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Competitividad e innovación en la industria pulquera, un análisis económico Competitiveness and innovation in the *pulquera* industry, an economic analysis

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Resumen

Introducción: El maguey está estrechamente relacionado con las zonas marginadas de México y carece de procesos de innovación, se produce principalmente en Oaxaca para mezcal y en Hidalgo y Tlaxcala para pulque. El objetivo de este estudio fue valorar financieramente la industria pulquera a través de su diferenciación generando un proyecto de producción de aguamiel para jarabe de agave con respecto a un proyecto que únicamente produce pulque considerando la volatilidad de los precios en los estados de Hidalgo, Tlaxcala y Oaxaca. Como hipótesis se plantea que la incertidumbre crea oportunidades que agregan valor y benefician al productor.

Método: Se emplearon las estadísticas del SIAP 2005-2018 para precios y rendimientos. Los costos de producción e inversión se obtuvieron de la Organización Xamini S.P.R. de R. I. y se consideraron para los tres estados. Se analizó la posibilidad de innovar el proceso del pulque desde un punto de vista tradicional por medio del Valor Actual Neto (VAN); sin embargo, dado que éste no considera la volatilidad de los precios se empleó la evaluación mediante opciones reales con árboles binomiales y fórmulas de Black-Scholes con escenario de expansión.

Resultados: Hidalgo tuvo en promedio los mejores rendimientos y se posiciona como principal productor de esta bebida; empero, su tendencia fue a la baja. Oaxaca fue la entidad con mayor valor crítico (1.771) debido a que presentó mayor volatilidad en el precio, por tanto, el riesgo en la inversión es mayor. Mediante la evaluación tradicional, los proyectos en la industria del pulque de Hidalgo y Tlaxcala fueron aceptados con valores mayores a la unidad, no así para Oaxaca. Con la evaluación de opciones reales, una vez que se innova, el valor del proyecto para Hidalgo aumentó

seis veces comparado con el VAN tradicional y en Tlaxcala el incremento fue de 37 veces más, para Oaxaca los números se volvieron positivos pero no alcanzó a recuperar la inversión inicial; situación similar pasa cuando se da la opción de expandir la innovación a dos hectáreas.

Discusión o Conclusión: cuando se opta por diferenciar el producto como elaborar jarabe de agave, aumenta el riesgo pero también las posibilidades de incrementar sus ingresos y ser competitivos en el mercado, lo que sucede cuando se asocia el producto a las necesidades actuales del consumidor, esto aplica para Hidalgo y Tlaxcala; sin embargo, para Oaxaca, el proyecto de diferenciar la industria pulquera es poco viable asociado a que su producción es irrelevante comparado con mezcal. La hipótesis planteada en este estudio se confirma, si aumentan los beneficios al productor cuando se diferencia en su proceso de producción pese a la incertidumbre.

Palabras clave: maguey pulquero; jarabe de agave; valor actual neto; opciones reales; volatilidad; riesgos; incertidumbre

Abstract

Introduction: Maguey is closely related to the marginalized areas of Mexico and lacks innovation processes; it mainly produces in Oaxaca for Mezcal and the production of pulque in Hidalgo and Tlaxcala. The objective of this study was to financially assess the pulque industry through its differentiation, generating a mead production project for agave syrup with respect to a project that only produces pulque considering the price volatility in states of Hidalgo, Tlaxcala, and Oaxaca. The hypothesis is that uncertainty creates opportunities that add value and benefit the producer.

Method: Maguey pulquero prices and yields from 2005 to 2018 were obtained from SIAP. Production costs and investments were obtained from the Xamini S.P.R. of R. I. and were considered for the three states. The possibility of innovating pulque process from a traditional point of view through the Net Present Value (NPV) was analyzed; however, since it does not consider the price volatility, an evaluation was used using real options with binomial trees and Black-Scholes formulas with expansion scenarios to two hectares.

Results: Hidalgo had, on average, the best yields, and which positions him as the main producer of this drink; however, its trend was downward. Oaxaca was the entity with the highest critical value (1.771) because it presented greater price volatility; therefore, the risk in investment is higher. Through the traditional evaluation, the projects in the pulque industry of Hidalgo and Tlaxcala were accepted with values greater than unity, not so for Oaxaca. With the evaluation of real options,

once it is innovated, the project increased six times more for Hidalgo and Tlaxcala increased 37 times more. The numbers turned positive for Oaxaca, but it did not recover the investment initially; a similar situation occurs when the option is given to expanding the innovation to two hectares.

