Extractive jojobyl alcohol as a pesticide for cotton's main pest, Spodoptera Littoralis: a study on environmental, economic, and global implications

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Abstract

Spodoptera littoralis is a current aggressive polyphagous pest that affects some of the most economically beneficial crops in various countries worldwide. In the search for geographically favorable regions for this project, Egypt represents a location where Spodoptera littoralis attacks cotton while the jojoba plant grows natively. While conventional pesticides have shown some effectiveness in combating Spodoptera littoralis in the short term, they lack safety criteria and long-term effects on the pest. The cited analytical and hypothetical research papers provide insight into the severity of Spodoptera littoralis' impact on economic, environmental, and global aspects. This paper aims to provide a comprehensive understanding of the main issues related to conventional pesticide use and its associated effects. Furthermore, it offers a collective overview of the possibility of developing a novel extractive pesticide for Spodoptera littoralis relying on the jojoba plant. The methodology for laboratory preparation, global application model, comprehensive economic model addressing real-world implementation, and potential side effects on various environmental factors will be discussed. Finally, hypothesized results, future recommendations, and limitations of application will be presented collectively.

Keywords: Spodoptera littoralis, Jojoba Oil, Biorefinery extracts, Extractive Jojobyl alcohols, Pests' modes of action, Toxicology, light Chromatography (LC), Mortality Index.

I. Introduction

Spodoptera littoralis, a member of the Spodoptera exigua family, is considered an aggressive pest that affects a wide range of economically beneficial crops, including cotton, maize, and okra *(Shenouda and Osman, 2000; El-Khawas and Abd El-Gawad, 2002)*. Currently, Spodoptera littoralis is causing significant damage to these crops in various countries, particularly in North African and Middle Eastern countries such as Egypt *(Kandil et al., 2003)*. With its ability to attack over 120 economically important crops and ornamental plants, as well as its high capacity for developing insecticide resistance, Spodoptera littoralis poses a significant threat *(Ismail S., 2019)*.

The Arthropod Pesticide Resistance Database has reported more than 100 cases of Spodoptera littoralis resistance, generating a second obstruction on the human ways to combat such a pest. The current field challenges revolve around the direct impacts of Spodoptera littoralis on various crops, specifically cotton, and the consequences of its resistance to chemical pesticides environmentally, economically, and globally. Therefore, this research aims to propose an alternative pesticide that can effectively combat the impacts of Spodoptera littoralis while managing its resistance.

Many of the currently available chemical pesticides lack long-term effectiveness against Spodoptera littoralis and also have detrimental environmental effects. The use of these chemical pesticides has resulted in the destruction of non-target species, such as the Rhynocoris marginatus insect, which further facilitates the exponential growth of Spodoptera littoralis *(Naqqash et al., 2016)*. Moreover, these pesticides have shown hazardous toxic effects on humans as well *(Costa et al., 2008; Mosallanejad and Smagghe, 2009)*. Consequently, these chemical pesticides have proven to be economically inefficient, as the scientific and industrial communities must constantly develop new aggressive pesticides with different modes of action against Spodoptera littoralis. This constant development for the chemical conventional pesticides makes them more and more aggressive against the environment, rather than the pest itself. Over the past 50 years, conventional inorganically based pesticides have been extensively used, but they have violated

the development of resistance by Spodoptera littoralis, rendering them gradually less effective as the pest's growth regulators and acceptors develop *(Aydin and Gurkan, 2006; Mosallanejad and Smagghe, 2009; Rizk et al., 2010)*.

In this research, the proposed alternative pesticide is Jojobyl alcohol, which is an organic extract derived from jojoba oil, obtained from jojoba plant seeds that grow naturally in Egypt. The process of extracting jojobyl alcohol relies on the biorefinery of jojoba oil. The connection between combating the challenges posed by Spodoptera littoralis and Jojobyl alcohol lies in the modes of action targeted by the alcohol, the geographic analysis of Spodoptera littoralis and the native areas of the jojoba plant, and the lower probability of Spodoptera littoralis developing resistance against jojobyl alcohol.

Jojoba is a dioecious, evergreen, woody shrub with brittle main stems that are easily broken. It is known to be long-lived and possesses a deep root system with main roots and a few surface-feeding roots. The leaves of the jojoba plant are xerophytic, with a thick cuticle and sunken stomata. They also contain a special tissue with a high concentration of phenol compounds *(Hogan et al., 1980)*. These characteristics make the jojoba plant an ideal reference point for finding an effective extractive component to combat Spodoptera littoralis. Additionally, jojoba is highly tolerant and can thrive in sandy soil with low organic matter (1.07 %) and a wide pH range of 6-8.5 *(El-Baz, EL-Deganwy, El-Shahat, and El. M. El-Hassan, 2010)*. These properties make jojoba a suitable match for countries that are facing Spodoptera littoralis infestation in economically important crops and have the required harsh conditions for jojoba plant growth.

The core extraction step is biorefinery, which is like traditional petroleum refineries that employ fractional distillation to obtain different fractions or components from crude oil. In the case of jojoba oil, biorefinery involves integrating various biomass treatment and processing methods into one system, resulting in the production of different components from the same biomass. This approach enhances economic viability, reduces waste generation, and allows to produce economically beneficial organic extracts like jojobyl alcohol.

By integrating biorefinery into the processing of jojoba oil, jojobyl alcohol - the lightest extractive component obtained from the process, which enhances its efficiency in targeting the vital functions of Spodoptera littoralis - can be used as an organic, environmentally friendly, and economically affordable pesticide to combat Spodoptera littoralis and reduce cotton crop losses.

