Factor Analysis of the Processes of Planting, Selection, Packaging, and Transport of Guava in Michoacán.

I.J. López Valle [1]; E. Oliva López[2]; C. León Puertos[3], C.G. León Vega[4]
[1,2,3,4]Instituto Politécnico Nacional, Escuela Superior de Ingeniería Mecánica y Eléctrica, Sección de Estudios de Posgrado e Investigación, Unidad Profesional Adolfo López Mateos "Zacatenco", Edificio 5 2do. Piso, Col. Lindavista, C.P. 07300, Ciudad de México
[1]girljaneth@yahoo.com.mx; [2]eoliva@ipn.mx; [3]cleon@ipn.mx, [4]cleonv@ipn.mx

Abstract— **This study was based on a survey of 20 guava (*Psidium guajava* L.) producers from Benito Juárez, Michoacán, aimed at understanding the correlation between the practices of harvesting, selection, packing, and transportation of fresh fruit for export. A factor analysis identified four components that explain 67.58% of the total variance. Additionally, a Cronbach's Alpha of 0.745 was obtained, indicating that the data is reliable. The results emphasize that providing proper training to producers, ensuring correct fruit selection, adhering to packing quality standards, and using refrigerated transportation can significantly improve the physical quality of the guava.**

***Keywords*— Guava, Physiological quality, Factorial Analysis**

I. INTRODUCTION

Guava is considered a highly perishable fruit, prone to physiological deterioration during harvesting, storage, and distribution. These damages often become visibly apparent as the fruit nears the end of its shelf life, which significantly limits its potential for commercialization in both domestic and international markets (García et al., 2011; López & Mercado, 2006; Yam et al., 2010)."

According to the standard (NMX-FF-040-SCFI-2002), guava quality is defined by its good appearance, allowing for minor imperfections such as scratches, abrasions, crusts, stains, or sunburns—provided they go through a careful selection process and do not compromise the fruit's overall quality. The quality of agricultural products influences whether consumers find them acceptable, and this quality is closely linked to their overall health—meaning they should be free from pests, excess moisture, strange odors, or off-flavors. Additionally, the shelf life of these products also impacts their quality and how well they are received by consumers. This understanding is supported by studies like those of Becerra et al. (2009) and Elorza et al. (2000).

In Mexico, guava cultivation is gaining significant importance, with the main contributing states being Michoacán at 43%, Aguascalientes at 28%, Zacatecas with 14%, and the remaining 15% coming from the States of Mexico, Jalisco, and Querétaro.

Since guava is a highly perishable fruit, after being detached from the plant, it experiences weight loss and deterioration during the marketing chain. This reduces its shelf life, leading to the search for alternatives to extend its useful life and improve its export quality (Martínez et al., 2005; García et al., 2010).

On the other hand, factorial analysis is a statistical technique used internationally by researchers as an exploratory or descriptive method to determine the appropriate number of components and the correlation between different variables (Fernández, 2015).

The purpose of factorial analysis is to create a new set of variables, fewer in number than the original ones, which can explain most of the total variables.

II. FACTORIAL ANALYSIS

The data obtained from the survey conducted with guava (Psidium guajava L.) producers from the municipality of Benito Juárez, Michoacán, were not normally distributed (Figure 1), so ANOVA analysis for parametric tests should not be applied. Therefore, factorial analysis was performed for non-parametric tests.

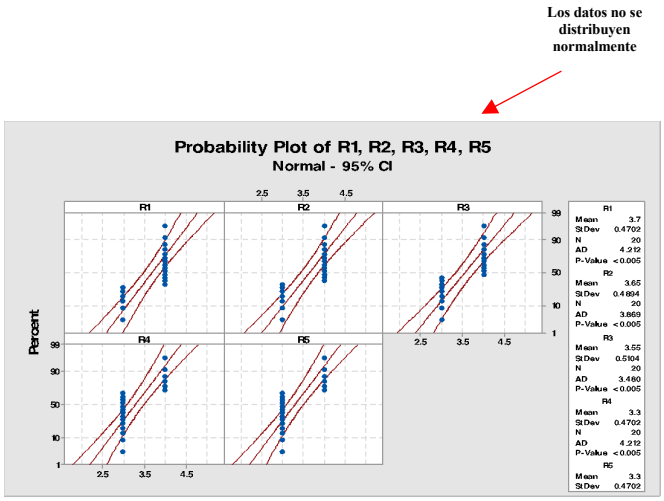

Figure 1. Normality Test of Data

The methodology of factor analysis is shown in Figure 2. The application is carried out step by step within the content of the document, starting with the reliability of the data.

