Optimization of Process Parameters for Castor Oil Production

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***Abstract*—Bean conditions, processing temperature and pressing time, solvent type and solvent-solid ratio were studied to optimize oil yield from castor beans. A maximum yield of 50.16% was obtained in this study. Moisture content of 3-3.6% was found compared to the range of 5-7% reported in literature. Isopropanol, hexane and their 50:50 by volume mixture were used as solvents for oil extraction. The optimum conditions were found to be isopropanol, temperature of 108^{0}C, pressing time of 60 minutes and solvent to liquid ratio of 6:1.**

***Index Terms*—Castor oil, extraction, optimization, pressing, process parameters, solvent ratio**

I. INTRODUCTION

Castor oil is viscous, pale yellow and non-drying oil with a bland taste and it is sometimes used as purgative [1]. There are an astonishing number of industrial applications for castor oil and its derivatives, and new ones are continually being discovered. Castor oil is used either in its crude form, or in the refined hydrogenated form. Typically, 65% of it is processed, 28% is refined, 12% is hydrogenated, 20% is dehydrated, and 5% is processed to manufacture other derivatives. Castor oil is used as a raw material for paints, coatings, inks, lubricants and a wide variety of other products. This oil is unique among vegetable oils and its uniqueness is derived from the presence of a hydroxyl fatty acid known as ricinoleic acid (12- hydroxyl-cis-9-octadecenoic acid) which constitutes about 90% of the total fatty acids of the oil. Castor oil is also distinguished from other vegetable oils by its high specific gravity, thickness and hydroxyl value. It is extracted from castor beans by either mechanical pressing or solvent extraction or combination of the two. In mechanical pressing, the seeds are crushed and then adjusted to low moisture content by warming in a steam-jacketed vessel. Then, the crushed seeds are loaded into a hydraulic press and pressed by mechanical means to extract oil. The resulting oil has a light colour and low free fatty acids [1]. Mechanical pressing only recovers about 45% of oil from the beans and the remainder in the cake can be recovered by solvent extraction. The crushed seeds are extracted with a solvent in a Soxhlet extractor or commercial extractor [1]. Solvents used for extraction include heptane, hexane and petroleum ethers. Refining is essential to remove impurities such as colloidal matter, free fatty acid, colouring matter and other undesirable constituents that make oil less resistance to deterioration during storage [2, 3]. Refining of castor oil includes degumming, neutralization, de-waxing, deodorization and bleaching. Castor oil has one double bond in each fatty acid chain and is classified as non-drying oil. Like all other vegetable oils, it has different physical and chemical properties that vary with the method of extraction [2]. Relative to other vegetable oils, it has a good shelf life and does not turn rancid unless subjected to excessive heat. Cold-pressed castor oil has low acid and iodine values, a slightly higher saponification value compared to that extracted using solvent extraction as well as being lighter in colour [3]. In literature, various attempts were made to optimize castor oil recovery. The optimum results were a recovery and moisture content of 48.75% and 5.8% respectively [2, 4, 5, 6]. The objective of this study was to optimize castor oil recovery from castor beans obtained from Mpumalanga Province of South Africa.

Manuscript received March 03, 2012; revised March 26, 2012. This work was sponsored by the RSA National Research Foundation and University of Johannesburg, South Africa.

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II. MATERIALS AND METHODS

A. Preparation of beans

- Cleaning: Hand cleaning was performed to remove foreign materials such as sand, sticks, stems and leaves.
- Drying: The cleaned beans were dried in the sun for seven hours until the casting splits and shed the seeds. These beans were further dried at 90^{o}C to a constant weight to reduce the moisture content initially at 5-7% [2].
- Winnowing: The shell was separated from nibs (cotyledon) by blowing in a tray to promote high oil recoveries [4].
- Grinding: The seeds were crushed to a sieve size of

ISBN: 978-988-19252-2-0
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

1.18mm using mortar and pestle to rupture cell walls for easy oil extraction. [7, 8].

B. Determination of Seeds Moisture Content

100g of cleaned bean sample was dried in an oven at 90°C, weighed at 1 hour intervals, reaching a constant weight after 6 hours. The moisture content was calculated using (1)

$$\%Moisture = \frac{W_1 - W_2}{W_2}(100) \quad (1)$$

Where W_1 and W_2 are the original and final weights of samples before and after drying respectively.

C. Size Reduction

A 100 g sample of castor seeds was crushed using a pestle and mortar into 1.18mm sieve size smooth paste.