II. Proposed Laboratory methodology

i. Experimental insects || Colony preparation

- A colony of newly germinated Spodoptera Littoralis should be carefully maintained under controlled laboratory conditions (27+/- 2oC, 65+/-5% relative humidity, photoperiod of 14 hours light and 10 hours dark) to ensure their traits' purity and observe their natural, non-pesticidal behaviors before their treatment with jojobyl alcohol.
- To conduct the experiment, the population will be divided into four cultures, with two cultures serving as the control sample and the other two as the treated samples.
- Fresh castor bean leaves (Ricinus communis) will be provided as the primary food source for the newly germinated Spodoptera littoralis larvae.
- As the larvae develop into pupae in a range of 15-30 days, they will be collected and placed in larger patches, along with some branches of fresh Tafla plant, which serve as oviposition sites during their later life stages.
- Upon emergence, the adult moths should be provided with a suitable environment allowing them to mate. The female moths will be given the previously provided branches to lay their eggs underneath withing 2-3 days from the mating time.
- The egg patches will be periodically collected and transferred into separate cultures for coming subsequent generations.

ii. Preparing Jojoba extracts

In contrast to the typical composition of common plant extractive oils, jojoba oil stands apart as it is derived from the seeds of the jojoba plant and exhibits a distinct chemical makeup. Unlike triglycerides found in many plant oils, jojoba oil is primarily composed of a blend of unsaturated long straight chain esters,

predominantly alcohols and carboxylic acids. The extraction process of obtaining jojoba oil involves either solvent extraction or cool pressing techniques, resulting in a yield of approximately 50% with respect to the jojoba seeds total biomass. However, the true potential of jojoba oil lies in its unique extractive products, which require further refining for optimal utilization. This refining in process entails several crucial steps, including transesterification, first crystallization, second crystallization, and final stream purification. A visual representation of these refining steps is illustrated Figure 1.

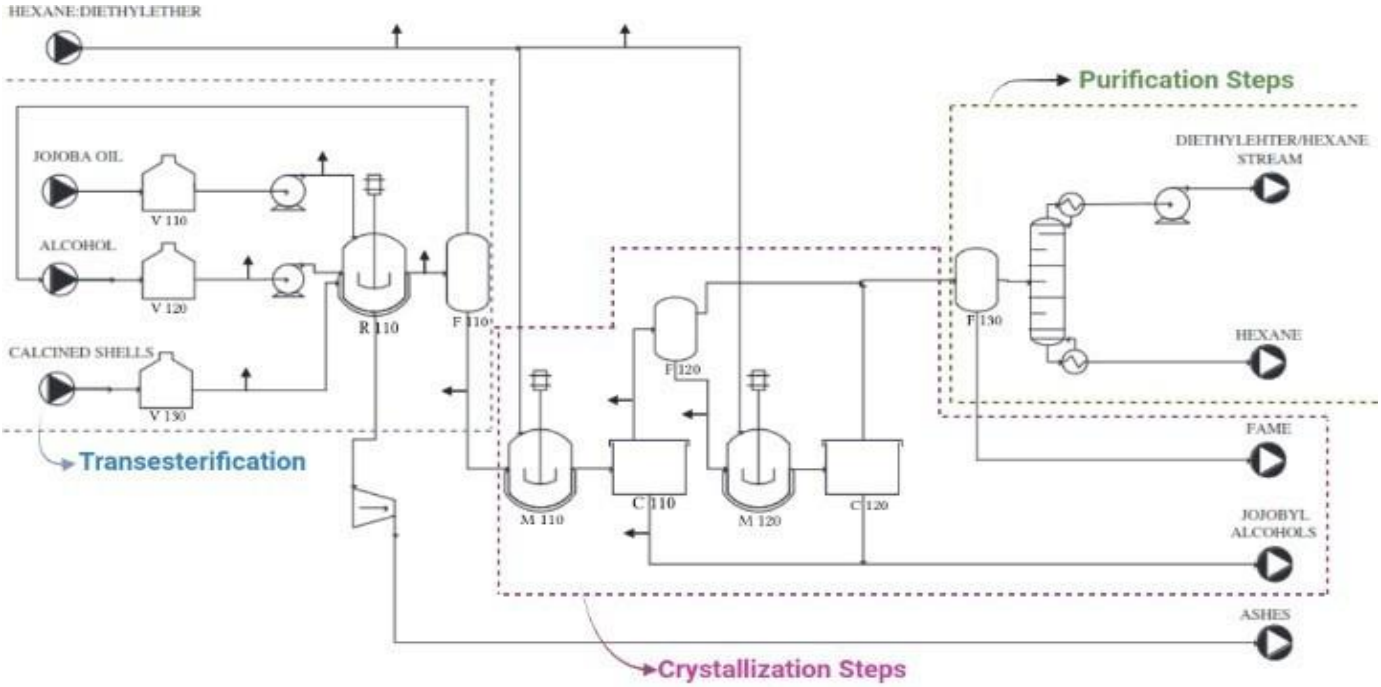

Figure 1 Scoping the processes of transesterification, crystallization, and purification.

Transesterification, a complex three-step process, involves the systematic conversion of a triglyceride molecule into diglycerides, followed by further transformation into monoglycerides. This sequential order of reactions is critical in the production of biodiesel in the form of fatty acid methyl ester (FAME) and crude glycerol. This transformative process, shown in Figure 2, plays a pivotal role in the synthesis of these valuable compounds like biodiesel.

