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Economic Efficiency of Fish Hatcheries in Fayoum Governorate: Data Envelopment Analysis Model (DEA)

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ABSTRACT

This research aims at measuring the economic efficiency of fish hatcheries in Fayoum governorate, where a primary data of five licensed operating fish hatcheries was used to achieve this aim. Results revealed that economic efficiency in case of a constant return to scale was totally achieved in the first hatchery, while it was also high in both the second and fifth hatcheries by about 95% and 99%, respectively. The least efficient hatcheries were the third and the fourth hatcheries with an efficiency of about 89% and 82% respectively. Therefore there is a need to increase production in both hatcheries by 11% and 18% respectively to reach the optimum size. The economic efficiency in the case of a variable return to scale was estimated too, where efficiency index was one in the first, fourth, and fifth hatcheries, while the economic efficiency was also high in both the second and the third hatcheries by about 95% and 90% respectively. Fish hatcheries in Fayoum governorate suffer from various problems such as, decreased quantities of agricultural drainage water received, marketing inabilities of fish hatcheries' owners, weak financing capacity of fish hatcheries' holders, difficult licensing procedures, and high prices of production inputs used in fish hatching process. The study recommends expanding the establishment of fish hatcheries in the Fayoum governorate, as they produce the basic core of fish farming, which is the fry, with an emphasize on the need to overcome the problems and obstacles it faces.

KEYWORDS: Economic Efficiency, Fish Hatcheries, Data Envelopment Analysis (DEA).

1. INTRODUCTION

Developing fisheries and aquaculture in Egypt is one of the important pillars to increase the average per capita of animal protein in general and fish protein in particular. The importance of fisheries is increasing in Egypt, where the contribution of fish production's value to the total value of agricultural production has risen to 48.25 billion pounds, representing about 9.43% of the agricultural income, and the amount of fish production from fish farms is estimated at 1.56 million tons, representing about 80.79% of the total amount of Egyptian fish production in 2018 (GAFRD, 2018).

The average area of fish farms in Fayoum Governorate is estimated about 2.82 acres (GAFRD, 2018), producing around 15.75 tons and represented 1.1% of the total production of private farms in Egypt in 2018. Fish farms help to balance the marketing season and supply, and to determine the quantity and quality according to consumer preferences and market requirements through fish farmers' control over the quantity produced whether of types or sizes (Arafa and Hammam, 2015), and thus overcoming the problems of marketing and storage.

Fish farms also contribute to the national economy by achieving fish self-sufficiency and providing job opportunities directly and indirectly, which highlights the importance of providing fish Fry due to the increasing importance of fish farming as one of the most fundamental sources of fish production in Egypt, as it contributes of 80% of the annual fish production (GAFRD, 2018), not only that, but the trends are increasing towards intensive fish farming with high amounts of Fry per unit area (Gaber and Hegazy, 2015).

Fish Fry are available in Egypt from two sources, the first one is the collection of marine fish Fry from natural sources where it contributed of about 45.5%, represented about 14.33% of the volume of Fry available in 2018, this source faces many obstacles, such as natural and environmental factors that are difficult to control, in addition to the fact that increased fishing of it poses a threat to fish stocks and thus to fish production (Fayed et al., 2018). The second source is the artificial spawning, where it is

highly needed, whether from governmental hatcheries, which produce about 179.5 million units of Fry and representing about 56.54%, or from private hatcheries, which produce about 92.5 million units of tilapia fish Fry and represents about 29.1% of the total production of tilapia Fry in Egypt of the licensed hatcheries, in addition to the unlicensed hatcheries which often produce more than these numbers of tilapia Fry.

In Fayoum Governorate, there are twelve fish hatcheries producing tilapia Fry, where all are private ones, of which only five hatcheries are currently operating, with a total Fry production of about 30 million units, offset by a number of obstacles such as low water quality which caused the suspension of the rest of the hatcheries (field data, 2020).

Fayoum Governorate is considered one of the fish-producing governorates due to the presence of Qarun and Wadi El Rayan lakes, moreover, the spread of fish farms which derives an increased demand for Fry and fingerlings, as it is the mainstay for the development of fish farming.