With the evaluation of real options, once it is innovated, the project increased six times more for Hidalgo and Tlaxcala increased 37 times more, for Oaxaca the numbers turned positive, but it was not able to recover the initial investment. A similar situation happens when the option is given to expand the innovation to two hectares.

Discussion or Conclusion: for a differentiated product such as agave syrup, the risk increases, but also the possibilities of increasing your income and being competitive in the market, which happens when the product is associated with the current needs of the consumer. This applies to Hidalgo and Tlaxcala, however, for Oaxaca, the project to differentiate the pulque industry is not very viable, since its production is irrelevant compared to mezcal. This study confirmed the hypothesis, when the product is differentiated in its production process, benefits increase, despite the uncertainty.

Keywords: maguey pulquero; agave syrup; net present value; real options; volatility; risks; uncertainty

Introduction

In order to respond to evolution to the demand and global dynamism, companies participate innovation and transformation processes, which drive their competitiveness and development, these are the pillars of business and national growth. (Zayas, 2018, p. 867)

Business is the basis of competitiveness itself, that defined as a process that allows the quality of life of the inhabitants of a country to be developed, in line with the productivity growth of its resources and which origins successful nation participation in the world scenario (Saavedra, 2012, p. 99).

Competitiveness is based on economic developments and market survival- based. Similarly, the knowledge of the different involved elements in the operation of companies and differentiation strategies development and value-added to the product or service are pillars in the competitiveness of companies, the above, giving them competitive advantage by submitting innovation systems that are hardly replicated by other companies (Ahumada and Perusquia, 2016, p. 131; Porter, 1985, p. 52). Thus, since Schumpeter (1967) innovation was already defined as the production of different objects (or the same) using different methods.

Londoño (2015, p. 205) points out that innovation strategies force economic units to reinvent themselves as a symptom of situations of social and economic change. In this order of ideas, Córdoba, Castillo, and Castillo (2018, p. 57) coincide in pointing out that companies with greater flexibility and resilience in the face of economic challenges are also those that continuously innovate and adapt more quickly to changes, suggest that the creativity and innovation are the binomial of economic growth.

Work on innovation in the agricultural sector has focused mainly argument on the use of technology. However, Aguilar-Gallegos *et al.* (2016, p. 198) point out that innovation involves updating and modernizing production techniques and products, and that agricultural innovation is the convergence of the willingness and participation of farmers, agro-industry, companies, researchers, financial institutions, retailers, and government. Therefore, innovation in the organization of work is not only modifies productive and economic activities but also the socio-cultural aspects of farmers.

The history of Mexico in its different times has the principal actor that is the common denominator: the agave or maguey, from the Greek "admirable" or "noble" of which there are approximately 150 species in Mexico and 200 in the American continent (Rodríguez, Martínez and Palomera, 2017, p. 73; Rojas, Viesca, Espeitx and Quintero, 2016, p. 1200). Among the agave species, the "maguey pulquero (*Agave salmiana* Otto ex Salm-Dyck)" is the main species for the production of pulque, a regional fermented beverage of Mexico of the heritage structure.

In Mexico, maguey is cultivated in 26 entities, most are focused in Oaxaca (23%) mainly for the mezcal production (Pérez, Chávez and González, 2016, p. 151), as for the production of pulque, the list is headed by Hidalgo (64%), and Tlaxcala, forming a geographical area in the center of the country in which the most representative *pulqueras* haciendas of the country converged during the colony (Rojas *et al.*, 2016, p. 1204; Narváez, Martínez and Jiménez, 2016, p. 34; Ramírez, 2017, Espíndola-Sostres, Trejo-Márquez, Lira-Vargas and Pascual-Bustamante, 2018, p. 523).

Maguey pulquero supports periods of drought and is easy to adapt to different climates and soils. It reaches up to two meters long and takes, on average, eight years to mature, at which time the mead that will be used for the production of pulque begins to be collected. Therefore, maguey is considered the fruit of the producer's dedication and patience (Valencia, Rojas, Alvarado and Duana, 2020, p. 20; Valadez, 2014, p. 45).

