-$T_{Boiling\ water}$) (45-65 °C) , vacuum pressure (25-70 kPa) and frying time (240-420

s), and the dependent variables: aw, moisture, color (Lin *, ain *, bin *) texture (maximum strength), antioxidant capacity (ABTS and DPPH), peroxide index and fat content. The analysis of variance (ANOVA) with a level of significance of 5% was used, being the optimal process conditions: Taceite: 136 ° C, frying time: 420 s and vacuum pressure: 59.4 kPa, and the values of the dependent variables: maximum force: 5.8 ± 1.1 N, distance: 1.4 ± 0.3 mm), Lin * (34.0 ± 5.2), ain * (14.5 ± 2.2), bin * (7.3 ± 2.7), Lout * (34.8 ± 6.1) ), aout * (13.6 ± 1.8), bout * (7.4 ± 2.8), moiture (3.4 ± 0.1%), aw (0.390 ± 0.020), IP (4.4 ± 0.6 meq H2O2 / kg), DPPH (0.5 ± 0.0 mg) trolox / g), ABTS (0.6 ± 0.0 mg trolox / g), fat content (26.7 ± 1.8%).

Finally, the reaction kinetics of the antioxidant compounds and products of the lipid oxidation of the variety Primavera potato fried in vacuum during storage were evaluated: temperature (15, 25.35 ° C), packaging atmosphere (N2, air) and time (0, 30, 60, 90, 120 and 150 days), determining the order of reaction and the activation energy for DPPH, ABTS, total phenols, peroxide index and acidity. It was found that the packing temperature and atmosphere significantly affected quality attributes, at higher temperatures and air atmosphere, there was greater degradation of color and texture; while, the antioxidant compounds present a 50% retention in packaging at 15 ° C and N2 during the 150 days of storage.

# INTRODUCCIÓN

## INTERÉS DEL ESTUDIO

La papa representa un cultivo de gran importancia a nivel mundial, debido a su aporte de nutrientes es esencial para la alimentación humana y su consumo en el mundo tiene una buena participación después del arroz y el trigo; así es considerado el principal alimento de origen no cereal y su cultivo alcanza más de la mitad de la cosecha mundial (Gómez et al., 2012).

En Colombia uno de los cultivos de papa, con gran crecimiento en producción y consumo en los últimos años, es el de la papa criolla, según las últimas estadísticas del Ministerio de Agricultura y Desarrollo Rural, la producción en el año 2013 alcanzó las 146960 ton, con un área de cultivo de 10280 Ha; lo cual representa un crecimiento considerable (414 % en producción y 418% en Ha sembradas) si se tiene en cuenta que la producción para el año 2006 estaba en 28549 toneladas distribuidas en 1984 Ha (Ministerio de Agricultura, 2013).

Estudios recientes en genética han utilizado el conocimiento y el uso del número de balance de endospermo y gametos, y han logrado la transferencia de caracteres deseables en generaciones posteriores, en forma eficiente (Gómez et al., 2012); así el grupo de papas criollas diploides *S. phureja,* es un recurso genético de gran importancia para el país, debido a su importante contenido de proteínas y antioxidantes, excelentes propiedades agronómicas, fuentes de resistencia a plagas, agradable sabor y textura y alto potencial de exportación en diversas formas de procesamiento (Ñústez L., 2011; Torres, Bautista J, & Ramírez M, 2012).

La Universidad Nacional de Colombia a través de los grupos de investigación en papa y el grupo de mejoramiento y producción de especies andinas y tropicales ha tenido un avance significativo desde el punto agronómico con el desarrollo de nuevas variedades de papa diploide: Paola, Primavera, Paysandú, Violeta y UN-San Pedro; que ofrecen ventajas agronómicas (resistencia a sarna polvosa, gota y mayor rendimiento), nutricionales (papas diploides con propiedades antioxidantes) y gastronómicas (papas criollas coloreadas, con mejoras en sabor y textura). Este panorama es muy positivo y genera mayor compromiso en la búsqueda de nuevas alternativas que impriman valor agregado a estas variedades y que que además respondan en forma efectiva a las necesidades del consumidor moderno, quien cada exige mayor calidad y que al mismo tiempo sean productos que contribuyan a prevenir enfermedades.

En este contexto, los retos de competitividad en el sector agroindustrial y agroalimentario, crecen diariamente, y para poder mantenerse en la economía global, debe existir un jalonamiento desde las industrias, universidades, centros de investigación, asociaciones, cooperativas, entre otros, que conduzca en un futuro y a mediano plazo, facilitar el ingreso a nuevos mercados que hagan más competitiva la cadena de la papa.

Con el fin de aprovechar estas grandes ventajas de las variedades de la papa diploide, se ha seleccionado la variedad Primavera con el propósito de desarrollar snacks freídos al vacío, de manera que se conserven la mayor cantidad de sus compuestos antioxidantes y así, estandarizar su proceso tecnológico que permita su transformación y la posibilidad de realizar su transferencia tecnológica a corto plazo.

## GENERALIDADES DE LA PAPA

La papa es una especie vegetal del género *Solanum*, familia Solanácea, cuenta con más de 2000 especies cultivadas actualmente en el mundo (Molina, Rabe, Rodríguez, Cerón, & Garnica, 2015). En el caso de Colombia, el cultivo predominante es el de *Solanum phureja*, conocido como "*papa criolla*", estas papas se cultivan desde el occidente de Venezuela hasta el centro de Bolivia, siendo Colombia el principal productor y exportador de estas papas (Bianeth, 2015), esta variedad se caracteriza por ser un tubérculo pequeño redondo y colores que van desde el amarillo hasta el púrpura, el rango de temperatura para su cultivo es de 10 a 20°C y se cultiva desde 2000 hasta 3000 msmm; el mejor suelo para el cultivo de la papa criolla es aquel que presenta un pH entre 5.2 y 5.9, un alto contenido de materia orgánica y una textura suelta y profunda, ya que evita la acumulación de humedad en la raíz (Barrientos, 2012). Su periodo vegetativo es de 4 a 5 meses, su planta alcanza 60 cm de alto, esta conformada por tallos delgados de color verde claro, ramificada en la parte baja de donde brotan flores color lila, blanco o rojo. El tubérculo tiene una alta variabilidad en la forma que va desde esférica a ovoide, es de tamaño pequeño, ojos de profundidad media distribuidos por toda la superficie, y colores que van desde amarillo al púrpura, tanto en la pulpa y la piel (Bonierbale et al., 2004); la planta pude producir hasta 40 tubérculos esparcidos en contorno.

La Papa criolla tiene un alto poder nutritivo (tabla 1), reporta el doble de nutrientes con respecto a la papa común (Cevipapa, 2005), igualmente dentro de los tubérculos es considerada por su mayor aporte proteico, concentración de carbohidratos, vitamina C y hierro. Dentro de los nutrientes que más se destacan y conocen de la papa criolla, están los carbohidratos, los cuales corresponden al 21,5 % de la porción comestible del tubérculo (Tian, Chen, Ye, & Chen, 2016), de estos el 60-80 % es almidón. El contenido de agua de la papa criolla se encuentra en un rango entre el 77-80 % y el de proteínas está alrededor del 2,5 %, contiene 1,8 % de fibra; además de estos macronutrientes, la papa criolla contiene cantidades importantes de compuestos fenólicos, después de la naranja y la manzana es la mayor fuente de consumo de antioxidantes por parte de la población mundial.

El sabor característico de la papa es debido al contenido de carbohidratos, la sacarosa se lleva la mayor participación con 92% frente a los monosacáridos glucosa, fructuosa, manosa. Su interés nutricional se debe además por los altos niveles de hierro, zinc, magnesio, calcio y azufre (C. Peña et al., 2015). La cascara presenta mayor contenido minerales como Zinc (0,89 mg), hierro (3,49 mg), magnesio (0,15 mg), cobre (0,23 mg), potasio, sodio (203,5 mg) frente a la pulpa (Mejía, 2004), así por el mayor contenido nutricional de la cascara del tubérculo es recomendable consumir la papa entera.

Si bien la papa no es considerada como fuente importante de proteína, la composición en aminoácidos esenciales la hace apta para la elaboración de suplementos alimenticios (Kapoor & Desborough, 1975). Se hallaron los aminoácidos metionina, lisina, triptófano, tirosina; encontrando mayores contenidos en papa criolla de cultivos fertilizados frente a los no fertilizados, por lo tanto, el buen manejo de los cultivos es un aspecto clave si se quiere preservar el contenido de proteínas.

Otra de las ventajas de *Solanum phureja* es que sus clones tienen la capacidad de cruzarse con otros genotipos de papa, debido a la naturaleza silvestre de sus variedades provenientes de los andes, en consecuencia, se han utilizado ampliamente en los programas de mejoramiento de papa, así los conocimientos en genética se han usado para transferir de forma efectiva la diversidad y atributos presentes en diferentes variedades de papas.

**Tabla 1.** Información nutricional de la papa criolla (*Solanum phureja*)

| Componente | Valor |
|---|---|
| Agua | 75.5 % |
| Proteína | 0.5 % |
| Grasas | 0.1 % |
| Carbohidratos | 18.7 % |
| Fibra | 2.2 % |
| Cenizas | 1.0 % |
| Calorías | 83 cal |
| Fósforo | 54.0 mg |
| Hierro | 0.60 mg |
| Riboflavina | 0.06 mg |
| Niacina | 2.50 mg |
| Ácido ascórbico | 15.0 mg |
| Tiamina | 0.08 mg |
| Calcio | 7.00 mg |

La papa contiene 12 cromososas , que se organizan en diferentes ploidías; el grupo de papas criollas diploide (2n=2x=24) denominada como *S. phureja* presenta propiedades agronómicas y nutricionales favorables (Gómez et al., 2012); los cruces con otras variedades y el mejoramiento genético han permitido obtener nuevas variedades resistentes al ataque de enfermedades comunes como la gota y sarna polvorosa, evitando así la aplicación intensiva de agroquímicos (Mosquera et al., 2013); además se han obtenido variedades con coloración en su pulpa y cáscara, con propiedades funcionales y gastronómicas interesantes.

Se ha estudiado que las papas con coloración tienen alto contenido de antioxidantes, los cuales comprenden un amplio grupo de sustancias, que en concentraciones bajas, son capaces de prevenir o retardar la oxidación de un compuesto determinado (Venereo Gutiérrez, 2002). Dentro de los antioxidantes más estudiados se encuentran, la vitamina E, vitamina C, carotenoides, antocianinas y otros pigmentos, flavonoides y compuestos fenólicos (Halliwell, 1996), los cuales pueden llegar a resultar benéficos para la salud, al prevenir enfermedades como el cáncer y daños al ADN celular, debido a que estos compuestos son capaces de neutralizar la acción de radicales libres, causantes de daños oxidativos a los compuestos celulares (Molina et al., 2015).

La coloración de los tubérculos depende principalmente del contenido de antocianinas y carotenoides presentes; dentro de los carotenoides más comunes en papas se encuentran las xantofilas, importantes en la prevención de daños a la retina, causadas por la luz UV, otros carotenoides encontrados son luteína, zeaxantina, violaxantina y β-caroteno (Fernandez-Orozco, Gallardo-Guerrero, & Hornero-Méndez, 2013); en cuanto a las antocianinas encontradas en papas, las más comunes incluyen glucósidos acilados de pelargonidina, glucósidos acilados de petunidina, delfidina y malvidina (Burmeister et al., 2011)

Por otro lado, otro grupo de compuestos antioxidantes importantes presentes en papas, es el de los fenoles, dentro de los que destacan en los tubérculos: cumarinas, flavonas, taninos, lignina, ácido clorogénico, ácido cafeico, ácido protocatechuico, quercetina, kaempferol, entre otros. (Fuenzalida, 2008)

## Papa en el contexto nacional e internacional

En Colombia se ha visto un leve aumento (2%) en la producción de papa de todas las variedades durante los años 2008 a 2015, mientras que las hectáreas sembradas disminuyeron en 9% (Figura 1), lo que refleja un aumento en la productividad (FEDEPAPA, 2015).

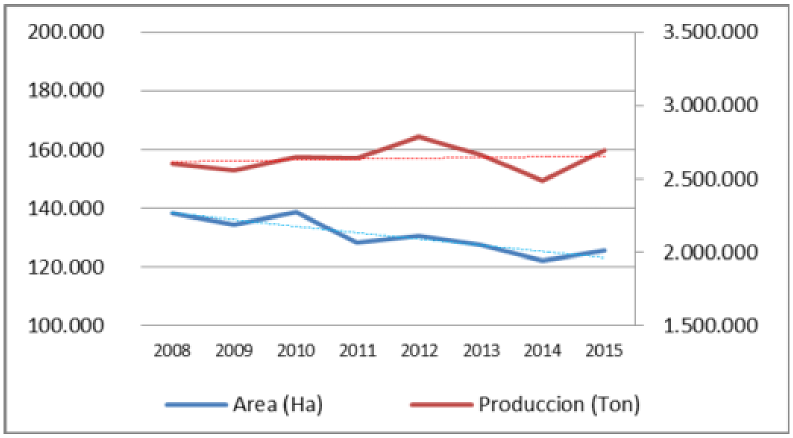


**Figura 1**.Área cosechada y producción de papa en Colombia entre 2008 y 2015

Fuente: Fedepapa.

Para el año 2017 la producción se incrementó un 13.5 %, respecto al año 2016 (FEDEPAPA, 2017a) y esta cifra representa el 0.7 % del total producido a nivel mundial (392 millones de ton/ año). Los departamentos con mayor producción de papa fueron Antioquia, Cundinamarca, Boyacá y Nariño. La clasificación de los productores de papa está organizada en pequeños (menos de 3 Ha), medianos (3-10 Ha) y grandes (>10 Ha), en Colombia se cuenta con 90000 productores de papa aproximadamente, que alcanzan a generar unos 20 millones de empleos al año. En el caso de la papa criolla para el año 2014 se tenían en Colombia 8.8 Ha sembradas, que correspondían al 6.8 % del total sembrado de papa.

En cuanto a la comercialización de la papa criolla en Colombia, los canales que más se utilizan para la distribución son las centrales mayoristas, en especial Corabastos en Bogotá, para finalmente seguir otros eslabones y llegar al consumidor final; cada eslabón de la cadena incrementa en promedio un 15 % del valor a la papa, llegando así al consumidor final, con un incremento aproximado del 60% del costo inicial. (Piñeros, 2009)

Las importaciones de diferentes variedades de papa en Colombia se calcularon, para el año 2014 en 29000 toneladas del producto precocido congelado, principalmente proveniente de Bélgica, Holanda, Alemania y Estados Unidos; en cuanto a exportaciones del tubérculo, se realizaron en este mismo año, 1200 toneladas de papa criolla a Estados Unidos y Japón (Gómez Rodríguez, 2015)

Uno de los mayores productos industrializados de papa son los chips y productos freídos, tan solo en Estados Unidos se procesaron 3.100.000 toneladas de papa para elaboración de chips en el 2013 (National Potato Council, 2014), de este producto se importaron 10000 toneladas y se exportaron 35000 toneladas (National Potato Council, 2015); este mercado generó en EEUU ventas por 527.2 millones de dólares en 2016 (Statista, 2016). Colombia por su parte importa en su mayoría el producto congelado y precocido, el cual represento una cifra de 42.000 ton para el año 2016 (FEDEPAPA, 2017b) hacia la Unión Europea.

Entre los parámetros que se toman en cuenta para la industrialización de la papa se tiene el contenido de materia seca, el cual determina el rendimiento industrial y también influencia el tiempo y calidad de fritura. El contenido de materia seca debe ser mayor al 23% y depende de la variedad, madurez del tubérculo, clima, suelo y prácticas de cultivo (Sumnu & Sahin, 2008). Paralelamente, el contenido de azucares reductores, se establece como máximo entre 3 y 5 mg/gramo de peso fresco, debido a su participación con el grupo amino de los aminoácidos en la reacción de Maillard produciendo un ennegrecimiento (Badui Dergal, 2006).

## FRITURA POR INMERSIÓN DE ALIMENTOS

La fritura por inmersión de los alimentos es uno de los más antiguos y comunes métodos de cocción de los alimentos, consiste en sumergir el producto en aceite caliente a una temperatura por encima del punto de ebullición del agua (Pedreschi, 2009).

Debido al sabor y textura que otorga a los alimentos, además de los tiempos de proceso rápidos, es una tecnología con gran aceptación mundial, aunque en los últimos años ha adquirido una imagen desfavorable, por el alto contenido calórico de los alimentos fritos y la formación de compuestos tóxicos, entre ellos las acrilamidas, relacionadas con problemas cardiacos y desarrollo de cáncer.(Jin, Wu, & Zhang, 2013); esto ha generado la búsqueda de nuevas alternativas y tecnologías, entre ellas la fritura al vacío, recubrimiento de los alimentos con hidrocoloides (Varela & Fiszman, 2011), secado del alimento antes de la fritura por inmersión y procesos de secado post-fritura (Ziaiifar et al., 2008).

### Fritura convencional

El proceso de fritura por inmersión consiste en la inmersión de un alimento en aceite a temperaturas entre 150°C-190°C; durante este proceso ocurren simultáneamente transferencia de calor y masa entre el alimento y el medio.(Choe & Min, 2007)

Los parámetros que influyen en el proceso de fritura por inmersión son (Vélez & Hernández, 1999):

- Temperatura: entre más alta sea la diferencia de temperatura entre el alimento y el aceite, mayor será la transferencia de calor y masa entre ambos, logrando un proceso más rápido y una menor absorción de aceite por parte del alimento; a su vez las altas temperaturas aceleran la degradación del aceite de fritura. (Stier, 2004)
- Tiempo de proceso: tiempos de proceso más prolongados aumentan las reacciones oxidativas de los aceite, generando mayor cantidad de hidroperóxidos y radicales libres; tiempos de fritura mayores, aumentan la absorción de grasa en el alimento y las reacciones de pardeamiento (Suaterna Hurtado, 2008).
- Calidad del aceite: se ha estudiado que a mayor formación de compuestos polares y otros surfactantes generados por procesos degradativos del aceite en la fritura, hay mayor absorción de grasa por parte del alimento, puesto que se disminuye la tensión superficial; se plantea la renovación de aceites de fritura como el método más sencillo para disminuir la cantidad de estos compuestos, así se deben establecer controles de calidad del aceite y plantear cronogramas de re cambio; otros procesos estudiados han planteado el secado previo de los alimentos antes de la fritura, con el fin de minimizar la salida brusca de agua en el momento de la inmersión y por tanto la gran formación de burbujas que deterioran el aceite (Ramírez Botero et al., 2012) .
- Características del alimento: en alimentos congelados se debe tener menores temperaturas de freído y mayores tiempos, con el fin de no generar un gradiente muy alto y formar rápidamente una costra que impida la cocción interna del alimento; el tamaño del alimento influye en el proceso de fritura, piezas más gruesas requieren mayores tiempos y menores temperaturas en el aceite; se han estudiado la aplicación de tratamientos previos al proceso de freído que

disminuyan la absorción de grasa por parte del alimento, algunos estudios plantean la aplicación de hidrocoloides en la superficie del producto (Varela & Fiszman, 2011).