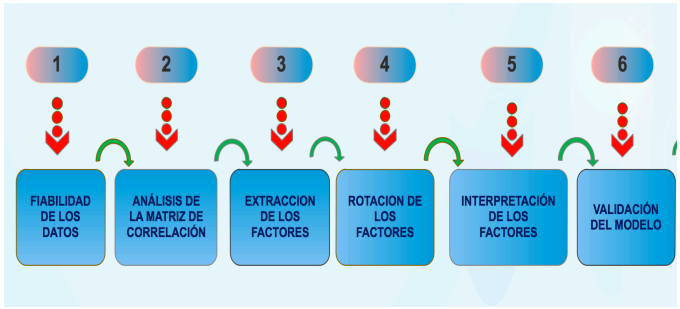

Figure 2. Metodology of Factor Analysis

A. *Data Reliability*

Three questionnaires were combined in order to achieve greater reliability in the factorial statistical study for non-parametric tests, and questions with a variance value of 0 were eliminated.

For an effective application of Cronbach's alpha, the Likert scale was used (Oliden & Zumbo, 2008).

The reliability test using Cronbach's alpha was performed in SPSS software, and the value was 0.745, which allows us to proceed to the next step of the factorial analysis. (Figure 3).

Reliability statistics

Alfa de Cronbach	N de elementos
.745	23

Figure 3. Alfa de Cronbach

B. *Correlation Matrix Analysis*

The correlation matrix shows the correlation coefficients of each variable with respect to the others. The highest correlation values are highlighted in red. It is shown that only 5 out of 10 variables have the highest correlation values (Figure 4).

VARIABLES		Estirilizacion_recipientes	Demanda_mercado	Cosecha_tratamiento	Cosecha_manual	Seleccion_norma	Trasporte_norma	Capacitacion	Empaque_norma	Lavado_y_secado	Etiquetado_norma
Correlación	Estirilizacion_recipientes	1.000	.296	.065	.131	.292	.213	.438	.161	.163	.157
	Demanda_mercado	.296	1.000	.118	.252	.232	.194	.473	-.041	.254	.261
	Cosecha_tratamiento	.065	.118	1.000	.126	-.109	.121	-.050	.076	-.134	.035
	Cosecha_manual	.131	.252	.126	1.000	.359	-.221	.195	-.007	.105	.192
	Seleccion_norma	.292	.232	-.109	.359	1.000	-.180	.303	.230	.163	.346
	Trasporte_norma	.213	.194	.121	-.221	-.180	1.000	-.112	.095	-.101	-.237
	Capacitacion	.438	.473	-.050	.195	.303	-.112	1.000	-.039	.620	.596
	Empaque_norma	.161	-.041	.076	-.007	.230	.095	-.039	1.000	.358	.050
	Lavado_y_secado	.163	.254	-.134	.105	.163	-.101	.620	.358	1.000	.379
	Etiquetado_norma	.157	.261	.035	.192	.346	-.237	.596	.050	.379	1.000

Figure 4. Correlation Matrix

The KMO and Bartlett's tests were conducted, with a KMO value of (.540), which is greater than 0.5, indicating that it is acceptable to proceed with the factor analysis. Bartlett's test of sphericity yielded a significance value of (0.000), suggesting that the null hypothesis is not significant. Since the value is less than 0.05, it is appropriate to continue with the factor analysis.

C. *Factor Extraction*

The scree plot arranges the values from highest to lowest. The first value is the highest possible. If a value approaches zero, it means it is unable to explain a relevant amount of the total variance, and therefore lacks analytical meaning. (Figure 5).