The pulque is highly associated to the marginalized areas of Mexico and the lack of technological processes; however, during the pre-Hispanic period, the beverage was intended only for elders and ritual ceremonies (Rojas and Viesca, 2017, p. 36). The smear campaigns experienced after the Porfiriato and the current policies have undermined its consumption and devalued the *pulquera* industry in this country (Narváez *et al.*, 2016, p. 34); in addition to these, the industrialization and emergence of other beverages have led to a decrease in their consumption, Rojas *et al.* (2016, p. 1203) indicate that the per capita consumption of the beverage during the first half of the 20th century was 22.4 L, while for the second half of the century the consumption was of 14.4 L, and, according to them. However, the current per capita consumption is unknown, its trend is to the decrease. However, Rojas-Rivas and Cuffia (2020) point out that this drink may have great potential in its consumption if it is valued in the market in its sensory characteristics and cultural aspects, mainly in the population of young consumers.

In the first decade of the 20th century, pulque contributed more than 25% of income in Mexico (Pérez-Zavala, Hernández-Arzaba, Bideshi y Barboza-Corona, 2020, p. 5328). Producing economic units of pulque continue to fall over time. In 2018, the Agro-Food and Fisheries Information Service (SIAP, 2018) reported a crop area of maguey pulquero of 8 230 ha, and a production of 172 413 thousand L, the growth rates of its production have decreased considerably. Physical and biological characteristics of agave have made it possible to detect the versatility of its uses, not only as food but also as raw material, for the production of utensils, fertilizer, textile, ornament, footwear, clothing, health, and beauty, as well as for the construction, and pulp of paper (Vázquez *et al.*, 2016, p. 69; Parra, Villar, and Prieto, 2010, p. 77; Rodríguez *et al.*, 2017, p. 73).

Espíndola-Sostres *et al.* (2018, p. 523) said that despite the high importance of maguey as raw material, "not all by-products have been used technologically"; evidence of this is the honey derived from maguey (agave syrup), which is made from dehydrated mead, also has functional properties to be antioxidant and prebiotic making it attractive both for consumers looking for healthy eating options and for the food industry and the pharmaceutical industry "as a substitute for fats, sugars, moisture retainer, and texture modifier" (Narváez *et al.*, 2016, p. 37; Sánchez, Concha, Prieto, and Carranza, 2016, p. 601). Agave fructans help lower glucose and cholesterol levels; and also help the excellent absorption of calcium in bones (Mellado and López, 2013, p. 234).

García and Rodríguez (2010, p. 10) establish that the innovations adoption index among maguey producers is relatively low, which make them uncompetitive; the majority occurs in the productive process: the selection of land, fertilization, and weed management, while sustainable land use, resource management, and value-added have minimum innovations. Salazar, Moreno, and Casas (2014, p. 233) report that innovation in the bacanora artisanal production, traditional liquor distilled from the agave, is achieved in changes made to techniques and/or materials that may contribute to the decrease of production and distribution costs.

Estrada, Vargas, and Antonio (2012, p. 34) indicate that the *pulquera* industry has seen hindered its growth. Hence, they suggest the innovation of marketing strategies to reposition among consumers tastes, especially among the youngest, mainly in the valorization of cultural and sensory characteristics (Rojas-Rivas y Cuffia, 2020, p. 8).

Álvarez-Duarte *et al.* (2018, p. 208) note that the innovation in the pulque production chain lies in three main aspects: improvement of crop, productive process, and add value to the final consumer; therefore, they highlight the idea to produce fructose syrup, inulin, pulque canned and bioethanol.

Most of the research that analyzes the innovation-competitiveness binomial in the *pulquera* industry is descriptive character and suggest as an innovation the mechanization of the processes for the elaboration of the pulque; under this perspective, this study's aim is to value a project of production of mead for agave syrup concerning a project that only produces pulque as part of a differentiation process for the *pulquera* industry considering the volatility of price in states of Hidalgo, Tlaxcala, and Oaxaca. The hypothesis is that uncertainty creates opportunities that add-value, and benefit the producer.

Method

The study was mainly conducted with the producer price and yield statistics of maguey pulquero the Agrifood and Fisheries Information Service (SIAP) for the period 2005-2018 of Hidalgo, Tlaxcala, and Oaxaca, which the entities that available information. The costs of production (labor, machinery hire, and organic fertilizers), initial investment (seedling and land), and agave syrup price were obtained from Xamini S.P.R. of R. I. Organization located in the State of Hidalgo, and these data are taken as reference data for the other federal entities.

