Technological and socioeconomic characterization of *Cucurbita argyrosperma* Huber production systems in Champotón, Campeche, Mexico

Caracterización tecnológica y socioeconómica de los sistemas de producción de *Cucurbita argyrosperma* Huber en Champotón, Campeche, México

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ABSTRACT

The state of Campeche, Mexico, occupies first place in the production of *Cucurbita argyrosperma* Huber, with the municipality of Champotón contributing 7% of state production. Chihua squash production systems were characterized based on their technological and socioeconomic level by applying a semi-structured questionnaire to those responsible for the Chihua squash production systems. The data were analyzed using principal components, clusters, and comparison of means with the Tukey test (P≤0.05). Three groups of producers were identified: G1, G2, and G3, grouping 28, 100, and 8 people, respectively. G1 has intermediate land availability, intermediate salaried labor, producer organizations, seed processing, average purchase-sale contract, medium use of technologies, higher income per unit of area, and represents 20.58% of producers; G2 has lower land availability, lower number of salaried labor, low organization of producers, seed processing, no purchase-sale agreement, low use of technologies, lower income per unit of area and utility, and concentrates 73.53% of producers; G3 has greater availability of land, greater number of salaried labor and producer organizations, does not process seeds, has greater purchase-sale agreement, high use of technologies, average income values, and represents 5.88% of the producers. The group with the highest technological index was not the one with the highest profitability, which was determined by producer organizations and the availability of land.

Key words: agricultural producers, Chihua squash, agricultural profitability.

RESUMEN

El estado de Campeche, México, ocupa el primer lugar en producción de *Cucurbita argyrosperma* Huber, donde el municipio de Champotón aporta el 7% de la producción estatal. Se caracterizaron los sistemas de producción de calabaza chihua, en función de su nivel tecnológico y socioeconómico, aplicando un cuestionario semiestructurado a los responsables de los sistemas de producción de calabaza chihua. Los datos se analizaron mediante componentes principales, conglomerados y comparación de medias con la prueba de Tukey (P≤0.05). Se identificaron tres grupos de productores, G1, G2 y G3, agrupando a 28, 100 y 8 personas cada uno. G1 tiene disponibilidad de tierra intermedia, mano de obra asalariada intermedia, organizaciones de productores, procesamiento de semillas, contrato de compra-venta media, uso de tecnologías medio, mayor ingreso por unidad de superficie y concentra al 20.58% de los productores; G2 presenta menor disponibilidad de tierra, menor número de mano de obra asalariada, baja organización de productores, procesamiento de semillas, sin acuerdo de compra-venta, bajo uso de tecnologías, obtiene menores ingresos por unidad de área y utilidad, y concentra el 73.53% de los productores; G3 presenta mayor disponibilidad de tierra, mayor número de mano de obra asalariada y organizaciones de productores, no procesa semillas, mayor acuerdo de compra-venta, alto uso de tecnologías, tiene valores de ingresos promedio y representa el 5.88% de los productores. El grupo de mayor índice tecnológico no fue el más rentable, debido a que estuvo determinado por las organizaciones de productores y la disponibilidad de tierras.

Palabras clave: productores agrícolas, calabaza chihua, rentabilidad agrícola.

Introduction

In Mexico, agriculture is an important economic activity as it is the main source of income for 13.21% of the rural population (INEGI, 2016), in which women and youth actively participate (FAO, 2015). In the state of Campeche, the high availability of natural resources destined to promote agriculture has been documented; however, there

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is a low production rate, and the development outlook is not very encouraging, mainly due to low investment in infrastructure and technology (Uzcanga Pérez *et al*., 2012). The agricultural systems in the state of Campeche reported a total production of USD 137,848,113.8 for the 2022 agricultural cycle; the main crops, both irrigated and seasonal, were grain corn (*Zea mays*), soybean (*Glycine max*), Chihua squash (*Cucurbita argyrosperma*), grain sorghum (*Sorghum bicolor*) and rice (*Oryza sativa*) with production values of USD 51,810,860.2; 15,208,653.4; 5,297,773.6; 3,443,426.6; and 5,280,917.4, respectively. The state leads the country in Chihua squash cultivation, with 15,426 ha of planted area as of 2022 and an average yield of 0.53 t ha^{-1} of seeds, equivalent to 31.69% of the total national production (SIAP, 2024).

Within the Chihua squash producing municipalities, over the past five years, the Champotón municipality has gone from third to fifth place in planted area (2,217 to 2,257 ha) and from fourth to fifth in seeds production (309.30 to 825.16 t) per agricultural cycle, reporting the lowest seed yield (0.37 t ha^{-1}) compared to other municipalities with yields ranging 0.40 to 0.86 t ha^{-1} (SIAP, 2024).

