

**A COMPARATIVE EVALUATION OF THE EMULSIFYING
PROPERTIES OF THE STARCH EXTRACTED FROM THE CERTAIN
SPECIES OF MUSA SAPIENTUM AND MUSA ACUMINATA**



BY

ADUMEKWE CHIAMAKA JANE

PHA1505077

**DEPARTMENT OF PHARMACEUTICS AND PHARMACEUTICAL
TECHNOLOGY**

FACULTY PHARMACY

UNIVERSITY OF BENIN

BENIN CITY.

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**FACULTY OF PHARMACY
UNIVERSITY OF BENIN
BENIN CITY.**

**SUPERVISED BY
PROF (MRS) EICHIE F.E**

SEPTEMBER, 2023.

CERTIFICATION

This is to certify that this project work was carried out by Adumekwe chiamaka jane in the Department of pharmaceutics and pharmaceutical technology, Faculty of pharmacy, University of Benin, Benin city.

Adumekwe chiamaka jane
Student

Date

PROF (MRS) EICHIE F.E
Supervisor

Date

PROF (MRS) EICHIE F.E
Head of department

Date

DEDICATION

The project is dedicated to God Almighty, my parents, Mr and Mrs Adumekwe, and to my siblings.

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My unending thanks to God almighty for his grace , favour and strength bestowed on me during the period of my pharmacy programme. My special appreciation to my parents Mr and Mrs Adumekwe for their encouragements and support morally, financially, emotionally and spiritually .

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ABSTRACT

Emulsions are generally unstable formulations, hence the need for an emulsifying agent to be incorporated into the preparation. Emulsifying agents can be obtained from natural sources which are readily available, cheap and biodegradable.

AIM of the study-This study investigated starches obtained from two banana species i.e *Musa acuminata* and *Musa sapientum* as naturally occurring emulsifying agents that can be used in the formulation of pharmaceutical emulsions.

SPECIFIC OBJECTIVE OF THE STUDY-The specific objective of the study was to extract and evaluate the emulsifying properties of starch obtained from certain banana species.

Method: Starches were isolated from ground unripe banana fruit species using already established method. The unripe banana fruit were peeled, washed, milled and the slurry was passed through a mesh sieve. The filtrate was allowed to settle and water was decanted to obtain the starch. Varying concentrations (5-30%w/v) of the starches obtained from the banana species were employed in the preparation of the emulsion. Physicochemical characterization of the starches obtained from the banana species were carried out and compared with maize starch as standard. Parameters evaluated included viscosity and the effect of age on globule size and size distribution and the globule structure.

Results: The result showed the yield of *Musa acuminata* and *Musa sapientum* was 10.17%w/w and 14.21%w/w respectively. It also showed an increase in viscosity (rate of flow) with an increase in the concentration of the emulsifying agent (5-30%w/v) with the range 760-10728±171.06(sec) for maize starch, 466-7204.8±82.12(sec) for *Musa acuminata* and 114-5618±299.83(sec) for *Musa sapientum*. It also showed that there was a decrease in the globule number of the emulsion and an increase in the globule size after 7 days which showed 1.75-3.94±1.37(mm) for *Musa acuminata*, 1.57-3.0±0.71(mm) for *Musa sapientum* and 2.25-3.0±0.71(mm) for maize starch which is the standard. The study showed that *Musa acuminata* is more favorable as an emulsifying agent than *Musa sapientum* when compared to maize starch. The study also showed cracking and phase separation in the emulsion from the 7th day and it was observed that there was a reduction in the viscosity of the preparation with time.

Conclusion: The study showed that the yield obtained from *Musa sapientum* and *Musa acuminata* were 14.21% and 10.17% respectively. However the yields are poor and not economical. This calls for improvement in the methods for extraction of the starch from the unripe fruit. *Musa acuminata* compared more favorably with maize starch than *Musa acuminata* and hence can be used as emulsifying agents in the formulation of pharmaceutical emulsions and hence they can be used as an emulsifying agent in pharmaceutical emulsions.

CHAPTER ONE

INTRODUCTION

1.1 PREAMBLE

Drugs which are preparations used in the treatment or prevention of illnesses are seldom administered alone; rather they are given or used as part of a formulation in combination with one or more non-medicinal agents that serve varied and specialized pharmaceutical functions. Selective use of these non medicinal agents referred to as pharmaceutical excipients produces dosage form of various types New and improved excipients are continuously being developed to meet the needs of these drug delivery systems.