Dentro de las principales etapas del proceso de fritura por inmersión, se encuentran (Tirado, Acevedo, & Guzman, 2012):

- Calentamiento inicial: es la etapa en la cual el alimento se calienta hasta llegar a la temperatura de ebullición del agua, la transferencia de calor ocurre por convección natural y conducción; en esta etapa no hay evaporación superficial del agua.
- Ebullición superficial: se inicia en el momento en que el vapor de agua sale de la superficie del alimento, hay formación de burbujas; se comienza a formar una costra superficial en el alimento y se forma turbulencia en el aceite alrededor de la superficie del producto; las burbujas formadas aumentan el área de contacto entre el aire y el aceite, lo que provoca mayores reacciones de degradación de los lípidos (Gertz, 2014).
- Periodo de velocidad decreciente: en esta etapa se dan cambios químicos dentro del alimento, como la gelatinización del almidón, desnaturalización de proteínas, y en general cocimiento en el interior del producto; el centro del alimento alcanza la temperatura de ebullición del agua y hay un aumento en la presión interna que hace migrar el agua hacia la superficie del alimento.
- Punto final de burbuja: se presenta una formación definitiva de la costra en la superficie del producto, se da principalmente en alimentos con tiempos de fritura largos y temperaturas elevadas, la textura de los productos se torna muy dura y no es deseable para los consumidores.

## Fritura por inmersión al vacío

La fritura por inmersión al vacío es un proceso que se lleva a cabo en condiciones de presión menores a la presión atmosférica (L. M. Diamante et al., 2015); lo que implica temperaturas de freído menores a las convencionales y al no tener contacto con el oxígeno, disminuyen los procesos de deterioro de los aceites.

Se han estudiado las ventajas del proceso de fritura al vacío, entre las que se encuentran, una disminución del contenido de aceite absorbido por los alimentos, menor formación de acrilamidas y otros compuestos tóxicos, mayor durabilidad de aceites de fritura, conservación de propiedades nutricionales y compuestos bioactivos de los alimentos, mejoramiento en propiedades sensoriales, tales como color, textura y sabor (Mir-Bel, Oria, & Salvador, 2012a).

El proceso de fritura al vacío requiere de un sistema que consta de una vasija o recipiente con agitador, una resistencia que calienta el aceite y una malla en la que se coloca el producto; un condensador que enfría los vapores generados en la fritura y una bomba de vacío que extrae el aire del sistema (Garayo & Moreira, 2002).

En el momento en que sumerge el producto, la presión del sistema tiene un leve aumento, debido a la rápida evaporación del agua del alimento (Pandey & Moreira, 2012); en general las etapas del proceso y los fenómenos de transferencia en la fritura al vacío son muy similares a los de la fritura convencional, explicada anteriormente, hay algunas diferencias en cuanto a que en la fritura al vacío, se espera una transferencia de calor inmediata y una evaporación rápida del agua debido a que la temperatura de ebullición del agua es menor; también se espera una diferencia del tamaño, cantidad y velocidad de formación de las burbujas (Mir-Bel, Oria, & Salvador, 2012b).

Este proceso se ha aplicado en diversas matrices alimentarias como chips de banano freída por inmersión al vacío a 110°C, 8 kPa y 20 min, obteniendo un producto crujiente (Yamsaengsung, Ariyapuchai, & Prasertsit, 2011); chips de yuca previamente escaldados y freídos por inmersión al vacío a 3 temperaturas (120, 130 y 140°C), 7 kPa y 2 min, en los que se evidenció una menor absorción de aceite y mayor crujencia que en los freídos de forma convencional a 165°C (García-Segovia et al., 2016); chips de piña freídos por inmersión al vacío a temperaturas entre 106.3°C y 117.7°C, tiempos de fritura entre 6.3-7.7 min y presión de vacío de 24 kPa, en donde el proceso permitió la conservación de los compuestos antioxidantes del producto (Perez-Tinoco et al., 2008); en chips de papa, se han realizado diversos estudios del proceso de fritura por inmersión al vacío, siendo esta una de las matrices en donde más se ha reportado este proceso.

**ALIMENTOS FUNCIONALES**

El término Alimento Funcional fue propuesto por primera vez en Japón en la década de los 80's con la publicación de la reglamentación para los "*Alimentos para uso específico de salud*" ("*Foods for specified health use*" o FOSHU) y que se refiere a aquellos alimentos procesados los cuales contienen ingredientes que desempeñan una función específica en las funciones fisiológicas del organismo humano (Kaur & Singh, 2017).

Actualmente se tienen varias definiciones para un alimento funcioanl, debido a que el término alimentos funcionales no es una categoría de alimentos legalmente reconocida por la Administración de alimentos y Drogas (FDA) de los Estados Unidos; sin embargo, las regulaciones de la NLEA (Ley de Etiquetado y Regulación Nutricional) y de la DSHEA (Ley de Suplementos Dietéticos Salud y Educación) se encaminan a preparar el camino legal en que se debe fundamentar el uso de estos productos. Por ahora, basados en la posición de la U.S.: "Las sustancias específicas de los alimentos pueden favorecer la salud como parte de una dieta variada, que se consumen en forma regular y a niveles efectivos " (Bello, 1995) los alimentos funcionales se pueden considerar como "aquellos productos a los cuales intencionalmente y en forma controlada se les adiciona un compuesto específico para incrementar su propiedades saludables" y define como alimentos saludables a "aquellos que en su estado natural, o con mínimo procesamiento, tienen compuestos con propiedades beneficiosas para la salud" (Biesalski, Aggett, & Anton, 2010).

Los alimentos funcionales comprenden aquellos que son fortificados con compuestos bioactivos y los que son naturalmente fuente de compuestos con actividad funcional (Araya L & Lutz R, 2003). Entre las principales propiedades funcionales que se han estudiado en los alimentos se encuentran las relacionadas con un óptimo crecimiento y desarrollo, la función del sistema cardiovascular, los antioxidantes, el metabolismo de xenobioticos, el sistema gastrointestinal, entre otros (Palou & Serra, 2000).

Los compuestos funcionales que se han estudiado principalmente comrpenden los fenoles, carotenoides, fibra dietaria, β-glucanos, inulina, ácidos grasos ω-3, probioticos y prebióticos, fitoestrogenos, proteínas de soya, esteroles, polioles, y algunas vitaminas y minerales (Wrigley, Corke, Seetharaman, & Faubion, 2016). Los fenoles son sustancias provenientes de plantas, se dividen en flanovonoides y no-flavonoides. Entre los flavonoides, se encuentran más de 6000 compuestos entre antocianinas, flavonoles, flavonas, isoflavonas, taninos, chalconas, cumarinas, entre otros. Se ha demostrado que los fenoles inhiben la propagación de radicales libres, mediante la donación de un proton, además son quelantes de metales pro-oxidantes, que pueden llegar a causar daños al ADN y proteínas celulares; previenen enfermedades cardiovasculares y se ha demostrado su efecto en la prevención en cáncer *in vitro* en células e *in vivo* en animales (Amini & Ghoranneviss, 2016).

# OBJETIVOS

## OBJETIVO GENERAL

Estandarizar el proceso tecnológico de fritura al vacío para la obtención de "*Snacks*" de papa (*Solanum phureja* cv Primavera) con potenciales propiedades antioxidantes.

## OBJETIVOS ESPECÍFICOS

- Evaluar la estabilidad de los atributos de calidad de la papa variedad Primavera durante el almacenamiento en estado fresco.
- Evaluar la influencia de las condiciones del proceso de fritura por inmersión al vacío sobre snacks de papa variedad Primavera (*Solanum phureja* cv Primavera)
- Modelar las cinéticas de reacción de los compuestos antioxidantes y productos de oxidación lipídica de snacks de papa variedad Primavera obtenidos por fritura al vacío, durante su almacenamiento.

**CAPÍTULO 1**

# EVALUATION OF QUALITY OF A NEW VARIETY OF DIPLOID POTATO WITH ANTIOXIDANT ACTIVITY DURING THE STORAGE

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## Abstract

Potatoes are one of the widest crops in the world. A variety of new diploid potatoes with high antioxidant compounds have been developed by Universidad Nacional de Colombia. In this study changes in quality attributes of potatoes variety Primavera were analyzed and modeled during the storage time of the tubers at a constant temperature of 4 °C. The attributes measured were: moisture content, antioxidant activity (methods ABTS and DPPH), phenolic compounds, texture and color. Some properties such as texture and color were affected during storage, although the tuber retained their antioxidant capacity. Potato variety Primavera has antioxidant properties (ABTS: 2.71 mg Trolox/g and DPPH: 2.33 mg Trolox/g) and total phenolic content (6.09 mg GAE/g) higher than other vatieties, making it a potential product for processing and consumption by the market

**Keywords**: Antioxidants, phenolic compounds, storage, texture, tubers.

## Introduction

Potato is one of the crops with the highest production worldwide, and China is one of the highest producer, with 95 million tons produced annually; in Colombia 2 million tons are produced annually (FAOSTAT, 2016); this product is wanted because it is versatile during steaming, and because of its high nutritional value, as potato is rich in starch and micronutrients (FAO, 2008).

An advantage of the group *Solanum phureja* (Andean ancient food), is that have better capacity to be polinizated with other potato species, given the wide range of wild-type spieces from the Ande, this tuber has been used widely in programs of crop genetic improvement (Juyó, Gerena, & Mosquera, 2011b).

With this selection process, diploid potatoes with antioxidant features and resistant to diseases as powdery scab and late blight have been obtained (Singh & Kaur, 2016); amongst these are the potato variety Primavera, developed at Universidad Nacional de Colombia, which presents a colored peel and pulp with red and purple colors (figure 1).

Figure 1. Potato (*S. phureja* cv Primavera)

One of the most important attributes in colored potatoes is the high antioxidant content including phenolic compounds like anthocyanins (Kita *et al.*, 2015), which have high biological activity, with free radical trapping and anti-mutagenic, anti-carcinogenic and antihypertensive effects (Venereo Gutiérrez, 2002).

Even though this kind of potato is a versatile gastronomic alternative, because of its color and bioactive compounds, this product has a short lifespan after it is harvested (Molina et al., 2015), which limits its storage for long time; because of this, a fast processing is required, and this represents a problem for industries, which discard the product because it does not meet the current quality standards in parameters like texture, dry matter and color (Van Dijk et al., 2002a); this issue generates around 500 thousand tons of waste annually (FAO, 2012).

The aim of this research was to characterize fresh potato variety Primavera and evaluate its stability during storage.

## Materials and methods

*Raw material*

Potato (*S. phureja* cv Primavera) which is a diploid potato was used, from field crop of Santa Elena, Antioquia, at an altitude of 2300 meters above sea level, 14.5 °C temperature average and a relative humidity average of 89 %, during may-august 2016. The potatoes were processed the fifth day after harvest, previously cleaned and disinfected with water and organic acids (1 ml/L); this day was considered the storage day 0.

The samples were analyzed at days 0, 7, 14, 21 and 30, they were stored in a refrigerator at 4°C, at local atmospheric pressure (640 mm Hg), in low-density polyethylene bags with holes to enable air exchange.

*Methods*

*Moisture content.* 2 g of chopped potato were weighed and taken to a forced convection oven at 105°C, for 5 hours; the moisture content was reported as the loss of weight in moisture base (AOAC, 2005).

*Antioxidant capacity.* The measurement of antioxidant capacity was done with indirect methods of DPPH (α, α-diphenyl-β-picrylhydrazyl) and ABTS (2, 2'-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid). The compound extraction of antioxidants was done by mixing 3.5 mL of Methanol reactive grade with 3 g of potato variety Primavera previously macerated with peel. The sample was sonicated for 20 min and centrifuged for 20 min at 9000 rpm.

The ABTS method was reported by (Re et al., 1999); 20 µL of methanolic extract was taken and mixed with 2000 µL of ABTS radical. After 7 min in darkness, the data of absorbance at 734 nm was registered and the concentration was reported in mg Trolox/g dry basis.

The DPPH method was done according to the methods reported by (Brand-Williams, Cuvelier, & Berset, 1995); 20 µL of methanolic extract was mixed with 1980 µL DPPH radical and were registered at an absorbance of 517 nm after 30 min in darkness, the results were reported in mg Trolox/g dry basis.

*Total phenolic compound.* The measurement was done according to the methods reported by (Wang et al., 2016); the extraction of fresh potato phenols was performed by mixing 3g of potato with 4 mL of Methanol: Water (60:40) solution. The mix was sonicated for 20 min and centrifuged for 30 min at 9000 rpm; 20 µL of the extract was taken and mixed with 480 µL of distilled water, 1250 µL of calcium carbonate 20% and 250 µL of diluted Folin reagent (1:1), the absorbance was read at 760 nm, after 2 horas of reaction in darkness. The results were reported as mg GAE/g dry basis.

*Texture.* Fracture and resistance assays were performed using a texture analyzer TA-XT2i Stable Micro Systems (SMS) and the Software Texture Exceed, version 2.64 (50 kg charging cell). During measurements, whole and sliced potatoes were placed on a reference surface SMSP/35 and an awl with spherical terminal (SMS P/0,25s) was used to measure fracturability of the chopped potatoes; an awl SMS P/2 was used to measure the whole potato.

*Color.* The color measurements were measured in the pulp with a spectrophotometer X-Rite (SP64 model) and are determined with coordinates CIE-L*a*b*, illuminate D65, 10° observer, specular included (SPIN). The ΔE quantity was computing as follow:

$$\Delta E = \sqrt{(L - \beta_0(L))^2 + (a* - \beta_0(a*))^2 + (b* - \beta_0(b*))^2} \qquad (1)$$

Where $L_0$, $a_0$*, and $b_0$* which are the parameters of color in CIE-L*a*b* coordinates at time 0.

*Statistical analysis.* The polynomial regression was used to estimate the performance of each quality attribute versus the time. The experimental error was partitioned in lack of fit and pure error (Walpole, Myers, Myers, & Ye, 2012). For the parameter of color a multi-response model consisting in that L, a*, b* were statistically correlated (Hadfield, 2010). All statistical analysis were performed in R environment (R Core Team, 2016) and the packages MCMCglm (Hadfield, 2010), and coda (Plummer, Best, Cowles, & Vines, 2006) were used.

## Results and discussion

The moisture values for the potato variety Primavera during storage were adjusted to a cubic model (Table 1). As can be seen in figure 1, a general water loss occurred  in the tuber throughout storage as (Rivero, Rodríguez Rodríguez, & Romero, 2003) reported in potatoes from Tenerife, which loss water during 20 weeks of storage at 12 °C; this process happens through the periderm layer, given its high permeability (Singh & Kaur, 2009). Mass transfer occurs because of the difference in water chemical potential that exists between the potato and the environment (Martínez-Navarrete, A, Chiralt, & Fito, 1998) and processes of breathing and transpiration of the tuber (Kaya et al, 2016);  around day 14 a change of direction in the slope indicated a gain of moisture of the product , this can be due to changes in environmental conditions, as relative moisture, which was not controlled during the experiment.

The moisture initial values of fresh potato variety Primavera were similar to those reported by Castaldi, (2009) in fresh *S.tuberosum* potatoes and by Bártová et al, (2015) (81%) in fresh *S. Phureja* diploid potatoes. Some investigations have suggested the use of close to 80% moisture values in potatoes for frying processes (Douches and Jastrzebski, 1993) as they may have a good sensorial acceptance by consumers.