During the initial stages of transesterification, the triglyceride will undergo a series of chemical changes, resulting in the formation of diglycerides. Subsequently, these diglycerides should

iii. Transesterification process

be further modified to yield monoglycerides, which will serve as intermediates in the production of biodiesel. The subsequent reaction of monoglycerides with methanol will lead to the formation of FAME, which represents a vital component of biodiesel fuels. Simultaneously, the byproduct of this process will be crude glycerol, which possesses its own set of applications and value.

Relying on the visionary of Figure 1, the process of transferring jojoba oil in Stream 1 to a dynamically stirred tank reactor should be accompanied by the addition of a carefully measured quantity of methanol and calcined shells. To ensure efficient methanolysis, the tank reactor (R-110) must possess a robust stirring mechanism, under a fixed pressure of 1 atm and a controlled temperature of 65ºC. Maintaining a constant impeller speed should end the process up with an optimal mixing of the reactants for a duration of 10 hours. Subsequently, the reaction mixture should be transferred to a flash separator (F-110), where excess methanol _treated as the catalytic factor of the process_ will be recovered and recycled for subsequent uses.

Operating conditions within the flash separator (F-110) must be carefully regulated, with a temperature set at 135ºC and a pressure of 0.8 atm. These specific parameters ensure the attainment of high-purity methanol, exceeding 99.5%, which can be effectively reused for future methanolysis processes.

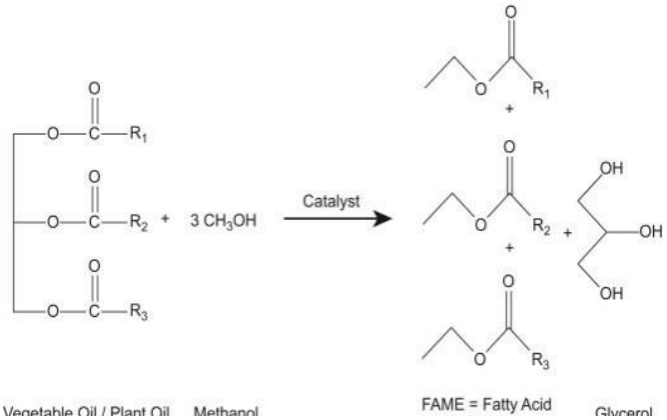

Figure 2 Chemical structure of transesterification process.

iv. First crystallization step

Inside the M-110, the output stream from the bottom of F-110, a transesterified jojoba oil, devoid of excess methanol, should be combined with the solvent's hexane and ethoxy ethane in a ratio of 3:1. Thoroughly mixing these components, the resulting mixture should then be introduced into the crystallization C-110, maintained at a temperature of -20 degrees Celsius for a duration of 24 hours. The primary objective of this step is to induce the separation of jojobyl alcohol from the initial input of FAME, yielding a final separation efficiency of 60%.

Upon completion of this process, two distinct streams emerged from the C-110. The bottom stream of C-110 should be comprising solid products enriched with jojobyl alcohols, while the upper stream should consist of a liquid phase containing uncrystallized jojobyl alcohols, FAME, and unreacted oil. These two streams should further be treated to eliminate any residual hexane and diethyl ether. Leveraging the variance in boiling points between hexane, diethyl ether, and other components, the utilization of flash separators F-120 (100ºC and 1 atm) and F-130 (200 ºC and 0.8 atm) should yield an effective separation for these components.

The stream obtained from the bottom of F-130 should hold the primary product, jojobyl alcohol, of a remarkable purity of approximately 99%. The only stream collected from the bottom of F-120 should still retain a significant concentration of valuable jojobyl alcohols, warranting further recrystallization alongside FAME and unreacted oil through a secondary crystallization step.

v. Second Crystallization step

After obtaining the mixture containing valuable jojobyl alcohol for recrystallization, the bottom stream of F 120 should be introduced into the mixer M-120 and mixed with the same components used in M 110. Crystallization should be carried out in C-120 under conditions of - 20ºC for a duration of 24 hours. The anticipated yield of jojobyl alcohols from the overall crystallization process is expected to be of a range 92-99%, relying on the efficiency of temperature fluxes of separation. As with the preceding step, two distinct streams emerged from C-120 (streams 23 and 24). Once again, the solid product was obtained from the bottom of C-120, while the liquid phase was collected from above the equipment.

To purify the streams coming out of C120, containing side solid and liquid products, a separation procedure should be conducted using F-140 (100ºC and 1 atm) and F-150 (150ºC and 0.8 atm). Following the separation process in F-140 and F-150, four separate streams will be obtained composed mainly of hexane, diethyl ether, FAME, and unreacted oil which all are essential in the re-processing in next generations of biorefinery, thus economically efficient as well.

vi. Stream purification step

The output streams originating from F-120, F-130, F-140, and F-150 will be combined in Mixer M-130 to ensure a homogeneous mixture before introducing then into the distillation column (T-120). The temperature of the mixer should be set at 25ºC, with a total condenser operating at 47ºC, and a reboiler set at 69ºC to produce hexane.

The mainstream obtained from the upper section of the distillation column should be comprising 90 % diethyl ether and 10% hexane, just with the appropriate management of this stream outside the biorefinery. On the other hand, the stream derived from the bottom of the column, will be primarily consisted of hexane, providing an additional source of revenue for the biorefinery.