Pharmaceutical excipients solubilize,suspend,thicken,dilute,emulsify,stabilize,preserve,color and fashion medicinal agents into efficacious and appealing dosage forms.

1.2 EMULSION

Emulsions are heterogeneous systems composed of at least two immiscible liquids, water and oil, one of which is usually uniformly dispersed as fine droplets throughout the other liquid phase by a mechanical agitation process (wadhwa et.al 2012) Emulsions are commonly used for topical pharmaceutical and cosmetic products, such as lotions and creams.The largest group of emulsions commercially available as medicines are dermatological products for topical application.Emulsions can be designed to facilitate drug penetration into and/or through the skin. Both oil-in-water and water-in-oil emulsions have been extensively used to deliver drugs and cosmetic agents to the skin, depending on the property of active agents and the indications of the medicines(Lu, G.W. and Gao2010).

Although the microstructure of many of these complex emulsions is now better characterized and understood,the underlying mechanisms by which the structure of an emulsion and the function of individual excipient,such as a penetration-enhancing agent,can influence drug bioavailability are far from clear.Droplet size of the emulsion may influence the drug penetration through the skin, but the effect often is not clinically significant. The evaporation of volatile excipients can occur and so affect the drug permeation across the skin.Judicious selection of an appropriate emulsifying agent and additional stabilizer is a critical factor in the design and development of emulsions.In order to disperse two immiscible liquids a third component is required, namely the emulsifier; the choice of emulsifier is crucial not only for the formation of the emulsion but also for its long-term stability (Fatima et. al 2014).

A third ingredient, known as an emulsifying agent or emulsifier is necessary to disperse two immiscible liquids; the choice of emulsifier is critical not only for the creation of the emulsion but also for its long-term stability.

Emulsions are heterogeneous systems made up of at least two immiscible liquids, such as water and oil, with one of the immiscible liquids typically being uniformly disseminated as tiny droplets throughout the other liquid phase through mechanical agitation. For topical pharmaceutical and cosmetic goods like lotions and creams, emulsions are frequently employed. Dermatological treatments for topical use make up the largest subset of emulsions that are commercially accessible as medications. Emulsions may be created to make it easier for drugs to enter the body through the skin or penetrate it. Depending on the properties of the active ingredients and the intended uses of the medicines, both oil-in-water and water-in-oil emulsions have been widely employed to deliver medications and cosmetic agents to the skin.

1.2.1 CLASSIFICATION OF EMULSION

Emulsions can be categorised based on the type or size of their droplets. Two accelerated ageing techniques storing emulsions at various temperatures and measuring the creaming process by centrifugation can be used to assess the physical stability. When the scattered globules are evenly distributed throughout the continuous phase, the emulsion is stable. This review discusses the main types of physical instabilities, such as flocculation, creaming, coalescence, and breaking, and it focuses on practical ways to increase emulsion stability

- I. Based on the type of dispersed system; they are divided into two categories: oil in water (O/W) and water in oil (W/O). A relatively complicated emulsion known as multiple emulsions can also be created in addition to these two types

a) Oil in water Emulsions.

Colloidal systems called "oil in water emulsions" have oil droplets spread throughout the water. Because of this, the continuous phase of this colloid is water, and the scattered phase is oil. Under normal circumstances, water and oil do not mix. But we can create an oil-in-water emulsion by properly mixing the two together and utilising stabilising chemicals. The smaller the oil droplets that are spread, the greater the efficacy of this technique. It makes medicinal products more bioavailable.

b) Water in oil Emulsions

Water in oil emulsions are colloidal systems having water droplets dispersed throughout the oil. Therefore oil acts as the continuous phase of this colloid while water is the dispersed phase. Oil does not mix with water under normal conditions. But with proper mixing and by using stabilizing agents, we can obtain oil in water emulsion. The effectiveness of this system enhances with a small size of dispersed oil droplets

Water droplets are spread throughout the oil in water in oil emulsions, which are colloidal systems. As a result, water is the dispersed phase of this colloid, and oil is its continuous phase. Under normal circumstances, water and oil do not mix. But we can create an oil-in-water emulsion with careful mixing and the use of stabilising chemicals. A modest size of distributed oil droplets improves this system's effectiveness.

c) Water/oil/water Emulsion/Multiple Emulsion

In a three phase system known as a W/O/W double emulsion, polymer is dissolved in the oil phase with an internal aqueous phase and submerged in an external aqueous phase with a surfactant or emulsifying agent. Double emulsions are of high potential for drug delivery of active ingredients. They consist of small droplets of one fluid suspended in larger droplets of a second immiscible fluid. The product properties in double emulsions are governed by the droplet size distribution (DSD) of both the internal and external emulsification.