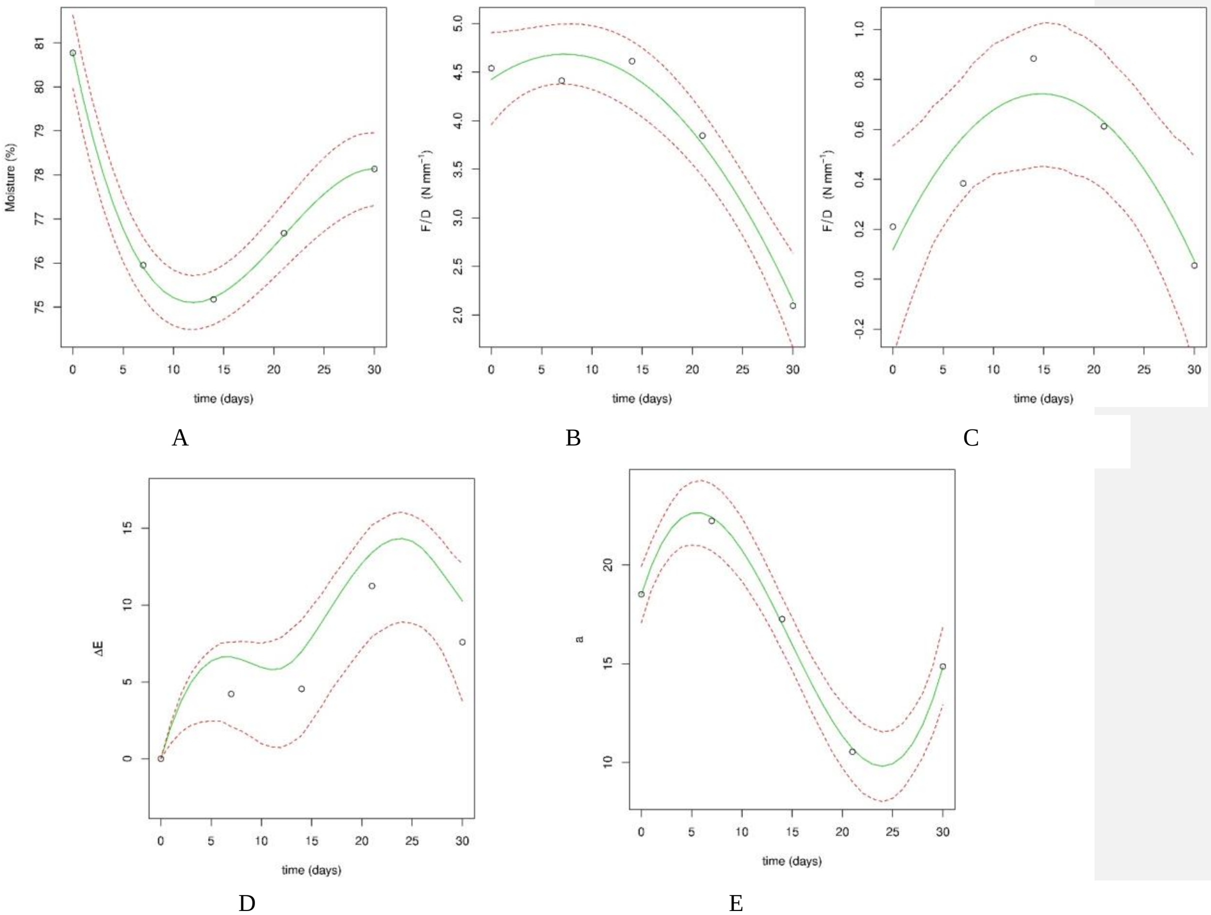
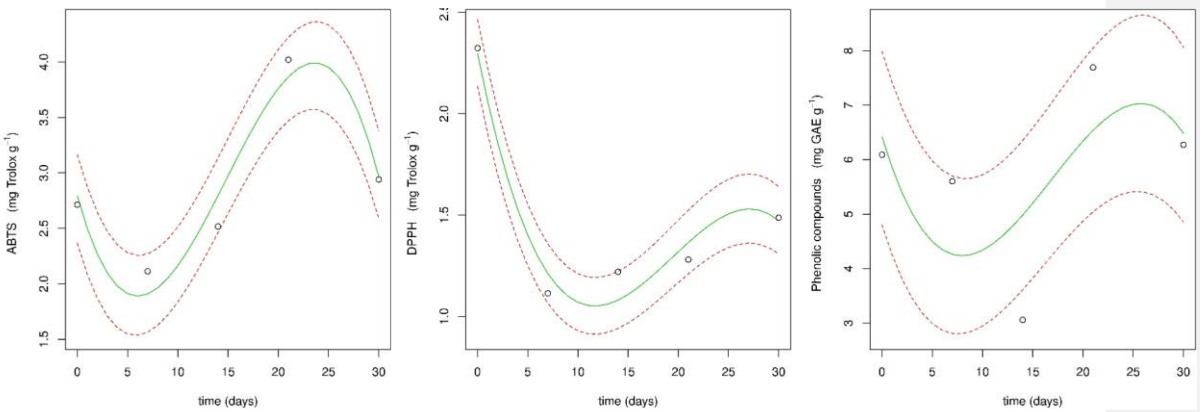



**Figure 2.** Mean values (o) and predicted values by polynomial model for changes in potato physical attributes during storage time A: moisture, B: texture for whole tube, C: texture for slices, D: ΔE (color insite slice), E: a* (red-green chromaticity).




A B C

**Figure 3.** Mean values (o) and predicted values by polynomial model in potato chemical attributes during storage time A: ABTS, B: DPPH, C: total phenolic compounds.

**Table 1.** Coefficients of the polynomial that models each of the quality attributes of the potato variety Primavera and its respective adjustment coefficient ($R^2$).

| Attribute | Coefficients | | | | $R^2$ |
|---|---|---|---|---|---|
| | $\beta_0$ | $\beta_1$ | $\beta_2$ | $\beta_3$ | |
| L | 37.46 | 0.410 | -0.070 | 0.0020 | 0.99 |
| a* | 18.52 | 1.610 | -0.180 | 0.0040 | 0.99 |
| b* | 5.24 | -0.230 | 0.005 | 0.0001 | 0.73 |
| ΔE | | | | | 0.99 |
| ABTS | 2.70 | -0.298 | 0.032 | -0.0007 | 0.92 |
| DPPH | 2.30 | -0.249 | 0.015 | -0.0003 | 0.96 |
| Phenolic compounds | 6.43 | -0.613 | 0.050 | -0.0010 | 0.39 |
| Moisture | 80.79 | 1.100 | 0.064 | -0.0010 | 0.99 |
| Texture (Whole tuber) | 4.42 | 0.072 | -0.005 | | 0.97 |
| Texture Slices | 0.12 | 0.085 | -0.003 | | 0.85 |

**Comentado [mg1]:** Por que no están los coeficientes de Delta E y estadísticamente que se hizo con el color, que en el análisis estadsiticos dice multi-repsonse

For both the whole potato and the slices, the model that best fit was the quadratic one. In the case of the whole potato, a slight increase in the slope F/d is observed until day seven and later a decrease that indicates a less turgor of the tissue; this would be due to the degradation of pectins and changes in monovalent and divalent ions in the cell wall of the tuber (Thybo, 1999), which causes a decrease in cell adhesion and therefore a lower resistance to breaking by puncture (Van Dijk et al., 2002b), this result was similar to the one reported by Solomon & Jindal, (2005) for crossed potatoes stored at 24 °C.

The results for texture analysis at time 0 for the whole potatoes, identified a product with an important firmness that contributes to a greater resistance to the mechanical damages during its postharvest handling, which could be attributed to the important pectic compounds present in the cell walls of the potato peels' tissue (Bordoloi, 2012). The penetration strength values found in the potato variety Primavera were higher than those reported by Castro Lara, (2008), in fresh potatoes from the *Hermes* variety, stored at 4°C, but lower than those reported by (Espinosa *et al.*, 1998).

The texture of sliced potato, identify in greater detail the level of deformation of the internal matrix; showing an important elastic component (slope F/D <45º), which contributes to that the food in its interior may be less turgid and firm (Rao, 2016). This last situation may be due to the plasticizing effect of water present in the matrix (Salvador, 2009). For the sliced potato, Figure 2 shows an increase in the slope F/D until day 14 and subsequent to this a decrease of the values; this behavior was consistent with the loss of water that the tuber suffered during the first 15 days, which makes it less elastic., and is also related to changes in starch content, which is degraded to simple sugars, making the sliced potatoes more fracturable (Van Dijk et al., 2002a).

The values of penetration strength in potato's slices were lower than those found by García-Segovia et al, (2008) for *Monalisa variety* potatoes (397 ± 35 N), therefore it will be expected a less turgid, more elastic and collapsed structure product.

Changes in texture and moisture influenced in the appearance of potatoes variety Primavera, it was observed that the whole tuber became rougher and less sparkly when the storage time increases.

The color change was adjusted to a cubic model. Figure 2 shows a gradual increase of ΔE in periods of 7 days, reaching its maximum value of 12.3 on day 21, followed by a decrease of ΔE until day 30. These changes are attributed mainly to three phenomena; initially to the sowing, geographical and environmental conditions that provide in potatoes a high variability between lots, in terms of size, pigmentation and shape; on the other hand, and consistent with the above, to the greater or lesser density of pigments that the equipment captures in the observation window used in the spectrophotometer (ϕ= 11mm), which is random and uncontrollable; finally, to the changes mainly in chromaticity a* attributable to the degradation of anthocyanins and carotenoid pigments present (Šulc et al., 2017). The propertie ΔE, showed an increase at the end of storgae respecting to day 0 of storage, this result is in agreement with the result obtained by Nourian, Ramaswamy, & Kushalappa, (2003) who found an increase in the color for the Chieftain Potato variety, stored at different temperatures including 4°C.

The changes in potatoes color during the storage, should be due to chemical reactions, in the case of brightness, this change is usually seen during the transformation of amyloplasts to chloroplasts (Grunenfelder, Hiller, & Knowles, 2006), because of the light presence during storage. In the case of chromaticity a*, its variation is mainly changes suffered in colored compounds, like anthocyanins, these reddish compounds transform in other types of compounds, by hydroxylation, methylation, and glycosylation, which generate color changes, by pH effects, temperature, and light (Reyes & Cisneros-Zevallos, 2007).

The behavior of the parameters associated with the antioxidant capacity of the diploid potato (ABTS, DPPH, total phenols) did not show a specific correlation with the color parameters, probably due to the same variability mentioned for the ΔE. However, the variability of antioxidant capacity is consistent with the factors associated with primary production, chemical and physical phenomena of the interaction of matter with the environment.

The fit to the model for ABTS and DPPH was cubic. In the case of DPPH, there was a decrease in values up to day 14 (from 2.33 to 1.20 mg Trolox/g) followed by a slight increase (from 1.28 to 1.48 mg Trolox/g) (Figure 3). Overall, a 50% decrease of antioxidant activity is observed by the DPPH method, and an increase in this quality attribute is observed with ABTS method (from 2.89 mg Trolox/g at day 0 to 2.94 mg Trolox/g at day 30) a differences in both measures occur because of the type of antioxidant assessed with each method. In general, ABTS measures hydro and lipophilic compounds (Kuskoski et al, 2005), DPPH measures hydrophobic antioxidant systems; Floegel et al., 2011 found great differences betwwen both methods in highky pigmented foods which is the case of potato variety Primavera. A similar behavior for antioxidant capacity is observed for colored potatoes, especially clone 'CO97227-2P/P', reported by (Külen, Stushnoff, & Holm, 2013), in which antioxidant capacity by ABTS showed considerable increase during storage at refrigeration conditions for 7 months; in contrast, with DPPH, the antioxidant capacity was constant over time.

DPPH and ABTS values at time 0, were higher than the one reported by Molina et al, (2015) ( DPPH: 458 µmol Trolox/ 100g for clon 2 of native potatoes), and the ones reported by Burlingame et al, (2009) for *S. Pinnatisectum* wild Andean variety (43-892 µg Trolox/g).

An outstanding feature of this potato variety, is a number of antioxidants, as phenolic compounds. In the case of this attribute, the adjustment model was cubic. Figure 2 presents a behavior similar to that one reported by (Singh & Kaur, 2016), which shows an increase in a number of total phenolic compounds, specifically the p- cumaric acid and quercetin, during potato storage, especially at temperatures of 4°C; low temperatures, light and some pathogens during storage could induce the generation of phenolic compounds, by the phenylalanine ammonia lyase, that regulates the synthesis of this compounds (Madiwale et al, 2011), taking into account that the majority of phenolic compounds in reddish diploid potatoes are anthocyanins (Rytel et al., 2014), the increase in total phenolic compounds with time in refrigeration conditions can be explained partly by enzyme anthocyanin synthase activity, which increases in lower temperatures (De Dios López et al, 2011), the degradation of the complex phenolic structures into phenolic acids, and de breakdown of cell structure which have the phenolic compounds strongly linked (Türkben et al., 2010).

## Conclusions

Potato variety Primavera has antioxidant properties and total phenolic content higher than that found in other potatoes with similar features, making it food with great potential for industrial exploitation. The stability study enabled the evaluation of some properties of potato in time, which presented an increase in the antioxidant capacity and phenol content during storage; at the same time, around day 21st, the potatoes displayed considerable rugosity and loss of turgor, along with color deterioration, making the product a perishable food that requires fast consumption and processing after harvest. In the models evaluated, none showed a lack of fick.

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**CAPÍTULO 2**

# Influence of vacuum deep fat frying process on quality of diploid potato snacks: a functional food with antioxidant properties

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**Abstract**

Potatoes with pulp coloration, have a large number of antioxidant compounds, new varieties with agronomic and nutritional properties have been developed, from which the diploid potato cv *Primavera* was selected, a process of vacuum frying (VF) was applied. The aim of the present study was to evaluate the effect of the process conditions on the snacks quality of potatoes. Response surface methodology was used by a central composite design, with independent variables: $\Delta T$ ($T_{oil}$-$T_{boiling\ point\ water}$) (°C), vacuum pressure (25-70 kPa), frying time (240-420 s) and dependent variables: antioxidant capacity, peroxides index, moisture, $a_w$, texture, color, fat content for potato chips and polar compounds inside the frying oil. The results for the VF optimization process were: VP = 59.4 kPa, $\Delta T$ = 50.8 °C and t =420 s. The VF optimization allowed to obtain a diploid potato snack with good quality attributes: high antioxidant compounds, low fat content, crunchy texture, and acceptable color, among others.

**Key Words:** Phenolic compounds, polar compounds, vacuum pressure, oil, oxidation.

## 1. Introduction

Potatoes are plant species of the genus Solanum, family Solanaceae, with more than 2000 species cultivated in the world (Molina *et al.*, 2015). Colombia, is the world´s largest producer of *Solanum phureja*, a native potato which is characterized by being a small round tuber with colors ranging from yellow to purple (Bianeth, 2015), its clones have the capacity to cross with other potato genotypes, thus they have been widely used in potato breeding programs (Juyó et al, 2011). Currently, the tuber that is marketed in Colombia, has yellow peel and pulp, but there are other non-commercial materials with different colors (Peña and Restrepo, 2013).

National University of Colombia has developed new varieties of colored diploid potatoes: *Paola, Primavera, Paysandú, Violeta* and *Milagros*, with agronomic improvements and antioxidant compounds. Tuber coloration depends on the anthocyanin, phenolic compounds and carotenoids present (Burmeister et al., 2011), phenolic compounds are also found such as coumarins, flavones, tannins, lignin, chlorogenic acid, caffeic acid, Protocatechuic acid, quercetin, kaempferol (Fuenzalida, 2008).

The diploid potato cv Primavera shows a variation in its internal and external coloration, being approximately 80-90% of its transverse area of reddish pigmentation, which has been characterized by its high content of antioxidants which can be beneficial to health, preventing diseases such as cancer and cellular DNA damage, because these compounds are able to neutralize the action of free radicals, is considered within the range of functional foods, which are the foods of higher expectations by the modern consumer, contributing to a better quality of life for the population (Kaur & Singh, 2017)

Vacuum frying (VF) is a process that presents some advantages compared to conventional frying: the process carried out under lower pressure conditions than the local atmospheric pressure (lower partial pressure of $O_2$), and lower frying temperatures; reducing final product and oil deterioration processes, in addition it diminishes the oil absorbed by the product and the formation of acrylamides and other toxic compounds, improving the nutritional, physical, sensorial properties and the contents of compounds with physiological activity present in the food (Mir-Bel et al, 2012). VF has been used with positive results in a wide variety of fruits and vegetables such as apples, bananas, kiwifruits, mushrooms, potatoes, sweet potatoes, purple yam, among others (Diamante et al, 2015).

This research was carried out to evaluate the effect of process conditions of VF on the snacks of potatoes variety Primavera, in order to obtain the best quality in the final snacks.

## 2. Materials and Methods

### *2.1 Materials*

Diploid potato (*S. phureja* cv Primavera) cultivated in Santa Elena, Antioquia was used, at an altitude of 2300 meters above sea level, 14.5 ° C temperature and a relative moisture of 89%.

### *2.2 Vacuum Fry*

For the VF process, the potatoes were cut into sheets of 2 mm thickness. The oil used was palm oil, high oleic (Palmali). A fryer (FVJCU001, Colombia) connected to a vacuum pump (Weg W22, Brazil) was used. The equipment has a PLC (Delta Electronics) type control system for oil temperature, vacuum pressure and frying time, as well as a steam trap before the pump in order to condense the water coming from the product. Initially the tank was charged with 16 L of oil under agitation at 60 rpm and heated under atmospheric conditions to the desired frying temperature, then 250 g of samples were placed in the basket and the tank hermetically sealed, applying the vacuum at the required vacuum pressure. The samples were submerged by a pneumatic system in the oil during the programmed time. At the end of this time, a vibration was applied for 30 s and an additional 10 s was left to rest, keeping the vacuum in place. Finally, the equipment was manually depressurized to local barometric pressure (85.3 kpa). The samples were removed and cooled to room temperature. From the initial oil load, every 5 fryings a 50% change was made for new oil.

The diploid potato VF process was optimized using the surface response methodology. A central composite experimental design (Table 1) as a function of three independent variables: $\Delta T$ ($T_{oil}$-$T_{water\ boiling\ point}$) (45-65 ° C), immersion time (t) (4-7 min), vacuum pressure (VP) (25-70 kPa), and the dependent variables: moisture, $a_w$, peroxides index (PI), fat content (FC), color, texture and antioxidant capacity (AC), was used; the optimization process was carried out for the dependent variables. Analysis of Variance (ANOVA), significant differences and correlations were developed in the experimental data adopting the method of least significant difference (LSD) and correlation of Pearson, respectively. The level of significance was less than or equal to 5%. Data were statistically analyzed with the software Statgraphics Centurion XVI. A regression analysis was used with a second-order polynomial model according to Equation 1:

$$Y = \beta_0 + \beta_A A + \beta_B B + \beta_C C + \beta_{AB} AB + \beta_{AC} AC + \beta_{BC} BC + \beta_{A^2} A^2 + \beta_{B^2} B^2 + \beta_{C^2} C^2 \quad (1)$$

Where $\beta_0$ is the intercept, $\beta_A, \beta_B, \beta_C$ are the factors coefficients, $\beta_{AB}, \beta_{AC}, \beta_{BC}$ are coefficients of the interactions between factors, and $\beta_{A^2}, \beta_{B^2}, \beta_{C^2}$ are the coefficients of double interaction.

Process conditions resulted from the optimization were verified and the experimental results were compared with predicted values from the optimized model.

### *2.3 Quality Analysis of products*

*Antioxidant capacity*. Extraction of the antioxidant compounds was done by mixing 3.5mL of reagent grade methanol with 3g of previously macerated fried potatoes; the sample was sonicated for 20min and centrifuged for 30 min at 9000 rpm. Measurement of AC was done by indirect methods: DPPH (2,2-diphenyl-1-picryl hydrazyl), as reported by Brand-Williams *et al.* (1995) and ABTS (2,2'-Azinobis ethylbenothiazole-6-sulfonic acid), as reported by Re *et al*. (1999).

*Peroxide index.* 1g of previously macerated fried potatoes was mixed with 10 mL of a mixture of Hexane: Isopropanol 3: 1), this was taken to evaporation in a convective stove at 70 ° C for 150 min; between 20-30 mg of the extracted oil were taken and mixed with 10mL of a Chloroform: Methanol (7: 3) mixture, to which 20 µL of thiocyanate solution and 20 µL of ferrous chloride were added. After 5 minutes in the dark, the absorbance lecture at 500 nm was read; the result was expressed in meq $H_2O_2$ kg dry basis$^{-1}$, as reported by Hornero *et al.* (2001).