D. Optimization of Parameters

50 ml of normal Hexane was weighed and poured into round bottom flask. 25 g of the sample was placed in the thimble and inserted in the centre of the extractor. The Soxhlet was heated at 70 and 108°C. The solvent boiled and vapourized through the vertical tube into the condenser at the top. The liquid condensate dropped into the cotton wool thimble in the centre containing the solid sample to be extracted. The extract seeped through thimble into the flask via the siphon. After extracting for 30 minutes, the sample was dried at 70^{0}C and weighed to determine the amount of oil extracted. Further extraction was performed, weighing the sample at 45 minutes intervals until the residue weight was constant. The procedure was repeated at initial extraction times of 45 and 60 minutes. At the end of the each extraction procedure, the mixture of oil and solvent was oven heated in at 70^{0}C for solvent recovery. The same procedure was followed for isopropanol and solvent mixture, recovering the solvents @ 108^{0}C.

E. Castor Oil Recovery

The % yield of castor oil was calculated using (2)

$$\%Yield = \frac{y_1 - y_2}{y_1}(100) \quad (2)$$

Where y_1 and y_2 are the weights of beans before after extraction in grams.

III. Results and Discussion

A. Oil Yield

The maximum recovery achieved was 50.16% and this was dependent on the nature of the solvent. High oil yields were obtained when extracting with 150 ml of isopropanol for 45 minutes at its boiling point as a result of the influence of temperature as also observed [5]. Extraction with hexane gave the lowest yield of 38.68%. The influence of temperature on solubility and diffusion as well as viscosity resulted in higher yields with increase in temperature [1]. At higher temperatures, the solvent viscosity decreased while the diffusivities of the solute and solvent increased resulting in high extraction rate. Akaranta and Anuisiem, 1996 [9] also observed that dry feint with a boiling point range of 78 – 94^{0}C gave better extraction yield compared to hexane. The yield of 50.16% obtained in this study fall within the literature range of 30-55% depending on castor bean variety [2]. Akpan et al, 2006 [10] using the same set of apparatus achieved an average recovery of 33.2%.

B. Effect of Extraction Time

The oil extraction abilities of the solvents for varying times ranging from 30-60 minutes using 50 ml of solvent are shown in Figs. 1-3. The extraction time was found to have a direct influence on recovery as a reported by [9] who recommended 2-3 hours of continuous extraction.

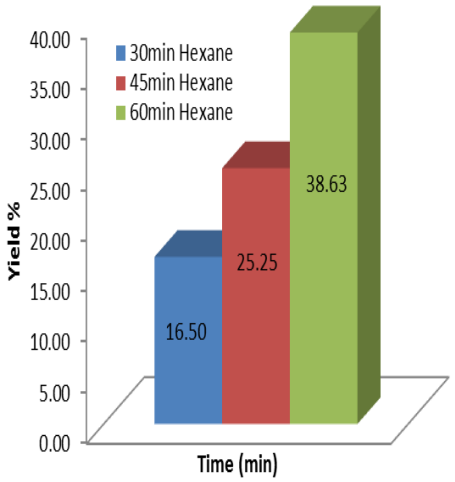

Fig. 1. Effect of extraction time on recovery using hexane

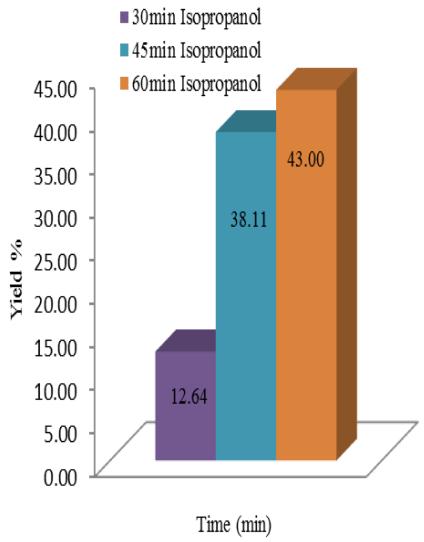

Fig. 2. Effect of extraction time on recovery using isopropanol

ISBN: 978-988-19252-2-0
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

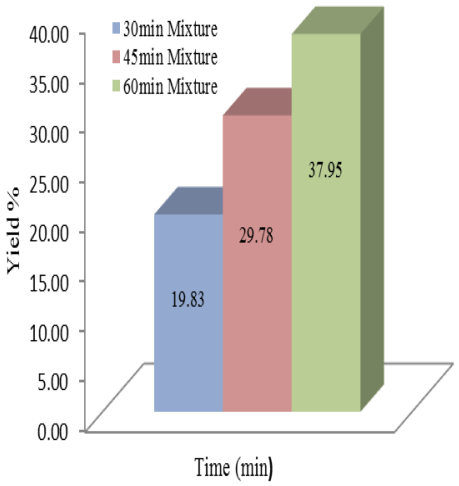

Fig. 3. Effect of extraction time on recovery using solvent mixture

C. *Moisture Content Determination*

Castor beans were oven dried at 90^0C for 6 hours to a constant weight with 3.6% moisture content. This varied with literature findings of 4.15% [9] and 5-7% [2]. The variation could be attributed to the difference in the nature of beans from different locations.