II. Based on the Size of liquid droplets

- a) Macro Emulsions: sizes of droplets range from 0.2-50mm
- b) Micro Emulsions: sizes of droplets range from 0.01-0.2mm
- c) Nano Emulsions: sizes of droplets range from 50-1000nm

1.2.2 HOMOGENIZATION OF EMULSION

Homogenization at high pressures or with high shear rates is required for the emulsion-making process.

The addition of stabilisers (i.e., emulsifiers) can offer stability to the emulsion. Both procedures introduce high energy into the system to create turbulent circumstances where the emulsion droplets are disrupted and scattered at the micrometre level. The search for natural and non-toxic emulsifiers that have the necessary qualities and capabilities to stabilise emulsions is on the rise. Due to its properties, including tiny particle size, high surface ratio-volume and biological

compatibility, starch nanoparticles (SNPs) have been used in a variety of material sciences fields, particularly in the field of pharmaceuticals there is pharmaceutical interest in modified banana starches in terms of drug delivery (Dhull et al 2021).

Difference between Oil in water and water in oil emulsions (Fatima .M et.al 2014)

Oil in water Emulsion	Water in oil Emulsion
Water is the dispersion medium and oil is the dispersed phase	Oil is the dispersion medium and water is the dispersed phase
Usually used in the preparation of internal formulations as oil unpleasant taste can be masked	Usually used in the preparation of external formulations such as creams .
Water soluble drugs are quickly released from oil in water emulsions	Oil soluble drugs are quickly released in water in oil emulsions
They are non greasy and easily removed from skin surface	They are very greasy and not water washable
They are used externally to provide cooling effect	They are used externally to prevent evaporation of moisture from the surface of the skin
They give a positive conductivity test as water is a good conductor of electricity	They give a negative conductivity test as oil is a poor conductor of electricity

1.2.3 TYPES OF EMULSION INSTABILITY

These macroemulsions are inherently unstable systems from a thermodynamic point of view, hence the only way to improve stability is to modify kinetics. Changes in the size, quantity, and arrangement of droplets in oil-in-water emulsions are caused by a variety of instability mechanisms.

- **Ostwald Ripening**

Due to changes in Laplace pressure, this entails the diffusional transfer of molecules from small to big particles in the disperse phase.

According to Laplace, the difference in pressure between the concave and convex sides of a curved interface is proportional to the interfacial tension times the curvature; for a sphere, the

curvature is determined by the reciprocal of its radius. As a result, little particles shrink (and will eventually disappear) while huge particles get larger because the solubility of the dispersion phase in the continuous phase is enhanced more for small than for large particles. For gas bubbles, this is simplest to imagine, but it also holds true for both solid particles and droplets. However, the rate of transfer is roughly proportional to the oil's solubility in the continuous phase. It is possible to mostly overlook the Ostwald ripening in food oil-in-water emulsions because practically all natural TAG is hardly ever soluble in most aqueous environments. However, essential oil emulsions will be susceptible to Ostwald ripening, and some paraffin oils are also affected.

- **Creaming.** This results from the disparity in mass density between the continuous water phase and the dispersed oil phase. The difference is almost always negative in oil-in-water emulsions, which causes the droplets to ascend. According to the Stokes equation, the rate at which a separate droplet creams is proportional to the mass density difference between the oil and the water, to the square of the droplet's diameter, to the acceleration acting on the droplet, and it is inversely related to the continuous phase's viscosity. Additionally, creaming is influenced by a number of additional factors, particularly if the volume fraction of the droplets is high. In any case, the droplets always form a close-knit cream layer as a result of this. Centrifugation, which can increase the acceleration up to hundreds or even thousands of times the acceleration due to gravity ($g = 9.81 \text{ m/s}^2$), can significantly increase the creaming rate.