*Moisture content.* Determined by weight loss in stove at 105 ° C for 5 hours (AOAC, 2005).

*Water activity* ($a_w$). A dew point hygrometer at 25 ° C (Aqualab 3TE series, Decagon, Devices, Pullman, WA, USA) was used.

*Color*. Carried out in an X-Rite spectrophotometer model SP64; the color was determined by using the CIE-L*a*b* coordinates, illuminant D65, observer 10°, specular compound included (SPIN). The color was measured in the internal zone of reddish tonality.

*Texture*. Fracture tests were performed using a texture analyzer TA-.XT2i (Stable Micro Systems, United Kingdom) and Texture Exceed Software, version 2.64, load cell of 50 kg, with accessories SMS P/0.25s and SMS /35.

*Fat content:* Performed by solvent extraction (AOAC, 2005).

*Polar compounds.* Measured in the frying oil after each experiment, with the instrument Testo 270 (Spain) (Chen et el, 2013).

## 3. Results and Discussion

VP-ΔT response surface plot shows that the best values of DPPH (0.49 mg trolox g $db^{-1}$) are at conditions of PV = 50 kPa and ΔT = 45 ° C (oil temperature = 126°C while the less favorable values (0.24 mg trolox g $db^{-1}$) were reached at VP = 75 kPa and ΔT = 65°C (oil temperature = 156 ° C) (Table 1, Figure 1). This result is attributed to the fact that antioxidant compounds have a greater degradation by the effect of heat, as reported by Juániz *et al.*, (2016) or also due to the increase of oxidation in the product since oil undergoes greater fry temperatures and lower vacuum in the system, which causes antioxidants to be involved in various reactions in order to stop radical formation and lipid oxidation (Jin *et al*., 2013).

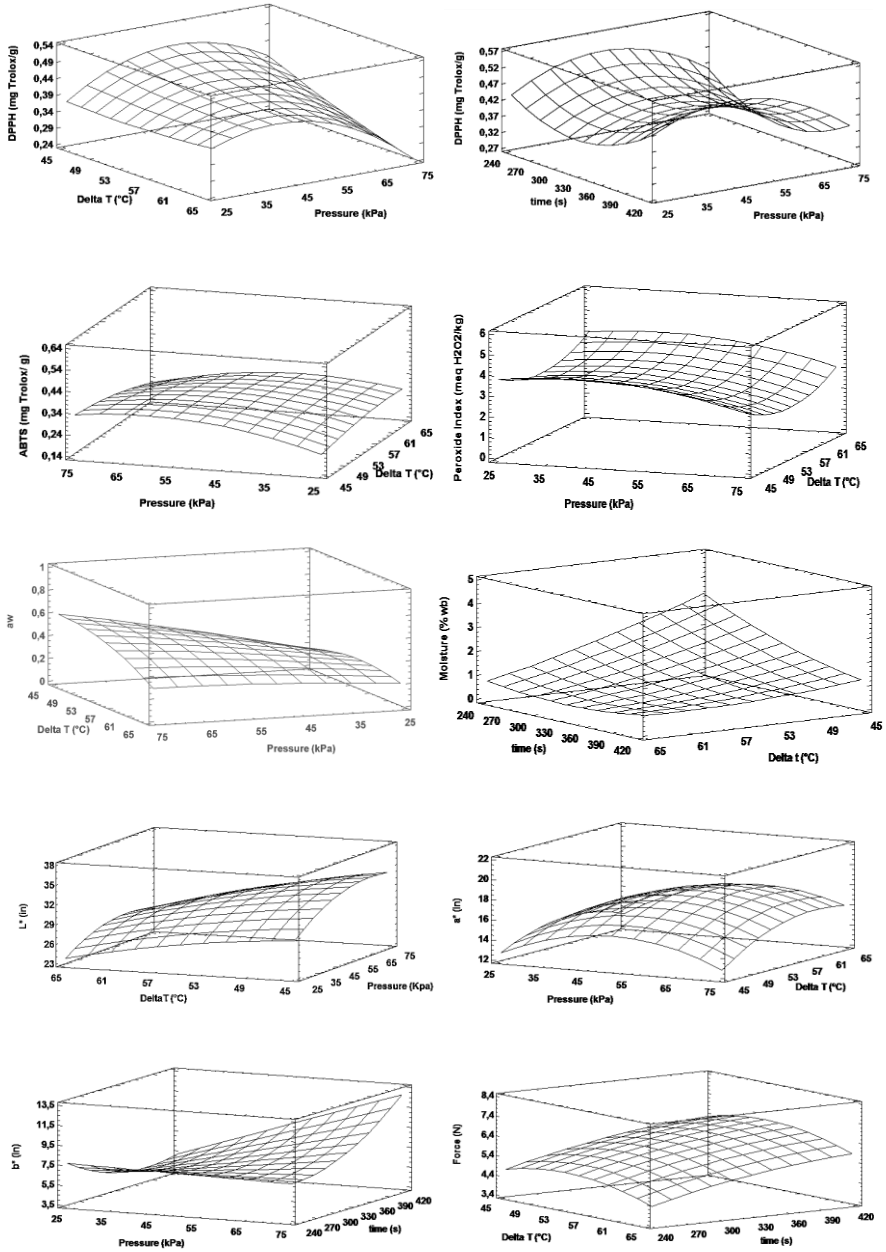
On the other hand, DPPH favors at low and high values of frying time (240 and 420 min respectively) and especially when the system operates at VP = 50 kPa, reaching DPPH values of approximately 0.50 mg trolox $g^{-1}$. The fact that the antioxidant capacity increase at high temperatures could be due to the formation of antioxidant compounds during Maillard reaction which is favored at high temperatures (Manzocco et al., 2000), however this hypothesis needs to be confirmed by a research for this potato variety. The results obtained for antioxidant capacity were similar to the one reported by Serpen and Gökmen, (2009), who found that the increase in frying times have a significant effect on antioxidant capacity for fried potatoes *(Solanum Tuberosum L.*) even more that an increase in temperature, due to the antioxidant compounds formed by Maillard reaction.

From Table 2, DPPH showed significant differences ($p<0.05$) regarding the quadratic interaction of time.

**Table 1.** Mean and standard deviations of the quality parameter of snacks of diploid potato.

| Experiment | PV (kPa) | ΔT (ºC) | Time (s) | DPPH (mg trolox/g db) | ABTS (mg trolox/g db) | IP (meq$H_2O_2$/kg db) | $a_w$ | Xw (%) | FC (%) |
|---|---|---|---|---|---|---|---|---|---|
| **1** | 47.5 | 55 | 330 | 0.492 ± 0.007 | 0.278 ± 0.047 | 3.4 ± 0.2 | 0.533 ± 0.060 | 1.9 ± 0.4 | 32.8 ± 0.1 |
| **2** | 47.5 | 55 | 330 | 0.392 ± 0.076 | 0.287 ± 0.063 | 2.1 ± 0.3 | 0.617 ± 0.016 | 1.8 ± 0.2 | 30.1 ±0 .3 |
| **3** | 47.5 | 65 | 240 | 0.392 ± 0.037 | 0.333 ± 0.059 | 3.5 ± 0.4 | 0.470 ± 0.084 | 0.8 ± 0.1 | 38.3 ± 0.4 |
| **4** | 25.0 | 45 | 330 | 0.456 ± 0.016 | 0.214 ± 0.011 | 4.9 ± 0.6 | 0.237 ± 0.012 | 1.4 ± 0.1 | 31.6 ± 2.1 |
| **5** | 25.0 | 45 | 240 | 0.456 ± 0.015 | 0.313 ± 0.029 | 3.4 ± 0.3 | 0.363 ± 0.049 | 3.1 ± 0.4 | 27.9 ± 0.7 |
| **6** | 70.0 | 55 | 330 | 0.376 ± 0.053 | 0.394 ± 0.043 | 3.0 ± 0.5 | 0.315 ± 0.062 | 1.4 ± 0.4 | 36.3 ± 1.7 |
| **7** | 47.5 | 65 | 330 | 0.373 ± 0.006 | 0.384 ± 0.038 | 3.2 ± 0.4 | 0.190 ± 0.008 | 0.4 ± 0.1 | 26.3 ± 2.3 |
| **8** | 47.5 | 55 | 330 | 0.381 ± 0.015 | 0.329 ± 0.058 | 1.5 ± 0.4 | 0.671 ± 0.010 | 1.9 ± 0.2 | 31.0 ± 1.4 |
| **9** | 25.0 | 45 | 420 | 0.500 ± 0.005 | 0.476 ± 0.022 | 4.1 ± 0.2 | 0.218 ± 0.016 | 0.5 ± 0.1 | 26.7 ± 2.5 |
| **10** | 47.5 | 55 | 330 | 0.503 ± 0.001 | 0.278 ± 0.010 | 3.5 ± 0.4 | 0.332 ± 0.012 | 0.8 ± 0.1 | 31.4 ± 1.7 |
| **11** | 25.0 | 65 | 420 | 0.500 ± 0.001 | 0.481 ± 0.061 | 3.8 ± 0.6 | 0.393 ± 0.022 | 1.2 ± 0.1 | 29.3 ± 3.0 |
| **12** | 47.5 | 55 | 240 | 0.492 ± 0.012 | 0.403 ± 0.052 | 3.8 ± 0.4 | 0.650 ± 0.024 | 1.6 ± 0.1 | 31.0 ± 1.9 |
| **13** | 70.0 | 65 | 420 | 0.352 ± 0.024 | 0.313 ± 0.036 | 3.5 ± 0.4 | 0.395 ± 0.027 | 0.9 ± 0.4 | 39.1 ± 0.1 |
| **14** | 70.0 | 45 | 240 | 0.510 ± 0.002 | 0.368 ± 0.007 | 3.1 ± 0.3 | 0.790 ± 0.007 | 4.2 ± 0.9 | 28.5 ± 2.3 |
| **15** | 25.0 | 55 | 330 | 0.277 ± 0.015 | 0.143 ± 0.005 | 2.5 ± 0.3 | 0.232 ± 0.017 | 0.4 ± 0.1 | 32.6 ± 0.8 |
| **16** | 47,5 | 55 | 330 | 0.499 ± 0.008 | 0.465 ± 0.024 | 5.8 ± 0.4 | 0.313 ± 0.013 | 0.5 ± 0.1 | 27.4 ± 0.1 |
| **17** | 25.0 | 65 | 240 | 0.483 ± 0.003 | 0.315 ± 0.013 | 5.1 ± 0.5 | 0.220 ± 0.047 | 1.1 ± 0.1 | 30.8 ± 2.4 |
| **18** | 47.5 | 55 | 330 | 0.498 ± 0.006 | 0.487 ± 0.038 | 3.2 ± 0.4 | 0.280 ± 0.013 | 1.1 ± 0.8 | 27.4 ± 3.8 |
| **19** | 47.5 | 55 | 420 | 0.489 ± 0.014 | 0.459 ± 0.021 | 2.8 ± 0.5 | 0.164 ± 0.020 | 0.4 ± 0.1 | 32.3 ± 4.7 |
| **20** | 70.0 | 45 | 420 | 0.511 ± 0.004 | 0.546 ± 0.025 | 2.6 ± 0.7 | 0.664 ± 0.029 | 2.7 ± 0.4 | 35.8 ± 0.3 |

| Experiment | PV (kPa) | ΔT (ºC) | Time (s) | Force (N) | Distance (mm) | $L_{in}$* | $a_{in}$* | $b_{in}$* |
|---|---|---|---|---|---|---|---|---|
| **1** | 47.5 | 55 | 330 | 5.1 ± 0.6 | 1.2 ± 0.8 | 26.6 ± 5.9 | 17.7 ± 2.7 | 5.7 ± 1.1 |
| **2** | 47.5 | 55 | 330 | 4.4 ± 0.9 | 1.4 ± 0.6 | 32.0 ± 1.3 | 17.9 ± 2.2 | 6.5 ± 1.6 |
| **3** | 47.5 | 65 | 240 | 4.0 ± 1.0 | 1.2 ± 0.7 | 29.7 ± 2.5 | 18.5 ± 0.8 | 5.9 ± 1.6 |
| **4** | 25.0 | 45 | 330 | 4.7 ± 0.4 | 5.3 ± 0.6 | 30.7 ± 3.8 | 15.1 ± 2.5 | 4.4 ± 1.7 |
| **5** | 25.0 | 45 | 240 | 5.9 ± 0.8 | 5.0 ± 0.8 | 36.3 ± 4.6 | 13.2 ± 1.2 | 8.3 ± 0.8 |
| **6** | 70.0 | 55 | 330 | 4.5 ± 0.9 | 1.5 ± 0.7 | 30.7 ± 2.5 | 16.9 ± 2.0 | 8.7 ± 1.7 |
| **7** | 47.5 | 65 | 330 | 3.6 ± 0.8 | 1.3 ± 0.5 | 27.0 ± 3.7 | 16.6 ± 1.4 | 6.9 ± 1.5 |
| **8** | 47.5 | 55 | 330 | 7.6 ± 1.0 | 1.2 ± 0.4 | 32.6 ± 3.6 | 17.6 ± 1.9 | 7.5 ± 1.2 |
| **9** | 25.0 | 45 | 420 | 4.4 ± 0.7 | 1.7 ± 0.7 | 27.2 ± 1.7 | 16.4 ± 1.2 | 3.5 ± 1.2 |
| **10** | 47.5 | 55 | 330 | 4.4 ± 0.9 | 1.2 ± 0.4 | 31.0 ± 2.4 | 18.3 ± 1.0 | 6.1 ± 1.5 |
| **11** | 25.0 | 65 | 420 | 4.4 ± 0.8 | 1.6 ± 0.6 | 27.4 ± 0.7 | 17.6 ± 0.7 | 4.8 ± 0.2 |
| **12** | 47.5 | 55 | 240 | 4.3 ± 0.8 | 1.1 ± 0.4 | 33.7 ± 4.1 | 18.6 ± 0.2 | 7.9 ± 1.6 |
| **13** | 70.0 | 65 | 420 | 5.8 ± 1.0 | 1.3 ± 0.1 | 28.7 ± 3.7 | 18.7 ± 2.4 | 8.5 ± 1.5 |
| **14** | 70.0 | 45 | 240 | 3.7 ± 0.8 | 2.2 ± 0.6 | 36.2 ± 3.9 | 14.9 ± 1.6 | 5.5 ± 3.7 |
| **15** | 25.0 | 55 | 330 | 5.6 ± 0.7 | 5.6 ± 0.7 | 25.2 ± 3.6 | 13.6 ± 3.0 | 5.0 ± 1.0 |
| **16** | 47.5 | 55 | 330 | 6.9 ± 0.7 | 1.4 ± 0.2 | 31.0 ± 2.4 | 18.8 ± 1.4 | 6.6 ± 1.2 |
| **17** | 25.0 | 65 | 240 | 3.4 ± 0.9 | 2.9 ± 1.00 | 25.5 ± 2.0 | 13.6 ± 1.1 | 4.3 ± 0.5 |
| **18** | 47.5 | 55 | 330 | 4.9 ± 1.0 | 0.4 ± 0.6 | 35.4 ± 5.2 | 17.1 ± 2.6 | 7.2 ± 2.4 |
| **19** | 47.5 | 55 | 420 | 4.7 ± 0.8 | 1.7 ± 0.8 | 30.5 ± 2.1 | 20.0 ± 1.0 | 8.5 ± 2.8 |
| **20** | 70.0 | 45 | 420 | 4.5 ± 0.8 | 1.1 ± 0.4 | 37.7 ± 4.5 | 16.1 ± 0.8 | 13.1 ± 0.9 |


DPPH (mg Trolox/g)
0,54 0,49 0,44 0,39 0,34 0,29 0,24
Delta T (°C)
45 49 53 57 61 65
Pressure (kPa)
25 35 45 55 65 75
DPPH (mg Trolox/g)
0,57 0,52 0,47 0,42 0,37 0,32 0,27
time (s)
240 270 300 330 360 390 420
Pressure (kPa)
25 35 45 55 65 75
ABTS (mg Trolox/ g)
0,64 0,54 0,44 0,34 0,24 0,14
Pressure (kPa)
75 65 55 45 35 25
Delta T (°C)
45 49 53 57 61 65
Peroxide Index (meq H2O2/kg)
6 5 4 3 2 1 0
Pressure (kPa)
25 35 45 55 65 75
Delta T (°C)
45 49 53 57 61 65
aw
1 0,8 0,6 0,4 0,2 0
Delta T (°C)
45 49 53 57 61 65
Pressure (kPa)
75 65 55 45 35 25
Moisture (% wb)
5 4 3 2 1 0
time (s)
240 270 300 330 360 390 420
Delta t (°C)
65 61 57 53 49 45
L* (in)
38 35 32 29 26 23
Delta T (°C)
65 61 57 53 49 45
Pressure (Kpa)
25 35 45 55 65 75
a* (in)
22 20 18 16 14 12
Pressure (kPa)
25 35 45 55 65 75
Delta T (°C)
45 49 53 57 61 65
b* (in)
13,5 11,5 9,5 7,5 5,5 3,5
Pressure (kPa)
25 35 45 55 65 75
time (s)
240 270 300 330 360 390 420
Force (N)
8,4 7,4 6,4 5,4 4,4 3,4
Delta T (°C)
45 49 53 57 61 65
time (s)
240 270 300 330 360 390 420

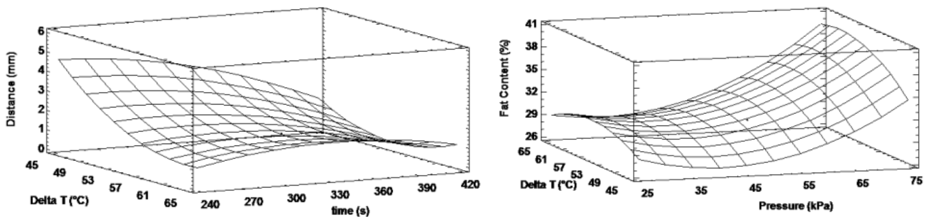



**Figure 1.** Surface response graphs of dependent variables as functions of independent variables.

According to the Alimentarius Codex, the maximum PI value for virgin oils and fats, and cold pressed oils is 15 meq $O_2$ $kg^{-1}$ (7.5 meq $H_2O_2$ $kg^{-1}$) and for other fats and oils it is 10 meq $O_2$ $kg^{-1}$ (5 meq $H_2O_2$ $kg^{-1}$) (Codex Alimentarius, 1999).