In light of developing spawning process from a random method that has a low productive efficiency to other patterns such as *"Habbat"*[1] that has its good productive efficiency, moreover, the suspension of a large number of hatcheries due to the deterioration of the aquatic environment conditions, it is necessary to study the economic efficiency of the current licensed operating hatcheries in Fayoum Governorate.

The research aims at analyzing costs and revenues structure of fish hatcheries in Fayoum Governorate, moreover, measuring its economic efficiency.

2. MATERIALS AND METHODS

Both primary and secondary data were used in the study, the primary data from five licensed operating fish hatcheries in Fayoum Governorate was collected through a structured questionnaire, where the secondary data was collected from various sources such as the General Authority for Fish Resources, the annual statistical book of the Central Agency for Public Mobilization and Statistics, and data of previous studies related to the topic.

Data envelopment analysis model (DEA) was used to measure the economic efficiency of fish hatcheries operating in the governorate, where, efficiency has been used as an indicator to measure the performance of a production unit in utilizing its available and scarce resources to achieve the best level of output. With regard to efficiency, a distinction must be made between four types of efficiency as follows (Al-Mohammad et al., 2018).

- Technical efficiency: It is intended to convert production inputs such as labor and capital into outputs with the best performance.
- Distributive efficiency: It means using the inputs in the correct proportions, at a certain level of prices, to produce a certain level of outputs.
- Economic efficiency: it means the production of the economic unit for a certain level of production at the lowest level of costs. Economic efficiency is the result of multiplying technical efficiency by distributive efficiency.
- Scale efficiency: It means that the production unit operates at increased, constant or decreasing volume yields. If the inputs are increased by a known percentage, the production will be increased by the same or greater or lesser percentage, respectively. The volumetric efficiencies provide quantitative information about the properties of volume.

Efficiency is measured in two ways, either by using parametric methods such as regression analysis, or by using non-parametric methods such as data envelopment analysis (DEA), where the concept of data envelope analysis is based on (Farrell, 1957), and the efficiency indicators for the five hatcheries were measured based on data envelope analysis in both cases: constant return to scale (CRS) and variable return to scale (VRS).

Figure (1) shows the estimation of economic efficiency according to concept of production, where it is assumed that there are two outputs (y1, y2) that are produced using a productive resource X. Assuming that the return on capacity is constant, the transfer curve (zz) can be expressed and point A expresses that the combination of the two commodities be inefficient, as this combination lies below the range of this curve. According to Farrell's concept of estimating efficiency, as shown in Figure (1), the distance AB represents technical inefficiency of enterprise, as it expresses the amount of increase in production that can be achieved without increasing the resources used in the production process, and therefore the estimation of technical efficiency can be expressed as follows (AlDamman and Alhaj, 2017):

TE= 0A/0B

Given the price of the productive resource used, it is possible to estimate the Iso-Cost that touches the transfer curve, and thus the distributional efficiency

[1] *Habbat*: A five-dimensional net hedges (bottom and four walls) with openings that only allow water to pass through (fish female and male are placed in during the mating and breeding period).

