Colegio de Postgraduados

Technical and financial feasibility of using plastic poles for chayote production [*Sechium edule* (Jacq.) Swartz]

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ABSTRACT
Objective: To evaluate the technical and financial feasibility of using recycled plastic poles for chayote production.
Design/methodology/approach: A structure (pergola) was designed to produce chayote [*Sechium edule* (Jacq.) Swartz], size 8 m×8 m, using recycled plastic poles of 2.5 m length, a square section of 95.25 mm and 16.26 kg, using eight balances to record the biomass weight during production. A financial run of 10 years was conducted to evaluate the plastic pole and its projection for one hectare of tapanco, comparing it with wood and concrete poles.
Results: The plastic poles did not show fractures or deformations, even when an average load of 200 kg was found in the production cycle. For the financial analysis, the following were used: current interest rate, investment, and operation costs. The results indicated that the benefit/cost ratio and the internal rate of return were favorable when using plastic poles, since for each peso invested there is a recovery of $1.04, compared to $0.81 and $0.80 of wood and concrete poles, respectively; the internal rate of return was nearly 9 times the interest rate.
Limitations on study/implications: The plastic poles are sold as ornamental elements and for the installation of fences. The company does not have a certificate of resistance tests.
Findings/conclusions: Recycled plastic poles can substitute wood poles in the productive structure of chayote.

Keywords: sustainable production, plastic recycling, pergola, standing poles, biomass.

Citation: Herrera-Gómez, Á. E., Ortiz-Laurel, H., Rosas-Calleja, D., & Leyva-Ovalle, O. R. (2025). Technical and financial feasibility of using plastic poles for chayote production [*Sechium edule* (Jacq.) Swartz]. *Agro Productividad*. https://doi.org/10.32854/97tqwj06

Academic Editor: Jorge Cadena Iñiguez
Associate Editor: Dra. Lucero del Mar Ruiz Posadas
Guest Editor: Daniel Alejandro Cadena Zamudio

Received: June 26, 2024.
Accepted: May 18, 2025.
Published on-line: July XX, 2025.

Agro Productividad, 18(6). June. 2025. pp: 45-53.

INTRODUCTION

Mexico is the primary global producer of chayote [*Sechium edule* (Jacq.) Swartz], with a surface of 3,334 ha, averaging a yield of 64 t ha^{-1} for an annual production of 213,269 t (Axayacatl, 2023; SIAP, 2021).

To achieve the full development and higher productivity of the crop, a wire structure (tapanco, pergola) must be built, similar to a net, since the plant is of climbing habit; it is the scaffolding raised from the floor at 2.0 to 2.2 m, held by wood posts/poles, which are the ones most frequently used.

Although cultivating chayote is profitable, it faces difficulties; on the one hand, the high investment in the purchase of poles, followed by the uncertainty about their timely supply and the safety in maintenance of the tapanco (Gamboa, 2005). In the chayote production cycle, the weight of the biomass (leaves, guides and fruits) rests on the mesh (net) of the scaffolding formed by thin wires with diameter of 1.291 mm (AWG #16), which covers the tapanco. They are supported by thick wires with diameter of 3.264 mm (AWG #8), and the load is transferred to them. At the same time, each end of the wires is secured on the superior ends of the opposite poles located on the periphery of the tapanco.

These last poles are the ones that resist the greatest effects of the biomass load during production, which is why the ones that show greater robustness and vigor are selected. Therefore, the importance of ensuring a constant and reliable supply of these materials (Figure 1).

Some producers are making concrete poles to replace the wood poles. Although they could have more durability, standardizing their manufacture could increase the costs of using finite raw materials.

Presently, recycled plastic poles are sold, which could be considered for their inclusion in the tapancos and to replace the wood poles, while they represent an alternative that is friendlier with the environment. The objective was to explore the technical and financial viability of using commercial poles made with recycled plastic, which are satisfied in the dimensions required for the correct installation of tapancos for chayote production.

MATERIALS AND METHODS

This study was conducted in the municipality of Coscomatepec in the state of Veracruz, Mexico (19° 04' 32.42" N and 97° 01' 33.8" W) at an altitude of 1515 masl. It is important to point out that all the poles used in the tapanco are subject to the effects of climate, such as rain, hail, temperature, wind, and solar radiation. All these events contribute to decreasing their useful life, which is why wood poles deteriorate (rot) easily, mainly in the low part of the pole, from the effect of moisture (Guevara-Hernández *et al.*, 2014). This reality cannot be avoided for any of the poles considered as viable.