Cucurbita argyrosperma cultivation is important due to the high demand for its seed, mainly by agribusiness to produce paste for traditional meals and snacks (INIFAP, 2014). This product reaches competitive prices in regional markets (Ireta-Paredes *et al*., 2018) and represents an economic opportunity for peasant families (Camino & Müller, 1993). In Campeche, Chihua squash cultivation is an important component for agrobiodiversity maintenance (Salazar-Barrientos *et al*., 2016); it is also the second most important economic element after maize for producers in rural areas (Dorantes-Jiménez *et al*., 2016). The crop is sown in temporary conditions in the spring-summer cycle (May-June) and under irrigation systems in the autumn-winter cycle (October-December) (INEGI, 2015). The most common technologies are soil preparation (plow and harrow), application of fertilizers, herbicides, and chemical insecticides (SAGARPA, 2015).

In Champotón, Campeche, the production of *C. argyrosperma* is traditionally an important economic activity for families due to the adaptation of the crop to the soil and climate conditions (Eguiarte *et al*., 2018). However, in recent cycles, a decrease in the area dedicated to its cultivation was observed as well as a decrease in productivity, negatively affecting the profitability of the production systems and the welfare of the producing families. To positively impact the profitability of the production system, the interaction of social, technological, and economic elements (Apollin & Eberhart, 1999) should be established. Given that references or consultation documents for the management of this crop are minimal, the objective of the study was to determine the technological and socioeconomic factors that influence the profitability of Chihua squash production systems in Champotón, Campeche, Mexico. This contribution aims to support future studies and development plans and to increase profitability through the use of appropriate technologies for the region in *C. argyrosperma* crop production systems.

Materials and methods

Study area location and sample size selection

The research took place in the municipality of Champotón, Campeche, Mexico (19°21’20” N, 90°43’24” W). The region is dominated by a warm subhumid climate with rains in summer (García, 2004), annual precipitation between 900 and 1200 mm, and an average temperature of 26.4°C.

To select the *C. argyrosperma* producing localities, the directory of producers at the office for attention to agricultural and fishing sectors of the Champotón municipality was used. Ten percent of the localities were selected, prioritizing those with the largest cultivation area: Santo Domingo Kesté, Mayatecun Module 1, Mayatecun Module 2, and Felipe Carrillo Puerto, with 683, 686, 233, and 190 families, respectively (INEGI, 2015). To determine the sample size, the finite population formula was used (Sierra Bravo, 2001):

$$n = Z^2pq \frac{N}{NE^2} Z^2 pq \qquad (1)$$

where n = sample size, Z = confidence level, p = positive variability, q = negative variability, N = population size, E = error precision.

In this research, a mixed quantitative-qualitative approach was used to obtain numerical results and information on the qualities of the systems through closed and open questions included in the surveys. The participatory actions method was used, where the object of research was the producer as a participant. The producer decides to participate, expresses their knowledge and experience on the phenomenon addressed and helps define the basis of improvement actions (Bernal, 2002). This approach made it possible to define and analyze the main study variables that characterize Chihua squash producers.

Technological and socioeconomic data compilation

A survey was applied to 136 producers responsible for the production units; the questionnaire had two sections: a) socioeconomic level, with 18 items: Age, schooling, main economic activity, total area of the plot, area destined for Chihua, years in activity, type of land tenure, type of soil, number of family members, reception of credit for agricultural production, access to domestic services, membership in a constituted organization, income from activity, family workforces, wage workforce, total workforce, purchase-sale agreement, profitability (production costs and labor costs), and b) technological level, with 38 items: more than five years of experience in cultivation, access to training courses, access to technical assistance, determination of wage needs, depth control of planting, density of 3,000 to 6,000 plants ha^{-1}, biological pest control, physical pest control, seed selection, pest and disease occurrence registry, crop relay, crop association, access to exclusive area for seed drying, seed separation, pre-harvest production estimate, production record, production cost record, harvest loss record, identification of potential buyers and transformation, soil nutrient analysis, tracking, burning of agricultural residues in the plot, plowing, furrowing, and use of agricultural calendar, use of synthetic herbicides, use of synthetic nematicides, fertilizer in sowing, in the development phase and in the flowering phase, use of organic fertilizers and application of insecticides, mechanical seed extraction and use of special dryer for seed, use of irrigation, irrigation water analysis, and calculation of irrigation sheet.

A consultation was conducted with experts in Cucurbitaceae cultivation and the characterization of agricultural production systems to define the variables of each section. The experts were researchers from the National Institute of Forestry, Agricultural and Livestock Research, College of Postgraduates, National Technological Institute of Mexico, and entrepreneurs specializing in the cultivation of Chihua squash. As a management reference, the technological package for the cultivation of Chihua squash developed by INIFAP (2015) was used. To produce a technological level index, the technologies applied by each producer were quantified from a total of 38 possible options. According to the sum of the used technologies, three technological levels were defined: low (<16), medium (16 to 30) and high (>30).

The total production costs (including the cost of family labor) and the total income from commercialization of the dehydrated Chihua squash seeds were calculated; these variables were calculated following the algebraic expressions based on economic theory (Samuelson *et al.,* 2009) as follows:

$$TC = P_xXTC \quad (2)$$

where TC=total cost, Px=price of input or activity x and X=activity or input,

$$TI = P_yY \quad (3)$$

where TI=total income (US$ ha^{-1}), Py=market price of crop Y (US$ t^{-1}); and Y=crop yield (t ha^{-1}),

$$R = TI - T \quad (4)$$

where R=profitability, TI=total income and TC=total cost.