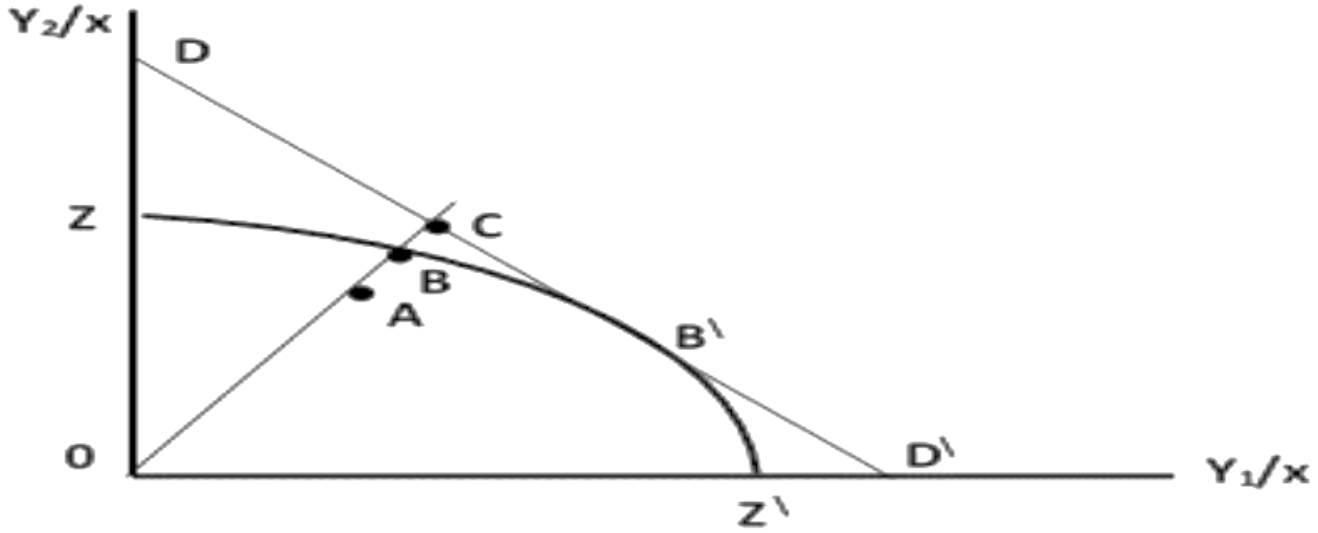

Figure 1. Economic efficiency according to the concept of production outputs

can be estimated as follows (Førsund and Sarafoglou, 2002):

AE= 0B/0C

The distributional efficiency according to the concept of production inputs assumes the reduction of production costs without the production itself, while in the case of estimating the distributive efficiency according to the concept of outputs or the final product, we assume that production will increase by using the same amount of resource (costs), and this can estimate the economic efficiency (total EE) of the enterprise as multiply of a coefficient of technical and distributive efficiency as follows:

EE= TE*AE= (0A/0B*0A/0B) = 0A/0C

3. RESULS AND DISCUSSION

3.1. Cost of establishing hatcheries and its life span:

Production costs are defined as the sum of the inputs' values that have been depleted in the production process in a certain period of time (Tawfiq, 1987), whether these values were paid or estimated, which expresses the nature of the relationship between the value of total costs as a dependent variable and the quantity produced from Fry as an independent variable, assuming that other factors affecting the production are held constant.

As indicated in table (1), the cost of establishing fish hatcheries in Fayoum governorate, which all operate in the type of "*Habbat*" (they are similar to each other in capacity and area), including the total average investment and operating costs amounted to 168.93 thousand pounds per hatchery where the average life span of "*Habbat*" is 5 years. The total average investment costs amounted to 57.65 thousand pound per hatchery, where the average cost of "*Habbat*" was 21 thousand pound represents 36.5% of the total investment costs, while the average cost of purchasing Females and Males is 19.5 thousand pound, representing 33.8% of the total investment costs, followed by the cost of constructing workers' housing, and the purchase price of wooden posts, irrigation machine, nets, barrels, refineries and buckets, at a cost of 7000, 3750, 3500, 2000, 500, 400 pounds, representing 12.1%, 6.5%, 6%, 3.5%, 0.9%, 0.7%, respectively.

The average operating (variable) costs of fish hatcheries in Fayoum, including the wages of labor that occupy the largest percentage of about 41.3%, with a total cost of 46 thousand pounds. It was also found that the costs of feeding Females and Fry amounted to 28 thousand pounds and representing 25.2% of the total variable costs, while the opportunity cost of the land amounted to 20 thousand pound and representing 18% of the total operating costs. The cost of purchasing hormone used to produce (single-sex) Fry amounted to 7.5 thousand pound and representing 6.7%, while the cost of energy (fuel and electricity) amounted to 7,000 pounds and representing 6.3% of the total operating costs, followed by the costs of oxygen cylinders, plastic bags, salts and vitamins at a cost of about 0.3, 0.2, 0.2% respectively.

Table 1. Relative importance of average investment and operating costs of licensed operating fish hatcheries operating in Fayoum governorate 2020

Items of investment costs	Average of investment costs	Life span in years	% of total average investment costs
"*Habbat*"*	21000	5	36.5
Workers housing	7000	15-20	12.1
Irrigation machine	3500	7-10	6
Net	2000	6	3.5
Wooden rolls	3750	8	6.5
Strainers and buckets	400	1	0.7
Drums	500	5	0.8
The price of Females and Males	19500	2-3	33.8
Total average investment costs	57650		100
Items of operating costs	**Average of operating costs**		**% of total average operating costs**
Energy (fuel and electricity)	7000		6.3
Workers' wages	46000		41.3
Feeding mothers, males and Fry	28000		25.2
Oxygen cylinders	350		0.3
The opportunity cost of land	20000		18
Larvae packages (bags)	250		0.2
Disinfection and maintenance of ponds	2000		1.8
Additives (vitamins and salts)	180		0.2
Hormone	7500		6.7
Total average operating costs	111280		100
Total average costs		168930	

