v. 3, n. 13, 2023

Journal of
Engineering
Research

COMPARATIVE STUDY OF CORN SHELLING SYSTEMS, BASED ON 4 PARAMETERS BASED ON SUSTAINABILITY

Jonatan Ali Ramos Rivera
National Autonomous "Universidade de Mexico", Center for Mechanical Design and Technological Innovation, Faculty of Engineering
Coyoacán Delegation - Mexico City, Mexico

Alejandro Cuauhtémoc Ramírez Reivich
National Autonomous "Universidade de Mexico", Center for Mechanical Design and Technological Innovation, Faculty of Engineering
Coyoacán Delegation - Mexico City, Mexico

Maria del Pilar Corona Lira
National Autonomous "Universidade de Mexico", Center for Mechanical Design and Technological Innovation, Faculty of Engineering
Coyoacán Delegation - Mexico City, Mexico

Brandon Emmanuel Hernandez Delgado
Promoting a Young Mexico AC
Aguascalientes - Aguascalientes, Mexico

 DOI 10.22533/at.ed.3173132325042

Abstract: The purpose of this work is to report the results of a preliminary study of the basic feasibility of bicimáquinas as a possible alternative to modernize postharvest processes, in order to reduce the productive problems of the Mexican rural economy. What is reported here focuses on the modernization of dry corn shelling, a productive task present in the vast majority of Mexican agrarian communities, and usually carried out by women. The basic feasibility evaluation was raised through a comparative study of sustainability between bicimáquina, manual shelling and commercial mechanical systems, taking as a parametric basis the premises of the economic and environmental dimensions of sustainable/sustainable development and appropriate technology according to various authors.
Keywords: Sustainability, Appropriate technology, Social and solidarity economy, Bicimáquinas.

INTRODUCTION

During the second half of the 20th century and these first decades of the 21st century, the flowering, massification and rise of the phenomenon of globalization has led to an accelerated opening of the Mexican market and a massive arrival of foreign investment, generating in turn the arrival of technological and scientific advances to Mexico; but causing in the process a disintegration between the social and productive identity in the middle and lower sectors of the population, which has mainly affected the rural sector. Because in Mexico the formation of productive chains economically integrated with the world market, predominantly with the North American, has allowed cities (regions with the capacity to incorporate technologies) to make enormous leaps in terms of growth and development, but in contrast, It has generated a huge gap with rural agrarian regions, which are less integrated into said economic scheme, whose trend is an increasingly focused approach on automation and technological developments for production on industrial scales; making these communities resent a marked technological inequality that ends up exacerbating a dialect of marginalization (in productive terms) in which Mexican rural communities have been trapped for several decades (Verhulst et al, 2017; CEDRSSA, 2018; CONEVAL, 2017; SAGARPA & FAO, 2014); characterized among other things by a marked migration of people of working age, which ends up obliterating the ability of communities to achieve stability and social well-being (Carton, 2009). whose trend is an increasingly focused approach on automation and technological developments for production on industrial scales; making these communities resent a marked technological inequality that ends up exacerbating a dialect of marginalization (in productive terms) in which Mexican rural communities have been trapped for several decades (Verhulst et al, 2017; CEDRSSA, 2018; CONEVAL, 2017; SAGARPA & FAO, 2014); characterized among other things by a marked migration of people of working age, which ends up obliterating the ability of communities to achieve stability and social well-being (Carton, 2009). whose trend is an increasingly focused approach on automation and technological developments for production on industrial scales; making these communities resent a marked technological inequality that ends up exacerbating a dialect of marginalization (in productive terms) in which Mexican rural communities have been trapped for several decades (Verhulst et al, 2017; CEDRSSA, 2018; CONEVAL, 2017; SAGARPA & FAO, 2014); characterized among other things by a marked migration of people of working age, which ends up obliterating the ability of communities to achieve stability and social

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This article presents the first results of the preliminary evaluation of the basic feasibility of bicimáquinas as an alternative for the modernization of the rural Mexican agricultural environment, addressing the case study of the modernization of the specific task of shelling corn. The preliminary evaluation of said basic viability was based on a comparison of 4 parameters (theoretical productivity, cost, productive efficiency and energy consumption) between bicimáquina, methods of manual shelling and commercial systems based on gasoline and/or electricity that run the same task. For the purposes of this article, the scope was limited to the shelling of corn, in the first instance because this is one of the productive tasks that is present in the majority of Mexican agrarian communities, and only to the 4 parameters mentioned. These parameters were chosen qualitatively based on the premises of the economic dimension and the environmental dimension of sustainable development, as well as the characteristics of the appropriate technology according to authors such as Teitel, Bowonder, Jéquier & Blanc, Wicklein, Akubue, Fisher and Murphy, among others (Blanco, 2018).

The article is structured as follows: In sections 2 and 3, corresponding to background and technical framework (respectively), a series of topics of interest are addressed that will contextualize the purpose and methodology of the work; in section 3, the objectives of the work in particular are described, as well as the methodology and quantitative data of interest used in it; section 4 "comparative study", presents the results obtained by the comparison of the parameters established between the proposed systems; Finally, in section 5, the conclusions inherent to the results obtained and the observations collected throughout the work are stated.