III. Criteria of study

i. Insecticidal activity

All mortalities of the treated and control groups, including larvae, pupae, and adults, will be recorded daily and subsequently adjusted using Abbott's formula *(Abbott, 1925)*, as illustrated in equation (1):

$$\%\ of\ corrected\ mortality = \frac{\%\ test\ mortality - \%\ control\ mortality}{100 - \%\ control\ mortality} \times 100$$

ii. Growth, Development, and metamorphosis

Larval Body Weight Gain: Each individual larva (whether treated or control) will be carefully weighed daily using a digital balance to record the weight gain, following equation (2):

$$Initial\ body\ weight\ (Before\ the\ start\ of\ the\ experiment) - Final\ body\ weight\ (At\ the\ end\ of\ the\ experiment).$$

Growth Rate: The growth rate will be calculated based on *Wal Dauer's method (1968)*, using equation (3):

$$\frac{Fresh\ weight\ gain\ during\ the\ feeding\ period\ (48\ h)}{feeding\ period`} \times The\ mean\ fresh\ body\ weight\ of\ the\ larva$$

Developmental Duration and Rate: *Dempster's equation (1957)* will be employed to calculate the developmental duration, while *Richard's equation (1957)* will be utilized to determine the developmental rate. The pupation rate will be expressed as a percentage of successfully developed pupae.

Adult Emergence: The percentage of successfully emerged adults will be calculated according to *Jimenez-Peydro et al. (1995)* as in equation (4):

$$\frac{Number\ of\ Completely\ emerged\ adults}{Number\ of\ pupae} \times 100$$

Morphogenesis: The occurrence and calculation of deranged metamorphosis and mor- phogenesis programs in larval-pupal or pupal-adult intermediates will be expressed as a percentage. Additionally, the percentage of pupal deformations will be calculated. *(Ghoneim, K.; Hamadah, Kh.; and Waheeb, H., 2020).*

IV. Testing procedure

i. Toxicity tests

The jojobyl alcohol obtained through the previously explained methodology will be formu- lated into four different concentrations, ranging from 0.062% to 0.5%, as required for the bioassay tests against the 2nd and 4th instars of S. littoralis *(Hanan, S. Abdel- Aziz, Hanan, H. Osman, Samya, Z. Sayed, and El-Gohary, September 2013).* The testing process will start from the early germinating pupae and continue until their maturation. The leaf-dipping technique, as described by *Abo El-Ghar et al. (1994),* will be employed to determine the median lethal concentration (LC50) of jojobyl alcohol. Serial concentrations of jojobyl alcohol (400, 200, 100, and 50 ppm) will be prepared using tap water. Freshly collected castor bean leaves will be dipped in each concentration for 20 seconds and then left to dry for one hour.

After drying, five replicates of 10 larvae from each concentration will be fed with the treated leaves for 48 hours. The surviving pupae will be transferred to a control environment where they will be fed castor bean leaves washed with distilled water. Meanwhile, the control samples will be fed solely on castor bean leaves dipped in distilled water. Mortality rates in both the treated and control samples will be recorded daily, plotted, and compared as shown in the proposed/expected results section.

ii. Biological Experiments

The study will focus on the effect of LC50s on various biological aspects of the treated instars and their subsequent developmental stages. Specifically, the 2nd and 4th instar larvae of S. littoralis will be selected for the experiment. These larvae will be fed with castor bean leaves that have been treated with the LC50s of jojobyl alcohol for a duration of 48 hours. In the control group, the leaves will be treated with distilled water only. The recordings will include the observation of larval and pupal duration, pupal weight, pupation

percentage, adult emergence percentage, adult longevity, malformation of different stages, and sex ratios *(Hanan, S. Abdel-Aziz, Hanan, H. Osman, Samya, Z. Sayed, and El-Gohary, September 2013)*.

iii. Tissue preparation

Samples of total body tissue will be collected from late 6th larval instars that have been treated as 4th instars and fed on leaves treated with the LC50 values of jojobyl alcohol. The insect bodies, whether treated or untreated, will be homogenized in distilled water using a chilled glass teflon tissue grinder. The homogenization process will be carried out for 3 minutes, with a ratio of one gram of insect bodies to 5 ml of distilled water. After homogenization, the homogenates will be centrifuged at 8000 r.p.m for 15 minutes at -2 degrees Celsius using a refrigerated centrifuge. The supernatant obtained from the centrifugation will be stored at -5 degrees Celsius for future use, not exceeding two weeks. This supernatant will be used to determine the activity of certain enzymes including chitinase, protease, AchE, - and - non-specific esterases. These digestive enzymes will be analyzed to assess the vitality of pests *(Hanan, S. Abdel-Aziz, Hanan, H. Osman, Samya, Z. Sayed, and El- Gohary, September 2013)*.

iv. Enzyme Activity

The frozen bodies, integuments, alimentary canal, and fat tissues will be broken into pieces and homogenized in 10 volumes of phosphate buffer with a pH of 7 using an electric homogenizer. The resulting homogenate and hemolymph will be centrifuged using a Beckman centrifuge at 11000 rpm for 30 minutes at 4°C. The supernatant obtained from the centrifugation will be used for the chitinase assay (Aziza H. Mohamady and Tarek R. Amin, 2017).

