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Feasibility Study for a Castor oil Extraction Plant in South Africa

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***Abstract*—**A feasibility study for the design and construction of a pilot plant for the extraction of castor oil in South Africa was conducted. The study emphasized the four critical aspects of project feasibility analysis, namely technical, financial, market and managerial aspects. The technical aspect involved research on existing oil extraction technologies, namely: mechanical pressing and solvent extraction, as well as assessment of the proposed production site for both short and long term viability of the project. The site is on the outskirts of Nkomazi village in the Mpumalanga province, where connections for water and electricity are currently underway, potential raw material supply proves to be reliable since the province is known for its commercial farming. The managerial aspect was evaluated based on the fact that the current producer of castor oil will be fully involved in the project while receiving training and technical assistance from Sasol Technology, the TSC and SEDA. Market and financial aspects were evaluated and the project was considered financially viable with a Net Present Value (NPV) of R2 731 687 and an Internal Rate of Return (IRR) of 18% at an annual interest rate of 10.5%. The payback time is 6years for analysis over the first 10 years with a net income of R1 971 000 in the first year. The project was thus found to be feasible with high chance of success while contributing to socio-economic development. It was recommended for lab tests to be conducted to establish process kinetics that would be used in the initial design of the plant.

***Keywords*—**Mechanical pressing, Net Present Value, Oil extraction, Project feasibility, Solvent extraction

I. Introduction

CASTOR oil is obtained from pressing castor beans (the seeds of a plant which has the botanical name *Ricinus communis* of the family *Eurphorbiacae* [1]. This is done by either one or a combination of mechanical pressing or solvent extraction. The oil is a pale yellow, viscous, non-volatile and non-drying with a bland taste. It finds uses as a purgative, a plastic and textile finishing material, in paints and varnishes, a feedstock to the transesterification process for the production of biodiesel, as well as in the beauty industry as a cosmetic and hair oil. Castor oil has an advantage over other mineral oils in that it is a biodegradable, eco-friendly and renewable resource [2]. There is currently no industrial scale production of the oil in South Africa and one known small scale producer in the Mpumalanga province. The producer can no longer meet local demand and hence the objective of this work; which is to analyse, by means of a feasibility study, the viability of venturing into large scale castor oil production. A feasibility study is a critical step in the business or project assessment process. If properly conducted, it may be the best investment any entrepreneur ever makes. Not only does it provide entrepreneurs and investors with pre-analysis of a project or business idea's viability; it can also go a long way in saving costs in terms of money that may have been invested in a venture or project that would eventually fail. Conducting feasibility studies is considered to be a good business practice and most successful businesses do not go into a new business venture without first thoroughly examining all of the issues and assessing the probability of business success [3]. Listed below are the feasibility aspects that this study aimed at investigating; and below each aspect, a list of questions that the investigation was expected to answer.

Market Feasibility: This was performed to establish the size and nature of industry, market, competitors, barriers to industry and project sales.

Technical Feasibility: The aim was to estimate the size and type of extraction facilities, establish reliability and limitations associated with extraction technologies, assess the suitability and availability of the proposed production site in terms of its proximity to raw materials, market, transport, labour, hazards, future availability and quality of raw materials.

Managerial Feasibility: The aim was to assess the skills of project initiators, investigate the availability of labour, wage rates and skill level and assess the need and potential to access and attract qualified management personnel.

Financial or Economic Feasibility: This was performed to estimate total capital requirements, expected revenue, costs associated with production, profit margins, and the payback period.