BACKGROUND

APPROPRIATE TECHNOLOGY

Hazeltine & Bull (2003) propose the following definition of appropriate technology (AT): "Any object, process, idea or practice that improves human fulfillment through the satisfaction of human needs"; considering, in addition, that a technology is appropriate when it is compatible with the local cultural and economic conditions (that is, the human, material and cultural resources of the economy), and uses locally available material and energy resources, with tools and processes maintained and operationally controlled by the local population". However, there is no definition from formal ontology that specifically denotes what an appropriate technology is; but a large number of authors such as Simón Teitel, Bowonder, Nicolas Jéquier & Gérard Blanc, Robert Wicklein, Anthony Akubue, Martin Fisher and Heather

Murphy, among others, have coined over the years a series of criteria that define the distinctive characteristics that an appropriate technology must meet to be considered as such (Blanco, 2018). Beyond the variations in the criteria of the different authors, product of the differences in the sociocultural, historical and historiographical context of these, these characteristics focus more than anything on the notion of improving the sustainability of a technology under the particular contexts of developing countries, and broadly speaking, they have been able to be summarized and grouped into sociocultural, productive, technical, manufacturing, operation and maintenance, labor, environmental and economic aspects, as illustrated in Figure 1 (White, 2018; Thomas, 2009). among others, they have coined over the years a series of criteria that define the distinctive characteristics that an appropriate technology must meet to be considered as such (Blanco, 2018). Beyond the variations in the criteria of the different authors, product of the differences in the sociocultural, historical and historiographical context of these, these characteristics focus more than anything on the notion of improving the sustainability of a technology under the particular contexts of developing countries, and broadly speaking, they have been able to be summarized and grouped into sociocultural, productive, technical, manufacturing, operation and maintenance, labor, environmental and economic aspects, as illustrated in Figure 1 (White, 2018; Thomas, 2009). among others, they have coined over the years a series of criteria that define the distinctive characteristics that an appropriate technology must meet to be considered as such (Blanco, 2018). Beyond the variations in the criteria of the different authors, product of the differences in the sociocultural, historical and historiographical context of these, these characteristics focus more than anything on the notion of improving the sustainability of a technology under the particular contexts of developing countries, and broadly speaking, they have been able to be summarized and grouped into sociocultural, productive, technical, manufacturing, operation and maintenance, labor, environmental and economic aspects, as illustrated in Figure 1 (White, 2018; Thomas, 2009). Over the years, they have coined a series of criteria that define the distinctive characteristics that an appropriate technology must meet to be considered as such (Blanco, 2018). Beyond the variations in the criteria of the different authors, product of the differences in the sociocultural, historical and historiographical context of these, these characteristics focus more than anything on the notion of improving the sustainability of a technology under the particular contexts of developing countries, and broadly speaking, they have been able to be summarized and grouped into sociocultural, productive, technical, manufacturing, operation and maintenance, labor, environmental and economic aspects, as illustrated in Figure 1 (White, 2018; Thomas, 2009). Over the years, they have coined a series of criteria that define the distinctive characteristics that an appropriate technology must meet to be considered as such (Blanco, 2018). Beyond the variations in the criteria of the different authors, product of the differences in the sociocultural, historical and historiographical context of these, these characteristics focus more than anything on the notion of improving the sustainability of a technology under the particular contexts of developing countries, and broadly speaking, they have been able to be summarized and grouped into sociocultural, productive, technical, manufacturing, operation and maintenance, labor, environmental and economic aspects, as illustrated in Figure 1 (White, 2018; Thomas, 2009).