Nominal producer prices were deflated with the Consumer Price Index (INPC) based 2018 = 100 reported by the National Institute of Statistics and Geography (INEGI, 2019). The formula for calculating real prices is:

$$PR = \left(\frac{PN}{INPC} \right) * 100$$

Where: **PR** = real price (MXN\$t-1), **PN** = nominal price (MXN\$t-1); **INPC** = Consumer Price Index.

Traditional assessment

One of the most frequently used methods in project evaluation is the Net Present Value (NPV) which deals with "how much the value of a company is expected to increase if it carries out the project". It consists in estimating the benefits and costs to reach the cash flow that is updated to period zero with the estimated discount rate, the positive result of its calculation implies the acceptance of the project (Vedovoto and Prior, 2015, p. 150). The formula for NPV estimation is defined as:

$$VAN = -A + \sum_{j=1}^N \frac{FC_j}{(1+k)^j}$$

Where: **A** = initial investment of the project, **FC_j** = expected net cash flows, **k** = discount rate appropriate to project risk or opportunity cost (5% for this project) and **n** = project time horizon (Valencia and Zetina, 2016, p. 238). Cost-benefit calculation was obtained by means of formula:

$$B/C = \frac{\sum_{t=1}^T B_t(1+r)^t}{\sum_{t=1}^T C_t(1+r)^t}$$

Where: **t** = years of the life of the project, **B** = updated benefits, **C** = updated costs, **r** = interest rate (Valencia-Sandoval, Brambila-Paz, and Mora-Flores, 2009, p. 957). To be considered attractive to invest in the project, the result of the ratio must be greater than the unit (Franco, Bobadilla, and Rebollar, 2014, p. 960).

Assessment with real options

Traditional assessment of the financial viability of a project determines its profitability. However, they can only be used for short-term projects that are characterized by not considering price volatility scenarios, while the financial assessment using real options considers that during the life of the project circumstances may change, so management may decide to continue with the project, to extend it, to reduce it or to abandon it (Álvarez, López, and Venegas, 2012, p. 128).

The combination of research and development (R&D) in the agricultural sector from the perspective of innovation means some investment uncertainty that is not easily measurable with traditional evaluation. Therefore, real options are instruments that consider the flexibility and risk of these types of projects; even if the NPV was positive it is not an indication to start now but that it might be worth waiting to know the market situation (Vedovoto and Prior, 2015, p. 148).

The risk and volatility faced by agricultural projects must be calculated for both the real price and the quantity produced (Brambila, Martínez, Rojas and Pérez, 2013, p. 285). To be incorporated into the evaluation, the first step was to calculate the continuous growth rates of the real prices, which algebraically expressed as:

$$r_t = \ln \left(\frac{P_t}{P_{t-1}} \right)$$

Where: r_t = continuous real price growth rate in year t, \ln = natural logarithm, P_t = real price in year t y, P_{t-1} = real price in year t-1. For the results obtained at this point, the average was estimated as the average trend of real prices, the standard deviation as a measure of price risk and variance as a measure of volatility.

$$\sigma = \sqrt{\sigma^2} = \sqrt{\frac{\sum_{i=1}^T (r_t - \alpha)^2}{t - 1}}$$

Where: α = average continuous rate of real price, σ = standard deviation, t = number of periods (Cadeza, Brambila, Chalita and González, 2017, p. 539).

The critical value (v^*) was calculated for each product, which is the yield required to accept a project under volatility scenarios. It means the minimum required by the project for each peso

invested, without loss, I = initial investment of the project. The formula for estimating the critical value is:

$$v^* = \frac{\beta}{\beta - 1} I$$

The value of β is determined by Bellman equation, Ito's Lemma and Brownian motion (Dixit y Pindyck, 1994, p. 135-152):

$$\beta = \frac{-\left(\alpha - \frac{1}{2}\sigma^2\right) + \sqrt{\left(\alpha - \frac{1}{2}\sigma^2\right)^2 - 4\left(\frac{1}{2}\sigma^2\right)(-\rho)}}{\sigma^2}$$

The formula is formed by the average continuous rate of real income (α), its variance (σ^2), and the discount rate (for this case $\rho = 5\%$) (Valencia *et al.*, 2020, p. 21). The real income was estimated with the real price and yield.