Figure 1. Production infrastructure (tapanco) for chayote.

Although there are different densities of chayote plantations, from 6 m×6 m, 8 m×8 m, to 10 m×10 m (IICA, 2016), in the study zone there are no accurate records of the preference of producers for any of these. However, the tapancos surrounding the study site use the 8 m×8 m model, so they were taken as reference for the study. Likewise, from the records of producers in the zone of Coscomatepec, Veracruz, 866 poles ha^{-1} were counted, which include those on the inside and the periphery, called crown, in addition to 40 storage units to supply the possible contingencies during the (one year) cycle. The decision was made to build a single experimental module of 8 m×8 m with faithful likeness to a conventional production tapanco, although using only nine recycled plastic poles, with separation of 4 m between the poles and forming a square of 8 m length and 8 m width, with a chayote plant in its geometric center (Figure 2).

Thin (galvanized) wires with a diameter of 1,291 mm (AWG #16) were placed to build the roof (grate), with a separation of 25 cm between them; and thick wire with diameter of 3.264 mm (AWG #8) was placed in the entire perimeter and the interior central cross that is formed (Ortiz-Laurel *et al.*, 2019).

The pole elaborated from the recovered plastic has a length of 2.5 m with a square transversal section of 95.52 mm per side and with an average weight of 16.26 kg. Each pole is buried at 0.5 m depth in the soil. The management of the crop in this module is similar to the one carried out by the producer in the commercial plantation. Therefore, during the production cycle, biomass pruning was carried out every 15 days, and the pruning was weighed in an electronic balance Rhino brand, model BAPCA-100.

The weight recorded exhibited the vegetative development of the chayote crop, in addition to determining the load capacity of this experimental module on its surface of 64 m^2. For this purpose, eight balances were installed (Roman Pretul with spring model BAS-100P) with load capacity of 100 kg (Figure 3). Each was placed in pertinent sites and between the ends of different sections of the thick load wires (Figure 4). Thus, the balances recorded the different weight variations; increase (new buds of biomass-leaves, guides, flowers, small chayotes, and heavier chayotes), and decrease (biomass pruning and fruit harvesting).

Figure 2. View of the experimental module with separation between poles of 4 m.

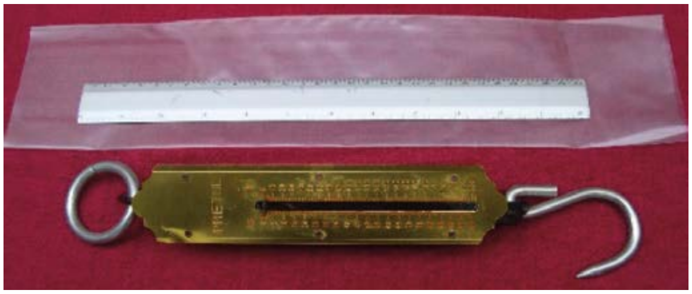

Figure 3. Roman spring balance used to record the biomass weight.

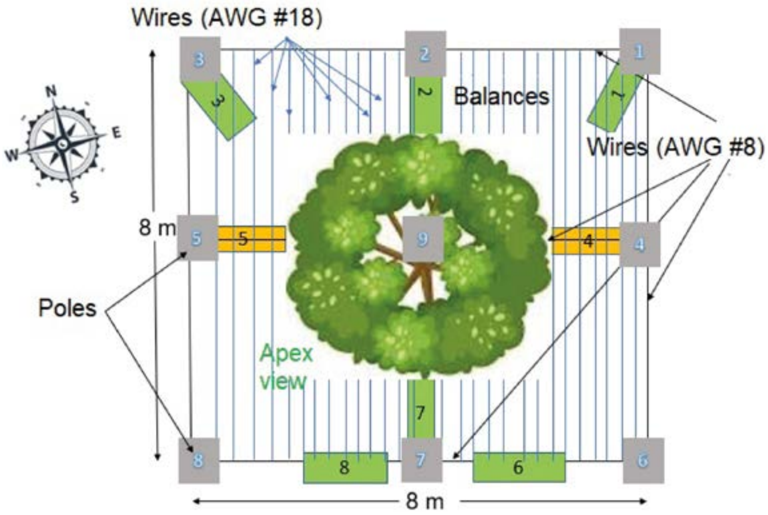

Figure 4. Distribution of the 8 balances inside the experimental tapanco.