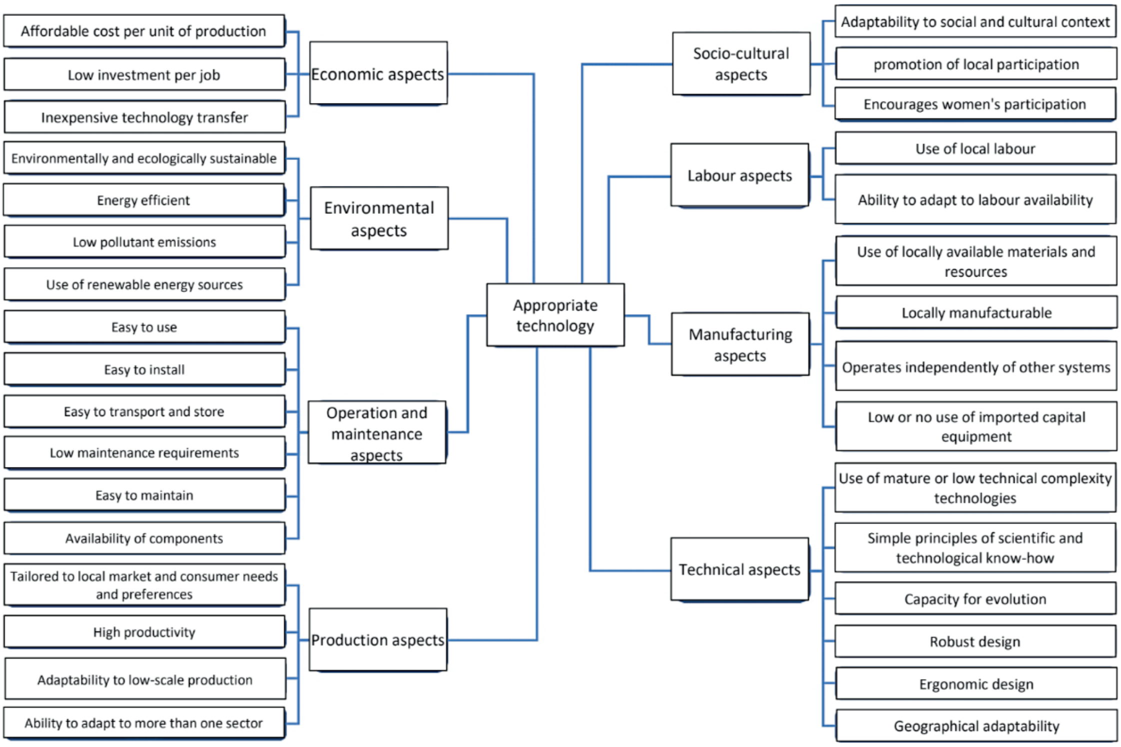

Figure 1 - Characteristics of an appropriate technology.

Source: White, 2018; Thomas, 2009

SOCIAL SOLIDARITY ECONOMY (ESS)

According to authors such as García (2017) and Collín (2008), a simple definition of social and solidarity economy (ESS) describes this concept as the set of collective and individual socioeconomic practices that prioritize the satisfaction of the needs and aspirations of its members. and/or other people above profit, regardless of whether these practices are carried out under formal or informal schemes (Fraga, 2021). However, according to Contipelli & Nagao (2017), evidently schemes like the social solidarity economy, in reality do not act in a field outside of capitalism and the formal market; Therefore, the enterprises and other initiatives under a social and solidarity scheme and related paradigms (circular economy, social innovation, collaborative economy, economy for the common good),

CONVERGENCE BETWEEN TA AND ESS

That said, among the points of convergence that share the appropriate technology with the social and solidarity economy (and other similar schemes), the "scale or level of production" is of particular interest, given that both concepts focus on the small scale; considering that the bases to solve in the short term very frequent problems in communities in poverty such as unemployment, the scarcity of natural resources and environmental degradation, are found in the operation of small organizations such as families, small groups of communities and micro-enterprises (Fraga, 2021). We say that it is of interest, given that the organizations of the social and solidarity economy that exist in Mexico such as cooperatives, communities and ejidos,

SUSTAINABLE DEVELOPMENT / SUSTAINABLE

The concept of sustainable development is in constant evolution since the emergence of its formal definition in 1987 through the "Brundtland Report", however, according to the World Commission on the Environment, it can be stated as: "The development scheme aimed at satisfying the needs of the present generation, without compromising the ability of future generations to satisfy The foundations of sustainable development, are based on 3 main dimensions (Figure 2):

- Social: Attends to the strengthening of aspects related to the quality of life of populations, such as community identity, inclusion, demographic stability, human rights and working conditions, among others.
- Environmental: Attends to the strengthening of a balance, in ecological terms, between human activities and the preservation of biodiversity and ecosystems.
- Economic: It attends to the strengthening of the profitability and efficiency with which humans produce, transform, distribute, exchange and consume, the material and/or financial resources with which they satisfy their needs.

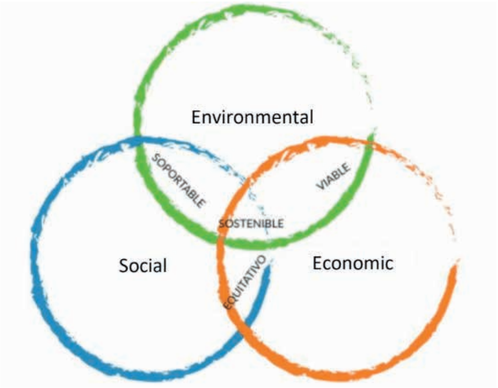

Figure 2 - Dimensions of sustainable development.

Source: Lira, 2018

It is worth mentioning that, although it is generally accepted that the concepts "sustainable development" and "sustainable development", are etymologically equivalent. Based on diverse literature (including the Brundtland report itself), in a stricter sense it can be inferred that both concepts differ only in the order of importance that each of the 2 concepts intrinsically grants to the 3 dimensions, being that in the sustainable development predominates the environmental dimension, while in sustainable development the economic dimension predominates, this relationship is schematized in Figure 3 (Barkin, 1998; Marten, 2001; Zarta, 2018).

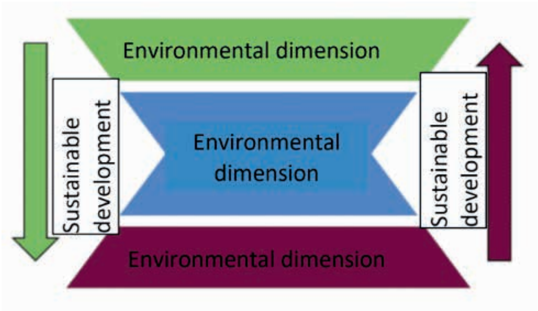

Figure 3 - Sustainable development and sustainable development.