Once the NPV of the Project and standard deviation continuous rate of real prices as a measure of risk was obtained, it began with the elaboration of binomial trees that allowed to quantify the right, but not the obligation to exercise an option over the life of the project (Cadeza *et al.*, 2017, p. 540). It was considered to evaluate the option of *pulquera* industry to invest not only in the product that its name indicates, but also in the differentiation to obtain agave syrup.

The binomial method or binomial tree offers a realistic overview in a period time with different options of variability in the process, in each interval have the option to go up (scenarios when the project is going favorably) ($UP = e\sigma$) and go down (when the project is counterproductive) ($DOWN = e-\sigma$), building as nodes of binary tree. It shows in **Fig. 1** (Brach, 2003, Vedovoto and Prior, 2015, p. 152).

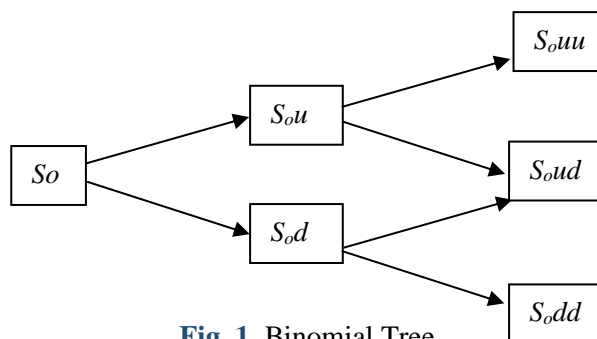


Fig. 1. Binomial Tree.

Where: **So** = present value of the cash flow; **u** = increase coefficient, multiplicative factor, UP; **d** = decrease coefficient, multiplicative factor, DOWN.

Formed the binomial method begins the backward induction; that is, the data are calculated at present value from right to left until reaching the value of the real option to consider the innovation and differentiation of the *pulquera* industry with the production of agave syrup, using the following formula:

$$Vp_a = \frac{pV_b + (1-p)V_c}{1+r}$$

Where: **Vpa** = initial cash flow, **p** = probability that the value of the project increases, **Vb** = superior node value, (1-p) = probability that the value of the project decreases, **Vc** = lower node value and **r** = risk-free real rate (r = 5%) (Valencia *et al.*, 2010, p. 958).

The real options complement the traditional assessment in risk and uncertainty scenarios so that the sum of the NPV and the real option value allows to obtain the total net present value (Forcael, Andalaft, Schovelin and Vargas, 2013, p. 62; Cadeza *et al.*, 2017, p. 541):

$$VAN_{TOTAL} = NPV + VOR$$

Where: **NPV** = traditional net present value, **VOR** = real option value, and **VAN_{TOTAL}** = sum of both once the project has been differentiated.

As mentioned, with the binomial trees, the right was quantified but not the obligation to exercise an option during the development of the project, then it was considered to identify what happens if the producer decides to extend its production to two hectares, Black-Scholes options were used in which with expansion scenarios of two hectares, the producer has the right to buy (call option) or sell (put option) (Isaza and Botero, 2013, p. 398).

The call option was calculated as follows:

$$C = SN(d_1) - Ke^{rt}N(d_2)$$

Meanwhile, the put option was identified as:

$$P = Ke^{-rt}N(-d_2) - SN(-d_1)$$

Where: **C** = put real option value, call, **P** = put real option price, **S** = initial value of the project, **K** = initial investment, **r** = continuous risk-free rate ($r = \ln(1+0.05)$), **t** = standard time for exercise the share (8 years), if appropriate; and $N(d_1)$ and $N(d_2)$ are the values of the standardized normal distribution function (Brambila, 2011, p. 312).

Results

In connection to the price paid to the pulque producers in each entity, **Table 1** shows that in Tlaxcala the average rural price was the highest (\$5.51/L); however, its trend has decreased, meanwhile, in Oaxaca the price only reached the onerous amount of \$2.10/L, but the trend is upward. Similar situation in terms of yield, Hidalgo had, on average, the best yields (114.29 L ha⁻¹), which positions it as the leading producer of this beverage; however, his trend is going down (-0.035).

Table 1. Trend of real rural average price and yield, 2005-2018.