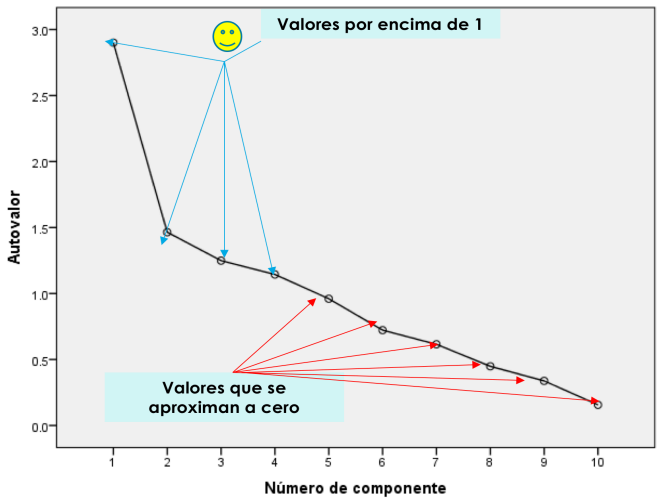

Figure 5. Scree Plot

The table of explained variance percentages shows the 10 variables included in the analysis (Table 1). However, just four factors are sufficient to explain 67.56% of the total variance.

Table 1. Total Expalined Variance

	Autovalores iniciales			Sumas de extracción de cargas al cuadrado			Sumas de rotación de cargas al cuadrado		
VARIABLES	Total	% de varianza	% acumulado	Total	% de varianza	% acumulado	Total	% de varianza	% acumulado
1	2.901	29.007	29.007	2.901	29.007	29.007	2.411	24.109	24.109
2	1.464	14.642	43.649	1.464	14.642	43.649	1.562	15.623	39.731
3	1.249	12.492	56.141	1.249	12.492	56.141	1.522	15.223	54.954
4	1.145	11.445	67.586	1.145	11.445	67.586	1.263	12.632	67.586
5	.961	9.607	77.193						
6	.722	7.223	84.416						
7	.615	6.153	90.569						
8	.449	4.487	95.056						
9	.338	3.380	98.436						
10	.156	1.564	100.000						

In the communalities table (Table 2), it can be observed that certain components are well represented by the factor solution, such as *Packaging_norm* (.905), *Training* (.866), *Transport_norm* (.760), and *Washing and drying* (.724).

Based on this table, it is possible to question whether the number of extracted factors is sufficient to adequately explain each of the variables included in the analysis.

Table 2. Communalities Table

	Inicial	Extracción
Estirilizacion_recipientes	1.000	.527
Demanda_mercado	1.000	.650
Cosecha_tratamiento	1.000	.472
Cosecha_manual	1.000	.688
Seleccion_norma	1.000	.590
Trasporte_norma	1.000	.760
Capacitacion	1.000	.866
Empaque_norma	1.000	.905
Lavado_y_secado	1.000	.724
Etiquetado_norma	1.000	.575

Método de extracción: análisis de componentes principales.

C. Factor Rotation

Factor rotation allows variables to be grouped into components so that they can be more clearly identified within clusters.

As shown in Table 3, the components exhibit high loadings. The Varimax rotation method was used, which is a technique that minimizes the number of variables with high loadings on each factor, thereby enhancing the interpretability of the factors.

Table 3. Factors Rotation

VARIABLES	Factores			
	1	2	3	4
Capacitacion	.899	.138	.179	-.082
Lavado_y_secado	.754	-.055	-.063	.385
Etiquetado_norma	.676	.335	-.060	-.033
Cosecha_manual	.072	.817	.107	-.067
Seleccion_norma	.304	.626	.018	.325
Trasporte_norma	-.149	-.476	.706	.114
Demanda_mercado	.481	.178	.588	-.204
Estirilizacion_recipientes	.357	.108	.586	.212
Cosecha_tratamiento	-.312	.309	.527	-.035
Empaque_norma	.014	.052	.079	.947

Método de extracción: análisis de componentes principales.
Método de rotación: Varimax con normalización Kaiser.

a. La rotación ha convergido en 8 iteraciones.

C. Interpretation of the Factors

Table 4 presents the four factors resulting from the factor analysis. **Factor 1** is labeled *Improvement in Quality Training* and consists of the variables *Training*, *Washing_Drying*, and *Labeling_Standard*. **Factor 2** is labeled *Harvesting and Selection According to Quality Standards* and includes the variables *Manual_Harvesting* and *Selection_Standard*. **Factors 3 and 4** will retain the same names as originally assigned.

Table 4. Interpretatión of the factors

Factor 1	Capacitación Lavado_ secado Etiqueta_ norma	**.899** **.754** **.676**
Factor 2	Cosecha_manual Selección_norma	**.817** **.626**
Factor 3	Transporte_ norma	**.706**
Factor 4	Empaque_norma	**.947**

C. Model Validation

To validate the results of the factor analysis, the sample was randomly divided into two halves, and the factor analysis was conducted separately for each subset. Table 5 presents the results of this procedure and confirms the validity of the findings.

