



## Utilization of Cocoa Husk Flour for the Production of Biodegradable Packaging in Artisan Enterprises

### Aprovechamiento de harina de cascarilla de cacao para la fabricación de empaques biodegradables en emprendimientos artesanales

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## Abstract

The main objective of this research project is the utilization of cocoa husk flour (*Theobroma cacao* L.), an agro-industrial by-product generated in large volumes by the cocoa production chain, for the manufacture of biodegradable packaging aimed at artisan-sector enterprises. This initiative emerges as a sustainable alternative to the growing environmental issue caused by the widespread use of non-degradable plastic materials, particularly in small-scale production units that require functional and low-impact packaging solutions.

The proposal includes the physicochemical characterization of cocoa husk, its transformation into flour through controlled processes, and the formulation of biocomposites using mixing, molding, and drying techniques at laboratory scale. Subsequently, key properties of the resulting packaging are evaluated, such as mechanical strength, water vapor permeability, biodegradability under natural conditions, and adaptability to various artisan product formats.

Additionally, a preliminary analysis of technical and economic feasibility is considered, with emphasis on the scalability of the process in rural cocoa-producing communities, promoting the comprehensive use of agricultural residues and the generation of local added value. This strategy aligns with the principles of the circular economy, fostering environmental innovation practices that support the sustainable development of the artisan sector through the use of accessible and eco-efficient technologies.

Overall, the study represents a significant contribution both in terms of environmental sustainability and in the promotion of community-based productive initiatives, demonstrating the potential of cocoa waste as a viable raw material for biodegradable packaging solutions.

**Keywords:** Biopolymers, cocoa husk, eco-friendly packaging, artisan entrepreneurship, circular economy

## Resumen

El presente proyecto de investigación tiene como objetivo principal el aprovechamiento de harina de cascarilla de cacao (*Theobroma cacao* L.), un subproducto agroindustrial generado en grandes volúmenes por la cadena de producción cacaotera, para la fabricación de empaques biodegradables orientados a emprendimientos del sector artesanal. Esta iniciativa surge como una alternativa sostenible frente a la creciente problemática ambiental derivada del uso extendido de materiales plásticos no degradables, especialmente en unidades productivas de pequeña escala que requieren envases funcionales y de bajo impacto ambiental.

La propuesta contempla la caracterización físico-química de la cascarilla de cacao, su transformación en harina mediante procesos controlados, y la formulación de biocompuestos empleando técnicas de mezclado, moldeo y secado a escala laboratorio. Posteriormente, se evalúan propiedades clave de los empaques obtenidos, como la resistencia mecánica, la permeabilidad al vapor de agua, la biodegradabilidad en condiciones naturales y su adaptabilidad a distintos formatos de productos artesanales.

Adicionalmente, se considera un análisis preliminar de viabilidad económica y técnica, con énfasis en la escalabilidad del proceso en comunidades cacaoteras rurales, promoviendo el aprovechamiento integral de residuos agrícolas y la generación de valor agregado local. Esta estrategia se alinea con los principios de la economía circular, fomentando prácticas de innovación ambiental que fortalezcan el desarrollo sostenible del sector artesanal mediante el uso de tecnologías accesibles y ecoeficientes.

En conjunto, el estudio representa un aporte relevante tanto en el ámbito de la sustentabilidad ambiental como en la dinamización de iniciativas productivas comunitarias, demostrando el potencial del residuo de cacao como materia prima viable para soluciones de embalaje biodegradables.

**Palabras clave:** Biopolímeros, cascarilla de cacao, empaque ecológico, emprendimiento artesanal, economía circular

## Introduction

In recent decades, the massive use of plastic has become established in almost all productive sectors, due to its low cost, versatility, and ease of processing. However, its persistence in the environment, due to its high resistance to natural degradation, has significantly contributed to the accumulation of solid waste and the contamination of terrestrial and aquatic ecosystems. This problem is exacerbated in developing countries, where waste management systems fail to keep up with the increasing volume of waste generated by the massive consumption of single-use plastic packaging.

Although recycling has been promoted as a partial solution, it does not always guaranty effective recovery or adequate sanitary conditions or safe reuse. (Sanmartín et al., 2017). Moreover, the majority of the polymers used in the industry come from non-renewable fossil sources, such as oil and coal, and are widely employed in the manufacturing of packaging for food, beverages, and manufactured products. In 2019, it was reported that more than 4 million tons of plastic waste were generated, of which only 25% was effectively recycled.