Chitin, a biopolymer of significant natural importance, is primarily produced by fungi, arthropods, and nematodes. It serves as a key structural material for supporting the cuticles of the epidermis, trachea, peritrophic membrane, and lining the gut epithelium in insects *(Qu et al., 2014)*. Chitinolytic enzymes and their genes have garnered considerable attention due to their chemical and physical regulatory properties. Their potential for development as biopesticides, chemical defense proteins in transgenic plants, and microbial control agents is

currently being explored *(Ghareeb, 2009; Kramer and Muthukrishanan, 1997; Singh et al., 2014)*. The determination of colloidal chitin will be conducted following the method described by *Bade and Stinson (1981)*.

v. Chitinase assay

The reaction mixture will be prepared following the method described by *Ishaaya Casida (1974)*. It will consist of 0.12 ml of phosphate buffer (0.2 M, pH 6.6), 0.3 ml of 0.5% colloidal chitin *(Bade Stinson, 1981)*, and 0.18 ml of enzyme solution. After incubating the mixture at 37°C for 60 minutes, the enzyme activity will be terminated by boiling. To remove undigested chitin, the mixture will be centrifuged for 25 minutes at 6000 rpm. The resulting supernatant will be used for the determination of N-acetylglucosamine (NAGA) following the method described by *Waterhouse et al. (1961)*.

For the measurement of NAGA, a double beam ultraviolet/visible spectrophotometer from Milton Roy Co. USA will be utilized, and the absorbance of the NAGA reaction will be recorded at 540 nm. One unit (U) of chitinase activity will be defined as the amount of enzyme required to release 1 nmol of NAGA per minute from colloidal chitin. The specific activity will be expressed as units of chitinase activity per milligram of protein (U/mg of protein).

V. Statistical analysis

The data obtained will be presented as the mean ± standard error (mean ± SE). The significant difference between the control and treated larvae will be determined using one- way analysis of variance (ANOVA) at a significance level of P ¡ 0.01. Mortality will be recorded daily after treatment until the end of the experiment and will be corrected according to Abbott (1925). *Probit analysis* (LPD line) will be conducted on the mortality values to obtain the LC50 and slope for each extract, following a method adopted by *Finney (1971)*.

The LC50 values will be computed and used to calculate the toxicity index,

$$\frac{LC\ 50\ of\ chemical\ (A)}{LC\ 50\ of\ chemical\ (B)} \times 100$$

(Sun, 1950), which will be used for comparing the relative toxicity of the insecticides used,

$$\frac{LC50\ of\ the\ lowest\ toxic\ insecticide}{LC50\ of\ tested\ jojobyl\ alcohol}.$$

To estimate the lethal dose that kills 50% of the animals (LD50), the LC50 values can be converted using the regression formula provided by the Interagency Coordinating Committee on the Validation of Alternative Methods (ICCVAM):

$\log LD\ 50(mg\ /\ kg) = 0.372 \log LC\ 50\ (\mu g\ /\ mL) + 2.024$, (ICCVAM, 2006).

VI. Geographic analysis

In investigating the geographic suitability of this project, it is essential to identify regions where cotton crops are susceptible to Spodoptera littoralis infestation and where native populations of jojoba plants thrive. By examining Figures 3 and 4, a clear positive correlation can be observed between the geographic analysis of the problem, as depicted in the distribution of Spodoptera littoralis in Figure 3, and the geographic analysis of the solution, represented by the distribution of jojoba plants in Figure 4 *(Villacorte, L.O., January 2014)*. This close geographic correlation indicates that introducing jojobyl alcohol as an easily accessible, eco-friendly, and economically affordable alternative to the range of environmentally polluting, economically unaffordable, and often imported pesticides is a reasonable approach.

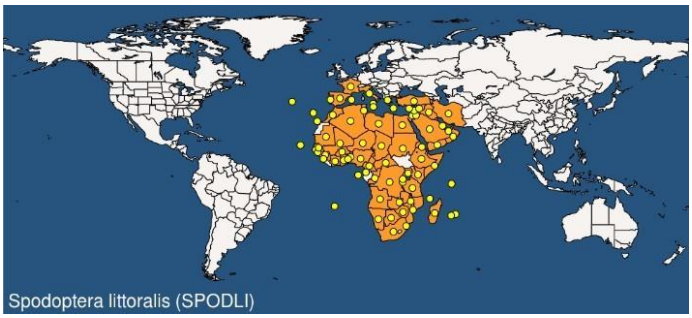

Figure 3 The global distribution of Spodoptera littoralis analyzed on the first of June 2023.

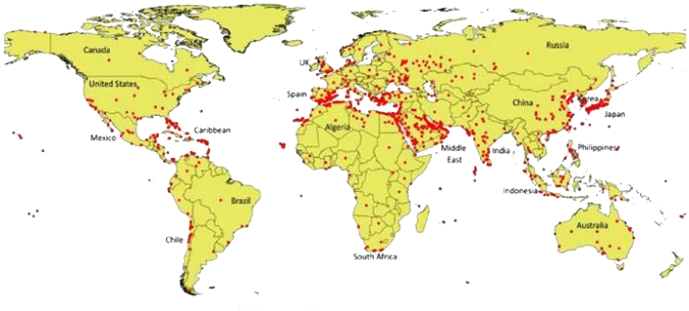

Figure 4 Global distribution of major RO plants (circle dots) with installed capacity of 30,000 as of January 2014.

i. Case study

While this study is primarily focusing on the economic and environmental aspects within the context of Egypt, analyzing these two maps expands the scope of the study to a global scale, extending its relevance to other regions that do also lack easily accessible alternatives like jojobyl alcohol for combating Spodoptera littoralis. Scoping with the two maps, it becomes evident that the findings and proposed solution can have a significant impact on a wider range of spots and areas with similar challenges.