II. THE CHEMISTRY OF CASTOR OIL

Castor is originally a tree or shrub that can grow above 10m high, reaching an age of about 4 years. At present, the cultivated varieties grow to a height of 60–120cm in 1 year, and several metres in perennial cultivation [4]. Castor grows in the humid tropics to the subtropical dry zones (optimal precipitation 750–1000mm, temperature 15–38°C) and can be also cultivated in southern Europe [5]. Harvesting the castor plant is fairly complex. When harvested by hand the ripe fruit (humidity <45%) are selectively cut, and later the capsules are removed. Due to the varying stages of ripeness of the seeds up to five separate harvests are necessary. Since the seeds are very poisonous, caution is needed during harvesting and processing: only 0.18g/kg of body mass can results in death

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[5-6].Castor oil contains ≤89% ricinoleic acid, Table 1 below and because ricinoleic acid contains double bonds in its lipid structure, it is prone to an undesirable reaction called lipid oxidation. Lipid oxidation occurs when the double bonds in the fatty acid react with oxygen to form peroxides; this changes the chemical nature of the oil [7]. There are many factors which influence the rate of oxidation in foods: fatty acid composition, free fatty acids versus the corresponding acylglycerols, oxygen concentration, temperature, pro-oxidants, radiant energy (visible and ultraviolet light), and the presence of antioxidants. Owing to these reasons, castor oil is stored in a controlled environment. That includes removing oxygen, storing the oil in a cool place, placing the oil in an opaque container, removal of pro-oxidants (e.g., cobalt, copper, iron, manganese, and nickel), and possibly adding antioxidants. Castor oil is not as prone to oxidation as much as other oils unless exposed to high temperatures.

TABLE I
TYPICAL FATTY ACID CONTENT IN COMMERCIAL AND REFINED CASTOR OIL

Fatty Acid	% Castor Oil
Ricinoleic Acid	≥ 89.00
Linoleic Acid	4.20
Oleic Acid	3.00
Stearic Acid	1.00
Palmatic acid	1.00
Dihydroxy - Stearic Acid	0.70
Linolenic Acid	0.30
Eicosanoic Acid	0.30

III. EXTRACTION TECHNOLOGIES

A. Mechanical Pressing

Before extraction, the ripe seeds are allowed to dry and go through dehulling to remove the shells. These seeds are then cleaned, cooked and put through secondary drying. Cooking is done to coagulate protein (necessary to permit efficient extraction), and to free the oil for efficient pressing. The first stage of oil extraction is pre-pressing, using a high pressure continuous screw press called the expeller. Extracted oil is filtered, and the material removed from the oil is fed back into the stream along with fresh material. Material finally discharged from the press, called cake, contains 8 to 10% oil. It is crushed into a coarse meal, and subjected to solvent extraction with hexane [8].

B. Solvent Extraction

Solvent extraction is also known as liquid-liquid extraction, and it involves the distribution of components between two immiscible phases [9]. In solvent extraction, the seeds are cleaned and oven dried before they are crushed and subjected to the solvent extraction process. Particulate matter (PM) and volatile organic compounds (VOC) are the principal emissions from vegetable oil processing. PM results from the transfer, handling and processing of raw seed whereas VOC emissions are from the oil extraction solvent, hexane, which is classified as a hazardous air pollutant. Small quantities of solvent (up to 0.2% by volume of oil) are present in the crude vegetable oil after the solvent is recovered by film evaporators and the distillation stripper [10].

IV. CASTOR OIL REFINING

The steps to refining the castor oil include four steps as outlined in fig 2 below.

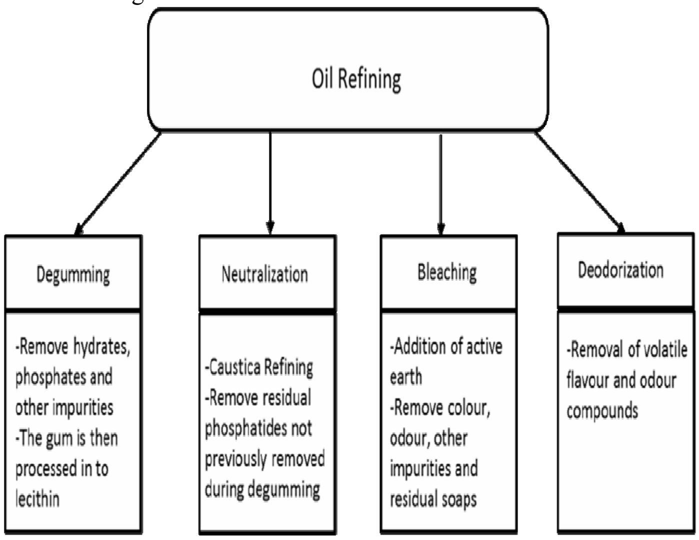

Fig. 1 Sub-sections of oil refining treatment [10]