Source: Calculated from the primary data of the research sample/ year 2020

3.2. Total and Net revenues of fish hatcheries:

As shown in table (2), the average amount of Fry produced from one hatchery is about 6 million of Fry/ year, while the average price of a thousand Fry is about 34.75 pounds, and the total value of the sale of Fry amounted to about 203.5 pounds/ year, in addition to and including the selling value of Females and Males of fish, which amounts to about 5000 pounds (Males and Females of fish that are dispensed within the process of hatching), and therefore the total annual revenue from the hatchery is 208.5 thousand pound, and the average net revenue for the hatcheries of the study sample amounted to 39.57 thousand pounds/ hatchery/ season.

Table 2. Total and net revenues of Fry's production from licensed operating fish hatcheries in Fayoum governorate in 2020

Item	Unit	Value
Number of Fry	Fry/ year/ hatchery	6 million
Value of Fry	Pound	203500
Males and Females' selling value	Pound	5000
Total costs	Pound	168930
Total revenues	Pound	208500
Net revenues	Pound	39570

Source: Calculated from the primary data of the research sample/ year 2020

3.3. Economic efficiency of fish hatcheries operating in Fayoum governorate:

3.3.1. Estimation of Economic Efficiency:

In order to estimate the economic efficiency of fish hatcheries, the study relied on the cost and revenues data for each hatchery, in the case of a constant return to scale (CRS) and in the case of a Variable Return to Scale (VRS), as shown in table (4).

3.3.2. In case of constant return to scale (CRS):

As illustrated in table (4), the economic efficiency in case of a constant return to scale for cost of hatcheries, is amounted one for the first hatchery, which means that the relative efficiency was achieved in that hatchery, in other words, it means also that all available inputs were used in the best possible way to achieve the outputs and thus the volume yield is constant, thus, there is no need to increase the current cost of production and this level of cost must be maintained.

Table 3. Total cost and revenues for hatcheries licensed operating in Fayoum governorate in 2020

hatchery	Investments cost	Operating (variable) cost	Total cost	Total revenues
hatchery 1	71400	130350	201750	280000
hatchery 2	54370	123200	177570	202500
hatchery 3	55300	109070	164370	195000
hatchery 4	57380	95710	153090	170000
hatchery 5	49800	98070	147870	195000
Average	57650	111280	168930	208500

Source: Calculated from the primary data of the research sample/ year 2020

Table 4. Relative economic efficiency index according to CRS and VRS models for cost of production in hatcheries

Hatcheries	Constant return to scale Model (CRS)		Variable Return to Scale Model (VRS)		Scale Yield	Scale Efficiency
	Efficiency Index for (CRS)	Degree of inefficiency	Efficiency Index for (VRS)	Degree of inefficiency		
hatchery 1	1	0	1	0	constant	1
hatchery 2	0.949	0.050	0.951	0.049	increasing	0.998
hatchery 3	0.899	0.100	0.901	0.099	increasing	0.998
hatchery 4	0.826	0.173	1	0	increasing	0.826
hatchery 5	0.998	0.002	1	0	increasing	0.998

*Scale Efficiency = CRS / VRS
Source: Based on XL DEA output.

While the economic efficiency was also high in both the second and fifth the hatchery by about 95% and 99%, respectively, and therefore the full efficiency was not achieved, because (the efficiency index is less than 1), however, the volume yield is increasing, so there is a need to increase production size in both hatcheries by 5% and 1% respectively in order to reach the optimum size. The least efficient hatcheries are the third and the fourth hatchery with an efficiency of about 89% and 82% respectively, and the volume yield is increasing, therefore there is a need to increase production in both hatcheries by 11%, 18% respectively to reach the optimum size.