Data analysis

The information gathered in the survey was captured in an Excel program and the data were analyzed with descriptive statistics. Subsequently, a principal component analysis (PCA) was applied to reduce the size of the data set and to allow the identification of a small number of variables representing most of the original variability of observations, corresponding to the variables with the highest variances (0.5) in factor 1 and 2 (Fig. 1).

With the most relevant variables of the PCA, multivariate statistical analyses were carried out (cluster analysis with complete distance chaining and Euclidean distances) to determine the groups in the systems (Peña, 2002), considering each group resulting from the analysis as a variation factor. Finally, to determine and contrast the variables of the technological and socioeconomic factors that affect the profitability of each group, a Spearman correlation, an analysis of variance and Tukey comparison of means (P<0.05) were performed using the statistical software STATISTICA v7.

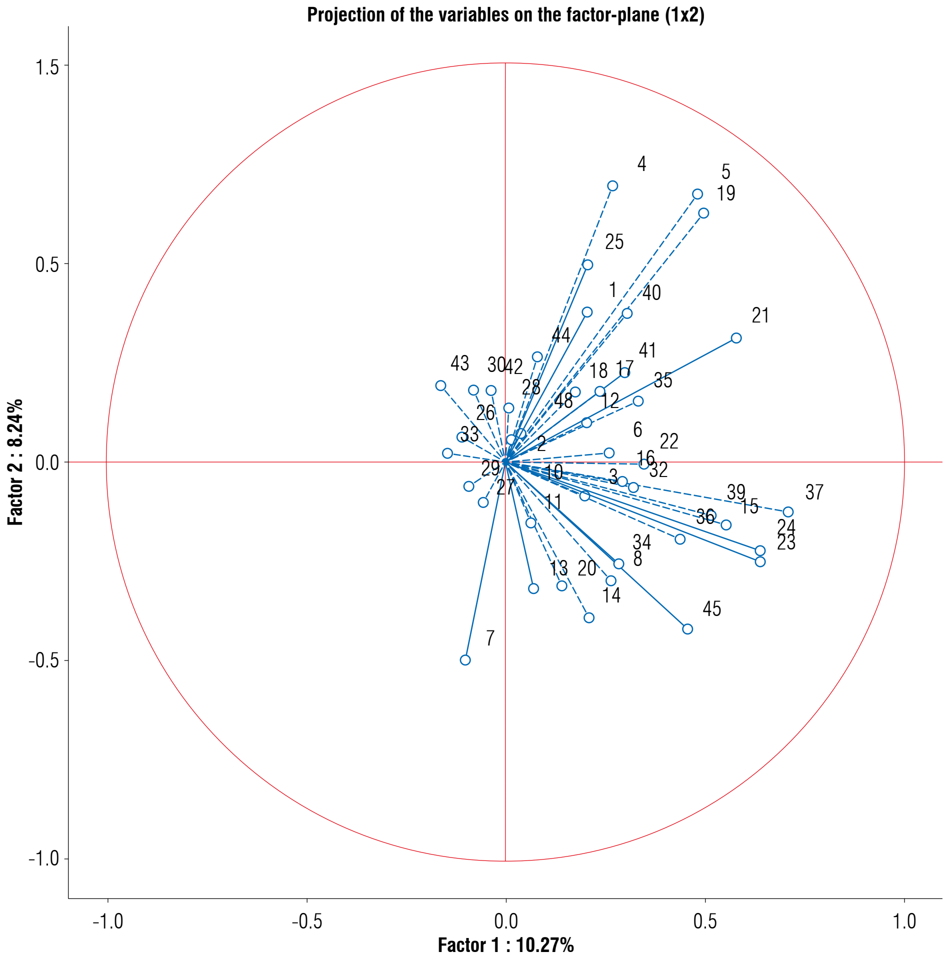

FIGURE 1. Principal components analysis with variables that affect the groups of the production systems of *Cucurbita argyrosperma*.

Results and discussion

Out of the total interviewed producers, 90.4% were men and 9.6% women, therefore, the cultivation is primarily supported by males. The participation of women is mainly oriented to postharvest management, such as the extraction and drying of the seeds, and to a lesser extent to the cultural activities around cultivation and decision-making. Fifty four percent of the producers mentioned that the decision and reason to grow Chihua squash is due to the high demand for dry seed in the regional and national market.

The low participation of women in the management of the crop was due to the fact that the activities of soil preparation, sowing, cleaning of weeds, pest control, fertilization and harvesting require high physical effort, while the activities of post-harvest management require greater manual dexterity. This situation is also observed in bean (*Vicia faba*) production systems at the state of Puebla and in grape cultivation in Aguascalientes (Mexico), where 4 and 2% of the producers were women (Borja-Bravo *et al.*, 2016; Rojas-Tiempo *et al.*, 2012). However, in milpa systems in Yucatán, Mexico, it was found that women are essential for the conservation of plant species (Salazar-Barrientos *et al.*, 2016). In banana production systems in Colombia, women have participated in the decision-making, indicating that women in the rural sector are moving from a secondary role (labor) to a primary one (management) (León-Agatón *et al.*, 2015).