Tabla 1. Tendencia del precio medio rural real y el rendimiento, 2005-2018.

| Entity | Real rural average price (MXN\$ L) | Trend of real rural average price | Average yield (1000 L ha ⁻¹) | Trend of average real |
|----------|------------------------------------|-----------------------------------|--|-----------------------|
| Hidalgo | 4.65 | 0.035 | 114.29 | - 0.035 |
| Tlaxcala | 5.51 | - 0.067 | 65.56 | 0.014 |
| Oaxaca | 2.10 | 0.183 | 61.83 | 0.001 |

Álvarez-Duarte *et al.* (2018, p. 208) mention that among the *pulquera* regions discouragement and change of land use predominates. In addition, they emphasize the decrease in beverage consumption, leaving to be the economically dominant activity in the region and becoming a traditional activity. The results of **Table 2** are consistent with the authors said, the real income of Tlaxcala and Oaxaca had a negative trend, and Hidalgo reached a minimal positive trend (0.0002) that congruently has the least volatility in the revenues derived from the pulque (0.025). On the other hand, Oaxaca was the entity with the highest critical value (1.771) because it presented greater volatility in the price; therefore, the risk in the investment is higher.

Table 2. Real income trend and critical value
Tabla 2. Tendencia del ingreso real y el valor crítico

| Entity | Trend of real income (α) | Volatility of real income (σ^2) | β | Critical value (v^*) |
|----------|--------------------------------------|---|---------|-----------------------------|
| Hidalgo | 0.0002 | 0.025 | 2.533 | 1.652 |
| Tlaxcala | - 0.0537 | 0.108 | 2.381 | 1.724 |
| Oaxaca | - 0.0007 | 0.035 | 2.296 | 1.771 |

Whereas the investment and the fixed and variable costs in the system of production of maguey pulquero through the traditional evaluation, the projects in the pulque industry of Hidalgo and Tlaxcala were accepted with values higher than the unit, these results are similar to the differentiation of maguey made by Franco *et al.* (2014). However, the situation is different for Oaxaca whose cost-benefit was just 0.50 because it had zero growth in yield and a low price which would make it unattractive for production. Besides, in this state, the pulquero agave does not figure as the mezcalero agave (Consejo Regulador Mezcal - CRM, 2020) and the largest production of this crop is with a family and artisanal structure (Blas-Yanez *et al.*, 2018) (**Table 3**).

Table 3. Cost-benefit with traditional evaluation (MXN \$)
Tabla 3. Beneficio costo con evaluación tradicional (MXN \$)

| Entity | Investment (I) | Cost (C) | Benefit (B) | Relation B/C+I |
|----------|---------------------------|---------------------------|----------------------------|----------------|
| Hidalgo | 138 095.24 (US\$6 128.25) | 119 426.35 (US\$5 299.78) | 531 154.52 (US\$23 571.04) | 2.06 |
| Tlaxcala | 138,095.24 (US\$6 128.25) | 119,426.35 (US\$5 299.78) | 361,194.67 (US\$16 028.73) | 1.40 |
| Oaxaca | 138,095.24 (US\$6 128.25) | 119,426.35 (US\$5 299.78) | 129,787.16 (US\$5 759.56) | 0.50 |

The construction of binomial trees required introducing the mead price risk, and thereby define when prices present a favorable scenario (UP) or an adverse scenario (DOWN). In **Table 4**, it can be seen that Hidalgo is the entity that presented the highest probability that product prices will rise, given that it has less risk in its prices. For its part, Oaxaca showed the highest differentiation rate because the mead price is lower concerning the agave syrup price (\$120.00/L).

Table 4. Differentiation rate, up, down, and probabilities for obtaining the binomial trees
Tabla 4. Tasa de diferenciación, up, down y probabilidades para la obtención de los árboles binomiales.

| Entity | Differentiation rate† | UP | DOWN | p |
|----------|-----------------------|-------|-------|-------|
| Hidalgo | 2.58 | 1.111 | 0.899 | 0.710 |
| Tlaxcala | 2.18 | 1.307 | 0.765 | 0.526 |
| Oaxaca | 5.72 | 1.201 | 0.833 | 0.590 |

†The differentiation rate corresponds to the relationship between the income of agave syrup the mead's income to elaborate pulque.