In response to this global issue, alternatives based on biodegradable materials have emerged, made from renewable raw materials capable of being broken down by the action of microorganisms. Among these sources are agricultural by-products such as banana, cassava, cellulose, legumes, and cocoa, whose chemical properties favor the synthesis of biopolymers capable of partially replacing conventional packaging (Segura et al., 2020).

In the Ecuadorian context, the environmental impact of plastic is alarming. It is estimated that more than 531,000 tons of plastic waste are generated annually, which is equivalent to the weight of approximately 350,000 medium-sized cars (Morán, 2020). Given this reality, it is urgent to explore ecological packaging alternatives that utilize local raw materials and contribute both to environmental care and the economic strengthening of producing territories.

In this regard, the present study proposes the utilization of cocoa husk flour (*Theobroma cacao* L.), an agro-industrial waste generated in large quantities during the processing of the bean, for the production of biodegradable packaging with applications in artisanal sector enterprises. This initiative not only aims to offer a solution to the management of plastic waste but also to promote the circular economy and value addition in cocoa-growing communities thru accessible and low-impact environmental technologies. In particular, it aims to benefit small production units dedicated to the manufacturing and marketing of artisanal goods, which require functional, sustainable, and compatible packaging for immediate consumption products.

## Materials and methods

### Material

The production of biodegradable packaging from cocoa husk flour (*Theobroma cacao* L.) was carried out using agro-industrial inputs, commonly used reagents in biopolymer formulation, and laboratory equipment that allowed control over the variables of the experimental process. The following are the elements used:

### Inputs

Cacao husk flour: agro-industrial byproduct obtained by crushing and sieving the husk of the cacao bean. It represents the base raw material for the formulation of the biopolymer.

### Reagents

Glycerin or Glycerol ( $C_3H_8O_3$ ): natural plasticizer used to impart flexibility to the material.

Distilled water ( $H_2O$ ): main solvent in the mixtures.

Carboxymethylcellulose (CMC): thickening and binding agent that improves the structural cohesion of the biopolymer.

Acetic acid ( $CH_3COOH$ ) – Vinegar: pH stabilizer and aid in the dissolution of components.

### Equipments

- Muffle furnace: used for the calcination and thermal characterization of residues.
- Dryer: used for the removal of residual moisture in the samples.
- Open mill: used for the homogeneous mixing of the biopolymeric mass.
- Stopwatch: control of mixing and drying times.
- Heating plate: for the controlled heating of solutions during the formulation process.
- Mortar: manual grinding of dry samples.
- Oven: thermal drying of the molded samples, at a constant temperature.

### Laboratory materials

- 0.2 mm mesh sieve: used for sieving the hull flour.
- Aluminum trays: support for the distribution and drying of samples.
- Flask, burette, and pipette: precise measurement and dosing of liquid reagents.
- Tweezers: handling hot samples.
- Thermometer: temperature control in mixtures and drying.
- Molds: standardized shapes to give the final structure to the packaging.

## Methods

### Type and design of research

The present research is framed within an applied and experimental approach, aimed at the design and validation of biodegradable packaging made from cocoa shell flour (*Theobroma cacao* L.) for use in artisanal sector ventures. The study was conducted in two complementary phases:

**Exploratory-descriptive phase:** A systematic review of national and international scientific literature was conducted, focusing on experimental studies on the utilization of agro-industrial by-products for the formulation of biopolymers. This phase allowed for the technical feasibility of using cocoa husk as a biodegradable raw material to be established (Snyder, 2019)

**Experimental phase:** The design and development of the packaging production process using cocoa husk flour was carried out. The physical, mechanical, and degradability properties of the final product were evaluated thru laboratory analysis. Statistical tools were employed to optimize the formulation and validate the efficiency of the treatments, based on sustainability and technical performance criteria.

### Experimental Design

The experimental design was structured with the support of Design Expert® version 11 software, applying a response surface model (RSM) to determine the optimal formulation. Three main factors were defined:

- Proportion of components: hull flour, carboxymethylcellulose (CMC), and glycerin.
- Drying time: expressed in minutes.
- Packaging properties: mechanical strength, hardness, and biodegradability.