Description of the grouped *C. argyrosperma* production system

Three groups of Chihua squash production systems were identified: G1 presents intermediate values of land availability, intermediate wage workforce, medium producer organization, seed processing, medium purchase-sale agreement, medium use of technologies. They obtain the highest income per unit of area and profitability; G2 reports average values of land availability, lower number of wage workforce, low producer organization, seed processing, no purchase-sale agreement, low use of technologies, low income and profitability; and G3 has the highest land availability, the highest number of wage workforce and producer organization, no seed processing, the highest purchase-sale agreement, high use of technologies, medium income and profitability (Fig. 2, Tab.1).

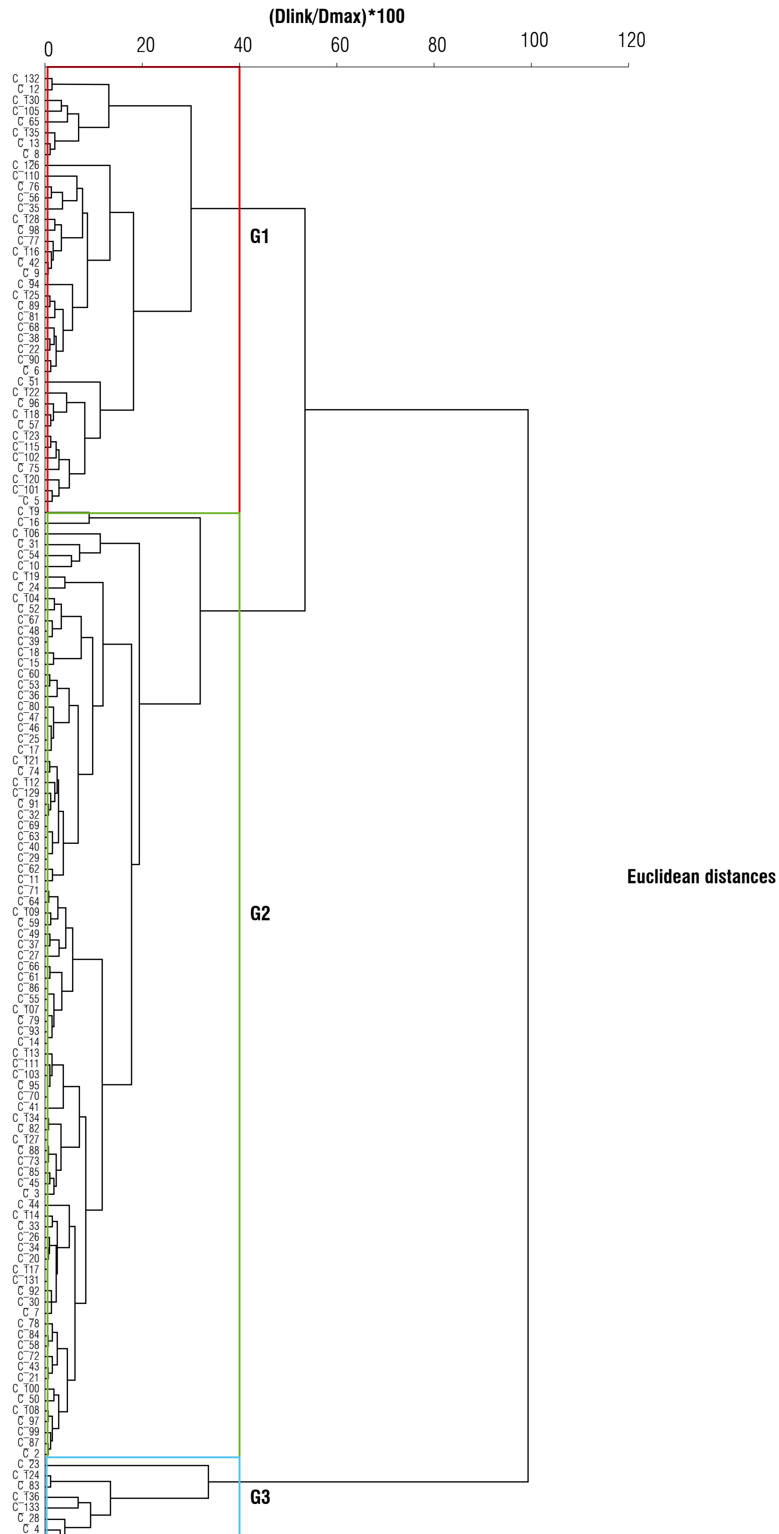

FIGURE 2. Groups of Chihua squash (*Cucurbita argyrosperma*) production systems in Champotón, Campeche, Mexico.

TABLE 1. Socioeconomic characteristics of the producers of *Cucurbita argyrosperma* in Champotón, Campeche, Mexico.