†La tasa de diferenciación corresponde a la relación entre el ingreso de jarabe de agave con respecto al ingreso del aguamiel para elaborar pulque.

The NPV of the project, when the maguey is only traditionally destined to pulque, it was positive for Hidalgo and Tlaxcala. In parallel once the project is innovated by producing agave syrup, the value with real options increases, in the case of Hidalgo, the traditional VAN was \$137 667.25 (US\$6 109.26), and with innovation in its process the total value amounted to \$849 688.44 (US\$37 706.62), that is, the benefit was six times more with the differentiated product, and for Tlaxcala, it was 37 times more. Narvaez *et al.* (2016, p. 44) conclude that the production of maguey pulquero is economically feasible if it is used in a full use, including agave syrup (**Table 5**).

Table 5. Traditional Net Present Value (NPV) and with real options (MXN \$).

Tabla 5. Valor Actual Neto (VAN) tradicional y con opciones reales (MXN \$).

| Entity | Tradicional NPV | VAN TOTAL | Real Option Value (VOR) |
|----------|-----------------|------------------|-------------------------|
| | 137 667.25 | 849 688.44 | 712 021.2 |
| Hidalgo | (US\$6 109.26) | (US\$37 706.62) | (US\$31 597.36) |
| | 22 631.73 | 836 782.17 | 814 150.45 |
| Tlaxcala | (US\$1 004.33) | (US\$37 133.88) | (US\$36 129.55) |
| | -133 994.00 | -101 051.8 | 32 942.136 |
| Oaxaca | (US\$5 946.25) | (US\$ -4 484.38) | (US\$1 461.87) |

Keeping in mind the option of expanding the production to two hectares, the prices of Put and Call were calculated; the latter was considered for the calculation of the profit-cost considering that it is the option but not the obligation to sell. Table 6 shows that with the use of binomial trees, the benefit-cost ratio for Hidalgo is 4.83 and with Call is 2.33, higher values than when a traditional evaluation is made when considering a differentiation (**Table 3**), the relationship for Tlaxcala increases in the same sense above the three points with the use of binomial trees, with the Black-Scholes formulas increases in a smaller scale; however, it is greater than with the traditional evaluation.

The situation for Oaxaca differs from its peers, since although in both cases the valuation increases, this increase is minimal, which can be explained despite the large percentage of agave maguey species, its production is mainly focused on mezcal and to a lesser extent on pulque, the results agree with Pérez *et al.* (2016).

Table 6. Put and Call options, profit - cost of real options and Black Scholes
Tabla 6. Opciones Put y Call, beneficio – costo de opciones reales y Black Scholes

| Entity | Put | Call | B+VOP/C+I | B+Call/C+I |
|----------|----------------------------|-----------------------------|-----------|------------|
| Hidalgo | 17 394.3 (US\$771.91) | 69 310.4 (US\$3 075.79) | 4.83 | 2.33 |
| Tlaxcala | 52 702.3 (US\$2 338.77) | 104 618.4 (US\$4 642.65) | 4.56 | 1.81 |
| Oaxaca | 22 799.4 (US\$1 011.77) | 74 715.5 (US\$3 315.65) | 0.63 | 0.79 |

Discussion or Conclusions

The real options based on binomial trees and Black-Scholes formulas are an analysis tool that complements the traditional evaluation of projects, by incorporating the risk and uncertainty derived from innovation as a natural part of the process, which adds value and differentiation to the project. The literature on its use is still incipient, especially in agricultural products, focusing mainly on NPV and IRR as references for making decisions.

The maguey pulquero and pulque production have been unattractive to investors despite its great potential as a functional food due to its low prices, which leads to a low profit in the project. However, when one chooses to differentiate the product, such as making agave syrup, the risk increases but also the possibilities of increasing their income and being competitive in the market, which happens when the product is associated with the current needs of the consumer. This applies to Hidalgo and Tlaxcala; however, for Oaxaca, the project to differentiate the *pulquera* industry is not very viable because its production is irrelevant compared to mezcal. The hypothesis presented in this study is confirmed, whether the benefits to the producer increase when the product is differentiated in its production process despite the uncertainty.

One limitation of this study is that due to no economic information for agave syrup production in the states of Tlaxcala and Oaxaca, the information of the Organización Xamini S.P.R. of R. I of the State of Hidalgo was used as reference.

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