For diploid potato snacks obtained by VF, the IP did not present significant statistical differences ($p > 0.05$) regarding to independent variables evaluated (table 3). Among the obtained results in VF diploid potato, the majority of IP values were below the Codex's established parameters; and, inferior to those reported by Vélez, (2014) for different commercial potato snacks fried through conventional frying (29.9-63.3 meq $O_2$ $kg^{-1}$).

Obtained results showed that VF contributes in IP reduction among fried products, in a previous study, IP was determined for the potato variety Primavera processed by conventional deep-fat frying (180°C, 300 s) and it was evidenced that the amount of peroxides was greater (12,67 ± 1,46 meq $H_2O_2$ $kg^{-1}$) than all those obtained in this research, even for the highest temperatures and times., it should be due to the reduction of the frying temperature and minimal contact between oil and oxygen during the process (Mariscal and Bouchon, 2008). During the VF process, the pressure of the processing system is low, so, oil and water vapor pressures of food are low too; which produces a fat reduction regarding fats contained in the finished product, as the oil absorption decreases (L. M. Diamante et al., 2015).

The ANOVA showed significant differences ($p < 0.05$) in the moisture content respecting to the independent variables ΔT and t, as is shown is table 3; in addition, with the interaction ΔT-t and ΔT-PV. It is observed that as t increases, final moisture from diploid potato snack decreases, mainly when the system operates at higher ΔT; while the increase in ΔT also reduces moisture content, but mainly to low frying t. The effect of the interaction between ΔT and time is more evident, when enhancing product's moisture decrease of at high times and ΔT. This situation is attributed to the fact that under these operating conditions a higher rate of evaporation of the water is reached and the product becomes drier. Moisture results obtained in the product varied between 0.37 and 4.23% (bh), being within the established by Pedreschi, (2009) as acceptable parameters for fried potatoes (1.67% bh).

The ANOVA showed significant differences of $a_w$ ($p < 0.05$) respecting to the PV (table 3), with an observable decrease of $a_w$ when the system operates at higher vacuum levels (PV → 25 kPa), which was consistent with the lowest moisture content found at this pressure condition. This situation is attributed to the fact that at lower pressures, the water vapor pressure is lower and there is a rapid evaporation of free water in the product, causing a decrease in the food's water activity (Yagua and Moreira, 2011).

The $a_w$ of VF diploid potatoes, was very fluctuating, with mean oscillating values range of 0.790 – 0.164, which identifies it as a critical dependent variable since it is directly related to shelf life (Cazier and Gekas, 2001). It is worth noting that when the system operated at minor t (t → 240 s), lower ΔToil (ΔT → 45 ° C) and lower vacuum levels (PV → 70 kPa), the product reached its highest $a_w$ value (0.790) and moisture (4.230%). Some investigations have reported potato chips $a_w$ values for conventional frying, between 0.185-0.977 for different varieties of potatoes (white, sweet and purple) fried at temperatures between 160 – 200 °C, for 1-5 minutes (Yuan et al., 2016)

The ANOVA showed a significant difference ($p < 0.05$) in the FC regarding the PV, with an observable decrease in the products' absorbed fat when the system operates at higher vacuum levels (PV → 25 kPa). This is due to the fact that when the system operates with lower PV, there is a higher water vapor gradient coming out of the products' surface, which prevents the oil from entering the food (Sandhu et al, 2013). In general, the FC values range between 27.4 and 39.0%, similar to the values obtained by Troncoso and Pedreschi, (2009) for VF potato chips.

Some investigations in diverse matrixes have identified that the greater rate of absorption of oil in the fried foods occurs at the moment of the pressurization and in the products' cooling, reason why there is a dependence of the speed of pressurization and free water of the food, since at the moment of frying, the oil that succeeds to enter the interior of the matrix is very little due to the impediment held by the water vapor gradient, which leaves the food towards the middle; At the time of cooling and pressurizing, the evaporation is reduced and the remaining steam condenses, allowing to create an oil flow gradient from the outside to the interior of food (Mir-Bel et al, 2009). On the other hand, VF creates a large hydrodynamic gradient, which can affect the microstructure of the product, and therefore modify the physicochemical and transport properties of the product (Yagua and Moreira, 2011).

For the internal zone or reddish color, ANOVA presented significant differences ($p<0.05$) in $L_{in}$*, $a_{in}$* and $b_{in}$* regarding the PV factor; while $a_{in}$* also had significant influences ($p <0.05$) respecting to ΔT, t and all quadratic and linear interactions except with ΔT- t. For outer zone color, the ANOVA showed significant differences ($p <0.05$) in $L_{out}$* regarding factors t and the quadratic interactions of PV and ΔT, as well as the interaction PV-ΔT (table 3). On the other hand, the $a_{out}$* chromaticity presented only significant differences ($p <0.05$) with ΔT factor, while the $b_{out}$* chromaticity respecting to the PV factor and the quadratic interaction ΔT. In fried products, color is an important attribute of quality where mainly changes in color during frying are mostly due to non-enzymatic browning (Maillard reaction), caused by the reaction of reducing sugars, amino acids and accelerated by the action of temperature and frying times (Mir-Bel et al., 2012a).

$L_{int}$* has a tendency to decrease with high vacuum levels (PV → 25 kPa) to any condition of ΔT, but the major changes take place when ΔT is lower; while ΔT confers a greater darkening in different combinations, ΔT: 60-61 ° C, 70 kPa or ΔT: 55 ° C, 20 kPa. Pedreschi, León et al. (2007), founding a minor dimming for potato chips when the system operated at lower t (240 s) and temperatures (ΔT = 45 ° C). Usually in conventional or vacuum frying processes as temperatures rise, various reactions are accelerated: carbohydrate degradation, sugar pyrolysis, ascorbic acid decomposition, oxidation of fatty acids, among others contributing to the reduction of luminosity and browning of the fried product (Juániz, Zocco et al., 2016).

Regarding a* and b* chromaticity, the most important changes occur in the inner zone, where $a_{in}$* increases with increasing PV, ΔT and t, potentiating the red coloration, probably associated with non-enzymatic browning processes, such as the one found in potato chips by Pedreschi et al., 2006.

In the border region, the values of chromaticity $a_{out}$* from diploid potato are important (16.7 ± 3.7), since they represent the presence of components such as anthocyanin and carotenoids (Avello and Suwalky, 2006) despite having a yellow or creamy colour. $a_{out}$* from diploid potato snack increased with the increase of ΔT, mainly when system operates at low t.

Texture is a very important parameter of quality in foods, and especially in snacks where consumers expect a crisp texture, which is determined experimentally with a texturometer where the maximum strength is measured and this indicates the hardness of the fried product (van Koerten et al, 2015). In the diploid potato snacks the fracture strength showed significant differences ($p < 0.05$) respecting to t, whereas the distance presented significant differences ($p < 0.05$) respecting to $\Delta T$, time and the interaction $\Delta T$- t. The fracture strength increased with increased t, which is attributable to a possible formation of superficial crust during frying, which is potentiated with the temperature difference between potatoes and oil. These results were similar to those reported by Su et al, (2016) for VF potatoes.

On the other hand, the distance at which the fracture occurs is greater at lower frying t (240 s) and lower $\Delta T$ (45 ° C); Which is logical since as the food is fried at lower $\Delta T$, the oil temperatures are low, there is a lower porosity and less evaporation of water, so the product presents a more flexible structure, which is reflected in an increase in the distance of rupture (Taiwo and Baik, 2007). At short frying t and low temperatures, it has been shown that there is no complete gelatinization of potato starch, which makes the food less brittle and crunchy. These results are consistent to the ones reported by Pedreschi et al, (2007) where temperature and t of frying directly influence the texture of fried products, since it affects the microstructure of the product, changing its porosity and making it brittle and crisper.

The polar compounds evaluation of high oleic palm oil during frying is presented in Figure 2. It can be observed that the polar compounds increase as the number of frying increases, this is because with each frying there is an addition of product and a water transference from food to the *medium (oil),* which causes a lipidic compound hydrolysis and increases the oil polar compounds (Ziaiifar et al, 2008); At the time of the replacement of 50% of the oil for every 5 frying, a dilution of these compounds took place. Therefore a decrease in the quantity is noticed; however, it can be observed that they do not return to the initial value, they continue growing in a scalonated way until the last group of frying (16 - 20) where it tended to have an asymptotic behavior.

The polar compounds are originated by the degradation (hydrolysis, oxidation and polymerization) undergone by oil due to high temperatures during the frying process. Foods with high water content, such as potatoes, accelerate this degradation; among the most common polar compounds in oils are: monoglycerides, diacylglycerols, free fatty acids and other compounds generated during frying (Ramírez Botero et al., 2012).

Currently regulations for polar compounds in frying oils, establish that these should not exceed 25% in the measurement (Masson et al., 1997).

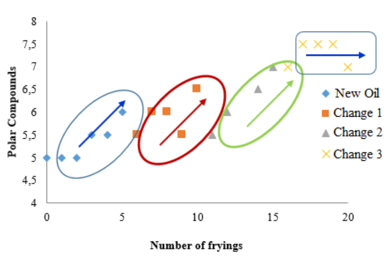


**Figure 2.** Evolution of polar compounds during vacuum frying of diploid potato snacks.

Within the analyzes performed for diploid potato frying oil; the polar compounds did not exceed this value at any time, they remained in ranges between 5 and 9%, lower than those reported by (Paz Robert et al., 2001) for extracted oils from conventional fried crisps method (8-11%), which can be explained because the vacuum frying process decreases the formation of polar compounds, mainly due to two factors: (1) the decrease in frying temperatures, and (2) lower oxygen pressure present in the process. Both factors lead to a lower production of hydro-peroxides, which are broken down into short chain compounds such as aldehydes, ketones, alcohols and other non-volatile compounds, which constitute polar compounds (Nayak, Dash, Rayaguru, & Krishnan, 2016). A similar behavior was observed by Chen et al.,( 2013), who used rich in saturated and monounsaturated fatty acids palm oil and other soybean oil for the conventional frying of pre-frozen french fries, finding a significant increase in polar compounds (10 → 30%) for 48 hours of frying in high oleic palm oil, compared to soybean oil (10 → 20%) in 48 hours of frying.

**Table 2.** Regression coefficient table for different response.

| Parameter | Intercept | $\beta_A$ | $\beta_B$ | $\beta_C$ | $\beta_{AB}$ | $\beta_{AC}$ | $\beta_{BC}$ | $\beta_A^2$ | $\beta_B^2$ | $\beta_C^2$ | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **DPPH** | 1.00 | 0.03 | -0.002 | -0.006 | -0.0002 | -0.000006 | -0.000009 | -0.0001 | 0.00009 | -0.00001* | 0.60 |
| **ABTS** | -0.13 | 0.02 | 0.03 | -0.007 | -0.0001 | -0.00001 | -0.00003 | -0.00009 | -0.0002 | 0.00001 | 0.46 |
| **Moisture** | 21.93 | 0.08 | -0.35* | -0.06* | -0.002* | 0.00007 | 0.0006* | 0.0003 | 0.002 | 0.00003 | 0.81 |
| **aw** | -0,31 | 0,03 | 0.08 | -0.01 | -0.0003 | -0.00001 | 0.00005 | -0,00003 | -0,0008 | 0.00001 | 0.49 |
| **PI** | 23.53 | 0.07 | -0.81 | 0.004 | -0,00002 | 0.00001 | -0.0002 | -0.0009 | 0.008 | 0.000006 | 0.21 |
| **$L^*_{in}$** | 71.20 | 0.41* | 0.28* | -0.3 | -0.003 | 0.0005 | 0.001 | -0.003 | -0.008 | 0.0003 | 0.70 |
| **$a^*_{in}$** | -21.33 | 0.41* | 1.65* | -0.13* | 0.002* | -0.0003* | -0,00002 | -0.004* | -0.01* | 0.0002* | 0.93 |
| **$b^*_{in}$** | -3.3 | -0.18* | 1.35 | -0.15 | -0.0007 | 0.0009* | 0.00006 | -0.000007 | -0.01 | 0.0002 | 0.73 |
| **Force** | -14.33 | -0.04 | 0.58 | 0.03* | 0.002 | -0.000001 | -5.55E-07 | -0.0007 | -0.006 | -0.00003 | 0.61 |
| **Distance** | 51.39 | -0.01 | -1.47* | -0.004* | -0.0005 | 0.00008 | 0.0009* | 0.001 | 0.01 | -0.00008 | 0.81 |
| **FC** | -23.67 | -0.94* | 2.60 | -0.02 | 0.004 | 0.0007 | -0.0009 | 0.007 | -0.02 | 0.00007 | 0.71 |

$\beta_A$, $\beta_B$, and $\beta_C$ are vacuum pressure, Delta T, and frying time respectively. * values presented significant differences (p-value < 0.05)

The experimental optimization of the VF process was done using statistical tools, with the objective of determining the conditions of the independent variables or of operation, which allowed obtaining a final product with desired quality attributes. The following considerations for the dependent variables or quality attributes were taken as optimization criteria: maximize DPPH, ABTS, moisture, strength, $L_{int}$*, $a_{int}$*, $b_{int}$*, $a_{out}$*, $b_{out}$*, and minimize PI $a_w$, Strength, $L_{out}$* and fat. According to the adjustment model for data, obtained results from independent variables for optimization of the VF process of diploid potato snacks were: PV = 59.4 kPa, ΔT = 50.8 ° C (Toil = 136 ° C) and frying time = 420 s (7 min)

**Table 3.** Quality Attributes Results for VF of diploid potato CV Primavera by multiple response optimization

| Quality Attribute | Theoretical Optimum | Experimental Optimum |
|---|---|---|
| **DPPH (mg Trolox/g)** | 0.51 | 0.49 ± 0.02 |
| **ABTS (mg Trolox/g)** | 0.48 | 0.57 ± 0.01 |
| **PI (meq $H_2O_2$/ kg)** | 3.28 | 4.42 ± 0.57 |
| **$a_w$** | 0.500 | 0.390 ± 0.02 |
| **Moisture (%)** | 2.24 | 3.41 ± 0.06 |
| **Distance (mm)** | 2.13 | 1.36 ± 0.35 |
| **Force (N)** | 5.45 | 5.84 ± 1.15 |
| **$L_{int}$*** | 34.95 | 33.98 ± 5.25 |
| **$a_{int}$*** | 16.11 | 14.53 ± 2.24 |
| **$b_{int}$*** | 10.48 | 7.29 ± 2.75 |
| **FC (%)** | 34.04 | 26.73 ± 1.79 |

## 4. Conclusions

The diploid potato cv *Primavera*, represents a raw material with a great agro industrialization potential, due to its quality characteristics and its antioxidant activity, ABTS (0.52 ± 0.03 mg Trolox/g) and DPPH (0.45 ± 0,02 mg Trolox/g). The use of statistical tools allowed the optimization of the VF process of the diploid potato, with the most suitable operating conditions PV: 59.4kPa, ΔT: 50.8°C and t: 420s. In general, most of the quality attributes assessed for diploid potato snacks are affected by these dependent variables. The VF allowed to maintain antioxidant properties at the diploid potato snack and to imprint customer-appreciated qualities in texture (crisp) and color.

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**CAPÍTULO 3**

# KINETICS OF THE QUALITY ATTRIBUTES DEGRADATION FOR POTATO CHIPS (*Solanum phureja* cv PRIMAVERA) DURING STORAGE

# CINÉTICA DE DEGRADACIÓN DE LOS ATRIBUTOS DE CALIDAD DE CHIPS DE PAPA (*Solanum phureja* cv PRIMAVERA) DURANTE EL ALMACENAMIENTO

Manuela GALLÓN B. MSc.[1], Misael CORTÉS R. PhD.[2*], José M. COTES T. PhD. [3]

## RESUMEN

**ANTECEDENTES**: La fritura por inmersión al vacío permite obtener productos de mejor calidad sensorial y conservar mejor las propiedades de los alimentos, especialmente compuestos bioactivos como antioxidantes, presentes en la papa variedad Primavera, la cual se propone como un pasaboca con propiedades funcionales. **OBJETIVO:** Determinar las cinéticas de degradación de los atributos de calidad de la papa variedad Primavera freída al vacío, durante el almacenamiento a diferentes temperaturas y atmósferas de envasado. **MÉTODOS:** Se usó papa variedad Primavera, cultivada en Santa Elena, Antioquia, durante mayo- agosto del 2016. La fritura al vacío se realizó mediante las siguientes condiciones: $T_{aceite}$=136 °C, presión de vacío=59.4 kPa y tiempo=420 s. Se determinaron atributos de calidad como capacidad antioxidante (DPPH y ABTS), compuestos fenólicos determinados por el método de Folin- Ciocalteu, índice de peróxidos por método espectrofotométrico y ácidos grasos libres por titulación. Las muestras se almacenaron en cámaras climáticas a humedad relativa del 65%, a tres temperaturas (15-25 y 35°C), dos atmósferas de empaque ($N_2$ y Aire) y se analizaron durante los días 0, 30, 60, 90, 120 y 150; se determinó el orden

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de reacción mediante una regresión y se determinaron las constantes de reacción para cada atributo. La energía de activación se calculó según el modelo de Arrhenius. **RESULTADOS:** Se presentó una disminución en los compuestos fenólicos y antioxidantes en las papas diploides freídas al vacío durante el período de almacenamiento. En todos los tratamientos se evidencia un aumento y subsiguiente reducción de peróxidos; además se observó un aumento en la cantidad de ácidos grasos libres. Los órdenes de reacción para la degradación de antioxidantes fueron ABTS: 1.24, DPPH: 1.21, fenoles totales: 1.87 y en el caso de la formación de compuestos los órdenes de reacción fueron ácidos grasos libres: 2.36, peróxidos: 2.50. Para todos los atributos se presentaron mayores velocidades de reacción a mayor temperatura y almacenamiento en aire. La energía de activación para la mayoría de atributos fue mayor para el envasado en $N_2$, mostrando una menor velocidad de reacción. **CONCLUSIONES:** Las velocidades de reacción aumentaron a medida que se aumentó la temperatura, evidenciando una mayor degradación en la calidad del producto, a bajas temperaturas y atmósfera de Nitrógeno se conservaron los atributos de calidad como los compuestos antioxidantes. A la temperatura de almacenamiento de 15°C y atmósfera de envasado con $N_2$, la mayoría de las propiedades se conservaron, resaltando un porcentaje de retención del 50% en los compuestos antioxidantes, lo cual permite obtener un producto con unas características adecuadas hasta el día 150 de almacenamiento.