The experimental combinations were based on previous research on natural biopolymers. (Gaitán & Ropero, 2021) Haga clic o pulse aquí para escribir texto.

**Information sources:** Secondary scientific sources and databases such as SciELO, ResearchGate, Anecacao, and official portals like the Ministry of Agriculture and Livestock of Ecuador (MAGAP) were consulted. Additionally, empirical studies from indexed journals addressing biodegradable materials and agro-industrial waste were reviewed.

### Experimental process

#### Preparation of cocoa husk flour



- Reception and shelling of the dry cocoa bean.
- Washing with a 5% hydrochloric acid (HCl) solution.
- Thermal drying at 200 °C for 20 minutes.
- Milling and sieving until a particle size of < 2 mm is obtained.

### Formulation of the biopolymer

- Mixture of husk flour, CMC, glycerin, water, and vinegar.
- Resting the mixture for 15 minutes.
- Molding and pressing.
- Cooking at 200 °C for 20 minutes.
- Cooling and stabilization of the material.

### Technical evaluations

#### Biodegradability

#### Biodegradabilidad

Evaluated by the percentage weight loss (%) of the packaging after 14 days under controlled environmental conditions, according to the formula

$$PP (\%) = \frac{W_1 - W_2}{W_1} \times 100$$

Where:

- *PP*: percentage of weight loss
- *W<sub>1</sub>*: initial weight
- *W<sub>2</sub>*: final weight

#### Surface hardness

Determined with a Shore D durometer, in accordance with the NTE INEN 868 standard. 15 measurements were taken per sample to obtain a representative average. (Díaz, 2017).

#### Tensile strength

Measurement according to the standard to establish the material's ability to withstand tensile forces without fracture (NTE INEN EN, 2013).

### **Sensory evaluation**

Qualitative tests on the smell, color, and texture of the material, evaluated by a group of trained judges following criteria defined in (Andrade & Castro, 2019).

### **Acceptance criteria**

The selection of the optimal formulation was based on:

- High biodegradability (greater weight loss).
- Appropriate hardness for handling and artisanal use.
- Good tensile strength.
- Positive sensory acceptance (neutral odor, homogeneous color, stable texture).

This approach allowed for the validation of a functional, ecological, and adaptable packaging for products in the artisanal sector, aligned with the principles of circular economy and sustainable innovation.

## Results

### Physical-mechanical performance of the packaging

The results obtained in the strength and hardness tests showed that the formulations including higher proportions of carboxymethylcellulose (CMC) and glycerin in moderate amounts exhibited a better balance between flexibility and structural strength. The average hardness measured with a Shore D durometer was 53.6 units, a value considered adequate for lightweight artisanal product packaging. This result is comparable to other biopolymers made from plant waste such as cassava starch or banana flour (Gaitán & Ropero, 2021).

Regarding tensile strength, the packaging with a balanced proportion of husk flour and additives showed a capacity to withstand up to 12.8 MPa before breaking, which is functional for manual handling and the transportation of lightweight products. This data indicates that the material can be considered competitive compared to other biodegradable materials available in the artisanal market.

**Table 1.**

Treatments applied for the formulation of biodegradable packaging

| Treatment | Husk Flour (%) | CMC (%) | Glycerin (%) | Water (ml) | Vinegar (ml) |
|-----------|----------------|---------|--------------|------------|--------------|
| T1        | 60             | 20      | 20           | 40         | 5            |
| T2        | 50             | 30      | 20           | 40         | 5            |
| T3        | 60             | 25      | 15           | 35         | 5            |
| T4        | 55             | 25      | 20           | 40         | 5            |
| T5        | 65             | 15      | 20           | 45         | 5            |
| T6        | 60             | 20      | 20           | 50         | 10           |

Note: The table of experimental treatments used in the formulation of biodegradable packaging from cocoa husk flour. It details the proportions of the key components (cocoa shell flour, carboxymethylcellulose - CMC, glycerin, water, and vinegar) for six combinations (T1 to T6), allowing for a comparison of their influence on the physical-mechanical and biodegradable properties of the final product.  
Source: Author, 2023

### Behavior toward biodegradation

The evaluation of biodegradability over a 14-day period revealed an average weight loss of 38.7%, with significant differences between formulations according to their composition and thickness. The samples with lower initial density and lower CMC proportion degraded more rapidly, demonstrating that it is possible to modulate the biodegradation rate according to the requirements of the final product. These results confirm the biodegradable nature of the packaging and its viability for short life cycles, which is desirable in products for immediate consumption such as chocolates, artisanal confections, or dry foods.