Financial evaluation of three pole alternatives in the construction of tapancos

For the financial analysis, the production costs of the chayote crop were obtained from among a group of producers in the region of Coscomatepec, Veracruz. The main parameters were the initial investment cost ($500,000.00 MX pesos) and the operation costs of all the agricultural activities during the production cycle. Likewise, the average cost of the kg of chayote was obtained with the data obtained, which fluctuates between $5.00 and $12.00 over the different months of the year.

The production costs of chayote were integrated into their main sectors, with the purpose of differentiating their magnitude and their variation regarding time. These were grouped into: costs for the establishment of the plantation (design of planting, soil preparation tasks, hollowing, seed conditioning, etc.); the costs of the tapanco structure (poles, wires, staples, tools, etc.); the costs of inputs (seed, fertilizers, phytosanitary products, etc.); the maintenance costs of the plantation (pruning, irrigation, pole replacement, etc.); the costs of machinery and equipment (tractor, farming implements, backpack pumps, machetes, scissors, irrigation pumps, etc.); the harvesting costs (bars, sacks and bags for packaging, yarn, raffia, etc.); and other expenditures and unforeseen costs, such as electricity, fuels, repairs, replacement parts, etc.

It is important to highlight that the workforce is and was used as workdays in every sector, although with different intensity. Likewise, it is emphasized that these concepts, their breakdown and costs were obtained directly with chayote producers in the region of Coscomatepec, Veracruz. Therefore, Table 1, Table 2 and Table 3 represent a concentrate of all the previous ones, differentiating between fixed costs and variable costs. It can be seen in these that they are the fixed costs, variable against time (year), referring to costs of the different types of poles and the costs associated to their maintenance and replacement in time.

The financial run was projected for a period of 10 years, where three scenarios were analyzed; the first is chayote production with tapanco built with wooden poles; the second with tapanco built with concrete poles (with the producer's manufacturing costs); and the third, built with recycled plastic poles (supplied directly by the manufacturer). These scenarios maintain a surface of one hectare, the same number of chayote plants (156), the same number of interior, plant and crown poles (866 in total), the same arrangement of the plants (8 m×8 m), equal agronomic management, a yield per hectare of 64 t ha^{-1}, and an average sale price of $8.7 kg. For each scenario, the following indicators of profitability were estimated: net value added (NVA), benefit/cost ratio (B/C), and internal rate of return (IRR).

The economic information used for the financial evaluation was obtained from official documents (INEGI, 2023), with an interest rate of 1.17% during January to July of 2023. Data from the Banxico portal (2023) for the equilibrium interbank interest rate (TIIE, for its initials in Spanish) was used, with a value at 182 days of 11.5% reported in August 2023, as well as the percentage of fixed-term investment, of 6.8% for June 2023.

RESULTS AND DISCUSSION

The nine recycled plastic poles from the experimental module did not exhibit adverse effects in bending, fissures or deformations from the effects of the weight of

Table 1. Production costs for one ha of chayote by using wooden poles for the pergola in the region of Coscomatepec, Ver. (2022).

Concept	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Fixed costs	$218,453.0	$30,000.0	$151,620.0	$30,000.0	$151,620.0	$30,000.0	$151,620.0	$30,000.0	$151,620.0	$30,000.0
Variable costs	$227,049.0	$146,050.0	$227,049.0	$146,050.0	$227,049.0	$146,050.0	$227,049.0	$146,050.0	$227,049.0	$146,050.0

Table 2. Production costs for one ha of chayote by using concrete poles for the pergola in the region of Coscomatepec, Ver. (2022).

Concept	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Fixed costs	$413,303.0	$30,000.0	$38,400.0	$30,000.0	$38,400.0	$379,570.0	$38,400.0	$30,000.0	$38,400.0	$30,000.0
Variable costs	$227,049.0	$146,050.0	$227,049.0	$146,050.0	$227,049.0	$146,050.0	$227,049.0	$146,050.0	$227,049.0	$146,050.0

Table 3. Production costs for one ha of chayote by using plastic poles for the pergola in the region of Coscomatepec, Ver. (2022).