**Palabra claves**: *oxidación, antioxidantes, almacenamiento, cinética, snacks, fritura al vacío.*

## ABSTRACT

**BACKGROUND:** Vacuum deep- fat frying allows to obtain products of better sensorial quality and preserves the quality properties of foods, especially bioactive compounds. Potato variety Primavera has a large amount of antioxidant compounds thus is proposed as a snack with functional properties. **OBJECTIVES:** Determine the degradation kinetics of the quality attributes of the vacuum fried potatoes variety Primavera, during storage at different temperatures and packaging atmospheres. **METHODS:** Potato variety Primavera from field crop of in Santa Elena, Antioquia during season mayo-august 2016, was used. Vacuum frying was performed under the following conditions: $T_{oil}$ = 136 ° C, vacuum pressure = 59.4 kPa and time = 420 s. Quality attributes were approached by antioxidant capacity (DPPH ABTS), phenolic compounds determined by the Folin-Ciocalteu method, peroxide value, and free fatty acids by titration. Samples were stored in climatic chambers at a relative humidity of 65%, at three different temperatures (15, 25 and 35 °C), two packaging atmospheres ($N_2$ and air), and were evaluated during the days 0, 30, 60, 90,120,150. The order of reaction was determined by a regression and the reaction constants for each attribute were determined. The activation energy was calculated according to the Arrhenius model **RESULTS:** There was a decrease in the phenolic compounds and antioxidants in the fried diploid potatoes during the storage period. The samples showed an overall moisture gain for all treatments, which was increased the water activity. There was also a decrease in texture. In all treatments an increase and subsequent reduction of peroxides were evident. There was an increase in the amount of free fatty acids. The reaction orders for the degradation of antioxidants were ABTS: 1.24, DPPH: 1.21, total phenols: 1.87. On the other hand, for the formation of compounds the reaction orders were free fatty acids: 2.36, peroxides: 2.50. For all attributes, higher reaction rates were presented at higher temperature and storage in air. The activation energy for the attributes was higher for $N_2$ packaging, showing a lower reaction rate. **CONCLUSIONS:** The temperature and packing atmosphere significantly affected the quality attributes of the diploid potato during storage, the reaction rates increased as the temperature increased, evidencing a greater degradation in the quality of the product; at low temperatures and atmosphere of nitrogen quality attributes were preserved, especially antioxidant compounds. At temperatures of 15 ° C and packing in an atmosphere of Nitrogen most of the properties and up to 50% of the antioxidant compounds were conserved, allowing to obtain a product with the desired characteristics and functional properties, until the 150 days of storage.

**Keywords**: *oxidation, antioxidants, storage, kinetics, snacks, vacuum frying.*

## INTRODUCTION

Potato is one of the most consumed crops worldwide, so it is one of the most important sources of carbohydrates and some other nutrients as antioxidants (Tian et al., 2016); new varieties of potatoes found in the Andean zone, with red and purple flesh has a higher amount of anthocyanins and phenolic compounds than yellow or white potatoes (Kita et al., 2015), these compounds are responsible for the scavenging of free radicals and have anti-mutagenic, anti-carcinogenic and anti-hypertensive activity, and also give potatoes pigments which are attractive to consumers (Albishi, John, Al-Khalifa, & Shahidi, 2013).

One of the most consumed forms of potato today is potato chips, which are thin slices of potatoes between 1 to 3 mm thick, and processed by deep-frying obtaining a dry, stable and crispness product (Singh & Kaur, 2016). In order to reduce the oil uptake, keep bioactive compounds and have a product with better organoleptic attributes, the vacuum frying process has been used recently (Lemuel M. Diamante, Savage, & Vanhanen, 2012), this process is carried out under pressures well below atmospheric levels, so the frying temperature is lower (Mariscal & Bouchon, 2008).

However, frying process presents some disadvantages, the oil in the product can be oxidized due to the reaction with environmental oxygen, and also hydrolyzed and polymerized, giving rise to several volatile and nonvolatile compounds which affect the quality of the product (Puyed, Begum, Saraswathi, & Prakash, 2010), these reaction also occurs during storage due to oxygen and water vapor present in the package atmosphere (Micić et al., 2015), temperature and light (Bodoira, Penci, Ribotta, & Martínez, 2017). Antioxidants have been shown to have an effect by retarding the lipid oxidation (El-Shourbagy & El-Zahar, 2014), these compounds could prevent lipid autoxidation by donating a proton to the free radicals formed during the early oxidation stages (Taghvaei et al., 2014).

Kinetic studies allow the determination of degradation reactions and formation of compounds and have been used in studies of lipid oxidation reactions and loss of antioxidants in food during storage in order to determine the shelf life of the products (Sapei & Hwa, 2014). This research was carried out determine the degradation kinetics of the quality attributes of the vacuum fried potatoes variety Primavera, during storage at different temperatures and packaging atmospheres.

## MATERIALS AND METHODS

### *1.1. Materials*

Potato (*S. phureja* cv Primavera) which is a diploid potato was used, from field crop of Santa Elena, Antioquia, at an altitude of 2300 meters above sea level, 14.5 ° C temperature average and a relative moisture average of 89%, during may-august 2016. For the VF process, the potatoes were cut into sheets of 2 mm thickness. The oil used was palm oil, high oleic (Palmali). The conditions for vacuum frying were stablished in previous studies: T oil=136 °C, Pressure=59.4 kPa and time=420 s.

### 1.2. *Quality analysis of products*

*Antioxidant capacity*. Extraction of the antioxidant compounds was done by mixing 3.5mL of reagent grade methanol with 3g of previously macerated potato chips; the sample was sonicated for 20min and centrifuged for 30 min at 9000 rpm. Measurement of AC was done by indirect methods: DPPH (2,2-diphenyl-1-picryl hydrazyl), as reported by (Brand-Williams et al., 1995) and ABTS (2,2'-Azinobis ethylbenothiazole-6-sulfonic acid), as reported by (Re et al., 1999). Results were expressed in mg Trolox/ g dry weight.

*Total Phenolic compounds.* The extraction was carried out following the methodology reported by (Yang et al., 2015). Mixing 1 g of potato chips previously macerated with 30 mL 80% acetone using a homogenizer, then samples were filtered through No. 2 Whatman paper. The extracted was evaporated at 45°C, 100 rpm under vacuum until 90% of the extracted had been evaporated. 10 mL of hexane and 5 mL of methanol was added to the extracted in order to remove oil phase, an evaporation process was done again at the same conditions. The extracted was added with water to a final volume of 10 mL. The quantification of total phenolic compounds was performed according to the Folin-Ciocalteu method. Results were expressed in mg gallic acid equivalents/g dry weight (mg GAE/g)

*Peroxide value.* The procedure was adapted according to the methodology reported by (Hornero et al., 2001), there was an oil extraction of 1g of Fried Potatoes with 10 mL of a mixture of Hexane: Isopropanol 3: 1), this was taken to evaporation in a convective stove at 70 ° C for 150 min; between 20-30 mg of the extracted oil were taken and mixed with 10mL of a Chloroform: Methanol (7: 3) mixture, to which 20 µL of thiocyanate solution and 20 µL of ferrous chloride were added. After 5 minutes in the dark, the absorbance lecture of 500 nm was read; the result was expressed in meq $H_2O_2$/ kg dry basis.

*Free fatty acids:* 10 g of oil extracted from the potato chips were used and mixed with 1 ml of ethanol and 1 ml of diethyl ether previously neutralized with 0.1 N KOH; 3 drops of phenolphthalein was added to the solution and then this was titrated with 0.1 N KOH. Results were expressed as the free oleic acid percentage.

### *1.3. Storage*

The stability of vacuum fried potatoes was carried out by real-time storage study, considering a split plot experiment under a completely random design. Climate chambers at the specific temperatures (15, 25, and 35°C) at a relative humidity of 65% were considered as the whole plot. Bags of laminated PET film, aluminum foil (ALICO®, Colombia), with permeability to $O_2$ <1 cc / ($m^2$ * 24h * atm), and water vapor permeability <1 g / ($m^2$ * 24h * atm), were used as packaging material, in two packing atmospheres ($N_2$ and air). Samples were analyzed at the following times: 0, 30, 60, 90,120,180 days.

### *1.4. Determination of kinetic parameters*

To determine the reaction order the general kinetic equation was integrated for different value of n, obtaining the equations 1 and 2 (Ramírez Flores, Fuentes Ramírez, & Rubio Rosas, 2006):

$$[\varphi]^{1-n} = -(1-n)kt + C_0 \qquad for\ n \neq 1 \qquad (1)$$

$$\ln(\varphi) = -kt + C_0 \qquad for\ n = 1 \qquad (2)$$

Where n is the reaction order, φ is the concentration of an specify compound, k is the rate constant ($days^{-1}$), $C_0$ is the quality parameter at time 0, and t is time (days).

The data for the different dependent variables were adjusted in regressions of a different order of which the correlation coefficient (r) was obtained. Each r was processed in a regression as a function of n truncated in the third term as equation 3 shows:

$$r = \beta_1 + \beta_2 n + \beta_3 n^2 \qquad (3)$$

A second-order polynomial was obtained which is derived in order to calculate the maximum value of r representing the reaction order (n) of the kinetics.

In the case of peroxide value (PV) and free fatty acids (FFA), the chemical reaction was given for the formation of these compounds and not by the degradation, so the inverses of the values were taken in order to determine the reaction order.

Once the order of reaction is calculated, the kinetic parameters k and $C_0$ were calculated for each variable according to the eq 1.

The temperature dependence of ABTS, DPPH, and Phenolic Compounds (PC) degradation and PV, and FFA formation was determined using the Arrhenius equation, and the activation energy ($E_a$) was calculated for each treatment:

$$k = Aexp^{-E_a/_{RT}} \qquad (6)$$

Where A is the frequency factor of the Arrhenius equation ($days^{-1}$), $E_a$ is the activation energy (J/mol), R is the universal gas constant (8.314 J/mol K), and T is the absolute temperature (K)

### *1.5. Statistical analysis*

Three experimental plots were used for each treatment. Raw data were used to determine kinetic parameters and the Arrhenius equation. Linear regressions considering lack of fit and pure error (Walpole et al., 2012) were estimated by the MCMCglmm (Hadfield, 2010) and coda (Plummer et al., 2006) packages in R environment (R Core Team, 2016). The fit to the models was determined based on the coefficient of determination ($R^2$).

## RESULTS

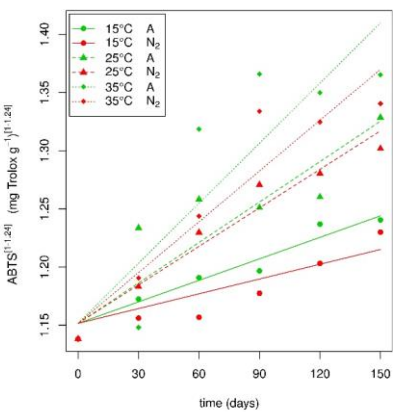
**Table 1.** Coefficients for the r polynomial as a function of n, and reaction order for each quality attribute of vacuum fried potato chips

| Polynomial coefficients | ABTS | DPPH | PC | FFA | PV |
|---|---|---|---|---|---|
| β1 | 0.886 | 0.945 | 0.866 | 0.776 | 0.836 |
| $\beta_2$ | 0.013 | 0.015 | 0.038 | 0.176 | 0.030 |
| β3 | -0.005 | -0.006 | -0.010 | -0.072 | -0.006 |
| $R^2$ | 0.998 | 0.999 | 0.991 | 0.995 | 1.000 |
| Reaction Order | 1.240 | 1.209 | 1.874 | 2.367 | 2.505 |

The real reaction orders for each quality attribute were determined by a regression, in which the coefficients of the second-order polynomial (Table 1) were obtained with a good adjustment coefficient, close to 0.99 in each attribute. The reaction orders for the attributes of antioxidant capacity are close to a kinetics of order 1, while for the other attributes a kinetics of order two can be approached.

The mean initial values for ABTS, DPPH, PC, PV, FFA, were 0.58 ± 0.01 mg Trolox/g, 0.51 ± 0.03 mg Trolox/g, 10.90 ± 1.35 mg GAE/g, 4.21 ± 0.53 meq $H_2O_2$ /kg, 0.1 ± 0.01 % oleic acid, respectively. In the case of antioxidant capacity and total phenols, a decrease (Figure 1) occurred in these compounds during storage time, while for PV, FFA an increase was shown indicating the formation of compound Hydroperoxides, free fatty acids and increased browning of the product.

By increasing the temperature and for packaging material with air atmosphere , a higher reaction slope was observed (Table 2) indicating a higher speed in the loss of antioxidant compounds, for treatment 35-A the lowest percentage of retention of antioxidants (ABTS: 47.37%, DPPH: 42.86%, phenolic compounds: 29.58%) was observed; while for the treatment at 15 °C and packaging atmosphere of Nitrogen, the degradation of antioxidant compounds was smaller and the highest percentages of retention were estimated (ABTS: 73.68%, DPPH: 69.69%, phenolic compounds: 53.21%) at the end of storage.

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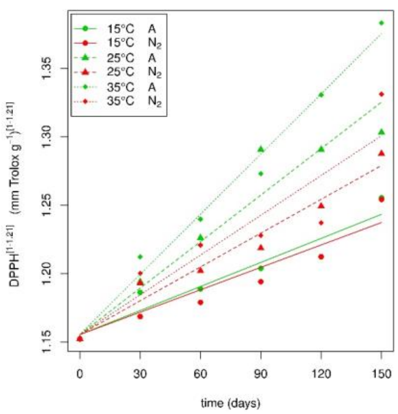


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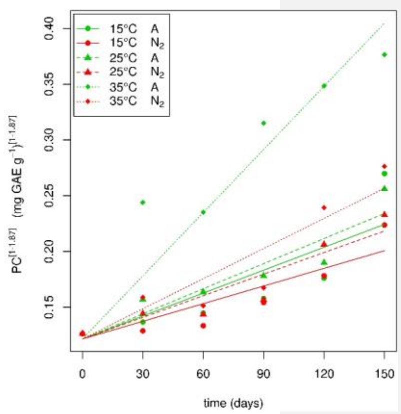


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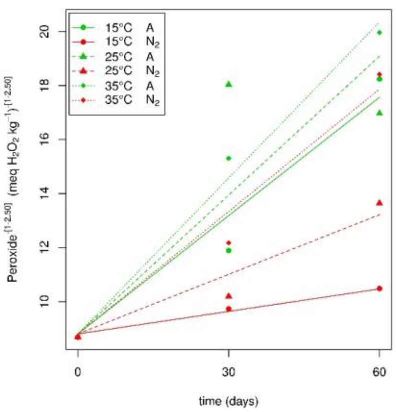


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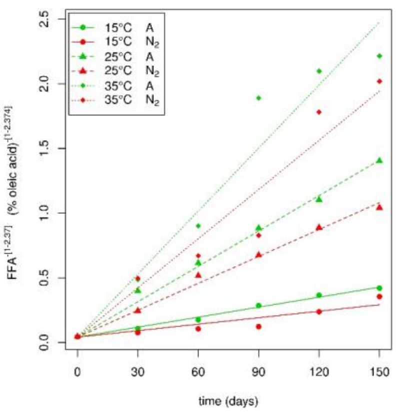


E

**Figure 1**. Experimental data and model predicted values of quality attributes during storage period for different treatments. A: ABTS (2,2'-Azinobis ethylbenothiazole-6-sulfonic acid), B: DPPH (2,2-diphenyl-1-picryl hydrazyl), C: total phenolic compounds, D: peroxide value, E: free fatty acids.

**Table 2**. Kinetic parameter of compounds degradation and formation for each treatment and their coefficient of determination of model fits ($R^2$).

| Attribute | Treatment | Kinetic degradation parameters | | |
|---|---|---|---|---|
| | | K ($days^{-1}$) | $C_0^{(1-n)}$ | $R^2$ |
| ABTS | 15-N2 | 0.0004 | 1.15 | 0.80 |
| | 15-A | 0.0006 | | 0.78 |
| | 25-N2 | 0.0011 | | 0.72 |
| | 25-A | 0.0012 | | 0.68 |
| | 35-N2 | 0.0015 | | 0.84 |
| | 35-A | 0.0017 | | 0.73 |
| DPPH | 15-N2 | 0.0005 | 1.16 | 0.87 |
| | 15-A | 0.0006 | | 0.77 |
| | 25-N2 | 0.0008 | | 0.89 |
| | 25-A | 0.0011 | | 0.88 |
| | 35-N2 | 0.0010 | | 0.80 |
| | 35-A | 0.0015 | | 0.97 |
| PC | 15-N2 | 0.0005 | 0.12 | 0.74 |
| | 15-A | 0.0007 | | 0.68 |
| | 25-N2 | 0.0006 | | 0.77 |
| | 25-A | 0.0007 | | 0.81 |
| | 35-N2 | 0.0009 | | 0.67 |
| | 35-A | 0.0019 | | 0.79 |

| Attribute | Treatment | Kinetic formation parameters | | |
|---|---|---|---|---|
| | | K ($days^{-1}$) | $C_0^{-(1-n)}$ | $R^2$ |
| PV | 15-$N_2$ | 0.028 | 8.80 | 0.12 |
| | 15-A | 0.146 | | 0.80 |
| | 25-$N_2$ | 0.071 | | 0.53 |
| | 25-A | 0.171 | | 0.55 |
| | 35-$N_2$ | 0.151 | | 0.92 |
| | 35-A | 0.192 | | 0.85 |
| FFA | 15-$N_2$ | 0.002 | 0.04 | 0.87 |
| | 15-A | 0.003 | | 0.96 |
| | 25-$N_2$ | 0.007 | | 0.99 |
| | 25-A | 0.009 | | 0.99 |
| | 35-$N_2$ | 0.013 | | 0.93 |
| | 35-A | 0.016 | | 0.94 |

In all treatments, an increase and subsequent reduction of peroxides were evidenced after 60 days (data no show) this behavior is typical of these compounds when more advanced stages of oxidation are presented in the food (Houhoula & Oreopoulou, 2004), however, for kinetic purposes only hydroperoxide formation data were taken, and not degradation data of these compounds. The formation of these compounds was given until days 60-90, therefore kinetics were only determined during this time.

For most of the attributes good fitted were made to the Arrhenius equation (Table 3), and the activation energies were generally greater for samples packaged in Nitrogen atmospheres, indicating a lower reaction rate. The great difference between the activation energy for the air and $N_2$ atmospheres for PV is shown, a value 7 times higher in the $E_a$ of

$N_2$. This indicates that it is a product sensitive to the presence of oxygen in its packaging, increasing oxidation levels.