- **Aggregation.**

Brownian motion causes droplets to regularly converge on one another. The droplets' ability to maintain sustained close contact, or aggregate, will then rely on the forces acting on them. Interaction forces come in two flavours: internal and external. The van der Waals attraction is the primary internal attractive force and it constantly operates, however the intensity of the attraction varies on the makeup of the two phases. Furthermore, an attractive depletion force may be generated in the continuous phase by the presence of non-adsorbing polymers. Electrostatic forces are the primary repelling forces and are caused by equal electric charges on both droplets, mostly due to substances adsorbed on the interface of the droplets. The pH, which affects the dissociation of ionisable groups, defines the net number of electric charges either negative or positive and thereby the strength of the repulsion. Moreover, the ionic strength of the continuous phase is an important variable: the higher it is, the more the ionic groups are screened, and hence

the weaker the electric repulsion. Another important repulsive mechanism is called steric repulsion, also caused by adsorbed substances. These contain hydrophilic polymeric chains that protrude into the continuous phase and the repulsive force can be quite strong. It is the balance of all these internal forces as a function of interdroplet distance that determines whether aggregation occurs or not. The majority of external forces are hydrodynamic, or brought on by the motion of the liquid (such as by stirring), and they work to break the aggregates. While coagulation refers to aggregation where strong forces are required to disrupt the aggregates and, in this case, new bonds between droplets are not or form very slowly, flocculation refers to aggregation where gentle stirring is sufficient to achieve this. If creaming or stirring do not prevent the aggregation of particles, it may also result in the creation of a particle gel.

- **Coalescence.**

This can happen if two droplets are placed in close proximity for an extended period of time, whether through aggregation or in a cream layer, and just a very thin film of the continuous phase separates them. A film of this type may spontaneously break, more so if its diameter is larger (leading to larger droplets), its thickness is lower (leading to a stronger net attraction between the droplets), and its oil-water interfacial tension is lower (which depends on the type and amount of emulsifier used). Due to the local high Laplace pressure and the oil's tendency to move to locations with lower pressure, as soon as the film breaks, the two droplets combine to form one larger drop.

The oil will flow to locations where the pressure is lower since the local Laplace pressure is extremely high. In order to achieve the lowest Laplace pressure, the oil then takes a spherical shape. One may add that the presence of a surfactant (the emulsifier) is necessary because without it, the drops will merge whenever they are near together, but in reality, this never happens.

- **Clumping, or partial coalescence.**

Only solid particles, which are almost invariably crystals of oil molecules, can be present in the droplets for this to happen. In that case, using the term globules rather than droplets may be preferable. In the most straightforward scenario, a few crystals emerge from a globule into the continuous water phase and form a solid network in the globules.

One system may experience all of these instability mechanisms at once, and the occurrence of one instability mechanism might spur the development of others.

For instance, depending on a number of factors, droplet aggregation may favour creaming, coalescence, and partial coalescence.

Due to the prolonged contact period between the droplets, "true" and partial coalescence are encouraged.

Particularly when the emulsion is exposed to temperature changes, partial coalescence will be promoted in this scenario (Albert .C et al 2019).

1.2.4 Pharmaceutical Application of Emulsion

Pharmaceutical applications frequently make use of emulsions. Creams are emulsions, along with some ointments, gels, pastes, transdermal patches, and vaccinations.

Pharmaceutical emulsions can be administered orally, topically (skin, transdermally, vaginally), intravenously, intramuscularly, ocularly, pulmonaryly, or nasally) by injection (intravenously, intramuscularly), by injection, by topical application (skin, transdermally, vaginally), topically by topical application on the skin (Wadhwa et al. 2012).

- **IMPROVED SOLUBILITY**

In basic emulsions, the oil droplets of an oil-in-water (O/W) emulsion contain the hydrophobic active pharmaceutical ingredients (API), whereas the aqueous droplets of a water-in-oil (W/O) emulsion contain the hydrophilic API. Pharmaceutical emulsions are primarily used because they increase the solubility and bioavailability of the encapsulated API while protecting it.

- **Mask Taste**

By the oral route, emulsions, in addition to improving API protection and absorption, also mask their possible unpleasant taste or texture, making them more palatable.

Improved

Absorption They can be applied topically and frequently increase the permeability of the API. Both O/W and W/O emulsions are acceptable. O/W emulsions have the benefit of not being greasy and being simple to wash off the skin's surface.