VII. Environmental model

By examining the extensive environmental impacts associated with the use of conventional pesticides, the proposed eco-friendly pesticide, jojobyl alcohol, emerges as a viable solution to mitigate many of the accompanying environmental consequences associated with treating lepidopterans. This comprehensive environmental analysis encompasses the degradation and restoration of freshwater systems, the crucially affected ecosystems surrounding cotton fields, and the health effects resulting from the use of conventional versus the newly proposed pesticide.

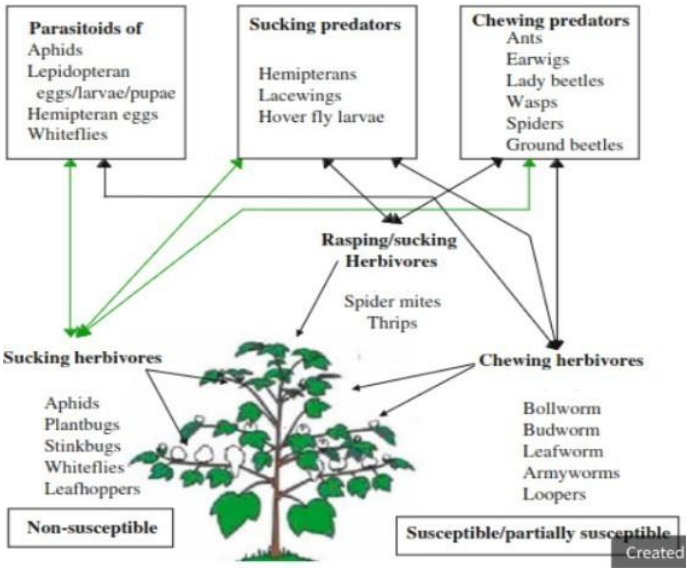

Figure 5 The vital ecosystem surrounding/interacting with a field cotton plant.

Figure 5 illustrates two scenarios that further support this assessment.

i. Condition one (On the use of conventional pesticides)

Relying on widely used conventional/chemical pesticides such as Agerin, Protecto, Profect, Virust, Lannate, Cord, Radical, and Flaxe can have detrimental effects on the intricate food web. These commercially available pesticides typically exhibit an average half-life of 30 days, indicating their persistence and slow degradation in the environment. Even though pesticides with a half-life ranging from 30 to fewer days are classified as non-persistent, their extended durations still pose environmental risks, ultimately causing harm to the depicted food web in figure 5.

Most of these chemical pesticides possess an average Soil Adsorption Coefficient of 72 g/g, indicating their strong affinity for the soil surface. The higher the Koc value, the greater the pesticide's binding to soil organic matter, reducing the likelihood of leaching. The Koc value serves as a measure of pesticide adsorption normalized by organic matter, providing a standardized representation across various soil types *(Howard Deer, October 2004)*.

While these pesticides may exhibit

limited adverse effects on nearby aquatic environments, they prove fatal to reptiles, mammals, and birds within the agricultural ecosystem. Their strong soil attachment poses significant risks to terrestrial organisms within the system.

ii. Condition two (On the use of jojobyl alcohol)

The risk assessment conducted on aliphatic alcohols, including jojobyl alcohol, revealed no exposure scenarios that raise ecological concerns. Volatilization was identified as the primary dissipation route for these alcohols. For the proposed compounds to be used as pesticides, namely 1-octanol and 1-decanol, estimated half-lives for volatility from soil were found to be 3.5 minutes and 1 minute, respectively *(Environmental Protection Agency, June 2007)*.

The volatility of aliphatic alcohols was considered when estimating potential ecological concentrations, which were then compared to endpoints from available ecotoxicity studies. It was determined that aliphatic alcohols are not acutely toxic to birds, even at doses significantly higher than anticipated exposure levels. Furthermore, the volatile nature of these alcohols makes chronic exposure unlikely, as estimated environmental concentrations decrease by more than an order of magnitude within 30 minutes.

Regarding mammals, a study on mammalian chronic toxicity demonstrated that aliphatic alcohols, including jojobyl alcohol, are not chronically toxic to mammals. Moreover, from a human health perspective, aliphatic alcohols, including jojobyl alcohol, are classified as food additives and are considered" Generally Recognized as Safe" by the U.S. Food and Drug Administration.

The status of safety recognition of aliphatic alcohols, including jojobyl alcohol, as pesticides validates the use of jojobyl alcohol in combating Spodoptera littoralis as an environmentally safe approach. By doing so, it helps preserve the introduced species within the food web depicted in Figure 5, thus maintaining the balance of the cotton field's ecosystem.

VIII. Economic Model

The economic model presented in this section focuses on key numerical aspects related to the extraction and refinement of jojobyl alcohol, the primary component obtained through the process. The currency used throughout the paper is the Egyptian

Pound (EGP), except for data obtained from literature which may be in US dollars (USD) - these values will be clearly indicated. Table 1 provides a quantitative analysis of the biorefinery process for raw materials, excluding costs associated with processing machinery, energy consumption, and other related expenses.

This economic table presents prices for various components of the process including Jojobyl alcohol, Diethyl ether treatment, Product failure, Advertisement and selling expenses, and Royalties. These prices are based on data from 2015, reflecting the limited market interest at that time in diversifying the uses of jojoba oil in industries beyond its predominant use in personal care products, cosmetics, and pharmaceuticals. Figure 6 provides insight into the Global jojoba oil derivatives market share in 2019, expressed as a percentage *(Grand View Research, 2020)*.