**Table 3.** Activation energy and the coefficient of determination of model fit, for each attribute in different packaging atmospheres

| Attribute | Ea (J/ mol K) | | $R^2$ | |
|---|---|---|---|---|
| | $N_2$ | air | $N_2$ | air |
| ABTS | 31502.95 | 25342.95 | 0.92 | 0.99 |
| DPPH | 14102.50 | 22555.55 | 0.95 | 0.95 |
| PC | 13519.90 | 24452.48 | 0.98 | 0.79 |
| PV | 46442.97 | 7053.81 | 0.99 | 1.00 |
| FFA | 50359.87 | 45450.28 | 0.96 | 0.96 |
| DE | 58117.59 | 54652.82 | 0.87 | 0.98 |

## DISCUSSION

It can be observed that for all treatments, a number of phenolic compounds and antioxidants in the vacuum fried diploid potatoes tended to decrease during the overall period of storage, the same behavior was reported by (Al-Weshahy, El-Nokety, Bakhete, & Rao, 2013) for freeze-dried potato peels. Antioxidants are compounds that could be easily oxidizable in the presence of $O_2$ and they are sensitive to the effect of temperature (Miranda et al., 2010). These compounds act by donating protons and/or electrons to the radicals (Apak et al., 2016), thus stopping the oxidation process. A decrease in the content of these compounds could be due to thermal degradation or an inhibition of oil oxidation in the potato variety Primavera.

Hydro peroxides are compounds formed during the initial stage of lipid oxidation, these compounds have no odor or taste until they degrade to aldehydes and ketones which give unpleasant flavors and odors to the fried products (Crosa et al., 2014). Oxidation is promoted by factors such as temperature and contact with oxygen, which is presented according to the results obtained in which the treatments at 35 °C in an atmosphere of air, and 25 °C in air packing atmosphere, presented a higher formation of hydro peroxides, whereas at temperatures of 15 °C and atmosphere of packing in nitrogen the formation of these compounds was smaller. This behavior was similar to that reported (Samotyja & Kozak, 2015), where hydroperoxide values were lower in potato snacks stored in modified nitrogen atmosphere. Another indicator of lipid deterioration is the free fatty acid, the lipid triacylglycerides present ruptures due to hydrolysis or the effect of the temperature generating free fatty acids, increasing the acid value of the food (Chen et al., 2013). Treatments of 35 °C in air and $N_2$ packing atmospheres presented the highest values of free fatty acids, this may be due to the fact that these samples had the highest moisture gains, hydrolyzing the oil present in potato chips (Nayak et al., 2016); on the other hand, the samples stored at 15 °C in nitrogen and air packing atmospheres had the lowest values of free fatty acids.

There was a general tendency to increase the reaction rate constants with temperature and these were in turn higher for the samples packed in air, indicating higher reaction rates at higher temperature and air atmosphere, as it was reported by (Nourian et al., 2003), for potatoes stored at different temperatures, and by (Bechoff et al., 2010) for dried sweet potato chips. This result was shown by (Dunno, Cooksey, Gerard, Thomas, & Whiteside, 2016), where an increase in oxidative rancidity for potato chips is observed, as oxygen levels increase in the headspace of the package.

The heterogeneity in the behavior of potato properties, identified with kinetic modeling, could be attributed to the fact that as the amount of water in the product is increased, it is passed to a non-thermomechanical metastable rubbery state, which does not present good fits to the kinetics (Gudmundsson & Kristbergsson, 2009), besides the reactions in food involve a large amount of additional compounds that are reacting at the same time, consequently the reaction kinetics may not be modeling the exact phenomenon (Boekel, 2008).

The $E_a$ was higher for $N_2$ atmosphere packing for most attributes, this may be due to the molecules can only complete the reaction once they have reached the top of the energy barrier of activation. The higher the barrier, the fewer molecules will have enough energy to overcome it at any given time (Menzinger & Wolfgang, 1969).

When comparing the data for phenolic compounds at day zero of the storage of fried potato with respect to another products considered high in antioxidants (Blackberry : 226 mg GAE/ 100 g, Acaí: 454 mg GAE/100 g, Acerola: 1063 mg GAE/ 100 g ) (Haminiuk, Maciel, Plata-Oviedo, & Peralta, 2012) it can be observed that the potato variety Primavera has similar values in concentration of phenols (10.9 mg GAE/g). Taking into account that potatoes are a high-consumption product in the world, and that consumers are increasingly buying products with an additional health benefit (Dueik, Marzullo, & Bouchon, 2013), it is important to recognize the market potential and industrialization that a potato variety Primavera snack could have in terms of the improvement of consumption of bioactive compounds by the consumer.

## CONCLUSIONS

The stability study of vacuum fried diploid potato allowed knowing the constants of the kinetic models of degradation of quality attributes. It was evidenced that the temperature and the packing atmosphere significantly affect the attributes of quality, at higher temperatures and air atmosphere, higher losses of bioactive compounds were presented. At temperatures of 15 ° C and packing in an atmosphere of Nitrogen most of the properties and up to 50% of the antioxidant compounds were conserved, allowing to obtain a product with the desired characteristics and functional properties, until the 150 days of storage.

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## CONCLUSIONES GENERALES

La papa variedad Primavera se identificó como un producto con alta cantidad de compuestos antioxidantes, sin embargo por su alta cantidad de agua, se considera un producto perecedero. Se modeló el comportamiento de las variables dependientes en función del tiempo de almacenamiento de la papa en estado fresco, durante 4 semanas de almacenamiento del tubérculo crudo, se presentaron cambios en la textura, color y humedad; las propiedades antioxidantes presentaron variaciones, los compuestos fenólicos presentaron un aumento durante el alamcenamiento.

Mediante la fritura al vacío se logró disminuir el contenido y actividad de agua del alimento, dándole una mayor estabilidad, a su vez se le otorgaron atributos sensoriales agradables en cuanto a textura, sabor y color; debido a que este procesamiento reduce la temperatura de freído y a presión parcial de oxígeno, las propiedades antioxidantes del producto se conservaron y se disminuyó su oxidación, por medio de la opimización por superficie de respuesta, se lograron obtener las mejores condiciones de procesamiento de friuta al vacío, con el fin de dar al producto final buenos atributos de calidad.

El estudio de almacenamiento de los snacks de papa variedad Primavera permitió identificar las mejores características en cuanto a temperatura, atmósfera de envasado y tiempo de almacenamiento del producto; se modeló la degradación de los atributos de calidad y se ajustaron a cinéticas de orden 0 y 1, se determinó a su vez, la energía de activación en cada uno de los tratamientos con el fin de establecer las velocidades de reacción y deterioro del snack.

En los próximos estudios se recomienda profundizar en la determinación de compuestos antioxidantes específicos de esta variedad de papa, especialmente antocianinas, debido a la coloración de su pulpa; así como en las reacciones que estos experimentan durante el almacenamiento del snack.

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# ANEXOS

## INSTRUCCIONES PARA LA PUBLICACIÓN DE ARTÍCULOS

## ANEXO A. INSTRUCCIONES PARA LOS AUTORES REVISTA ACTA AGRONÓMICA

### CAPÍTULO 1:

### LINEAMIENTOS

**Tipos y características de los documentos**. Para que un documento sea aceptable y susceptible de ser publicado, debe despertar un potencial interés para la comunidad académica y científica, realizar una contribución significativa en términos del avance del conocimiento científico o hacia una mejor comprensión de conceptos existentes. Los trabajos sometidos a publicación no podrán someterse a otra revista mientras dure el proceso de revisión. Los errores de ortografía y la omisión de normas de presentación de documentos según la política editorial de AcAg son causales de rechazo.

**Artículo científico**. Presenta los resultados de investigación científica basada en hipótesis teórica o experimental, que signifique un aporte original al conocimiento en alguna de las secciones de interés de la revista. Relata la manera de delimitar la pregunta de investigación, el camino para someterla a prueba (análisis estadístico del experimento, protocolos disciplinarios) y la confrontación de los datos generados con la literatura actual.

El rango aceptable para la configuración del documento es de 3500 hasta de 5000 palabras y hasta 20 referencias bibliográficas, incluyendo títulos (en el idioma original y en inglés), resumen (hasta 250 palabras), abstract, introducción, materiales y métodos, resultados, discusión y referencias bibliográficas.

**Artículo de revisión**. Será enviado a la revista únicamente por invitación directa del comité editorial o editora jefe de Acta Agronómica. Contiene el resultado de trayectorias dedicadas a la investigación o temas de frontera en las áreas de interés de la revista. Los límites máximos del documento son 10.000 palabras y hasta 80 referencias bibliográficas, incluyendo título (idioma original e inglés), resumen, abstract, introducción, capítulos y subcapítulos para desarrollar el tema y referencias bibliográficas.

**Preparación y formato del documento:**

- Software Microsoft Office Word (Documento de Word 97-2003).
- Fuente Bookman Old Style, 14 para títulos, 12 para texto.
- Ajuste del documento al tamaño de papel carta (21.5 x 27.9 cm) y márgenes de 2.5 cm.

- Digite a doble espacio a través de todo el texto (incluyendo tablas y figuras).
- Las palabras claves de su resumen o key words de su abstract, deben ir ordenadas alfabéticamente. Recuerde no incluir palabras del título.
- Únicamente usar la designación de Tabla y Figura. Presente las figuras (fotos, mapas, gráficos, esquemas) en plancha, tratando de economizar el mayor espacio posible.
- Las figuras deben ser de 400 a 1000 kb y ajustarse a 6x10 cm en formato jpg.
- Los agradecimientos son opcionales y pueden contener máximo 30 palabras
- La bibliografía debe citarse conforme se relacione con el cuerpo del documento, debe ir en orden alfabético y sin numeración alguna. Recuerde usar el estilo de la American Psychological Association (APA). No utilizar referencias como tesis, folletos, cartillas, resúmenes de congresos o eventos científicos. Todos los links deben estar activos
- La revista adopta el Sistema Internacional de Unidades (SI).

**El título**. Debe ser conciso y contener máximo 16 palabras que suministren suficiente información para que el lector forme una idea del interés del estudio y del nivel científico. Debido a que con exactitud, el título identifica y describe el contenido del documento, no utilizar expresiones como: "estudio detallado" o "estudio preliminar". Debe ser escrito en minúsculas y sólo las primeras letras o los nombres propios en mayúscula. No debe contener términos que necesiten aclaración, abreviaturas y fórmulas. Debe incluir el nombre científico de la especie.

**Afiliaciones**. En la lista de autores se deben incluir los nombres y apellidos completos de cada investigador. Se señala la afiliación de los autores en el siguiente orden: Universidad- Sede - Facultad o Instituto - Escuela o Departamento - Grupo de investigación o Laboratorio - Dirección, Ciudad. Código Postal (de acuerdo con la empresa de Correos de Colombia 4-72) - País y Correo electrónico, indicando el autor que mantendrá correspondencia con el editor y equipo editorial. Evite usar títulos académicos o posiciones institucionales.

**Resumen**. Es una versión condensada de todo el documento. De manera sintética debe abarcar los objetivos, métodos y resultados del trabajo. Es necesario presentar los resultados más significativos y en la medida que fuese posible, utilice términos cuantitativos y absténgase de citar referencias. Si el texto se redacta en castellano o portugués incluya la versión del resumen en inglés (abstract). Si se redacta en inglés incluya la versión en castellano.

Escribir cinco palabras clave en orden alfabético sin repetir las del título, idealmente palabras normalizadas o descriptores del Tesauro AGROVOC (http://aims.fao.org/es/agrovoc) o la Real Academia Española (RAE). Adicione también el abstract y de la misma forma, las key words.

**Cuerpo del trabajo**. Un artículo científico original trata de contar la historia de una investigación. Es una historia en cuatro capítulos, cada uno de los cuales debe proporcionar una información concreta:

1. Introducción: ¿cuál fue la pregunta de investigación?;
2. Materiales y Métodos: ¿cómo se estudia esa pregunta?;
3. Resultados: qué se encontró?
4. Discusión: ¿Cuáles son las implicaciones de los resultados que se obtuvieron?;

**Introducción**. La introducción de un artículo científico original deberá atraer la atención del lector y explicar por qué el investigador realizó el estudio. Por lo tanto, debe brindar testimonio de la relevancia del aporte original, estableciendo el marco contextual del problema a resolver o la pregunta de investigación. Debe escribirse en presente y apoyarse en referencias científicas apropiadas con el objeto de establecer una discusión de trabajos muy relacionados con la hipótesis planteada. Los elementos fundamentales de la estructura de una introducción son la razón de ser del estudio, la pregunta de investigación y el diseño del estudio.

La introducción finaliza haciendo referencia a la pregunta de investigación o hipótesis, que son punto clave porque exponen el valor que tiene la investigación original en el marco del conocimiento actual y condiciona el diseño del estudio. Se cierra con el o los objetivos.

**Materiales y Métodos**. Debe responder a la pregunta, ¿cómo se estudia el problema?, da cuenta de los pasos seguidos y de los protocolos empleados para llegar a los resultados. En tal sentido presenta los materiales evaluados, diseño experimental y el análisis estadístico de los datos Se escribe en tiempo verbal pasado describiendo cuidadosamente la metodología biológica, analítica y estadística de la investigación de manera que otros investigadores la puedan replicar o que los lectores puedan conocer los límites de interpretación de los datos.

Debe informarse al lector de la localización espacial del experimento (coordenadas geográficas, características edafoclimáticas, provincias biogeográficas, zonas de vida), indicar el origen de los materiales biológicos o reactivos no corrientes y dar a conocer los cambios en los protocolos habituales.

Apoyándose en tablas, se puede exponer la información más relevante obtenida. Si se realizan experimentos, se debe enunciar el diseño estadístico correspondiente con sus tratamientos, unidad experimental, repeticiones, variables de repuesta y frecuencia de mediciones.

La utilización incorrecta o inadecuada de los métodos estadísticos es inaceptable. No se debe describir los tratamientos estadísticos corrientes. Se debe incluir la referencia. Finalmente, la descripción de los modelos estadísticos y el diseño experimental debe realizarse con software estadístico especializado.

**Resultado**. Se debe responder a la pregunta: ¿cuáles fueron los hallazgos?, exponer los nuevos conocimientos que arrojó la investigación original, brindando la información de manera clara, objetiva e imparcial sin elementos interpretativos. Incluir los resultados obtenidos en la investigación que responden al objetivo planteado en el trabajo. Los resultados más importantes a nivel estadístico se deben describir brevemente. Se pueden incluir tablas y figuras que amplíen los resultados sin que en ningún caso duplique o repita los datos y lo consignado en el texto.

**Tablas y figuras**. Presente cada tabla y figura enumerada y correctamente referenciada en el texto. El título se coloca al pie de la figura y a la cabeza de la tabla, describiendo concisamente el contenido. Marque con línea continua los límites externos de la primera y de la última fila y la separación entre títulos de las columnas y los datos; no marque los límites de las columnas (no use líneas verticales).

Use los símbolos de las unidades del Sistema Internacional de Pesos y Medidas. No separe los números en miles, use el punto para los decimales. Presente los parámetros estadísticos. Los resultados que evidencien diferencias estadísticas se deben señalar por letras en exponente y definirlas al pie de la tabla por el nivel de significancia estadística ($P<0.05$).

Utilice la figura para destacar puntos importantes y específicos. No las encierre en cajas. Use barras y símbolos negros, blancos (abiertos) y rayado grueso. Prefiera como símbolos círculos, cuadrados y triángulos, negros o blancos.

**Discusión**. La discusión está avalada por las evidencias encontradas y su interpretación se debe basar en los resultados estadísticos y no en apreciaciones personales o subjetivas y en publicaciones científicas que tratan el tema. Adicionalmente, se pueden señalar futuras investigaciones que podrían desarrollarse a partir de los hallazgos obtenidos. Al final de este apartado se deben incluir las conclusiones de la investigación. Recuerde que es una síntesis de lo que se encontró y lo que se discutió. Debe concordar con el objetivo planteado (el objetivo se menciona siempre al final de la introducción).

**Agradecimientos (opcional)**. Se debe mencionar a las personas e instituciones que han prestado asesoría técnica, científica o estadística a la investigación y las fuentes de financiación. En el caso de la Universidad

Nacional de Colombia se debe referenciar el código HERMES del proyecto (s) asociado (s) al artículo. Citas y referencias bibliográficas. La revista usa el estilo APA de citación, a partir del Volumen 64-3 del 2015.

**Fotografía de portada**. Para cada número se convocará a los autores que publiquen ahí sus resultados, a presentar fotografías inéditas, alusivas al tema de investigación. La editora jefe seleccionará la fotografía que reúna las características y requerimientos de la revista.

## ANEXO B. INSTRUCCIONES PARA LOS AUTORES REVISTA FOOD CHEMISTRY

**CAPÍTULO 2**:

**LINEAMIENTOS**

**General**: Manuscripts must be typewritten, double-spaced with wide margins. Each page must be numbered, and lines must be consecutively numbered from the start to the end of the manuscript. Good quality printouts with a font size of 12 or 10 pt are required. The corresponding author should be identified (include a Fax number and E-mail address). Full postal and email addresses must be given for all co-authors. Authors should consult a recent issue of the journal for style if possible. The Editors reserve the right to adjust style to certain standards of uniformity. Authors should retain a copy of their manuscript since we cannot accept responsibility for damage or loss of papers.

**Article structure**

Follow this order when typing manuscripts: Title, Authors, Affiliations, Abstract, Keywords, Main text, Acknowledgements, Appendix, References, Vitae, Figure Captions. Do not import the Figures or Tables into your text, figures and tables should be submitted as separate files. The corresponding author should be identified with an asterisk and footnote. All other footnotes (except for table footnotes) should be identified with superscript Arabic numbers. The title of the paper should unambiguously reflect its contents. Where the title exceeds 70 characters a suggestion for an abbreviated running title should be given.

**Subdivision - numbered sections**

Divide your article into clearly defined and numbered sections. Subsections should be numbered 1.1 (then 1.1.1, 1.1.2, ...), 1.2, etc. (the abstract is not included in section numbering). Use this numbering also for internal cross-referencing: do not just refer to 'the text'. Any subsection may be given a brief heading. Each heading should appear on its own separate line.

**Essential title page information**

• **Title.** Concise and informative. Titles are often used in information-retrieval systems. Avoid abbreviations and formulae where possible.