- **Better Tolerated**

O/W emulsions administered via the ocular route are more tolerable than solutions and suspensions and do not cause the vision blurring effect associated with ointments.

- **Occlusive Effect**

W/O emulsions possess an occlusive effect by hydrating the upper layer of the skin and avoiding evaporation. They are also greasy and not water washable.

- **Promote Stability of Api**

Since the API is contained in the oil droplets of the O/W or W/O/W (water-in-oil-in-water) emulsions typically employed in this situation, the emulsion form may aid to reduce the tendency of poorly water soluble API to crystallise when administered intravenously.

Multiple emulsions can have drawbacks despite their allure due to their complicated structure and thermodynamic instability brought on by a surfactant exchange between the outside and inner droplet interfaces. Emulsion formulation and long-term stability both depend on the employment of stabilisers since emulsions are thermodynamically unstable systems. Up until now, synthetic surfactants have mostly been used to stabilise emulsions (Dash. A. et al 2014).

1.2.5 ADVANTAGES OF EMULSION

- To administer medications that are poorly soluble in water but well soluble in oils, pharmaceutical emulsions may be employed. For instance, the drug material is dissolved in the internal or discontinuous oil phase of oil-in-water emulsions. The medicine may then be absorbed by the typical oil absorption process after oral delivery of the oil droplets. When provided as an emulsion rather than another oral comparable formulation, several medications are more easily absorbed.
- Pharmaceutical emulsions, in which the medicine is dissolved in the internal phase of an o/w emulsion, may be used to cover up the bitter taste and odour of medications. The required sweetening and flavouring ingredients can then be added to the formulation of the exterior phase.
- Drugs that exhibit better stability in an emulsion dosage form are those that are more stable in an oily phase compared to an aqueous medium.
- Intravenous emulsions of contrast media have been developed to assist in diagnosis.

- Emulsion can be used to prolong the release of the drug (especially semisolid emulsions) thereby providing sustained release action. The oily phase can serve as a reservoir of the drug, which slowly partitions into the aqueous phase for absorption
- To aid in diagnosis, intravenous emulsions containing contrast media have been produced.
- Specially semisolid emulsions, can be employed to delay the release of the medication and provide prolonged release action. Drugs that slowly partition into the aqueous phase for absorption can be stored in the oily phase.
- Essential nutrients can be emulsified and given to bedridden patients as sterile intravenous emulsions, including vitamins, lipids and carbs.
- Patients who have trouble swallowing solid dosage forms may be treated using pharmaceutical emulsions.
- Drugs that are vulnerable to oxidation or hydrolysis are protected by emulsions.
- Emulsions are frequently used to create items that are applied externally, such as lotions, creams, liniments, etc.

1.2.6 DISADVANTAGES

- Pharmaceutical emulsions must be developed to stabilise the emulsion and prevent phase separation because they are thermodynamically unstable.
- Producing pharmaceutical emulsions might be challenging.
- Stability may be impacted by storage conditions.
- Heavy, challenging to move, and prone to container breaking.
- Susceptible to microbiological deterioration, which may cause cracking.
- Accurate and uniform dosing might not be possible.

1.3 Qualities of an ideal emulsion preparation

- Content uniformity (dose to dose and bottle to bottle inside the same container): An appropriate homogeneity of drug content should be present in every dose dispensed from a certain multidose container. The medication content must also be consistent across all bottles of an emulsion batch.

- **Volume separation or creaming:**An emulsion may exhibit some degree of dispersed phase separation from the dispersion medium after being left undisturbed for a while.For instance, creaming of an emulsion is occasionally seen in the case of an o/w emulsion, which denotes a larger concentration of the dispersed oil phase in the top layer of the emulsion.Because of the top phase's increased light obscuration and diffraction,the bottom phase can be seen as being different.
- **Size distribution of the dispersed phase:**Throughout the emulsion's shelf life,the size distribution of the dispersed phase should remain reasonably stable.When globules collide with one another due to Brownian motion,handling agitation?and gravitational motion of the dispersed phase,coalescence or agglomeration may happen,increasing the size of the dispersed phase.A decrease in the size of the dispersed phase globules during storage is a sign that the emulsion is not physically stable by nature(Mahato, R. and Narang, A. 2018).
- **The amount of drug:** When the drug concentration in the emulsion is nearly equal to the drug's solubility,crystallisation can occasionally happen because of changes in storage temperature,the preferred evaporation of one phase,compatibility issues with packaging materials,or accidental nucleation.
- **Palatability** By dissolving them in the dispersed phase, an emulsion dosage form can increase the palatability of medications that are especially bitter.However,depending on the compound's partition coefficient (logP),some drugs may unintentionally partition into the continuous phase,making inclusion of the medication in the dispersed phase insufficient.Sweeteners,flavours and colourants can be added to the emulsion to make it more palatable.Complexation is one type of specialised taste-masking technique that may be required in some circumstances.Of course,parenteral emulsions are exempt from these factors.Osmotic pressure and tissue irritability are crucial factors to take into account when using parenteral emulsions
- **Redistributibility:**A moderate shake of the container should easily cause a divided or creamed emulsion to recombine
- **Flow**