Source: Barkin, 1998; Martin, 2001; Zarta, 2018

TECHNICAL FRAMEWORK

CORN SHELLING

In addition to the use of utensils, implements and machines, there are a large number of techniques and methods for shelling corn, which may even have variations depending on the region of Mexico to which reference is made (International Labor Organization, 1984).

MANUAL METHODS

Manual method using thumbs: This is the simplest and most traditional method for shelling (Figure 4A); It consists of detaching the grains by applying pressure with the thumbs (Castelán & Vázquez, 2017).

Figure 4 – Shelling by hand using: (A) thumbs; (B) friction between ears.

Manual method by friction of 2 ears: It consists of detaching the grains by rubbing 2 ears, or an ear and a cob, against each other (Figure 4B). It has almost the same advantages and disadvantages (Table 1) as the manual method using thumbs (Castelán & Vázquez, 2017); however, while it is less damaging to the worker's fingers, it is also easier to break the grains in use, so it offers slightly less grain integrity. It is worth mentioning that, in most cases, the general manual technique consists of combining this technique with the thumb technique.

Advantages	Disadvantages
* High precision. * High grain integrity. * Possibility of separating the grains in a state of decomposition during shelling.	* Low performance relative to other methods. * Requires intensive labor for large harvests. * The yield depends to a great extent on the characteristics of the maize, as well as the experience and skill of the worker.

Table 1. – Characteristics of manual shelling

Manual method using tools (stone, corn cob, staple table): This method consists of detaching the grains by rubbing the ears against stones, or against utensils that are usually manufactured by the workers themselves, such as oloteras (Figure 5) or tables embedded with staples (Castelán & Vázquez, 2017).

Advantages	Disadvantages
* High yield in relation to traditional manual methods. * Low manufacturing cost.	* They can only be used properly when the corn is dry enough. * The skill and experience of the worker are factors influencing the integrity of the grain. * They can cause damage to fingers, such as cuts, blows or bruises.

Table 2 – Characteristics of manual shelling using tools

Figure 5 – Shelling by means of an olotera.

MECHANIZED METHODS

Shelling by manual implements: There are some rotary manual shellers built using wood, castings or steel profiles (Castelán & Vázquez, 2017).

Advantages	Disadvantages
* Less effort. * Less time compared to other manual methods. * Good grain integrity after the shelling operation.	* They cannot be adapted to ears that have a very large difference in size. * They carry ergonomic risks in the long run, since they do not allow the user to get into the correct posture.

Table 3 – Shelling characteristics using manual implements

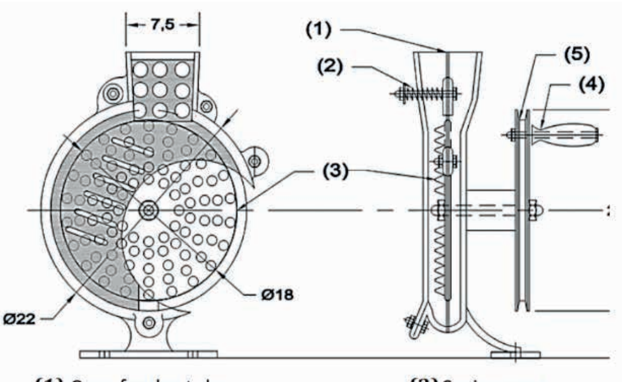

Figure 6 – Usual structure of manual implement.

Source: El Helew, 2017

Shelled by manual machines: Within the shellers without motor, these are the ones with the highest quantity-time performance, they work by means of a crank, replicating the principles of manual implements. Its manufacture begins to resemble motor machines, although only in volume of material used and dimensions, since they do not approach their hourly performance. Currently it is difficult to find someone who manufactures and sells them in Mexico.

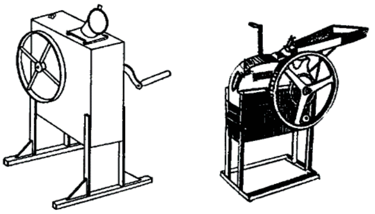

Figure 7 – Manual shelling machine.

Source: International Labor Organization, 1984.

Shredding by electric and gasoline machines: These machines are among the highest performance, normally work with electric motors (1 to 7 hp), or with gasoline engines (generally OHV) (4 to 16 hp), the power increases depending on of the amount of harvest; its capacity ranges from 700 to 5000 kg/h; being the most efficient electrical machines (Castelán & Vázquez, 2017).

Figure 8 – Mechanical shelling machine: (A) gasoline; (B) electrical.

Source: https://www.bomeri.com

Advantages	Disadvantages
* High hourly performance. * They separate the corn from the chaff. * Requires little labor.	* They are only economically feasible for harvests of more than 50 tons. * The cost of these machines is high. * High risk of breakdowns due to exposure to environmental factors. * There is no separation of grains damaged by humidity or that are infested by insects or worms. * In some cases the cob is crushed or fractured and combined with the grains and their separation is difficult. * High risk of CO2 poisoning if proper maintenance is not given.

Table 4 – Shelling characteristics using electric and gasoline machines.

HUMAN PROPULSION ENERGY

Human motive energy is one of the most frequently used renewable energy sources. Curiously, human power and its use is an area little investigated in relation to other renewable energies.