V. INDUSTRY AND MARKET

The world castor seed production is over 1.3 million tons per annum fig 2. India is major producer with over 60% share, followed by China and Brazil with about 20% and 10 % respectively [6]. Other countries that produce small amounts of castor beans are West Indies and some regions of Africa. Castor oil merely has less than 0.15% in the international oil seed trade market. For this reason Oil World, a well-known vegetable oil statistics, only note the production, trade and consumption data in the margins. The 1.3 Mt of castor oil seeds produced in total per year corresponds to about 550 kilo tons of oil. Since the beginning of the 1970s, castor oil seed production has increased continuously but it is, in some cases, subject to yearly fluctuations of about 20%, which are above all the result of storm damage in the main regions of cultivation. About half of all the castor oil produced in the world is exported.India contributes 80% of the global castor oil export and therefore largely dominates the market. More than 30 internationally operating wholesalers have joined together in the International Castor Oil Association (ICOA) Inc, which was founded in 1957 [5], and they currently produce over 90% of the entire castor oil world trade. As a result of fluctuations in production and speculation, the price of castor oil varies considerably. In the past, it was between 650 and 1500 U$ per ton without tax. The average price in the past 10 years was about US$900/ton and therefore almost twice the price of rapeseed oil in Germany. America uses about 40% of the castor oil and derivatives produced, and they import 90% of their consumption. Castor plants have not been farmed on a commercial scale in the United States since the early 1970s [5].

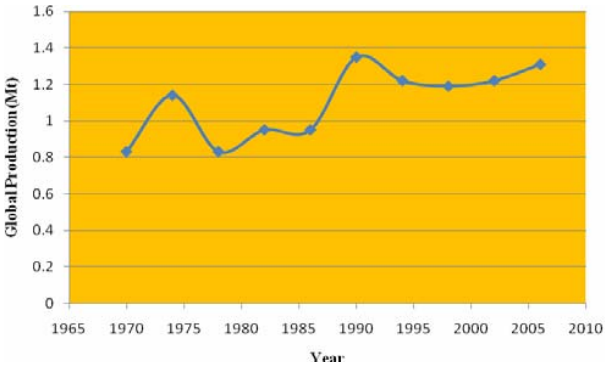

Fig. 2 Production of castor oil (in Mt) globally

VI. METHODOLOGY

Methods of Investigation

- Sourcing from literature
- Evaluation by observation
- Interviews
- Questionnaires
- Economic projections

The above were used to assess the four aspects of a feasibility study, namely: market, technical, financial and managerial feasibility in accordance with the aspect points stated under "Introduction". Evaluation by observation applied mainly to assessing the suitability of the proposed production site in terms of its proximity to raw materials, labour, transport and market. Interviews and questionnaires apply to the evaluation of the managerial aspect, and these were conducted with potential management and individuals currently involved in the project.

VII. Results And Discussion

A. Market and Demand

Based on current production and demand trends, the possible extraction facility should meet a capacity of close to 60kg/day, which is equivalent to 21.9t/y. Market for castor oil is surprisingly large in South Africa. Consumers use the oil primarily for problem skin, hair loss and other cosmetic needs. It is also predicted to become an important source of biofuel in the future. More people are showing interest in the product as it gains its popularity on local newspapers and radio stations. Sasol Technology has agreed to help the current producer with further market research as well as costing and pricing to help achieve high profit margins. The current market price of castor oil is about R9-00 for a 100mL, at 100% sales the net income would be approximated at R1 971 000 p.a.An interview held with the current producer of castor oil shed light on the factors currently hindering progress. One important factor was the lack of product certification. Potential customers from the pharmaceutical and related industries are willing to distribute the locally produced oil provided that it is certified castor oil; however the South African Bureaux of Standards (SABS) does not have castor oil certification standards. Affiliation with a German scientist, Prof. Mark Rusch gen. Klaas proved to be very significant as he was able to assist with a fatty acid profile analysis of the locally produced oil; which was done in the chemical laboratories of Neubrandenburg University of Technology (Germany) in June 2010; the laboratory is a non-certified research institution. The analysis was done in accordance to DGF/AOCS procedures, where the locally produced oil was compared to commercial, refined castor oil (certified DAB quality); the results are as shown in Tables II and III below.