Concept	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Fixed costs	$451,407.0	$30,000.0	$38,400.0	$30,000.0	$38,400.0	$30,000.0	$38,400.0	$30,000.0	$38,400.0	$30,000.0
Variable costs	$227,049.0	$146,050.0	$227,049.0	$146,050.0	$227,049.0	$146,050.0	$227,049.0	$146,050.0	$227,049.0	$146,050.0

the biomass and climatological events during the production cycle. The installation remained stable.

Figure 5 illustrates the weight recorded for each of the balances during the production cycle of six months. The curves show a continuous increase and decrease; the decrease shows the fruit harvest and the pruning biomass. This confirms the dynamic development of the plant, because of the accumulation of dry matter (Valverde and Sáenz, 1985).

When the average of these weights was calculated, there would be a distribution of more than 30 kg in each perimeter point, where the balances of the modular structure of the tapanco were placed. This weight could be considered permanent, which represents a constant load on the recycled plastic poles. It is also quite likely that a similar weight is found in the central points of the modules.

The maximum biomass weight found was 252 kg in the month of October. This weight has a relatively short presence in time and space, due to: a) fruit harvesting, and b) pruning of guides and leaves; this is perhaps the most notable effect on the temporary decrease of records.

Figure 6 shows that 400 kg is the amount of plant material that is taken from the module in this six-month production period. From this, practically half (50%) corresponds to the harvested fruit, even when in percentage the chayotes harvested represent 4% of all the plant biomass.

Regarding financial feasibility, the production costs and income were processed to determine the Net Present Value (NPV) (Table 4). It is obtained from the sum of the actualized income from year one to year 10, with the same process for the actualized costs. Therefore, the total costs are subtracted from the total income, defined as NPV (Table 4).

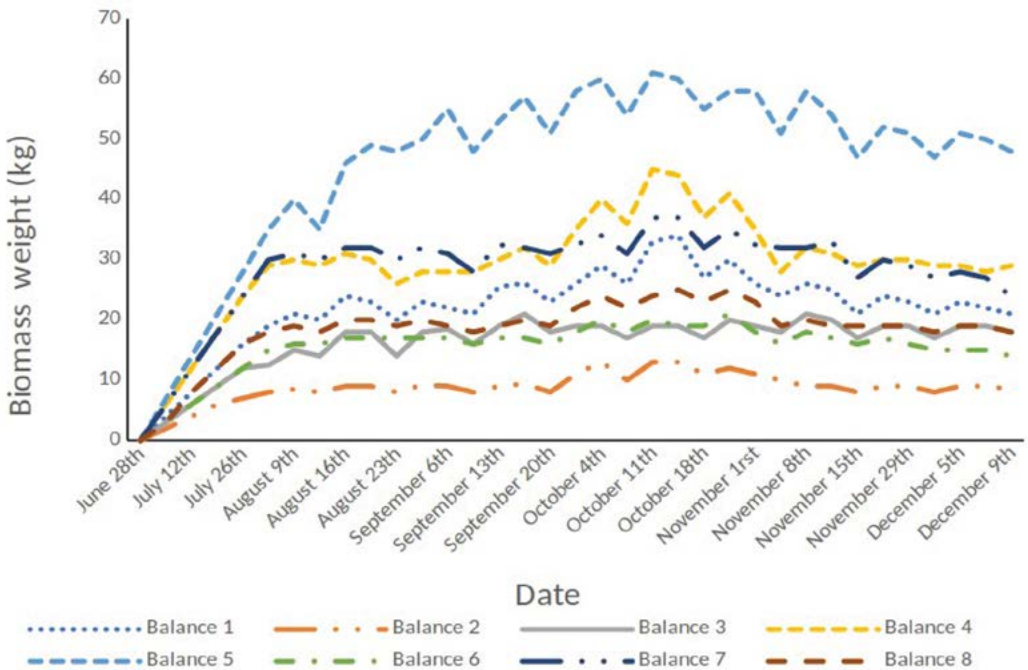

Figure 5. Accumulated weight of the biomass during the chayote cultivation cycle in the experimental tapanco.

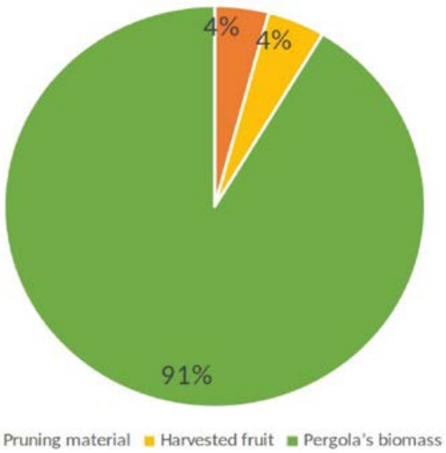

Figure 6. Percentage distribution in the plant biomass weight on the modular structure of 64 m^2 during the chayote production cycle.