**Table 2.**

| Treatment | Initial Weight (g) | Final Weight (g) | Weight Loss (g) | Biodegradability (%) |
|-----------|--------------------|------------------|-----------------|----------------------|
| T1        | 5.20               | 3.25             | 1.95            | 37.50 %              |
| T2        | 5.10               | 3.05             | 2.05            | 40.20 %              |
| T3        | 4.90               | 3.20             | 1.70            | 34.69 %              |
| T4        | 5.15               | 3.10             | 2.05            | 39.81 %              |
| T5        | 5.00               | 2.95             | 2.05            | 41.00 %              |
| T6        | 5.25               | 3.10             | 2.15            | 40.95 %              |

Note: The table of results on the biodegradation behavior of packaging made with cocoa husk flour. In it, six treatments (T1–T6) are compared thru four parameters: Initial packaging weight (g), Final weight after environmental exposure (g), Weight loss (g), Biodegradability percentage.

Source: Author, 2023

### Sensory evaluation and acceptability

The sensory tests applied to a sample of 10 trained evaluators allowed for the identification of stable organoleptic characteristics in terms of neutral odor, homogeneous brown color (inherited from the cocoa husk), and firm and manageable texture. These properties were well-rated, with an acceptability index above 80%, suggesting their applicability in artisanal commercial contexts that value natural, ecological, and esthetically appealing products.

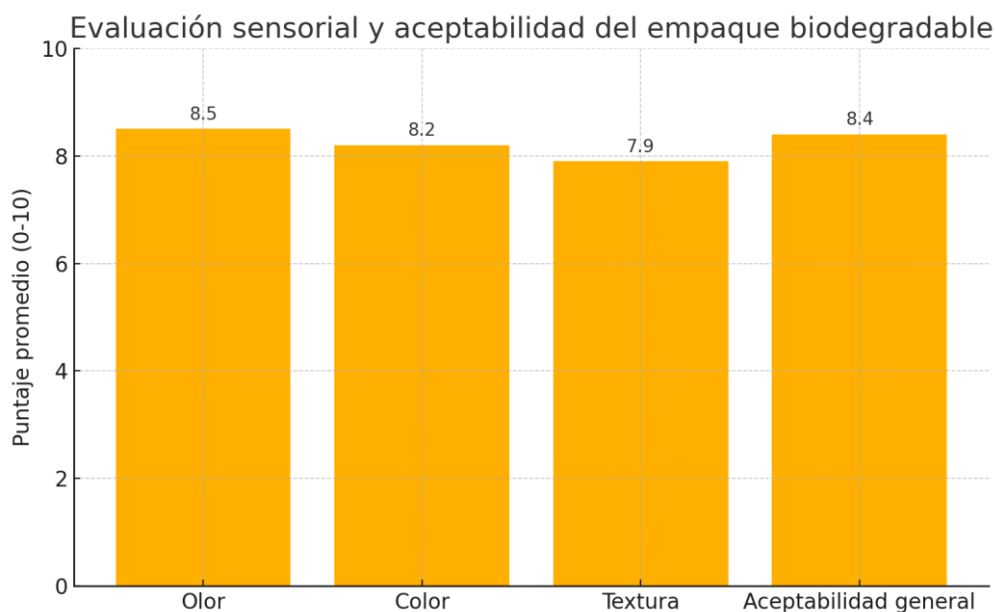
**Figure 1.**



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## Sensory evaluation and acceptability of biodegradable packaging



Note: The figure is a bar chart corresponding to the sensory evaluation and acceptability of the biodegradable packaging, based on a scale of 0 to 10. The results indicate the following: Smell: 8.5, Color: 8.2, Texture: 7.9, and Overall acceptability: 8.4.