TABLE II
FATTY ACID PROFILE FOR COMMERCIAL AND REFINED CASTOR OIL

Signal Peak No	Start (min)	End (min)	Peak Height	Peak Area	Peak %Max	% of Total
1	8.605	8.689	31640	614248	0.38	0.338
2	8.799	8.896	125228	2201014	1.36	1.212
3	10.268	10.346	405868	7789534	4.81	4.29
4	10.349	10.405	335072	6039187	3.73	3.326
5	10.408	10.448	26130	313590	0.91	0.173
6	10.558	10.641	138159	2546138	1.57	1.402
7	11.978	12.194	4293108	1.62E+08	100	89.258

TABLE III
FATTY ACID PROFILE FOR LOCALLY PRODUCED OIL

Signal Peak No	Start (min)	End (min)	Peak Height	Peak Area	Peak %Max	% of Total
1	10.263	10.329	144972	2509183	3.6	3.341
2	10.331	10.391	100622	1608456	2.31	2.142
3	10.393	10.436	7958	87990	0.31	0.117
4	10.548	10.629	48301	898695	1.29	1.197
5	10.954.	12.136	2494428	69673408	100	92.768
6	10.34	14.438	10451	327197	0.47	0.436

According to Table III above, the sample of locally produced oil shows a ricinoleic acid (as methylester) content of 92.8 % (uncorrected value), whereas that of the comparison commercial, refined castor oil (table-2) is 89.3 % (uncorrected value). This proves that the sample of locally produced oil is indeed a castor oil of highly valuable quality.

B. Technical Aspect

The current producer maintains that the design and construction of the plant is necessary because of the difficult methods currently being employed. In October 2009, the Department of Economic Development, Environment and Tourism (DEDET) invested R150 000 in the project when she won the first prize in the Mpumalanga Youth Entrepreneur Programme. The Department of Agriculture, Rural Development and Land Administration (DARDLA) recently honoured her with operating space of about 10ha of land on the outskirts of her residential area, Nkomazi in Mpumalanga.

Subsequently, some of the money from the DEDET has been used to prepare the land for farming (to cultivate the seeds required for production), as well as connecting utilities such as water and electricity. She also maintains that subsequent supply of raw materials would come from local farmers that she has agreed to bring on board once the project starts running. This supply proves to be reliable since the province is known for its commercial farming (sugar cane, paw-paw, oranges, e.t.c.). The climate is suitable, so much so that the castor plant can even be cultivated during the winter season. Onsite labour will be recruited from local, unskilled individuals who would subsequently receive on-the-job training. This will form part of the project's contribution to community upliftment. Based on literature, the process selected as best suitable for the pilot plant would be that of mechanical pressing. The SABS could not provide information regarding the allowable hexane emissions, and since the plant will be located near a residential area, solvent extraction technicalities could not necessarily be regarded as environmentally viable. Furthermore, this process (solvent extraction using a Soxhlet Extractor) is difficult to scale up and would require further literature on counter-current extraction processes, which are industrially applicable to the extraction of edible oils. Castor beans contain on average 45% oil. Extraction of oil through mechanical pressing involves the use of simple and conventional equipment such as oil press and cooker. Such production equipment can be supplied by countries in Europe, Asia and the Far East. In addition to this equipment and the obvious requirement of raw materials in the form of castor bean, the plant would require other materials such as drums (metallic) and sacks.