Author	Year	Available Power (Watts)
Bahaley et al.	2012	60 - 90
Gradjean	1988	75
fuller and aye	2012	75 - 150
Avallone et al.	2007	50 - 150
Tiwari et al.	2011	60
Gilmore	2008	65 - 90

Table 5 – Human mechanical power in pedaling.

Among the authors who have studied and estimated human motor power and its mechanical use, there are discrepancies. Table 5 summarizes the results obtained by some authors, regarding the available mechanical power, for bicycle-type mechanisms, in higher pedaling intervals. to one hour executed by average adults (Ruiz Rivas et. al, 2017). Similarly, various authors studied the mechanical power that a human can develop using the arms (Table 6) and the whole body (Table 7).

Author	Year	Available Power (Watts)
Gilmore	2008	15 - 30
kennedy and rogers	1985	30
fraenkel	1986	30

Table 6 – Human mechanical power using only the arms

Author	Year	Available Power (Watts)
Mack and Hasle Grave	1990	10 - 55
kennedy and rogers	1985	40 - 50

Table 7 – Human mechanical power using only arms and body

DESCRIPTION OF OBJECTIVES AND METHODOLOGY

GOALS

Preliminary evaluation of the feasibility of a bicimáquinas-based maize shelling system.

- Economic dimension: Preliminary feasibility in terms of productivity, cost and production efficiency.
- Environmental dimension: Preliminary feasibility in terms of energy consumed.

METHODOLOGY

DESIGN AND MANUFACTURING

Using a basic appropriate technology design process (Fig. 9) (Sianipar et al, 2013), based on the design limitation of a machine that does not require fuel and/or electricity, a sheller prototype was developed, based on in the functional structure of a commercial machine, evaluating the replacement of its energy source, an electric or gasoline motor, by a bicimáquina (Fig. 10 and Fig. 12).

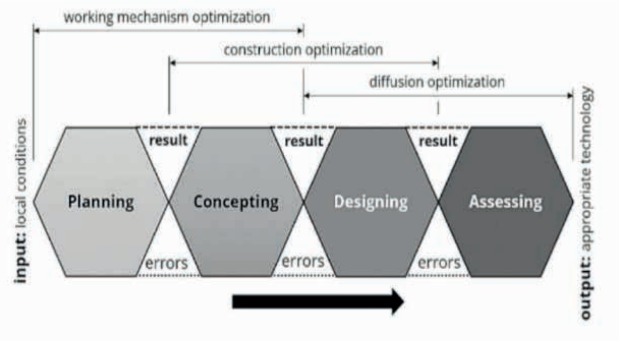

Figure 9 - Basic design process for appropriate technologies.

Source: Sianipar et al, 2013

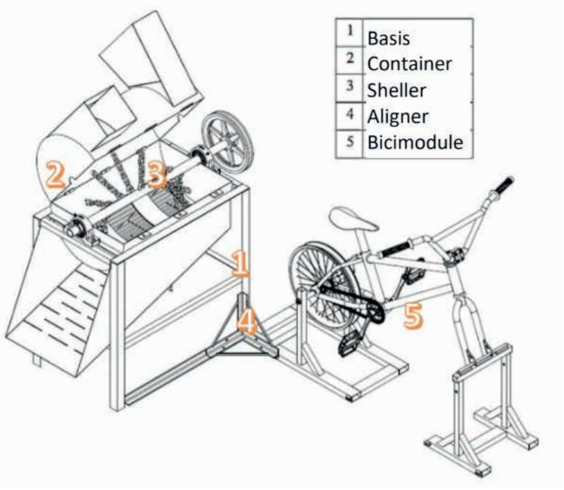

Figure 10 – Scheme of the prototype.

Carrying out a series of iterations and improvement phases (Fig. 11A and 11B), based on the observations made by 17 users.

Figure 11 – Prototype of the functional module: (A) Initial manufacturing; (B) Phases of improvement.

Figure 12 – Prototype: (A) Bicimodule; (B) Process module.

DESCRIPTION OF TESTS

The testing of the prototype consisted first of preliminary tests, the purpose of which was to find the combination of pinion-star of the bicycle and the time that a determined measure of ears must be processed, inside the machine, to achieve shelling with maximum grain integrity. possible, for which some of the most common types of maize were chosen (Fig. 13) from the Western and Central-northern regions of the country (Ron Parra et. al, 2006), one of which (Ancho) is also quite common in the Central South region. The average obtainment of visible damage in grains of less than 10% was achieved, based on the mass of broken grains and the total mass of grains, calculated based on the formula (El Helew, 2017). $(D_V(\%))(G_R(kg))(G_T(kg))$ [1]

Figure 13 – Types of corn: (A) Ancho; (B) Red pozolero; (C) I paint.

$$D_V(\%) = \left(\frac{G_R(kg)}{G_T(kg)}\right) \cdot 100 \qquad \boxed{1}$$

Subsequently, tests were carried out to evaluate the performance of the machine, in which 17 women participated, which consisted of measuring the mass of grain that they shelled in 1 load cycle (duration between 25 and 45 seconds, 20 to 40 ears per bucket). A shelling test was also carried out using manual methods (Fig. 4A and 4B), with 7 women, as well as a test with an olotera (Fig. 5), all carried out by people with experience in said tasks.