Variables	G1	G2	G3
Number of producers	28	100	8
Number of endemic dialects	7	6	2
Participation of women (%)	50	35	25
Number of public services	5	5	5
*Seed transformation (%)	10.7	12.0	0
Age (years)	43.39 ± 13.84^{a}	44.94 ± 14.46^{a}	55.62 ± 16.36^{a}
Schooling (years)	6.46 ± 3.38^{a}	5.04 ± 4.07^{a}	5.12 ± 3.94^{a}
Total area of the plot (ha)	14.50 ± 26.67^{a}	8.80 ± 18.31^{a}	46.94 ± 51.78^{b}
*Area destined for Chihua crop (ha)	3.30 ± 2.83^{a}	2.25 ± 1.53^{a}	10.31 ± 4.43^{b}
Years in activity (years)	16.86 ± 9.40^{a}	15.50 ± 10.58^{a}	15.5 ± 8.48^{a}
Family members (number)	4.53 ± 1.89^{a}	4.32 ± 2.21^{a}	4.25 ± 2.19^{a}
*Belongs to a constituted organization	0.21 ± 0.42^{ab}	0.11 ± 0.32^{a}	0.50 ± 0.53^{b}
Receive credit for agricultural production	0.071 ± 0.26^{a}	0.11 ± 0.31^{a}	0.38 ± 0.52^{a}
Family workforce	12.32 ± 9.68^{a}	15.44 ± 9.12^{a}	16.25 ± 13.74^{a}
*Wage workforce	24.64 ± 13.63^{ab}	13.10 ± 11.60^{a}	26.38 ± 18.83^{b}
Total workforce	36.96 ± 11.82^{a}	28.54 ± 14.53^{a}	42.63 ± 11.76^{a}
*Purchase-sale agreement	0.04 ± 0.19^{a}	0^{a}	0.25 ± 0.46^{b}
*Income (USD ha^{-1})	946.42 ± 457.92^{b}	629.25 ± 404.23^{a}	780.86 ± 370.82^{ab}
*Profitability	507.31 ± 528.27^{b}	272.16 ± 417.71^{a}	362.94 ± 347.55^{b}
*Technological index	18.11 ± 3.79^{ab}	17.34 ± 3.78^{a}	21 ± 3.62^{b}

$^{a, b, c}$ Different letters in the same row indicate significant differences according to the Tukey's test ($P<0.05$). *Variables with an asterisk are those that served to form the groups.

Socioeconomic characteristics of *C. argyrosperma* production systems

The age and education of the producers were similar in the three groups, with an average age of 47.99 and 5.54 years of education (Tab. 1). These values were similar to those reported in agricultural production systems in Colombia, where those responsible have an average age of 50 years (Rocha-Rodríguez *et al*., 2016). In this sense, the FAO mentions that the rural population is tending to grow old, and young people are migrating to urban environments (FAO, 2014). Agriculture represented the main economic activity for 89.3, 96.0, and 87.5% of the G1, G2, and G3 producers, respectively.

Of the three groups, G3 presented the largest total land area (P=0.00007) with an average of 46.94 ha, of which 22% was allocated to planting Chihua squash. Despite the large planting area, G3 had the lowest yields (rs=-0.879582; P<0.05), negatively affecting profits (rs=-0.904762; P<0.05), and utility (rs=-0.952381; P<0.05) and profitability of this crop (rs=-0.785714; P<0.05).

The highest seed yield was recorded in G1 with 635.24 kg ha^{-1} (P=0.00280) (Tab. 3), generating higher income (rs=0.948435, P<0.05), profitability (rs=0.879417, P<0.05), and economic utility of production (rs=0.918839, P<0.05).

The experience of the producers in the management of the Chihua squash crop ranged between 1 to 50 years, with an average of 15.95 in the three groups. The longer they have been in activity, the more access they have to governmental support (rs=0.495393, P<0.05). In the last five years, 82% of producers received government support for agricultural production, 59% of which came from the Secretary of Agriculture and Rural Development.

Land tenure in G1 was private, ejido, loaned, rented, and a combination of these, with 64.29, 3.57, 3.57, 3.57, and 17.85% each, respectively. In G2, it was privately owned, ejido, rented, loaned, communal property, and a combination of these, with 41.41, 10.94, 10.94, 3.13, 0.78, and 16.40%, respectively. In G3, it was ejido, private property, and loaned-private property, with 50.0, 37.5, and 12.5%, respectively. The type of soil according to the Maya (Bautista *et al.,* 2012) and INEGI (2017) classification was as follows: in G1, 58.62% of the plots were k'an kab or Luvisol type soil; in G2, the predominant soils were yaxx kom-ak' al che or Gleyic Vertisol and k'an kab or Luvisol in 53 and

39% of the cases, respectively; in G3, the predominant soils were yaxx kom-ak' al che or Gleyic Vertisol and k'an kab or Luvisol with 50 and 25%, respectively.

The average family in the three groups consisted of 4.37 individuals. In G2, 50% of adult women (mostly the producer wives) participate in the different processes of the Chihua squash cultivation. In G2, 35% participated. In G3, 25% contributed as labor, 12.5% supported other activities such as the seeds marketing, and 12.5% contributed financial resources for cultivation.

