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ENZYMATIC HYDROLYSIS OF SHEA BUTTER FOR THE OPTIMUM PRODUCTION OF FATTY ACID

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Abstract

In recent times, the demand for unconventional natural resources has risen and this has turned the attention of researchers towards abundant resources like Shea butter. Shea butter is a vegetable oil that is extracted from the Shea tree (*Vitellaria Paradoxa*). *It can serve as a feedstock for production of free fatty acid which will in turn be used to produce soap, chemicals, pharmaceuticals, etc. In this research study, Shea butter was enzymatically hydrolyzed at varying process conditions to produce free fatty acid (a key material needed for soap and drug production). Process parameters such as temperature, time and agitation speed were used to determine the design of experiment through the Response Surface Methodology technique. The physiochemical properties of the Shea butter was observed to have values within a close range with other oils used as feedstock for the production of soap, chemical, pharmaceuticals, etc. The optimum yield of free fatty acid produced after the completion of the experiment was observed to be 88%, and it was produced at a temperature 50^{o}C, time of 145 minutes and 240 rpm. It can then be concluded that the use of Shea butter as feedstock would be economically viable and environmentally friendly in several chemical/process industries.*

Keywords: *Hydrolysis, Shea Butter,*

INTRODUCTION

Shea butter is a form of vegetable oil that is extracted from the fruits of the Shea tree (*Vitellaria Paradoxa*). The Shea tree is a major component of the forestry parkland in the dry zone of sub Saharan Africa. It is also the major indigenous oil producing plant in this sub Saharan region (Lovett, 2005). Natural vegetable oil and fats have become very important sources of dietary energy, antioxidants, biofuels and raw materials for the manufacture of industrial products. They are used in food, pharmaceutical, cosmetics as well as oleo chemical industries (Okullo *et al.*, 2010). Shea butter is traditionally used as a source of Vegetable fat for cooking or as a moisturizer to tackle harmattan effects in West African winds (Loveth, 2005). One of the highest quality Shea butter in Africa and the world is found in Nigeria and available at very low cost. Shea butter is popularly known as '*Kadanya'* in the northern part and '*Ori'* in the south-western part of Nigeria. It is soft and creamy and has a beige colour. Other traditional uses include soap making, medicine, walls waterproofing and fuel for lamps.

The extraction of Shea butter in Africa has been ongoing for years and over 2.5 million metric tons (MMT) is extracted annually in Africa (Lovett, 2005). In Nigeria, Shea trees grow in an extremely vast area of Niger, Nasarawa, Kebbi, Kwara, Plateau, Benue, Kogi, Oyo, Ondo, Kastina, Kaduna, Adamawa, Taraba, Borno and Sokoto States (Kontagora, 2011).

The production of soap from triglycerides and alkalis has been achieved for more than two thousand (2000) years by a process known as saponification. It is the alkaline hydrolysis of triacylglycerol (TAG). The hydrolysis reactions produce the fatty acids that form the basis for most oleo-chemical processes (Salimon *et al.*, 2011). Since oils and fats make up the primary feedstock, a valuable by-product is glycerol. Glycerol and fatty acids are widely used as raw materials in food, cosmetics and pharmaceutical industries, hence their production from oils. Physical and chemical methods have extensively been employed as the basis for the Production of fatty acids (Serri *et al.*,2008). Over the years, several research studies has been conducted to

develop various techniques in the preparation of fatty acids. Some of these methods include enzymatic hydrolysis, sub-critical and super-critical water, and potassium Hydroxide catalyzed hydrolysis of esters also known as saponification (Salimon *et al.*, 2011). It has been observed and proven over time that high temperatures and pressures usually accompany chemical catalysed hydrolysis of oils and fat (Serri *et al.*, 2008). Therefore a catalyst with an ability to work under mild conditions would generally be preferred. An excellent choice of catalyst for this research project is lipase. This natural enzyme is known to be specifically suitable for oils and fats thereby making it the most suitable catalyst for the hydrolysis of Shea butter.

MATERIALS AND METHODOLOGY

Material and Equipment

The entire chemicals to be used in this study will be analytical grade (98-99.5%). They include Potassium Iodide, Urea, Sodium Hydroxide, Deionized water. The equipment used are pH meter, weighing balance, beakers and conical flask, oven, stirrer, Furnace, Separatory funnel, Heating mantle, magnetic stirrer, Thermometer, burette and pipette and water bath.

Methodology

Characterization of Shea Butter oil

The physiochemical properties of the Shea butter oil were evaluated by determining the Acid value test, Iodine value test, Saponification value, Peroxide value, free fatty acid and Specific gravity.

Hydrolysis of Shea Butter Oil

50grams of the Shea butter oil was poured into a stoppered 250 ml conical flask containing 30 ml of iso-octane and 30 ml of phosphate buffer solution with a pH of 7.0. Three sets of identical mixtures above were also prepared. 0.3 g of solid lipase (enzymes) was then added to the three sets of reaction flasks and then heated and stirred at an initial temperature and speed of

30°C and 100 rpm respectively. Sample cuts were withdrawn from the flask at every 30 minutes. The last reaction flask was kept as control for the experiment (Serri *et al.*, 2008).
The experiment was then repeated for 20 runs and process parameters such as Temperature, time and speed were varied.