VARIABLES	Componente			
		2	3	4
Estirilizacion_recipientes	.088	.002	.359	.120
Demanda_mercado	.171	.028	.365	-.230
Cosecha_tratamiento	-.252	.279	.380	-.021
Cosecha_manual	-.128	.576	.061	-.064
Seleccion_norma	-.004	.393	-.031	.237
Trasporte_norma	-.045	-.323	.490	.079
Capacitacion	.405	-.079	.051	-.152
Empaque_norma	-.092	.034	.017	.766
Lavado_y_secado	.350	-.187	-.116	.250
Etiquetado_norma	.272	.110	-.097	-.084

Método de extracción: análisis de componentes principales.
Método de rotación: Varimax con normalización Kaiser.

II. CONCLUSIONS

It was concluded that the variables highly associated with the first factor are *Training*, *Washing and Drying*, and *Labeling Standards*. This indicates that proper washing and drying of the fruit, along with training in these processes, ensures the physical quality and safety of the product—especially when destined for international markets.

The variables associated with the second factor are *Manual Harvesting* and *Selection Standards*. This suggests that producers should be trained to identify the optimal harvest time, which ensures that the fruit is picked at the ideal stage of ripeness. This not only reduces the risk of physical damage but also optimizes the shelf life of the product.

The variables strongly related to the third factor are *Transport Standards*, *Market Demand*, *Sterilization of Containers*, and *Harvest Treatment*. Based on these findings, the following is proposed: Transport must comply with quality standards for guava export because it ensures:

1. **Quality and Freshness**: Guava is a highly perishable fruit that is sensitive to temperature, humidity, and handling. If transport does not meet the required conditions—such as refrigeration, ventilation, and hygienic handling—the fruit may deteriorate before reaching its destination.
2. **Compliance with International Regulations**: Countries enforce strict regulations on how fresh products must be imported, including sanitary conditions during transport and proper documentation. Meeting these logistical requirements fosters buyer confidence.

The variable *Packaging Standards* is not associated with any other variable. This indicates that a culture of quality in packaging practices has not yet been established among guava producers. As a result, farmers are not currently in a position to export, as they lack knowledge of international quality standards for perishable goods. Proper packaging protects the product from physical damage, crushing, contamination, and moisture loss, which is essential for maintaining the fruit's quality and freshness.

III. ACKNOWLEDGMENTS

The authors would like to thank the National Polytechnic Institute, the Graduate Studies and Research Section of the Higher School of Mechanical and Electrical Engineering at the Zacatenco Unit, and the National Council of Science and Technology of Mexico City for their support.

IV. REFERENCES

[1] T. J. A. Yam, «Una revisión sobre la importancia del fruto de Guayaba (Psidium guajava L) fruit importance and their main ones characteristic in the postharvest,» *Revista ciencias técnicas agropecuarias,* vol. 19, nº 4, pp. 1-12, 2010.

[2] M. v, A. L y R. M. A, «Composición química y capacidad antioxidante en fruta, pulpa y mermelada de guayaba (Psidium Guajava L.),» *Archivos latinoamericanos de nutrición. Venezuela,* vol. 58, nº 1, 2008.

[3] A. 8. P. C. P. D. G. E. M. E. E. U. TRIENIO, «SAGARPA,» 03 ENER0 2016 2016. [En línea]. Available: http://www.sagarpa.gob.mx. [Último acceso: 27 FEBRERO 2017].

[4] J. D. M. Sangerman, S. B. S. Larqué, B. A. Navarro, d. R. R. Schwentesius, H. M. á. Damián y S. J. A. Cuevas, «Producción de guayaba (Psidium guajava L) en el Estado de México,» *Revista mexicana de ciencias Agrícolas,* vol. 4, nº 7, pp. 1081-1093, 2013.

[5] H. Salinas, Efecto del gardo de madurez, encerado y frigoconservación sobre la maduración y calidad de la guayaba Media China. Tesis de maestria., Mexico, Edo. de Mex.: Colegio de postgraduados.

[6] e. a. c. R. Refashioning nature: food, «Goodman, D; Redclift, M.,» 1991.

[7] PROMEXICO, «PROMEXICO,» 23 Enero 2017. [En línea]. Available: http://www.promexico.gob.mx/comercio/mexico-y-sus-tratados-de-libre-comercio-con-otros-paises.html.