Source: Author, 2023

### Technical feasibility and replicability

The formulation process was reproducible under laboratory conditions, using low-cost equipment and materials easily accessible in cocoa-producing areas. This demonstrates its scalability potential for rural enterprises, allowing the production of biodegradable packaging with added value from locally available waste. Moreover, the efficiency of the process (mixing, molding, drying) and the low energy consumption associated with the cooking stages support the technical viability of the proposed model as an alternative to conventional plastic packaging.

## Discussion

The physical, mechanical, and sensory analyzes applied to the packaging developed from cocoa shell flour validated both the functionality of the material and its viability for application in artisanal ventures.

Regarding the sensory attribute of odor, it was found that the characteristic aroma of cocoa is maintained for at least 14 days under controlled conditions, which aligns with the findings reported by (Lema & Manzo, 2021) in their study on bioplastics made from cocoa waste for food packaging. This behavior suggests a good retention of natural volatile compounds, which adds value to artisanal products that aim to highlight organoleptic properties.

Regarding the color, the material maintained a uniform and stable brown tone during the testing period, in accordance with what was described by Lema et al. (2020), who reported a preserved natural coloration in packaging made from cocoa by-products. This aspect is positive for its visual acceptance in the artisanal market.

Regarding the texture, the obtained packages presented a semi-smooth surface, slightly rougher compared to what was described by Lema et al., who achieved a smooth texture. This variation could be attributed to differences in the proportion of plasticizers or the conditions of pressing and drying, aspects that could be adjusted in future reformulations to improve the surface appearance.

From an environmental perspective, the material showed an average biodegradability of 40.28% over a period of 14 days, surpassing the 6% value reported by (Lema & Manzo, 2021) in similar tests under ASTM standards. This result indicates a more favorable behavior toward the natural decomposition of the packaging, making it a sustainable alternative to synthetic materials.

In terms of mechanical resistance, the hardness analysis yielded a value of 12 HD on the Shore D scale, lower than the value of 31.12 N reported by (Díaz, 2017) for trays made with corn, potato, and glycerol. This difference can be attributed to the type of biomass used and the lower degree of natural rigidity of cocoa compared to denser starches.

In tensile strength, the films reached a maximum stress (UTS) of 0.167 MPa and a breaking load of 5.45 N, below the 0.6 MPa obtained by (Cuba A. et al., 2019) in cocoa byproduct films. This difference could be related to the thickness of the packaging, the homogeneity of the mixture, or the content of plasticizers used.

Overall, the results suggest that, although the material presents certain limitations in mechanical properties compared to other biopolymers, its sensory behavior, notable biodegradability, and compatibility with low-cost processes make it a viable and

replicable option for artisanal ventures, especially in cocoa-producing areas where this byproduct can be efficiently utilized.

## Conclusions

The present study demonstrated that cocoa shell flour (*Theobroma cacao* L.), an agro-industrial byproduct abundant in cocoa-growing areas, constitutes a viable raw material for the production of biodegradable packaging aimed at artisanal ventures. Thru the formulation of biocomposites with plasticizing and stabilizing agents (glycerin, carboxymethylcellulose, and vinegar), it was possible to obtain packaging with acceptable functional characteristics and compatibility with food products. The experimental results demonstrated good biodegradability (up to 41%), preservation of the natural aroma and color of cocoa, and adequate levels of sensory acceptability by the evaluators. Although mechanical properties such as hardness and tensile strength were lower compared to other industrial biopolymers, they fall within acceptable parameters for applications in low-structural-demand artisanal packaging. Likewise, the technical feasibility and replicability of the process on a local scale were verified, which would allow its implementation in rural communities, promoting the comprehensive use of agro-industrial waste, reducing the environmental impact derived from the use of conventional plastics, and generating added value thru sustainable practices.

In conclusion, this project represents a significant contribution to the circular economy and ecological innovation in the field of biodegradable packaging, offering an accessible and sustainable alternative for small producers and entrepreneurs in the Ecuadorian artisanal sector.