• **Author names and affiliations.** Please clearly indicate the given name(s) and family name(s) of each author and check that all names are accurately spelled. Present the authors' affiliation addresses (where the actual work was done) below the names. Indicate all affiliations with a lower-case superscript letter immediately after the author's name and in front of the appropriate address. Provide the full postal address of each affiliation, including the country name and, if available, the e-mail address of each author.

• **Corresponding author.** Clearly indicate who will handle correspondence at all stages of refereeing and publication, also post-publication. **Ensure that the e-mail address is given and that contact details are kept up to date by the corresponding author.**

• **Present/permanent address.** If an author has moved since the work described in the article was done, or was visiting at the time, a 'Present address' (or 'Permanent address') may be indicated as a footnote to that author's name. The address at which the author actually did the work must be retained as the main, affiliation address. Superscript Arabic numerals are used for such footnotes.

**Abstract**

A concise and factual abstract is required. The abstract should state briefly the purpose of the research, the principal results and major conclusions. An abstract is often presented separately from the article, so it must be able to stand alone. For this reason, References should be avoided, but if essential, then cite the author(s) and year(s). Also, non-standard or uncommon abbreviations should be avoided, but if essential they must be defined at their first mention in the abstract itself.

The abstract should not exceed 150 words.

**Highlights**

Highlights are mandatory for this journal. They consist of a short collection of bullet points that convey the core findings of the article and should be submitted in a separate editable file in the online submission system. Please use 'Highlights' in the file name and include 3 to 5 bullet points (maximum 85 characters, including spaces, per bullet point). You can view example Highlights on our information site.

**Chemical compounds**

You can enrich your article by providing a list of chemical compounds studied in the article. The list of compounds will be used to extract relevant information from the NCBI PubChem Compound database and display it next to the online version of the article on ScienceDirect. You can include up to 10 names of chemical compounds in the article. For each compound, please provide the PubChem CID of the most relevant record as in the following example: Glutamic acid (PubChem CID:611). Please position the list of compounds immediately below the 'Keywords' section. It is strongly recommended to follow the exact text formatting as in the example below:
Chemical compounds studied in this article
Ethylene glycol (PubChem CID: 174); Plitidepsin (PubChem CID: 44152164);
Benzalkonium chloride (PubChem CID: 15865)
More information.

**Formatting of funding sources**

List funding sources in this standard way to facilitate compliance to funder's requirements:

Funding: This work was supported by the National Institutes of Health [grant numbers xxxx, yyyy]; the Bill & Melinda Gates Foundation, Seattle, WA [grant number zzzz]; and the United States Institutes of Peace [grant number aaaa].

It is not necessary to include detailed descriptions on the program or type of grants and awards. When funding is from a block grant or other resources available to a university, college, or other research institution, submit the name of the institute or organization that provided the funding.

If no funding has been provided for the research, please include the following sentence:

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

**Units**

Follow internationally accepted rules and conventions: use the international system of units (SI). If other units are mentioned, please give their equivalent in SI.

Temperatures should be given in degrees Celsius. The unit 'billion' is ambiguous and should not be used.

**Artwork**

**Electronic artwork**

General points

• Make sure you use uniform lettering and sizing of your original artwork.

• Embed the used fonts if the application provides that option.

• Aim to use the following fonts in your illustrations: Arial, Courier, Times New Roman, Symbol, or use fonts that look similar.

• Number the illustrations according to their sequence in the text.

• Use a logical naming convention for your artwork files.

• Provide captions to illustrations separately.

• Size the illustrations close to the desired dimensions of the published version.

• Submit each illustration as a separate file.

A detailed guide on electronic artwork is available.

**You are urged to visit this site; some excerpts from the detailed information are given here.**

Formats

If your electronic artwork is created in a Microsoft Office application (Word, PowerPoint,

Excel) then please supply 'as is' in the native document format.
Regardless of the application used other than Microsoft Office, when your electronic artwork is finalized, please 'Save as' or convert the images to one of the following formats (note the resolution requirements for line drawings, halftones, and line/halftone combinations given below):
EPS (or PDF): Vector drawings, embed all used fonts.
TIFF (or JPEG): Color or grayscale photographs (halftones), keep to a minimum of 300 dpi.
TIFF (or JPEG): Bitmapped (pure black & white pixels) line drawings, keep to a minimum of 1000 dpi.
TIFF (or JPEG): Combinations bitmapped line/half-tone (color or grayscale), keep to a minimum of 500 dpi.
**Please do not:**
• Supply files that are optimized for screen use (e.g., GIF, BMP, PICT, WPG); these typically have a low number of pixels and limited set of colors;
• Supply files that are too low in resolution;
• Submit graphics that are disproportionately large for the content.

Please insert the following text before the standard text - Photographs, charts and diagrams are all to be referred to as "Figure(s)" and should be numbered consecutively in the order to which they are referred. They should accompany the manuscript, but should not be included within the text. All illustrations should be clearly marked with the figure number and the author's name. All figures are to have a caption. Captions should be supplied on a separate sheet.

**Color artwork**
Please make sure that artwork files are in an acceptable format (TIFF (or JPEG), EPS (or PDF), or MS Office files) and with the correct resolution. If, together with your accepted article, you submit usable color figures then Elsevier will ensure, at no additional charge, that these figures will appear in color online (e.g., ScienceDirect and other sites) regardless of whether or not these illustrations are reproduced in color in the printed version. **For**

**color reproduction in print, you will receive information regarding the costs from Elsevier after receipt of your accepted article**. Please indicate your preference for color: in print or online only. Further information on the preparation of electronic artwork.

**Figure captions**

Ensure that each illustration has a caption. Supply captions separately, not attached to the figure. A caption should comprise a brief title (**not** on the figure itself) and a description of the illustration. Keep text in the illustrations themselves to a minimum but explain all symbols and abbreviations used.

**Tables**

Please submit tables as editable text and not as images. Tables can be placed either next to the relevant text in the article, or on separate page(s) at the end. Number tables consecutively in accordance with their appearance in the text and place any table notes below the table body. Be sparing in the use of tables and ensure that the data presented in them do not duplicate results described elsewhere in the article. Please avoid using vertical rules and shading in table cells.

**References**

**Citation in text**

Please ensure that every reference cited in the text is also present in the reference list (and vice versa). Any references cited in the abstract must be given in full. Unpublished results and personal communications are not recommended in the reference list, but may be mentioned in the text. If these references are included in the reference list they should follow the standard reference style of the journal and should include a substitution of the publication date with either 'Unpublished results' or 'Personal communication'. Citation of a reference as 'in press' implies that the item has been accepted for publication.

**Web references**

As a minimum, the full URL should be given and the date when the reference was last accessed. Any further information, if known (DOI, author names, dates, reference to a source publication, etc.), should also be given. Web references can be listed separately (e.g., after the reference list) under a different heading if desired, or can be included in the reference list.

Example: CTAHR (College of Tropical Agriculture and Human Resources, University of Hawaii). Tea (Camellia sinensis) a New Crop for Hawaii, 2007.
URL http://www.ctahr.hawaii.edu/oc/freepubs/pdf/tea_04_07.pdf. Accessed 14.02.11.

**Data references**

This journal encourages you to cite underlying or relevant datasets in your manuscript by citing them in your text and including a data reference in your Reference List. Data references should include the following elements: author name(s), dataset title, data repository, version (where available), year, and global persistent identifier. Add [dataset] immediately before the reference so we can properly identify it as a data reference. The [dataset] identifier will not appear in your published article.

**Reference management software**

Most Elsevier journals have their reference template available in many of the most popular reference management software products. These include all products that support Citation Style Language styles, such as Mendeley and Zotero, as well as EndNote. Using the word processor plug-ins from these products, authors only need to select the appropriate journal template when preparing their article, after which citations and bibliographies will be automatically formatted in the journal's style. If no template is yet available for this journal, please follow the format of the sample references and citations as shown in this Guide.

Users of Mendeley Desktop can easily install the reference style for this journal by clicking the following link:
http://open.mendeley.com/use-citation-style/food-chemistry
When preparing your manuscript, you will then be able to select this style using the Mendeley plug-ins for Microsoft Word or LibreOffice.

All publications cited in the text should be presented in a list of references following the text of the manuscript. See Types of Paper for reference number limits. In the text refer to the author's name (without initials) and year of publication (e.g. "Steventon, Donald and Gladden (1994) studied the effects..." or "...similar to values reported by others (Anderson, Douglas, Morrison & Weiping, 1990)..."). For 2-6 authors all authors are to be listed at first citation. At subsequent citations use first author et al.. When there are more than 6 authors, first author et al. should be used throughout the text. The list of references should be arranged alphabetically by authors' names and should be as full as possible, listing all authors, the full title of articles and journals, publisher and year. The manuscript should be carefully checked to ensure that the spelling of authors' names and dates are exactly the same in the text as in the reference list.

**Reference style**

Text: Citations in the text should follow the referencing style used by the American Psychological Association. You are referred to the Publication Manual of the American Psychological Association, Sixth Edition, ISBN 978-1-4338-0561-5, copies of which may be ordered online or APA Order Dept., P.O.B. 2710, Hyattsville, MD 20784, USA or APA, 3 Henrietta Street, London, WC3E 8LU, UK.

List: references should be arranged first alphabetically and then further sorted chronologically if necessary. More than one reference from the same author(s) in the same year must be identified by the letters 'a', 'b', 'c', etc., placed after the year of publication.

Examples:

Reference to a journal publication:

Van der Geer, J., Hanraads, J. A. J., & Lupton, R. A. (2010). The art of writing a scientific article. Journal of Scientific Communications, 163, 51–59.

Reference to a book:

Strunk, W., Jr., & White, E. B. (2000). The elements of style. (4th ed.). New York: Longman, (Chapter 4).

Reference to a chapter in an edited book:

Mettam, G. R., & Adams, L. B. (2009). How to prepare an electronic version of your article. In B. S. Jones, & R. Z. Smith (Eds.), Introduction to the electronic age (pp. 281–304). New York: E-Publishing Inc.

Reference to a website:
Cancer Research UK. Cancer statistics reports for the UK. (2003). http://www.cancerresearchuk.org/aboutcancer/statistics/cancerstatsreport/ Accessed 13.03.03.
Reference to a dataset:
[dataset] Oguro, M., Imahiro, S., Saito, S., Nakashizuka, T. (2015). Mortality data for Japanese oak wilt disease and surrounding forest compositions. Mendeley Data, v1. https://doi.org/10.17632/xwj98nb39r.1.

**Supplementary material**

Supplementary material such as applications, images and sound clips, can be published with your article to enhance it. Submitted supplementary items are published exactly as they are received (Excel or PowerPoint files will appear as such online). Please submit your material together with the article and supply a concise, descriptive caption for each supplementary file. If you wish to make changes to supplementary material during any stage of the process, please make sure to provide an updated file. Do not annotate any corrections on a previous version. Please switch off the 'Track Changes' option in Microsoft Office files as these will appear in the published version.

**RESEARCH DATA**

This journal encourages and enables you to share data that supports your research publication where appropriate, and enables you to interlink the data with your published articles. Research data refers to the results of observations or experimentation that validate research findings. To facilitate reproducibility and data reuse, this journal also encourages you to share your software, code, models, algorithms, protocols, methods and other useful materials related to the project.

Below are a number of ways in which you can associate data with your article or make a statement about the availability of your data when submitting your manuscript. If you are sharing data in one of these ways, you are encouraged to cite the data in your manuscript and reference list. Please refer to the "References" section for more information about data citation. For more information on depositing, sharing and using research data and other relevant research materials, visit the research data page.

**Data linking**

If you have made your research data available in a data repository, you can link your article directly to the dataset. Elsevier collaborates with a number of repositories to link articles on ScienceDirect with relevant repositories, giving readers access to underlying data that give them a better understanding of the research described.

There are different ways to link your datasets to your article. When available, you can directly link your dataset to your article by providing the relevant information in the submission system. For more information, visit the database linking page.

For supported data repositories a repository banner will automatically appear next to your published article on ScienceDirect.

In addition, you can link to relevant data or entities through identifiers within the text of your manuscript, using the following format: Database: xxxx (e.g., TAIR: AT1G01020; CCDC: 734053; PDB: 1XFN).

**Data in Brief**

You have the option of converting any or all parts of your supplementary or additional raw data into one or multiple data articles, a new kind of article that houses and describes your data. Data articles ensure that your data is actively reviewed, curated, formatted, indexed, given a DOI and publicly available to all upon publication. You are encouraged to submit your article for Data in Brief as an additional item directly alongside the revised version of your manuscript. If your research article is accepted, your data article will automatically be transferred over to Data in Brief where it will be editorially reviewed and published in the open access data journal, Data in Brief. Please note an open access fee is payable for publication in Data in Brief. Full details can be found on the Data in Brief website. Please use this template to write your Data in Brief.

**AudioSlides**

The journal encourages authors to create an AudioSlides presentation with their published article. AudioSlides are brief, webinar-style presentations that are shown next to the online article on ScienceDirect. This gives authors the opportunity to summarize their research in their own words and to help readers understand what the paper is about. More information and examples are available. Authors of this journal will automatically receive an invitation e-mail to create an AudioSlides presentation after acceptance of their paper.

**Interactive plots**

This journal enables you to show an Interactive Plot with your article by simply submitting a data file. Full instructions.

**Additional information**

Abbreviations for units should follow the suggestions of the British Standards publication BS 1991. The full stop should not be included in abbreviations, e.g. m (not m.), ppm (not p.p.m.), % and '/' should be used in preference to 'per cent' and 'per'. Where abbreviations are likely to cause ambiguity or may not be readily understood by an international readership, units should be put in full.

Current recognised (IUPAC) chemical nomenclature should be used, although commonly accepted trivial names may be used where there is no risk of ambiguity.

The use of proprietary names should be avoided. Papers essentially of an advertising nature will not be accepted.

## ANEXO C. INSTRUCCIONES PARA LOS AUTORES REVISTA VITAE

**CAPÍTULO 3**:

**LINEAMIENTOS**

SUBMISSION OF MANUSCRIPTS

The Journal VITAE receives either English or Spanish written articles for evaluation. The submission of the article must be done through the Open Journal System platform, where the Journal manages the evaluation and publication processes. For this, the authors must go to the web page: www.udea.edu.co/vitae. Likewise, the requested documentation by the Editorial team must be attached as it is specified through the information available in the web page: the forms (information about the manuscript and the authors) and the Open access license. The document must be submitted in Word® format, double spaced, font type Time News Roman - 12 pts, and symmetrical margins of 3cm. The articles of research results submitted to The Journal VITAE must have an extension of a maximum of 25 pages, including Tables and Figures, the short articles a maximum extension of 15 pages and Structured reviews must have a minimum of 50 references.

STRUCTURE OF THE MANUSCRIPTS

FIRT PAGE

The first page of every manuscript must contain:

Title and information of all authors

Title in Spanish and English (a maximum of 20 words); information of the authors: a) Names of the authors, as cited in the different publications or, alternatively, as he or she prefers to be quoted. b) Highest academic degree. c) Institutional affiliations: must comprise the name of the institution, including city and Country, and may also contain the position of every author. The main author must indicate, in footnote, the e-mail address to which correspondence is to be sent, with an asterisk, exclusively for this, along with the phrase “Author to whom correspondence should be directed”.

Abstract

In the articles as in the reviews it must be included a structured Abstract of one single paragraph both in Spanish and English, compressing a minimum of 300 words and no longer than 350, with different sections and labeled with the subtitles BACKGROUND,

OBJECTIVES, METHODS, RESULTS and CONCLUSIONS, in bold uppercase. The abstract must be written in indicative past tense, except the conclusions, and must fulfill the following criteria:

- BACKGROUND: The context must be presented, and the justification for the study

- OBJECTIVES: It must be specified what is attempted with the study.

- METHODS: It must be presented the most important aspects of the design of the study or design of experiments, the sampling, the obtention and way of measurement of the data, as well as the analysis and statistical procedures. For the reviews, must be presented the way of selection and inclusion of the references. The methods must allow the fulfillment of the objectives and be coherent with the results.

- RESULTS: It must be presented the most significant findings, along with the respective statistical proofs; the results must respond to the objectives and maintain correspondence and coherence among them and with the body of the manuscript.

- CONCLUSIONS: It must be presented at least one conclusion. The conclusions must be supported by the results and be coherent with the objectives.

Keywords: A number of three to five keywords must be included, both in Spanish and English; at least two of them must be included in the Health Sciences Descriptors (DeCS) that appears in the web page: http://decs.bvs.br/, or be MeSH terms.

ARTICLES OF RESEARCH RESULTS

The complete articles present in detail the original results of completed research projects, which have not been previously published. When it's a matter of standardization and/or validation of analytical methods, it must be followed official norms of the different sectors or guidelines of international norms.

Introduction: The context and background of the study must be presented, in other words the nature of the problem and its importance, referencing to the most relevant works previously published. In this section it is specified the aim and objectives of the article, or the proved hypothesis by the study or observation. Both the main objective (general objective) and the secondary objectives (specific objectives) must be clear and, if necessary, must be previously described any subgroup of specific analysis. Must be given only direct and appropriate references, and must not be included data or conclusions obtained in work that is being reported.

Materials and methods: Must contain the information and the necessary procedures for the reproducibility of the experiments or process utilized, indicating the established methods in the literature and every substantial modification over them. Must include the aspects related to the design of the study or design of the experiments, the sampling (or the selection and description of participants in the case of clinic studies), the criteria for inclusion and exclusion, the obtention and way of measurement of the data and its analysis along with the statistical processing.

Results: Must be presented the most significative findings in a logical sequence, using tables and figures in order to synthesize the information, avoiding its interpretation. When is presented summarized data in this section, it should not be restricted to the derived final results (such as percentages) and, therefore, must include the numerical values utilized for the calculations, and specify the statistical method used in the analysis.

Discussion: Must stand out the novel results or the most significative contributions, contextualized in the set of available evidence, comparing the results with others reported in similar studies, establishing similarities and/or differences. Moreover, the explanations must be supported, standing out the strengths or novelty of the results, justification of the contribution and the inputs to the investigation in the topic. Must end with a paragraph that exposes the main limitations of the research.

Conclusions: Must be reported the assertions about the development of the research, associated to the objectives of the work, omitting those statements that are not supported by the results. Must be avoided conclusions of economical nature, except when the article includes these analyzes. It may include new hypothesis supported by the results, but clearly describing them as such.

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