The use of different endemic dialects from southern Mexico and Guatemala was recorded among the producers of the three groups. In G1, Kanjobal, Maya, Mam, Chuj, Q'eqchi, Cachiquen, and Quiché were registered (28.57, 14.28, 10.71, 7.14, 3.57, 3.57, and 7.14%). In G2, the main dialects were Kanjobal, Maya, Mam, Quiché, Q'eqchi, and Chuj (31, 14, 10, 6, 6, and 4%), while, in G3, only 12.5% spoke Chuj combined with Kanjobal.

The families in the three groups (G1, G2, and G3) have access to 71.4% public services, including piped water, electricity, garbage recollection, road access, telephony (telecommunications and networks), education and health services. The use of private loans is increasingly common among producers without sufficient capital: these were used by 7.1, 11.0, and 37.5% of the producers of G1, G2, and G3, respectively.

The presence of organized producers was higher in G3 (P=0.00770) followed by G1 and G2, with an average of 50, 21, and 11%. Affiliation to constituted organizations showed a high correlation with the years dedicated to Chihua squash production (rs=0.888889, $P<0.05$).

The origin of the employed labor in the three groups was similar. In the G1 systems, the labor distribution was family workforce-wage workforce, family workforce, and wage workforce (78.57, 14.29, and 7.14%). In G2, it was family workforce-wage workforce, family workforce, and wage workforce (79, 20, and 1%). In G3, it was family workforce-wage workforce, family workforce, and wage workforce (75, 12.5, and 12.5%). G3 presented the highest use of labor per each cultivated hectare with 42.6 wages (P=0.00135) followed by G1 and G2 with 36.9 and 28.5 wages.

Additionally, of the total organized producers, 25% in G1 and 3.57% in G3 (P=0.00001) carried out purchase-sale contracts before the Chihua squash planting for the 2016 agricultural cycle. These sale-purchase contracts were mainly conducted by producers with fewer academic degrees (rs=-0.765092, $P<0.05$).

The production cost per ha was similar among groups, with an average value of USD 404.70 during the 2016 cycle, mainly due to wages, payments and purchase of inputs. The highest incomes were reported in G1 (P=0.00206) with USD 946.5.00 ha^{-1}, compared to G3 and G2 (USD 780.85 and 629.25 ha^{-1}). The calculated profitability varied among the three groups; iG1 had the highest (P=0.04726) with USD 507.30, followed by G3 (USD 363.00) and G2 (USD 272.10). The higher profitability observed in G1 was due to productivity, product quality, and production organization amongst producers. When there are deficiencies in these elements, the systems cannot negotiate with intermediaries and become vulnerable (Muñoz *et al*., 2014).

Seed transformation for an added value gain is an uncommon activity. Only 10.71 and 12% of the producers in G1 and G2 registered such activity. It mainly consists of roasting the seeds on a "comal" in an artisanal way for its commercialization in the main cities of the state (Fig. 3), at an average price of USD 3.50 kg^{-1}. The three groups presented a medium technological index. However, G3 stands out for its greater use of technologies, with 21 of the possible 38 (P=0.02819) compared to 18.11 and 17.34 in G1 and G2. The generation of added value in agricultural products is a strategy that promotes the development of agrarian systems by increasing their income. In this study, only G1 and G2 producers (10.71 and 12%) carry out some process to include an added value into a part of their production. These values coincide with those reported when analyzing the marketing schemes of agricultural producers in the market of Costa Rica (Rodríguez-Sáenz & Riveros, 2016), who mention that low added value, poor product

FIGURE 3. Seed transformation of *Cucurbita argyrosperma* in Champotón, Campeche, Mexico.

differentiation and little diversity in the supply are the most relevant characteristics and challenges faced by small and medium-scale producers, as well as rural micro, small, and medium-sized enterprises.

Technological characteristics of *C. argyrosperma* production systems

In Table 2, the technologies used in the Chihua squash production systems are recorded, covering stages from sowing to postharvest handling, including use of machinery, equipment, infrastructure, application of agrochemicals and the techniques to carry out each of the activities. Among the groups, only G1 and G2 carry out seed processing, while G3 invests more in irrigation systems.

TABLE 2. Main uses of technology in *Cucurbita argyrosperma* production systems in Champotón, Campeche, Mexico.

	Producers (%)		
Technologies	**G1**	**G2**	**G3**
Agrochemicals (pesticides)	100	100	100
Machinery and equipment	100	100	100
Seed selection	90.3	91	89.7
Crop relay	92.9	88	87.5
Seed separation	35.7	50	50
Cultivation record	28.9	18	38.9
Crop association	17.8	16	15.2
Technical assistance	17.9	8	25
Training courses	14.3	12	25
Transformation	10.7	12	0
Chromotropic traps	9.3	8	11.5
Irrigation	3.6	8	14.9

G1, G2, and G3 – three groups of the plant production systems.