Considering the diagram in Figure 6

Economic parameters studied on the related expenses to jojoba oil and alcohol extract procedure and its limits.	
Variable	**Average Price**
Jojobyl Alcohols (EGP/ℓ)	12180-12420
Jojoba Oil (EGP/ℓ) [GLOSS, May 24, 2023]	1000-1660
Diethyl Ether Treatment (EGP/kg)	1.5-15
Methanol (EGP/ℓ)	150-315
Product Failure (%)	0-0.05
Tax (%)	10-50
Advertisement and selling expenses (EGP/ℓ MP)	0-3000
Royalties (EGP/ℓ MP)	0-7700
***MP: Marginal Product, the increase in the product's output as a result of applying additional inputs. The prices of methanol and jojoba oil date back to the 5th of May, 2023.**	

Table 1 Economic Parameters studied on the related expenses to Jojoba and its extracts.

(Marcos Sa´nchez, Jorge M. Marchetti, Noureddin El Boulifi, Mercedes Mart´ınez, and Jose´ Aracil, September 29, 2014), a comprehensive process comprising four input streams: Jojoba oil, methanol, hexane, Diethylether, and Calcined shells is previewed. The precise adjustment of input quantities for each of these components is crucial, with particular emphasis on the average net production of jojobyl alcohol per unit of jojoba oil input. Notably, the net yield of jojobyl alcohol from jojoba oil is approximately 2:1, indicating that for every

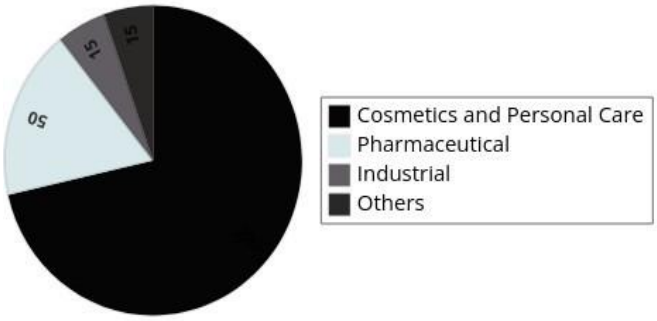

Figure 6 Global Jojoba Oil Market the year of 2022

200 kg of jojoba oil used as input, a corresponding 100 kg of jojobyl alcohol can be obtained as output.

When attempting to calculate or estimate the price of jojobyl alcohol as the main product derived from the jojoba oil biorefinery process, challenges arise due to the nature of the formed jojobyl alcohol, which consists of a mixture of three alcohol forms (11-eicosenol, 13-docosenol, and 15-tetracosenol) with varying concentrations depending on the process conditions. This complexity makes it difficult to evaluate the market value of jojobyl alcohol.

To overcome this challenge, a strategy has been adopted, focusing on setting limits for the prices of the process components to determine the minimum price at which these alcohols should be priced to achieve a net profit. According to *(Marcos Sa´nchez, Jorge M. Marchetti, Noureddin El Boulifi, Mercedes Mart´ınez, and Jose´ Aracil, September 29, 2014)*, the price of the integrated mixture of jojobyl alcohols should exceed 513 US dollars/kg (mentioned in US dollars due to the lack of an Egyptian source on this matter) to recover at least the initial investement.

The profitability of the entire process, including the marketing plan if applicable, is closely tied to the Initial Rate of Recovery for the invested costs. Notably, the time required to recoup the initial investment decreases as the price of the main product increases, particularly in the global jojoba market. Although this approach

contradicts the market requirements for traditional products with lower prices per unit, it proves to be more economically beneficial for the jojoba oil biorefinery by

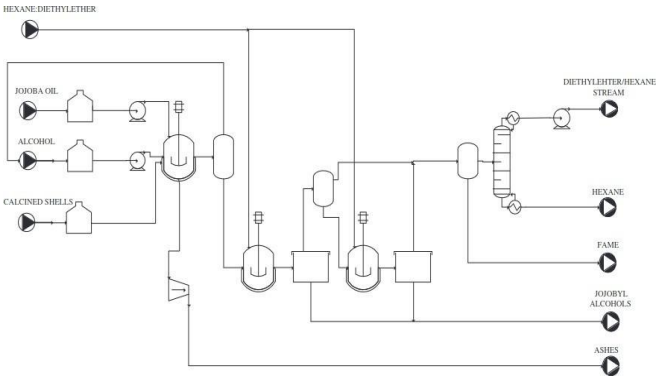

Figure 7 Biorefinery diagram

scaling up the feed streams, thereby increasing the yield of product streams, as shown in Figure 7.

IX. Future Recommendations

i. Controlled ecosystem for growing jojoba with the highest oil yield

To achieve optimal commercial application for the project, maximizing the yield of jojoba oil per plant becomes crucial, despite the plant's natural tolerance to harsh conditions. Therefore, for future project applications, it is preferable to establish controlled and optimized conditions that are most suitable for jojoba plant growth. This will ensure the highest oil yields, ultimately leading to a more profitable process and efficient production of jojobyl alcohol.

The oil content in the seeds of both cultivated and wild jojoba plants has been observed to be approximately 52%, with a range spanning from 44 to 59% (Gad, H., Roberts, Hamzi, Gad, Touiss, Altyar, Kensara, and Ashour, (2021, May 24).

A notable positive correlation exists between seed size and oil content, which is primarily influenced by the conditions provided to the plants during their growth period, particularly during blooming and fruit/seed formation stages. Figure 8 illustrates the standard supplement for the conditioned environment that is designed to create an ideal setting for cultivating jojoba plants.