3.3.3. In case of a variable return to scale (VRS):

The economic efficiency in the case of a variable return to scale (VRS) for cost of hatcheries was estimated, where the efficiency index is one in the first, fourth, and fifth hatchery, which means achieving the relative efficiency, in other words, it means that all inputs were exploited in the best way to achieve the outputs, and thus the volume yield is constant, thus, there is no need to increase the current cost of production, where the current level of cost must be maintained.

While the economic efficiency was also high in both the second and the third hatchery by about 95%

and 90% respectively and therefore the full efficiency was not achieved, because (the efficiency index is less than 1), however, the volume yield is increasing, so there is a need to increase production in both hatcheries by 5% and 10% respectively to reach the optimum size.

3.3.4. Scale efficiency of the production stage:

Dividing technical efficiency of constant return to scale (CRS) on technical efficiency of Variable Return to Scale (VRS), the scale efficiency of the five hatcheries is obtained. As it is obtained from the results of data envelopment analysis that the scale efficiency of the fourth hatchery is about 83%, this means that the hatchery must increase its production volume by 17% to reach the optimum use, while the scale efficiency of the rest hatcheries reached to about 99.9%, or nearly 100%, which means that they achieve the optimal utilization of the cost production.

3.4. Problems facing fish hatcheries in Fayoum governorate:

According to fish hatcheries' owners in the study sample in Fayoum Governorate, fish hatcheries suffer from various problems, which the most important can be listed as follows:

- Decreased quantities of agricultural drainage water received by fish farms area in Fayoum governorate as a result of its intensive use in new lands using pumping stations from the main drains (Al-wadi and Al-Batus), moreover, the increase in harmful waste as well.
- The marketing inabilities of fish hatcheries' owners.
- The weak financing capacity of fish hatcheries holders to finance their production, in addition to the high value of taxes on fish farms at the start of construction.
- Difficult licensing procedures of hatcheries due to complicated technical and environmental requirements, multiplicity of administrative and supervisory authorities, and length of period required to obtain a license to start the activity, which make farmers working without a license and increase tax evasion.
- High prices of production inputs used in fish hatching such as (hormone, fodder and concentrates) due to its unavailability in the local market.

3.5. Suggestions to overcome the current problems of fish hatcheries in Fayoum governorate:

- Establishing new fish hatcheries for new species such as Sea bass and sea bream which bear salinity and is of great economic value compared to tilapia.
- Providing appropriate funding resources for hatcheries' owners, and a governmental support for fish farming such as tax exemption, moreover, providing them with marketing training to market their production with suitable prices.
- Facilitating licensing procedures of fish hatcheries in a way that does not harm the environment.
- Encouraging the locally produced inputs needed for hatcheries or/ and exempting these inputs from customs duties, which will contribute to reducing their prices.

4. CONCLUSION

Fish hatcheries are considered to be the basic core of fish farming in Fayoum governorate. There are twelve fish hatcheries in Fayoum Governorate producing tilapia fry, of which they are all private, where only five are currently operating, with a total fry production of about 30 million units, offset by a number of obstacles such as low quality of water that obliged the rest of the hatcheries to stop its production. The economic efficiency in the five hatcheries is almost achieved; however, they are suffering from various problems such as, decreased quantities of agricultural drainage water received, weak financing capacity and marketing skills of fish hatcheries' holders, difficult licensing procedures, and high prices of production inputs used in fish hatching process, which need intervention to solve these problems in order to preserve this vital sector in the governorate that is qualified to cover the fish gap in all of Egypt.

5. REFERENCES

AlDamman EZ, Alhaj AZ (2017). Estimation of the Efficiency of Sheep Breeding Lines in AlKarim Research Center using the Data Envelope Analysis (DEA). Assiut J. Agric. Sci., 48 (5): 76-85.

Al-Mohammad et al. (2018). The Technical Effciency of Cotton Crop Production of Field Schools Farmers in Idleb Governorate. Syrian Journal of Agricultural Research, 5 (2): 70 - 81.

Farrell M (1957). The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society. Series A (General), 120* (3): 253-290.

Fayed et al. (2018). Economic Study of Fish Hatchery Patterns at Kafr El Sheikh Governorate. The Egyptian Journal of Agricultural Economics, 28 (4): 1737-1752.

Førsund FR, Sarafoglou N (2002). On the Origins of Data Envelopment Analysis. Journal of Productivity Analysis, 17: 23- 40.