[8] P. Oliden y B. Zumbo, «Coeficientes de fiabilidad para escalas de respuesta categòrica ordenada,» vol. 20, nº 4, pp. 896-901, 2008.

[9] Morton, Guava. In: Fruits of warm climates, Miami Florida, 1987, p. 356.

[10] T. O. Mayorga, B. Contreras, E. Leonardo, T. Vargas y L. Fernando, «Análisis de cosotos y utilidad del ciclo de vida del producto,» *Tecnura,* vol. 12, nº 24, pp. 99-108, 2009.

[11] B. Mata y A. Rodríguez, Cultivo y producción del guayabo, Mexico: Trillas, p. 160.

[12] M. A. Maldonado, «El pensamiento sistémico en la teoría literaria alemana I,» *Revista de la Filología Alemana ,* vol. 7, pp. 15-60, 1999.

[13] J. E. Málaga y G. W. Williams, «La competitividad de México en la exportación de productos agrícolas,» *Revista mexicana de agronegocios ,* vol. 14, nº 27, pp. 296-309, 2010.

[14] A. S. A. Jose, El desarrollo empresarial en el marco de la actualización del Modelo Económico Cubano, La Habana: Ediciones CUJAE , 2011.

[15] N. G. Gutierrez, S. S. Dussan y J. C. Castro, «Fisiología y atributos de calidad de la guayaba "pera" (Psidium guajava cv.) en poscosecha.,» *Revista de ingeniería,* nº 37, pp. 26-30, 2012.

[16] C. N. González, «Transporte y logística,» *Transporte y territorio ,* nº 14, pp. 1-4.

[17] E. G. Gaona, Guayaba. Su cultivo en México, vol. 1, Pabellón, Aguas Calientes: Inifap, 2002, p. 192.

[18] B. Fine, M. Heasman y J. Wrigth, Consumption in the age of affluence: the world of food., Routledge., 1996.

[19] T. Fernandez, F. A. Cortés y J. Isabel, «Ciencia y tecnología en la agricultura mexicana: I. Producción y sostenibilidad,» vol. 23, nº 2, pp. 265-272, 2005.

[20] A. A. Fernández, «Aplicación del análisis factorail confirmatorio a un modelo de medición del rendimiento académico en lectura,» *Ciencias Económicas,* pp. 39-66, 2015.

[21] R. O. Flores y G. Pérez, «La evolución en el transporte de las mercancías,» *Observatorio de la economía latinoamericana,* 2013.

[22] M. S. Estrada, L. S. Restrepo de Ocampo y S. p. Ballesteros, «Análisis de los costos logísticos en la administración de la cadena de suministro,» *Scientia et Technica,* vol. 15, nº 45, pp. 272-277, 2010.

[23] C. M. Delgado, «El sistema agroalimentario globalizado: imperios alimentarios y degradación social y ecologica,» vol. 10, nº 10, pp. 32-61, 2.

[24] W. Boyd, W. Prudhan y R. A. Shurman, «Industrial dynamics and the problem of nature,» *Society&Natural Resources,* vol. 14, nº 4, 2001.

[25] J. Baena, «Transporte internacional,» Barcelona, España, Logis Book, 2002, p. 42.

[26] S. J. A. Acevedo, Diagnóstico del estado de arte de la logística en cuba, La Habana, Cuba: LOGESPRO, ISJAE, 2003.

[27] R. A, A. B. MF, F. N y H. Z, «The effects of consumption of guava (Psidium guajava) or papapa (Carica papaya) on total antioxidant and lipid prolife in normal male youth.,» *Asia Pac J Vlin Nutr,* vol. 13, p. 106, 2004.

[28] P. H. r. Álvarez, La logística y su influencia en el perfeccionamiento empresarial, Pinar del Río, Cuba: Ponencia publicada en el Evento Nacional LogMark, 2004.

[29] D. D. Cruz, J. A. R. Leos y J. R. C. Altamirano., «México: Factores explicativos de la producción de frutas y hortalizas ante la apertura comercial,» *Revista Chapingo Serie Horticultura ,* vol. 19, nº 3, pp. 267-278, 2013.

[30] C. Contreras y J.

[31] J. C. Calderon, L. Calderon, E. Guerra y B. García, «Antioxidant capacity, phenolic contents of 62 fruits pulp, peel and seed from 24 exotic fruits from Colombia,,» *Food Research International: ,* vol. 44, nº 7, pp. 2047-2053, 2010.