The emulsion must not be too viscous to pour freely from a bottle or to flow through a needle syringe or an IV infusion set (for parenteral emulsions).

Deliverability: Under standard dispensing circumstances, a patient should be able to take the indicated number of doses and volume of emulsion from a bottle. This is typically accomplished by emptying the container of the prescribed number of doses and making sure that the last dose may be consumed completely in a fair amount of time.

9. Flow The emulsion must not be too viscous to flow through a needle syringe or an IV infusion set (for parenteral emulsions) or to pour freely from a bottle.

Drug discharge: The release of the drug from the dispersed phase into an aqueous solution in a suitable dissolving vessel is quantified and controlled as an indicator of the drug's bioavailability because an emulsion contains the drug in the dispersed phase. This might be crucial in the case of semisolid emulsions. Topical emulsions should also have the right amount of fluidity to spread smoothly, but not too much that it runs off the surface too rapidly. The emulsion must provide an elastic layer shortly after application and shouldn't be overly oily. A sweetener is not required, but the dosage form must also have a pleasing colour and smell.

1.4 FACTORS TO BE CONSIDERED IN THE FORMULATION OF EMULSIONS

Formulating emulsions involves careful consideration of various factors to achieve the desired properties and performance of the product. Here are key factors to consider in emulsion formulation:

Type of Emulsion: Determine whether you need an oil-in-water (O/W) emulsion or a water-in-oil (W/O) emulsion, as this choice will influence the selection of ingredients and processing methods.

- **Phase Ingredients:** Select the appropriate oil and water phase ingredients based on the desired properties of the emulsion. These may include oils, water, emulsifiers, thickeners, and other functional additives.
- **Emulsifier/Emulsion Stabilizer:** Choose the right emulsifier or combination of emulsifiers to facilitate the formation and stability of the emulsion. Emulsifiers reduce interfacial tension between oil and water phases, preventing phase separation.

- **Emulsion Processing:** Determine the most suitable method for emulsion preparation, such as high-shear mixing, homogenization, or ultrasonication. The processing method affects droplet size and distribution.
- **Emulsion pH:** Consider the pH of the emulsion, as it can affect the stability and compatibility of ingredients. Adjust the pH as needed for specific applications.
- **Viscosity Control:** Adjust the viscosity of the emulsion by adding thickeners or rheology modifiers. This affects the product's texture and application properties.
- **Stability Testing:** Conduct stability tests under various conditions (e.g., temperature, pH, and storage duration) to ensure that the emulsion remains stable over time.
- **Preservatives and Antioxidants:** Incorporate appropriate preservatives and antioxidants to prevent microbial growth and oxidation, respectively, especially in water-containing emulsions.
- **Active Ingredients:** If the emulsion contains active ingredients (e.g., drugs, vitamins, or botanical extracts), ensure their compatibility with other formulation components and their stability throughout the product's shelf life.
- **Texture and Appearance:** Consider the desired texture, color, and appearance of the emulsion, as these attributes influence consumer perception.

1.5 EVALUATION OF EMULSION

When evaluating an emulsion, several important parameters and characteristics should be considered to ensure its quality and suitability for its intended purpose. Here are some key parameters to assess:

- **Stability:** Determine if the emulsion remains stable over time, without phase separation or creaming.

Particle Size Distribution: Analyze the size and distribution of particles in the emulsion, which can affect its texture and stability.