Over 90% of the producers considered that the seed selection activity most influences crop yield; 91.91% manually conducted this activity considering the following criteria: 1) squash size, 2) seed size, and 3) presence of complete seeds (Fig. 4). The soil preparation for planting mainly includes tracing, plowing, furrowing, and chemical analysis of available mineral nutrients (Tab. 3). Seed selection is a practice that is traditionally carried out by Chihua squash producers, consisting of choosing large and robust pumpkins, extracting their seeds by cutting the fruits in half, and then drying the seeds under the sun without removing

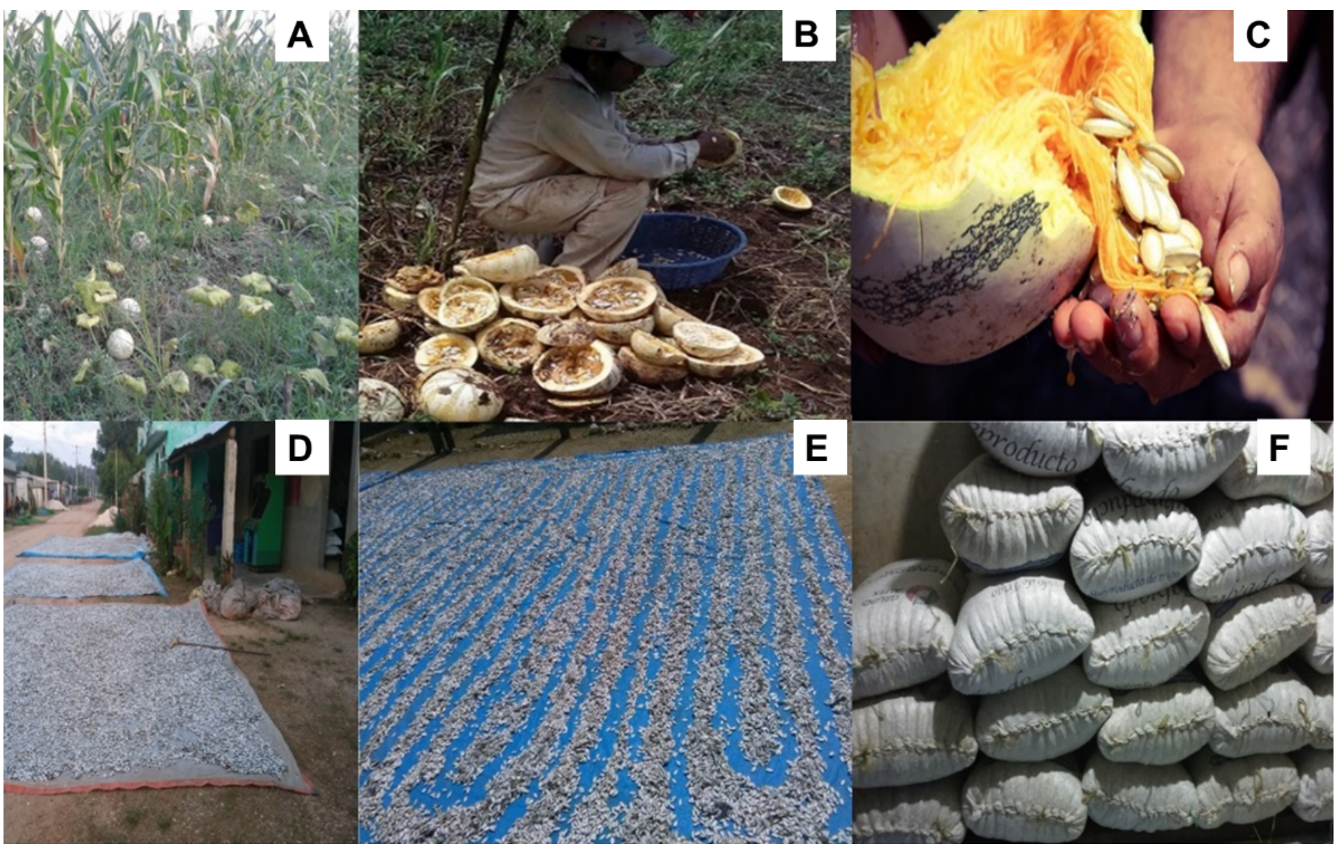

FIGURE 4. Seed selection and packaging process of *Cucurbita argyrosperma*: A) fruit harvest, B) manual seed extraction, C) manual seed selection, D) solar drying of seeds, E) final drying phase, and F) seed packing.

the remaining pulp or separate vain seeds. This activity is carried out in the same way by producers in Jesús Carranza, Veracruz (Ortiz-Timoteo *et al*., 2014). In contrast, in bean crops with squash in Yaxcabá, Yucatán, only 38% of producers select squash seed before sowing, while 62% do so at the time of harvest (Latournerie - Moreno *et al*., 2005). However, Rönicke *et al*. (2023) mention that the seeds used for planting are not improved varieties, so the crop has serious problems such as low germination percentage, low vigor, high heterogeneity in the size and shape of fruits, varying number and weight of seeds per fruit, and incidence of pests and diseases.