PRODUCTIVE CHARACTERISTICS

From the results, the theoretical productivity in kg/h was projected, both for the bicimachine (Fig. 14), and for the manual methods (Fig. 15), based on the shelled maize mass in kg and the net shelling time. in hours; using the formula (El Helew, 2017). $(R_T)(M_G)(T_D)$ [2]

$$R_T\left(\frac{kg}{h}\right) = \left(\frac{M_G(kg)}{T_D(h)}\right) \cdot 100 \qquad \boxed{2}$$

For the bike machine, average yields of 172 kg/h were obtained with wide corn; 200 kg/h with red corn and 246 kg/h with red corn (Figure 14).

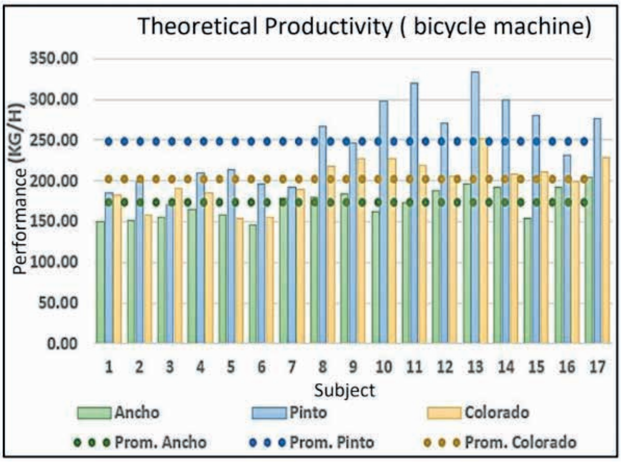

Figure 14 – Theoretical productivity (bicycle machine).

In shelling by hand, average yields of 28.26 kg/h were obtained with wide corn, 16.98 kg/h with red pozolero corn and 16.19 kg/h with pinto corn; In the shelling by means of olotera, yields of 80.35 kg/h were obtained with wide corn, 48.07 kg/h with red pozolero corn and 57.14 kg/h with pinto corn.

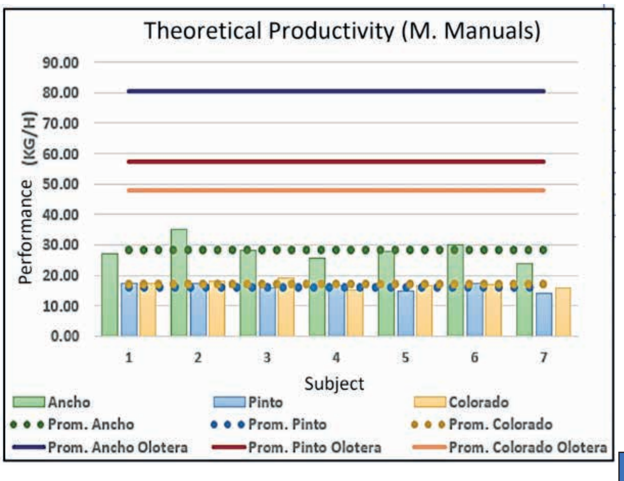

Figure 15 – Projected average yields, manual methods.

For manual implements (Table 10), as well as for manual commercial machines (Table 8) with a gasoline engine (Table 9) and with a single-phase motor (Table 11), the performance and characteristics of the basic models available on the market were considered. Mexican, offered by various providers.

Brand	Model	Production (kg/h)	Price (mxn)
IH McCormic	pony	80 - 100	$5,000 - $16,000
Penagos	DM2	85	$7,000
John Deere	1 B	150 - 200	$4,100 - $9,500

Table 8 – Characteristics of manual implements.

Brand	Model	Power (Hp)	Production (kg/h)	Price (mxn)
swissmex	612010	6.5	1500	$19,862
Aztec	501370	4	1500	$16,297
Raiken	RKDM1800	6.7	1700	$14,131
sands	D1750	5.5	1750	$14,319
fumasa	DM-1800	5.5	1800	$13,351
Ahead	G-1000	4	700	$12,998
matep	DP1500	5.5	1500	$12,150
matep	DP1800	6.5	1800	$14,850
Bomeri	DEG2	5.5	1500	$13,700
macroffi	DESG03	6.5	1000	$14,165
antharix	DL1800K6	6	1205	$16,171

Table 9 – Characteristics of commercial gasoline shelling machines.

Brand	Model	Production (kg/h)	Price (mxn)
luma	492251	60	$1,672
Raiker	JIM-002	fifty	$1,450
balfe	PTD-012	fifty	$1,215
Tecsa	narpad	Four. Five	$1,425
mekatech	MKT-DSGM-1R	fifty	$1,300
Rooster	dmg	60	$1,200

Table 10 – Characteristics of manual implements

Brand	Model	Power (Hp)	Production (kg/h)	Price (mxn)
swissmex	612001	2	1500	$19,862
Aztec	501390	2	1500	$16,297
Raiken	RKDM1800W1	1	1000	$11,707
Raiken	RKDM1800W1.5	1.5	1500	$12,111
Raiken	RKDM1800W2	2	2000	$12,927
sands	D1750	1.5	1500	$12,000
sands	D1750	2	2000	$13,351
fumasa	DM-1800	2	1800	$13,351
Ahead	G-1000	1	700	$12,500

matep	DP1500	2	1500	$12,150
Bomeri	DESG2E	2	1500	$11,100
macroffi	DESG02	2	1000	$14,383
antharix	DL1800S1	1	1205	$13,589

Table 11 – Characteristics of electric commercial shelling machines

MANUFACTURING COST OF THE PROTOTYPE

To compare the prices of the products, the manufacturing cost of the prototype was broken down (Table 12), considering the following costs:

Direct costs: Costs directly associated with materials and their transformation (Table 13 and Table 14).