- **Viscosity:** Measure the thickness or flow behavior of the emulsion, as it can impact processing and application.
- **pH Level:** Ensure the pH of the emulsion is appropriate for its intended use, as it can affect stability and compatibility.

- **Zeta Potential:** Assess the electrostatic charge on particles in the emulsion, which can influence stability and dispersion.

1.6 VISCOSITY OF FLUIDS

The viscosity of a fluid may be described as its internal resistance to flow or movement. Viscosity of emulsion is of great importance for stability and pourability of emulsion. As viscosity of the dispersion medium increases, the terminal settling viscosity decreases, thus the dispersed phase settles at a slower rate and they remain dispersed for a longer time, therefore leading to a higher stability of the emulsion. On the other hand, as the viscosity of the emulsion increases, its pourability decreases and inconvenience to the patient for dosing increases. Thus, the viscosity of emulsion should be maintained within optimum range to yield stable and easily pourable emulsion. Combination of two emulsifying agents can enhance the stability of emulsion.

1.6.1 DETERMINATION OF VISCOSITY

The determination of viscosity is crucial for assessing the thickness or flow behavior of liquids, including emulsions. There are several methods to measure viscosity, and the choice of method depends on the nature of the emulsion and the desired accuracy. Here are some common methods for determining viscosity:

Viscometers are specialized instruments designed to measure viscosity. There are various types of viscometers, including:

- **Rotational Viscometers:** These instruments measure viscosity by rotating a spindle or bob in the liquid and measuring the torque required to overcome resistance. Examples include Brookfield viscometers and Rheometers.
- **Capillary Viscometers:** These viscometers measure the time it takes for a specific volume of liquid to flow through a narrow capillary tube. Ostwald and Ubbelohde viscometers are examples.
- **Cone and Plate Viscometers:** These viscometers use a rotating cone and a stationary plate to measure shear stress and shear rate, allowing for the calculation of viscosity.

- **Ford Cup Viscometer:**This method involves filling a standardized cup with the emulsion and measuring the time it takes for the liquid to flow out through an orifice at the bottom of the cup. Different cups are used for various viscosity ranges.
- **Brookfield Viscometer:**The Brookfield viscometer is commonly used for emulsions and measures viscosity by rotating a spindle at a constant speed in the sample.The resistance encountered by the spindle provides viscosity data.
- **Ostwald Viscometer:**An Ostwald viscometer is a type of capillary viscometer that measures the flow of liquid through a calibrated capillary tube.Viscosity is calculated based on the flow time.
- **Cone and Plate Rheometer:**This instrument uses a cone and a flat plate to measure shear stress and shear rate.Viscosity can be calculated from the relationship between these two factors.
- **Vibrational Viscometers:**These viscometers measure viscosity by analyzing the vibration characteristics of a vibrating probe or rod immersed in the emulsion.
- **Online and In-line Sensors:**In some industrial settings, online and in-line sensors can continuously monitor viscosity during manufacturing processes,providing real-time data for quality control.

When performing viscosity measurements,it is essential to consider factors like temperature, as viscosity is often temperature-dependent.Additionally,ensure that the chosen method is appropriate for the viscosity range of your emulsion and that the instrument is properly calibrated. Accurate viscosity data is crucial for quality control and product consistency in various industries, including food,pharmaceuticals and cosmetics.

1.7 RHEOLOGY OF EMULSIONS

Significant variables affecting emulsion rheology were discussed.Emulsion rheology makes extensive use of volume fraction,phase rheology,droplet size, and colloidal interactions.(B.C et.al 2017)

The size, shell thickness,wettability,concentration, and oil/water ratio of the stabilisers are all variables that affect emulsions.Emulsion formation and stabilisation are also influenced by the homogenization procedure, oil volume proportion,and surfactant to oil ratio.The characteristics and stability of emulsions can also be impacted by the chemical make-up and viscosity of the

dispersed phase, preparation conditions, and storage temperature. The creation of multiple emulsions depends on the structure and solubility of the emulsifier as well as the polarity of the oil. These elements have been thoroughly investigated to comprehend how they affect emulsion stability and develop to create methods for producing functional materials and encapsulating bioactive substances.