C. Management Aspect

The current producer would remain the sole owner of the possible enterprise. Sasol Technology is another role player keen to provide business development support to the project by assisting her with the following:

- Branding of the product. This branding intervention includes marketing and packaging.
- Technical support: provide advice on the fabrication of the plant, a good manufacturing and separation process to avoid contamination and sediments on the final product.

Within the Department of Trade and Industry (DTI), the current producer has a personal advisor who has connected her with possible overseas customers. In June 2010, the DTI flew her to an expo in China to showcase her product, where she networked with individuals who showed clear interest in her product. In August 2010, DARDLA awarded her Top Young Entrepreneur, 2010. The plant will require manpower for production work. Since it is a small capacity plant, administrative staff would not be necessary at the beginning as the manager would be required to do the administrative work as well as oversee the production process. As stated under technical aspect above, unskilled labour would be employed and trained in oil milling technology, in accordance with their role specifications. The skills of engineers and technicians would be employed at a consultation basis. As mentioned earlier, Sasol Technology, the Technology Station in Chemicals (TSC) as well as other government owned institutions are willing to assist where necessary.

D. Financial Aspect

The factorial method of cost estimation gives the fixed capital cost of the project as a function of the total purchase equipment cost. This method is normally used to make quick estimates in the early stages of projects. Using this method, the estimated fixed capital cost was thus calculated, and hence the working capital and total initial investment. Annual production costs were also estimated.

TABLE IV
ESTIMATED CASH FLOW STATEMENT FOR THE PROJECT

Year	Net Income (ZAR)	Net Cash Flow (ZAR)	Present Value (ZAR)
1	1 971 000	485 656	439 508
2	2 168 100	682 756	559 166
3	2 384 910	899 566	666 724
4	2 623 401	1 138 057	763 335
5	2 885 741	1 400 397	850 041
6	3 174 315	1 688 971	927 788
7	3 491 747	2 006 403	997 430
8	3 840 922	2 355 578	1 059 740
9	4 225 014	2 739 670	1 115 418
10	4 647 516	3 162 172	1 165 099
Total		**16 559 226**	**8 544 247**

Table IV above shows an estimated cash flow statement for the first ten years of the project. Here, net cash flow (net profit) is defined as the difference between net income and production costs. This economic evaluation was done under the assumption that sales increase at 10% annually. From the cash flow statement, it can be seen that breakeven is reached in the sixth year; the payback period is hence 6 years. The interest rate used to calculate the NPV was 10.5% per annum (current interest rate in South Africa), and this was found to be R2 731 687 and IRR was 18%.

For NPV greater or equal to Initial Investment, a project is considered to be profitable, and hence financially viable. Current interest rate is 10.5% per annum and an IRR of 18% means that if the interest rate were to increase to any value ≤18% during the lifetime of the project, the project would still be profitable. The project has earned support from various governmental and education institutions. These include SEDA, Nkomazi Municipality, Department of Economic Development, Environment and Tourism, and the Department of Trade and Industry. All these institutions have been helping the current producer diligently. The TSC, SEDA and Sasol Technology have agreed to cover the capital costs required to set up a pilot plant.

VIII. CONCLUSION

The project will be financed by the three stakeholders, namely Sasol Technology, the TSC and SEDA however is in unknown how the costs will be split amongst the three. An economic evaluation was conducted, which confirmed that the project is financially viable with an NPVand an IRR of R2 731 687 and 18% respectively at an annual interest rate of 10.5%. The payback time is 6 years with a net income of R1 971 000 in the first year. The project should be pursued further. Further work is recommended in the form of lab tests where a Soxhlet extractor should be used with hexane as the solvent. The amount of oil extracted relative to the amount of solids fed, the temperature of the cooling water, the feed and the product, the pH of the feed and the product should all be monitored during these tests. This way, process kinetics will be gathered, which will help with the initial design of the extraction plant, and ultimately the construction thereof. The product obtained from the lab should be analysed for ricinoleic acid content.

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