D. *Influence of Solvent Type*

The nature of solvent used had an effect on extraction. The order of performance was isopropanol > solvent mixture > hexane, Fig 4 as a result of boiling point differences. This was also observed by Akaranta and Anusiem, 1996 [9].

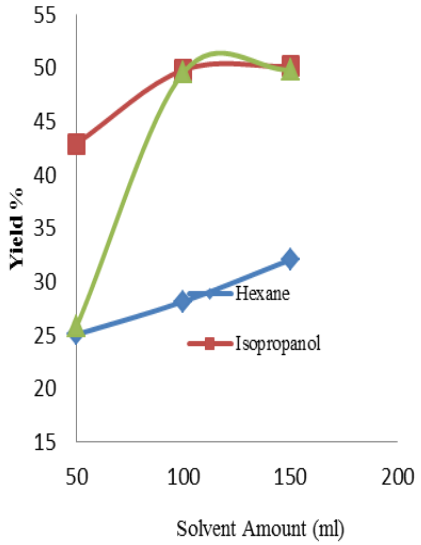

Fig. 4. Influence of solvent on oil yield

E. *Influence of Solvent to Solid Ratio*

Figs. 6 to 8 show that oil recovery increased with increase in solvent – solid ratio.

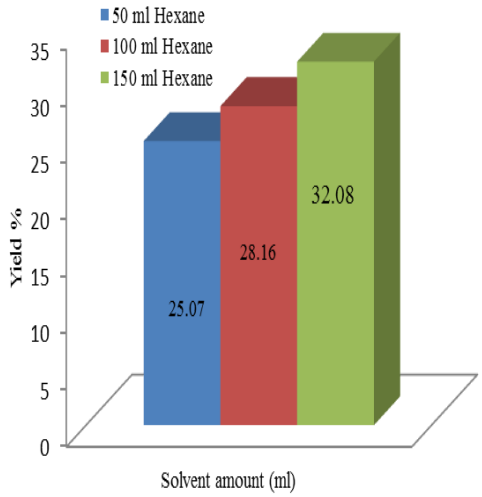

Fig. 5. Influence of solvent to solid ratio on recovery (hexane)

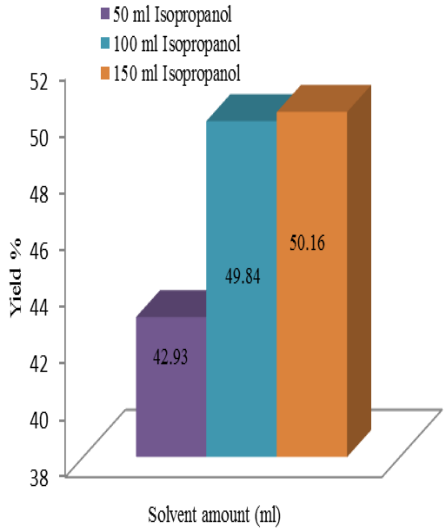

Fig. 6. Influence of solvent to solid ratio on recovery (isopropanol)

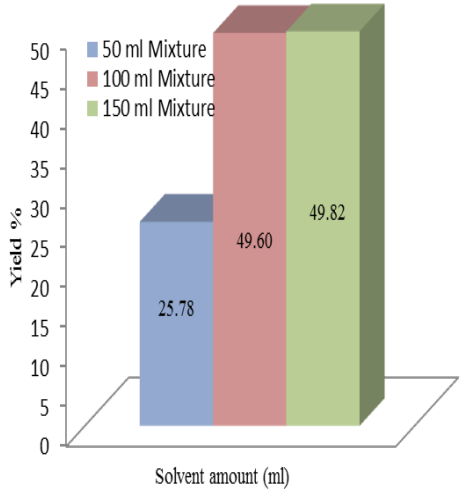

Fig. 7. Influence of solvent to solid ratio on recovery (solvent mixture)

ISBN: 978-988-19252-2-0
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

IV. Conclusion

The optimum conditions were found to be isopropanol solvent, 60 minutes leaching time, solvent – solid ratio of 6:1 as well beans crushed into paste. The process parameters must be carefully controlled during leaching.

Acknowledgment

The authors acknowledge financial support from the NRF and the URC of the University of Johannesburg.

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ISBN: 978-988-19252-2-0
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)