Table 4. Net present value (NPV) for three materials for the poles.

Poles	Total income ($)	Total cost ($)	NPV ($)	Result	Decision
Wood	8,054,069.46	4,452,879.10	3,601,190.36	NPV>0	Accepted
Concrete	8,054,069.46	4,462,235.39	3,591,834.07	NPV>0	Accepted
Plastic	8,054,069.46	3,931,945.05	4,122,124.41	NPV>0	Accepted

The NPV variable determines the economic viability of the project. In this study, the profitability is accepted in the three scenarios, since they all have a value higher than zero and the highest value of NPV corresponds to the tapanco with wooden poles, which is the one of greatest use, equally expensive than using concrete poles; meanwhile, the use of recycles plastic poles is up to 12% less expensive according to the evaluation period of 10 years.

The benefit/cost ratio helps with decision making regarding the investment, for which both the total income and the benefits of the project are considered, and they are divided by the total costs (Table 5). It can be observed that the income is higher than the costs in the ten-year period of the project, and it is defined as profitable.

According to the results from the financial run (10 years), it is established that for the plastic poles, for each peso invested in the production costs, there is a profit of $1.04; meanwhile, for the concrete and the wooden poles, it is only $0.80 and $0.81, respectively.

The profitability of an investment implies considering the interest rate of the business, and the Internal Rate of Return should be calculated; therefore, with the data processed from the actualized income and costs, the benefits are estimated, from which the initial

Table 5. Benefit-Cost ratio (B/C) for three materials for the poles.

Poles	Total income ($)	Total cost ($)	B/C	Results	Decision
Wood	8,054,069.46	4,452,879.10	1.81	B/C>1	Accepted
Concrete	8,054,069.46	4,462,235.39	1.80	B/C>1	Accepted
Plastic	8,054,069.46	3,931,945.05	2.04	B/C>1	Accepted

investment is discounted, and thus the net cash flows are obtained from year one to year 10 for each of the scenarios in this study.

Once the cash flows are determined, the IRR value is calculated (Table 6). The fixed investment rate provided by Banxico (2023) was 6.8% at the time of determining the results presented. It is evident that chayote production is profitable with the traditional exploitation system, using wood materials for the construction of tapancos. However, it is a reality that this resource needs more attention in its management and use.

Table 6. Value of Internal Rate of Return (IRR) for each pergola assembled.

Type of pergola	Value of IRR (%)
Wood poles	86
Concrete poles	58
Recycled plastic poles	60

Likewise, the proposal of this study to use recycled plastic poles is viable because the value of this financial indicator is as competitive as the concrete poles. The existing difference from the Internal Rate of Return (IRR) regarding the traditional system with wooden poles does not mean that it should not be considered. The project of using the recycled plastic poles is profitable since it provides an interest rate that is nearly 9 times the value established by Banxico as fixed interest rate. Rather than a value or decision from the economic point of view, the importance of the contribution to a friendlier management with the environment for the preservation of natural resources that are exploited to be used in the construction of traditional tapancos with wood materials should be considered.

CONCLUSIONS

The recycled plastic poles are a technically and economically viable option for the construction of tapancos. These poles kept their stability during the six months of evaluation in the experimental module, where the biomass weight reached a continuous average of 200 kg. The poles did not exhibit fractures or deformities that would affect their functionality. This alternative must be disseminated for its acceptance and adoption by producers of the different chayote-producing zones. Regarding the financial feasibility (analysis at 10 years), the financial indicators of the benefit/cost ratio (B/C), as well as the internal rate of return (IRR) illustrate the viability of the proposal, since for each Mexican peso invested, $1.04 are generated in comparison to the $0.81 for the case of the wooden trunk poles. Concerning the internal rate of return, the value is almost 9 times the fixed interest rate established, which means that it is a totally profitable project considering the investment and that it is risk-free.

AKCNKOWLEDGEMENTS

I wish to thank the Consejo Nacional de Ciencia y Tecnología (CONACYT) for granting me a scholarship to carry out graduate studies; and Colegio de Posgraduados Campus Córdoba, for providing me with the opportunity of academic growth.

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