General Authority for Fish Resources Development (GAFRD) (2018). Ministry of Agriculture and Land Reclamation. Fisheries Statistics Annual Book.

Tawfiq JA (1987). Fundamentals of Financial Management. Arab Renaissance House for Printing, Publishing and Distribution, 1: p.127.

Gaber M, Hegazy RH (2015). An Economic Study Of Fish Fry Incubated Station In Akiad Of Sharkia Governorate. The Egyptian Journal of Agricultural Economics, 25 (2): 511-520.

Arafa SA, Hammam NM (2015). Economic Analysis of the Value Chain of Fish Farming in Fayoum Governorate. The Egyptian Journal of Agricultural Economics, 25 (2).

الملخص العربي

الكفاءة الاقتصادية للمفرخات السمكية في محافظة الفيوم: نموذج تحليل مغلف البيانات

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استهدفت الدراسة مقارنة التكاليف الاستثمارية والتشغيلية بالمفرخات السمكية المختلفة بمحافظة الفيوم حيث تم ذلك من خلال دراسة بنود التكاليف وكمية الإنتاج والإيراد الكلى وصافى الإيراد لهذه المفرخات، كما جري تقدير الكفاءة الاقتصادية للمفرخات السمكية المرخصة العاملة بالمحافظة باستخدام نموذج تحليل مغلف البيانات. أوضحت النتائج أن مؤشر الكفاءة الاقتصادية في حالة ثبات العائد علي السعة CRS للمفرخ الاول بلغ الواحد الصحيح بما يعني تحقيق الكفاءة النسبية به، في حين كانت الكفاءة الاقتصادية مرتفعة أيضاً في كلا من المفرخ الثاني والمفرخ الخامس بنحو ٩٥% و٩٩% علي الترتيب، وكان أقل المفرخات كفاءة هو المفرخ الثالث والرابع بكفاءة بلغت نحو ٨٩%، ٨٢% علي الترتيب وبغلة حجم متزايدة، وبالتالي هناك حاجة إلي زيادة الانتاج بنسبة ١١%، ١٨% علي الترتيب وذلك للوصول إلي الحجم الأمثل. كما بلغ مؤشر الكفاءة الاقتصادية في حالة تغير العائد علي السعة VRS للمفرخ الاول والرابع والخامس الواحد الصحيح بما يعني تحقيق الكفاءة النسبية به، في حين كانت الكفاءة الاقتصادية مرتفعة أيضاً في كلا من المفرخ الثاني والثالث بنحو ٩٥% و٩٠% علي الترتيب، وبالتالي هناك حاجة إلي زيادة الانتاج بنسبة ٥%، ١٠% علي الترتيب وذلك للوصول إلي الحجم الأمثل. ويتضح من نتائج تحليل مغلف البيانات أن كفاءة السعة للمفرخ الرابع بلغت نحو ٨٣% وهذا يعني ان علي هذا المفرخ زيادة حجم انتاجه بنسبة ١٧% للوصول الى الاستخدام الامثل، أما كفاءة السعة في باقي المفرخات بلغت نحو ٩٩.٩% أي ما يقارب من ١٠٠%، أي انها تحقق الاستغلال الامثل لتكاليف مرحلة الانتاج. هذا وتواجه المفرخات السمكية بالمحافظة العديد من المشاكل والتي من أهمها قلة كميات مياه الصرف الزراعي بالمصارف المجاورة لمنطقة المزارع السمكية، ضعف القدرة المالية والتمويلية والمهارات التسويقية لدى حائزي المفرخات السمكية، ارتفاع قيمة الضرائب على المزارع السمكية عند بدء الانشاء، صعوبة ترخيص المفرخات لكثرة الاشتراطات الفنية والبيئية وتعدد الجهات الإدارية والرقابية، وارتفاع أسعار مستلزمات الإنتاج المستخدمة في التفريخ. هذا وتوصي الدراسة بصرورة التوسع في انشاء المفرخات السمكية في محافظة الفيوم لكونها تنتج النواة الاساسية في الاستزراع السمكي وهو الزريعة والتي بدونها لا يمكن التوسع في الاستزراع السمكي، مع ضرورة تذليل وحل المشاكل والعقبات التي تواجهها.

الكلمات المفتاحية: الكفاءة الاقتصادية، المفرخات السمكية، تحليل مغلف البيانات.