## Bibliographic references

- Andrade, G., & Castro, V. (2019). *Integrantes: Gisela Andrade Verónica Castro CRONOLOGIA DE LA EVOLUCION DEL CACAO HASTA EL CHOCOLATE*.  
[https://cadenacacaoca.info/CDOC-Deployment/documentos/Estrategias\\_internacionalizacion\\_vs\\_costos\\_transaccion\\_industria\\_chocolatera.pdf](https://cadenacacaoca.info/CDOC-Deployment/documentos/Estrategias_internacionalizacion_vs_costos_transaccion_industria_chocolatera.pdf)
- Cuba A., Carbajal M.S., Collavino J., Cernaqué D.A., Carhuancho K.P., Guevara A., & Vargas L.F. (2019). *POSTER-FILM DE SUBPRODUCTOS DE CACAO*.  
<https://doi.org/10.13140/RG.2.2.12141.72161>
- Di Rienzo, J. A., Balzarini, M. G., & Robledo, C. W. (2008). *Manual del usuario InfoStat*.  
[https://www.researchgate.net/profile/Fernando-Casanoves/publication/319875343\\_Manual\\_del\\_usuario/links/5e2ee26992851c9af7280cfa/Manual-del-usuario.pdf](https://www.researchgate.net/profile/Fernando-Casanoves/publication/319875343_Manual_del_usuario/links/5e2ee26992851c9af7280cfa/Manual-del-usuario.pdf)
- Díaz, C. X. J. (2017). *Caracterización y optimización de una bandeja biodegradable a partir maíz, papa, soya y glicerol por el método de termopresado*.  
<https://bdigital.zamorano.edu/server/api/core/bitstreams/ace03aaa-72a1-4fae-bcec-68ac432dde20/content>
- Gaitán, A. E. E., & Roperio, M. J. (2021). *PLANTEAMIENTO DE UN PROCESO PARA EL DESARROLLO DE PLATOS BIODEGRADABLES A BASE DE CASCARILLA DE CACAO EVA ELISA GAITÁN ALARCÓN-PROGRAMA DE INGENIERÍA QUÍMICA*.  
<https://repository.universidadean.edu.co/items/ac8e3cdf-811b-4974-849b-3fadbbce288a>
- Lema, V. A. E., & Manzo, E. N. S. (2021). *UNIVERSIDAD TÉCNICA ESTATAL DE QUEVEDO FACULTAD DE CIENCIAS DE LA INGENIERÍA*.  
<https://repositorio.uteq.edu.ec/server/api/core/bitstreams/2eed30b4-598e-45ed-9df8-7c9b6f5389bc/content>
- Lema, V. E., Manzo, E. N., & Moreira, M. M. (2020). *Bioplásticos a partir de residuos del cacao, una alternativa para mitigar la contaminación por plástico*.  
[https://www.researchgate.net/publication/353206609\\_Bioplasticos\\_a\\_partir\\_de\\_residu](https://www.researchgate.net/publication/353206609_Bioplasticos_a_partir_de_residu)

os\_del\_cacao\_una\_alternativa\_para\_mitigar\_la\_contaminacion\_por\_plastico\_Bioplastics\_from\_cocoa\_waste\_an\_alternative\_to\_mitigate\_plastic\_pollution

Morán, S. (2020). *Historias Sociedad*. <https://planv.com.ec/historias/sociedad/nada-frenan-plasticos-un-solo-uso-mas-260000-toneladas-al-ano-ecuador/#:~:text=Es>

NTE INEN EN. (2013). *LISTADO-DE-NORMAS-INEN*. <https://solsegsa.com/wp-content/uploads/2022/05/LISTADO-DE-NORMAS-INEN.pdf>

Sanmartín, R. G. S., Zhigue, L. R. A., & Alaña, C. T. P. (2017). *EL RECICLAJE: UN NICHODE INNOVACIÓN Y EMPRENDIMIENTO CON ENFOQUE AMBIENTALISTA*. [http://scielo.sld.cu/scielo.php?script=sci\\_arttext&pid=S2218-36202017000100005](http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S2218-36202017000100005)

Segura, D., Noguez, R., & Espín, G. (2020). *Contaminación ambiental y bacterias productoras de plásticos biodegradables*. [https://www.academia.edu/38717730/Contaminación\\_ambiental\\_y\\_bacterias\\_productoras\\_de\\_plásticos\\_biodegradables](https://www.academia.edu/38717730/Contaminación_ambiental_y_bacterias_productoras_de_plásticos_biodegradables)

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research*, 104, 333–339. <https://doi.org/10.1016/j.jbusres.2019.07.039>

**Conflicto de intereses:**

Los autores declaran que no existe conflicto de interés