	Subsystem	Direct (mxn)	Indirect (mxn)	Profit (mxn)	Cost (mxn)
1	Base	$581	$87	$100	**$768**
2	Container	$1,910	$287	$330	**$2,527**
3	sheller	$1,711	$257	$295	**$2,263**
4	aligner	$360	$54	$62	**$476**
5	bicimodule	$1,925	$289	$332	**$2,546**
				Total	**$8,580**

Table 12 – Cost of the prototype

Cost	Description	Considerations
Materials (Matt)	1.- Commercial and recycled steels. 2.- Mechanical parts 3.- Bicycle parts 4.- Other inputs	1.- Profiles, sheets, tubes. 2.- Belts, pulleys, chains, bearings. 4.- Painting, screws, welding.
labor (MO)	5.- Real salary of the personnel that performs a task divided by their performance per day.	5.- Calculated according to ; Nominal salary equal to the minimum salary according to the federal labor law ($172.87 mxn); Real wage factor (FSR) of 1.35;
waste and wear (DD)	6.- Manufacture 7.- Machinery 8.- Tool 9.- Equip. of security	6.- 5% of the cost of the material 7.- 4% of the cost of MO 8.- 3% of the cost of MO 9.- 3% of the cost of MO

Table 13 – Description of direct costs

$$M_o = \frac{S_r}{R_j} = \frac{S_n \cdot F_{SR}}{\text{Units per day}} \quad [3]$$

	Subsystem	Mat (mxn)	MO (mxn)	DD (mxn)	Total (mxn)
1	Base	$386	$160	$35	$581
2	Container	$1,107	$730	$73	$1,910
3	sheller	$1,153	$469	$89	$1,711
4	aligner	$191	$145	$24	$360
5	bicimodule	$1,666	$160	$99	$1,925

Table 14 – Breakdown of direct costs

Indirect costs: Operating costs not included in direct costs, such as administration, facilities, contingencies, among others. We consider them as a pro rata of 15% of the direct cost.

Utility: Projected profit for execution of work items, we consider it 15% of the sum of direct and indirect costs.

PRODUCTIVITY AND POWER

To corroborate the available power supplied to the function module by the bicimodule (Fig. 10, Fig. 11 and Fig. 12), an experiment was carried out with 4 women, in which the function module was instrumented using the components in the table 15 (Fig. 16), following the logic of the Prony brake; measuring the power, through the revolutions captured by the RPM sensor and the dynamic torque registered by the load cell via the collars. The reading reported an average power of 64 watts (Fig.17).

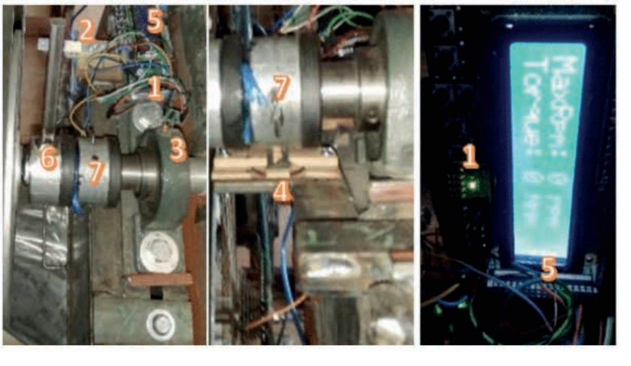

Figure 16 – Instrumentation assembly.

Journal of Engineering Research ISSN 2764-1317 DOI 10.22533/at.ed.3173132325042

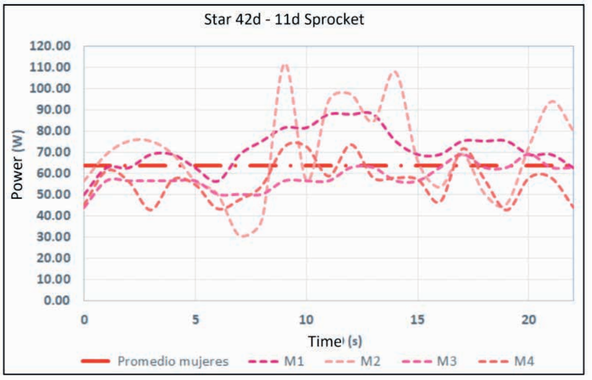

Figure 17 – Power measurement.