Determination of Degree of Hydrolysis of Shea butter

5 ml ethanol and two drops of phenolphthalein were added as the indicator to the reaction flask after the Hydrolysis reaction, and the mixture was titrated against 0.1 M NaOH. The amount of NaOH required to neutralize the acid was noted. A blank titration was also performed as the control sample.
The degree of hydrolysis which is the percentage conversion was then calculated using the equation;

$$\%\ conversion\ = \frac{(ml\ NaOH\ used)\ (molarity\ of\ NaOH)\ (weight\ of\ fatty\ acid)}{10 \times weight\ of\ sample\ of\ oil}$$

(3.1)

RESULTS AND DISCUSSION OF RESULTS

TABLE 3.1: Physicochemical Properties of Shea Butter Oil

Results of Characterization of Shea butter oil

The Shea butter oil was characterized in terms of specific gravity, acid value, iodine value and saponification value, acid value, free fatty acid value, peroxide value and Viscosity. The results are presented in Table 1.0. The Shea butter oil was seen to have high acid content which necessitated the pre-treatment of the oil for one hour before the actual Hydrolysis.

Table 1.0: Physiochemical Properties of Shea butter oil

Property	Experimental value	Okullo *et al* (2010)
Acid Value (mgKOH/g)	12.86	12.59
Iodine Value (mg iodine/gm)	68.60	41.37
Viscosity (CP)	48.30	2.80
Saponification Value (mgKOH/mg)	228	192.15
Specific gravity	0.926	-

Free Fatty Acid (%)	6.43	-
Peroxide Value (mol/kg)	10.34	2.10

Experimental Results for the Central Composite Design

Table 1 showed the design considered in this study in terms of coded and natural values. The experiment was carried out based on the design guidelines in table 3.2. The optimum percentage yield of free fatty acid was observed to occur at a temperature of 50^{o}C, an agitation speed of 240 rpm and time of 145 minutes. The R-squared value was evaluated to be 0.9903 from the Design Expert software and this gives enough convictions about the experimental results.

Run	Temperature ^{o}C	Speed (rpm)	Time (min)	Percentage yield (%)
	35	75	145	60
	50	75	145	80
	35	75	30	61.5
	50	75	30	74
	45	157.5	87.50	78
	45	157.5	87.5	78
	45	157.5	87.5	53
	45	157.5	9.20	78
	45	157.5	87.5	78.5
	42.50	157.5	87.5	84
	55.11	157.5	87.5	84
	42.50	18.75	87.5	68
	42.50	157.5	184.20	82
	42.50	296.5	87.50	80
	42.50	157.5	87.50	78
	50.00	240	145	88
	42.50	157.5	87.50	78
	35.00	240	145	72
	50.00	240	30	80
	35.00	240	30	58

Table 3.2: Design of Experiment with percentage yield of free fatty acid after Hydrolysis of Shea Butter

Final Equation in Terms of Actual Factors:

Free Fatty acid= 78.07+8.98A+3.13B+2.43C+0.69AB+0.19AC+2.19BC-3.83A2 --1.89B2+0.23C2

Where A = Temperature
B = Speed
C = Time

CONCLUSION

The characterization of Shea butter oil showed that the oil is saturated and makes it suitable for the production of fatty acid. The saponification value of the Shea butter oil was 228 mg KOH/g. which is quite high, but falls within the standard. High saponification value indicates that the oil is a normal triglyceride and very useful in the production of fatty acid on hydrolysis.

Experimental result showed that the free fatty acid FFA content of Shea butter oil was 6.43 mg KOH/g. The significant effects of the FFA are on the rate at which hydrolysis will take place.

The iodine value of Shea butter oil was found to be 68.60 mg I_2/g. This value measures the amount of unsaturation of fats and oils in the Shea butter. This value is low which indicates low unsaturation of fats and oils. Limited unsaturation in the oil is necessary due to the fact that heating during hydrolysis of higher unsaturated fatty acid may only result in polymerization of glycerides. The acid value and peroxide value of Shea butter oil were found to be 12.86 mg KOH/g and 10.34 mmol/kg respectively. These values are of no significant importance on the degree of hydrolysis of the oil. Viscosity is defined as the resistance of a liquid to flow. Viscosity increased with molecular weight but decreased with increasing temperature and unsaturation. The viscosity of the Shea butter oil at room temperature was found to be 48.30 cp. The viscosity of the Shea butter must be reduced to enhance efficient hydrolysis.

The rate constant K_m was determined using the Michaelis-Menten Equation:

$$\frac{1}{V} = \frac{Km + [S]}{Vmax\,[S]} = \frac{Km\,[\frac{1}{S}]}{Vmax\,[S]} + \frac{1}{V}$$

This value was found to be 0.9 g/ml. The value indicates the rate at which the enzyme is being used up during the conversion (hydrolysis) process. This value was determined at the optimum temperature of 50℃. Hence, beyond this temperature, the value of the rate constant changes. This is observed from the fact that the enzyme becomes less active at higher temperature and the rate of conversion will be less.

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