X. Future Limitations

i. Global Warming and temperature rise

Temperature exerts significant influence on chemical and biochemical reactions, as high- lighted by *Hochachka and Somero (2002)*. The kinetic energy of biochemical

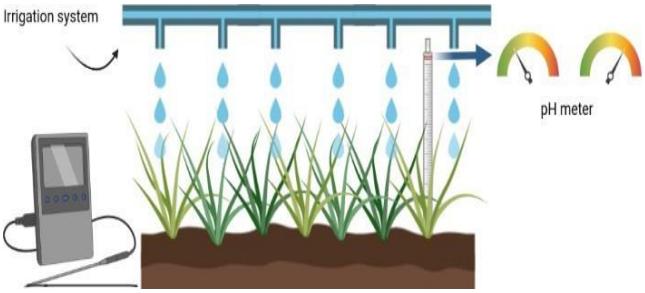

Figure 8 Configured Optimum system for the perfect fit of Jojoba plant.

reactions in- creases with higher

temperatures, leading to accelerated metabolic processes that ultimately impact the physiology and behavior of organisms *(Angilletta, 2009)*. In the context of insect biochemistry, proteins have been a subject of great interest due to their potential roles in growth, development, morphogenesis, and various metabolic pathways of insects *(Kar et al., 1994)*.

Lepidopteran larvae, with their rapid growth rates, are particularly sensitive to environ- mental warming as they require high protein diets *(Lee et al., 2004)*. Studies by *Ehsan et al. (2011)* revealed that fourth instar larvae of the Pistachio white leaf borer reared at 25°C exhibited lower levels of glycogen but higher levels of protein compared to larvae reared at 35°C. Glycogen serves as an energy storage form, and the rise in temperature leads to increased metabolic rates, shorter development periods, and higher levels of stored nutrients. The protein content in larvae reared at 25°C was significantly higher than in those reared at 35°C, while glycogen content was higher in larvae reared at 35°C compared to 25°C.

Figure 9, illustrating the effects of different constant temperatures on the biochemical activities and yields of fourth instar S. littoralis larvae, provides further insights. The Figure demonstrates an overall increase in biological yields in Spodoptera littoralis at elevated temperatures, posing a threat to currently used pesticides and even our proposed one. To effectively combat higher levels of larval vitality, particularly in the digestive tract and middle gut, pesticide formulations

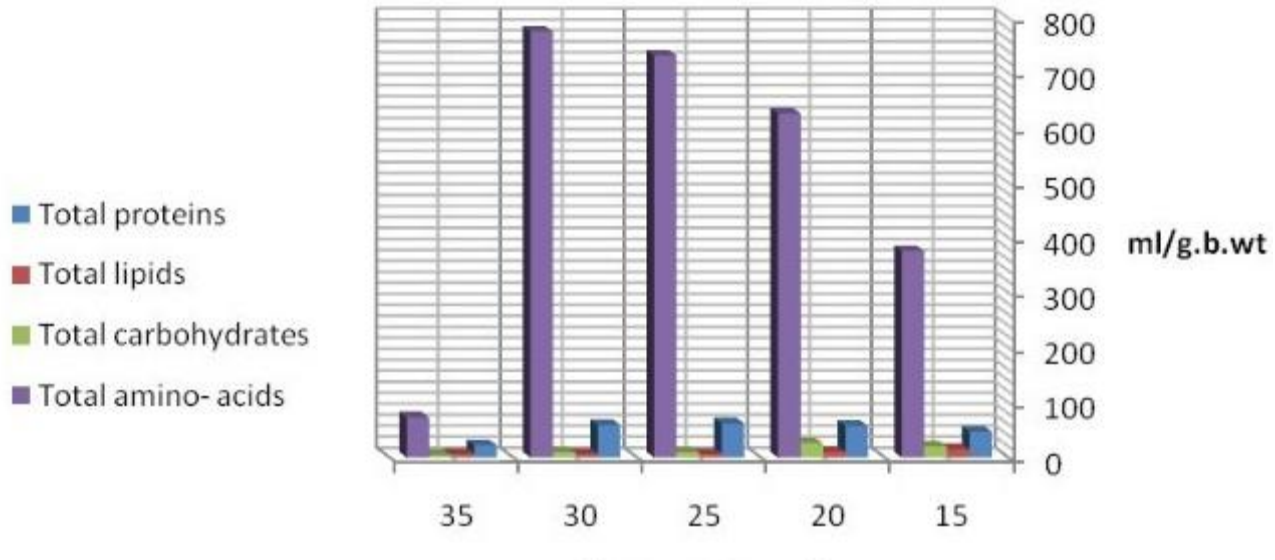

Figure 9 The effect of temperature on the vital and biochemical processes and yields in Spodoptera littoralis, 4th instar.

should be designed to be more efficient.

XI. Conclusion

In conclusion, it is evident from the analysis conducted in this study that the application of biorefinery processes on jojoba oil can facilitate the derivation of an environmentally friendly, economically affordable, and easily accessible alternative to the current polluting, expensive, and unsustainable pesticides utilized for combating the highly aggressive pest, Spodoptera littoralis, which predominantly affects economically beneficial crops such as cotton.

By employing the biorefinery approach, the potential of jojoba oil can be harnessed to address these challenges. The production of pesticides from jojoba oil offers numerous advantages, including the reduction of environmental harm, cost-effectiveness, and ease of accessibility. Sustainable practices are followed throughout the biorefinery process, ensuring responsible production of pesticide alternatives while minimizing the adverse impacts associated with conventional pesticides.

Furthermore, the cultivation of jojoba plants can be optimized to enhance oil yield and productivity. By creating controlled and favorable growing conditions, higher yields can be achieved, thereby improving profits and overall productivity.

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