Component	Description
1	Arduino Mega 2560
2	20 kg load cell Electrocrea YZC131
3	Hx711 amplifier module for load cell
4	Tecneu LM393 RPM sensor module
5	Dfrobot Gravity Dfr0009 LCD shield for arduino
6	Load Cell Lever Collar
7	Collar with vanes for RPM sensor

Table 15 – Instrumentation

Corroborated these data for the bicimáquina, the productive efficiency of the different forms of shelling was determined, based on the formula, and the energy consumed using the formula (El Helew, 2017). .4 (E_C) 5

$$S_R\left(\frac{kg}{Wh}\right) = \frac{R_T\left(\frac{kg}{h}\right)}{P_T(W)} \quad \boxed{4}$$

$$E_C\left(\frac{kJ}{kg}\right) = \left(\frac{P_T(W)\cdot T_D(h)}{M_G(kg)}\right)\cdot 3.6 = \frac{3.6}{S_R\left(\frac{kg}{Wh}\right)} \quad \boxed{5}$$

COMPARATIVE STUDY

For the calculations, the power and the upper limit of the productivity ranges described by the suppliers of the commercial products were considered, and of the power described in tables 5, 6 and 7, in the case of methods, implements and machines, based on in human power. For manual shelling, the price and energy were considered negligible, due to the lack of data on the mechanical power developed by human fingers.

For the study, the first comparison was made between price, productivity and productive efficiency (Fig. 18), which is an index that in economic terms allows us to give an idea of the ratio between the resources obtained and the resources supplied for the different products to be compared, in this case between the mass of grains obtained and the power required. The second comparison was between price, productivity and energy consumed (Fig. 19). In both cases, grouping the types of shelling into one of the following 7 categories: manual method, shelling with cobs, bike machine, manual implements, manual machines, electric machines, gasoline machines.

Within the first 3 categories, the shelling of the 3 types of corn used in the tests was included, while for the other categories all the brands and commercial models collected were included. The way to interpret the graphs, for both cases, is that the further to the right, on the ordinate axis, and the further down the abscissa axis, the better the productivity-price ratio is for the weighted product, the difference being between both comparisons, that for the first (Fig. 20), the products with the largest bubble represent the options with the best productive efficiency, while for the second (Fig. 19) the products that consume the least energy are those with the bubbles. smaller.

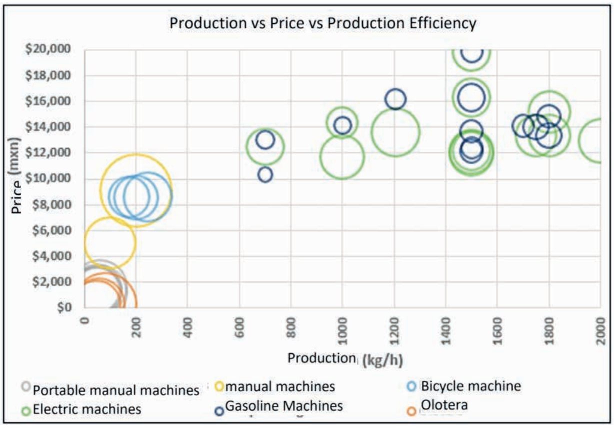

Figure 18 – Production/price/eff ratio.
productive

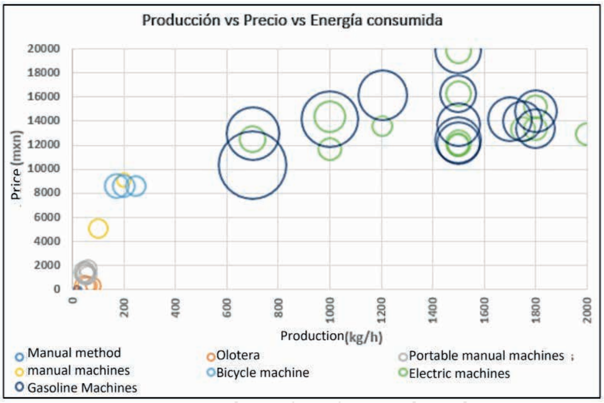

Figure 19 – Production/price/energy relationship

RESULTS

From figures 18 and 19, we can see that the bicimáquina:

It surpasses by a wide margin, in terms of production, the manual method, the method with olotera, and manual implements. In terms of price-output-energy, it is very similar to a high-capacity manual machine, although cheaper in price. It is very far in terms of productivity from electric machines, but it has comparable production efficiency.

CONCLUSIONS

In terms of productivity, the bicimáquina is very far from that of electric and gasoline machines, but much higher than conventional manual forms, equating the productivity of a high-capacity manual machine and the productive efficiency of an electric machine, for a slightly lower price, being preliminarily corroborated the feasibility in terms of cost, productivity and productive efficiency, although with need for improvement.

Regarding the environmental dimension, in terms of energy consumption there is not much difference between an electric machine and a bicimachine, but since human motive power is an energy source with lower emissions in general, the viability is preliminarily corroborated. However, although the bicimáquina is very far from electric and gasoline machines in terms of productivity, given the scarce commercial presence of manual machines, we can perceive a situation in terms of social and solidarity entrepreneurship for it, since it has a productive efficiency and energy use comparable to that of electric machines, and there is precisely a market for gasoline-powered machines, due to the low availability of electricity in plots and fields.

THANKS

This article was carried out thanks to the master's degree scholarships granted by CONACYT to the UNAM students involved in the study on which it is based.

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