The cultivation of Chihua squash is mainly associated with the cultivation of corn. This association was recorded in 16.2% of the evaluated cases and demonstrates an efficient horizontal use of the plot. The incorporation of Chihua squash in the corn crops preserves the "milpa" traditional system (Ebel *et al*., 2017; Lira *et al*., 2016), a polyculture practice by agricultural peasants since pre-Columbian times to preserve the diversification in the systems (Gliessman, 1998; Morales Tapia & Guzmán Gómez, 1998).

TABLE 3. Main practices in land preparation for the sowing of *Cucurbita argyrosperma* in Champotón, Campeche, Mexico.

	Percentage of producers		
Practices	**G1**	**G2**	**G3**
Tracking	75	69	75
Plowing	67.8	68	75
Furrows	10.7	15	25
Use of agricultural calendar	11	11	14
Soil chemical analysis	14.3	10	12.5

G1, G2, and G3 – three groups of the plant production systems.

Other relay crops were also recorded, mainly corn (80%) and other species such as *Hibiscus sabdariffa, Arachis hypogaea*, and *Phaseolus vulgaris* (11%). In all the evaluated systems, agrochemicals are applied for pest control, disease management, weeds management, and fertilization. Only 9.56% of the interviewed producers mentioned carrying out preventive management to control pests and diseases through chromotropic traps.

The application of agrochemicals in the cultivation of Chihua squash is the most widely used technology in the region. It is generally carried out without any control, prevention, and adequate equipment and represents a high economic cost to the systems (Schiesari *et al*., 2013). In contrast, the use of agricultural irrigation in Chihua squash production systems is minimal, due to the high cost of installation and operation. This situation also occurs in the peasant agricultural systems in the Río Segundo basin, Argentina, where irrigation represents a costly investment and a financial risk that farmers are not willing to assume (Riera & Pereira, 2013).

About 9% of the interviewed producers had access to irrigation, while 91% stated that it is an inaccessible option due to the high cost of installation and limited access to wells. In all cases, the harvest is done manually, starting with the harvest, dividing the fruits, and extracting the seeds; due to their manual agility, mainly women and youth participate in this activity. About 29% of the producers mentioned keeping production records, a practice learned through training courses and technical assistance (13.23 and 11.03%, respectively). The technological index is the sum of the technologies adopted and adapted to the production systems (Borja-Bravo *et al*., 2016). The production systems in G3 recorded the highest technological index, due to use of technology irrigation systems. This trend coincides with that reported in small production agricultural systems (Ayala-Garay *et al*., 2013; Vilaboa-Arroniz *et al*., 2009).

Regarding the seed commercialization, a variation in sale price was recorded, ranging from USD 2.25 per seed kg at the beginning and USD 1.55 at the end of the season, which represents a 31% difference. These prices were set by buyers, including local, regional, and national collectors (Tab. 4). In the production systems evaluated, profitability did not improve with a greater sowing or a higher technological index. Additionally, it seems that the use of irrigation systems affects the profitability of the system, making irrigation an unsuitable technology for the cultivation of *C. argyrosperma* under the conditions of Champotón, Campeche.

TABLE 4. Main forms of commercialization of the *Cucurbita argyrosperma* production systems in Champotón, Campeche, Mexico.

Variable	Number of producers/%
Not identified	24/17.65
[1]In the community	4/2.94
[2]Internal collector	52/38.23
[3]External collector	45/33.09
[4]Intermediary	11/8.09
Total	136/100

[1]Sold to a neighbor who in turn takes it to the Campeche or Ciudad del Carmen market, [2]Sold to a neighbor who acts as an intermediary collector, [3]A person from another municipality or state (Champotón, Escárcega and Hopelchén belonging to Campeche or Yucatán, Veracruz, and Puebla), [4]A neighbor of another community of Champotón, Campeche, who resells it. Source: Authors, based on the data obtained in the interviews, 2016.

Conclusions

In the Champotón municipality, Campeche, three types of Chihua squash production systems are clearly differentiated by area of the plot, constituted organization, wages workforce, seed processing, purchase-sale agreement, income (USD ha^{-1}), profitability, and use of technologies. These differences determine three technological levels that in turn, affect the economic profitability of the systems. In this sense, the group with the highest technological index ranked second in profitability, so this variable does not improve by increasing the number of technologies used. Therefore, to increase the profitability of Chihua squash production systems, it is necessary to organize producers to receive technical advice that reduces production cost, manage financing, industrialize the seeds to increase their value and explore innovative and fair marketing channels.

Likewise, the results of the study showed that in rural systems some technologies suitable for industrialized systems, such as irrigation, do not have the same effect and can negatively impact the system. Similarly, within the family labor force, the participation of women is evident, contributing 25 to 50% of the labor, focused on the management of seeds after harvest. Therefore, future studies should encourage the participation of women in the different cultivation activities and promote fair compensation for their work.

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Conflict of interest statement

The authors declare that there is no conflict of interests regarding the publication of this article.

Author's contributions

Conceptualization: HCKC, BCM, and CFB; methodology: JCI; software and validation: SFC, VRM; writing-review and editing: JCI, BCM, CFB. All authors have read and approved the final version of the manuscript.

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