Emulsion theories have been developed from the perspectives of colloid and interface science, as well as the production of commercial emulsions. Theoretical tools are needed to address various physical phenomena in emulsions, such as the thermodynamics and kinetics of phase separation, emulsion stability, and the coarsening, Brownian motion, and coalescence of emulsion droplets. Multiple scattering theories have been used to predict the ultrasonic velocity and attenuation coefficient of emulsions, with good agreement for dilute emulsions but less accuracy for more concentrated emulsions. The dynamic behavior of emulsions has been studied experimentally and theoretically, including self-emulsification, thin liquid films, phase inversion phenomena, and the use of emulsions as templates for solid foams. To address a variety of physical phenomena in emulsions, such as the coarsening, Brownian motion, and coalescence of emulsion droplets, as well as the thermodynamics and kinetics of phase separation, emulsion stability, theoretical tools are required. The ultrasonic velocity and attenuation coefficient of emulsions have been predicted using a variety of scattering models, with reasonable agreement for diluted emulsions but less precision for more concentrated emulsions. Experimental and theoretical research on the dynamic behaviour of emulsions has focused on self-emulsification, thin liquid films, phase inversion events.

1.8 LITERATURE REVIEW

Starches

Starch is an abundant storage polysaccharide in plants, widely used in the food, biomedical, pharmaceutical, chemical and paper industries due to its low cost, biodegradability, biocompatibility, and non-toxic attributes (Chen et al., 2018; Bashir and Aggarwal, 2019). In order to enhance the texture, gel formation, adhesion, moisture retention, viscosity and homogeneity of the products, starch is frequently employed in the food business as a colloidal stabiliser, thickening, bulking component, gelling agent and water retention ingredient. Amylose and amylopectin make up 98–99% of the dry weight of starch, which also contains trace amounts

of phosphate, lipids and protein. While amylopectin (AP) has a highly branching structure, amylose (AM) contains linear molecules. Maize starch's molecular make-up includes crystalline and amorphous regions. The crystalline region is made of amylopectin, easily disrupted due to heating, while the amorphous part mainly contains amylose (Nnyigide and Hyun, 2020). Generally, waxy, normal and high amylose starches contain 0%, 20–35% and over 50% amylose, respectively (Tester et al., 2004). The ratio of amylose to amylopectin in starch has an important effect on the characteristics of starch such as texture, solubility, viscosity, stability, gelatinization, moisture retention, retrogradation, and syneresis which are the main criteria of selecting an appropriate starch for food products (Klaochanpong et al., 2015).

Although native starch's intrinsic drawbacks, such as its retrogradation tendency and low resilience to mechanical and thermal treatments, frequently restrict its usage in the food business, these drawbacks can be fixed by altering starch through chemical, physical, and enzymatic means (Zhang et al., 2019). However, the demand for clean-label or safely-processed starches has grown in recent decades due to the high expense of chemical and enzymatic processes and the detrimental impact of chemically altered components on human health (Ma et al., 2019). By combining starches with appropriate hydrocolloids or biopolymers, adding proteins (Sun and Xiong, 2014), and blending starches with various compositions (Juhász and Salgó, 2008), it is possible to address several flaws in native starch. The shear and thermal stability, viscosity, retrogradation qualities, and stability of food products can all be improved using these safe and practical altering procedures. The production of food items with the specified specifications may benefit from information on the relationship between the amylose/amylopectin ratio and functional features of starch (Juhász and Salgó, 2008). Accordingly, one of the effective approaches for comprehending the technological and functional characteristics of starch is the analysis of pasting curves (Sulaiman, 2011).

Emulsion stability is related to both surface elasticity and surface viscosity, as derived from interfacial rheological measurements, with a greater dependence on the first named parameter.

Different activation energies derived from the temperature dependence of surface elasticity and emulsion stability show that another component, such as dehydration of the Tween polyoxyethylene chains, is also involved in globule coalescence. Coalescence could result from a force pressing nearby globules together, creating a compressive stress that grows over

time(Byod.J Etal).The interfacial membrane around the globules starts to break down and coalescence starts when it exceeds a critical value,which will be related to the maximum deformation that the globules can withstand.

The stability of emulsion globules is one of the main challenges to using emulsion liquid membranes for industrial separations.Globule rupture and osmotic swell are two events that affect the stability of an emulsion.The liquid membrane thins and, in certain situations, ruptures as a result of interfacial shear between the continuous and membrane phases,which affects separation.Emulsion globule migration (creaming, sedimentation) and size variation or aggregation (coalescence, flocculation) are destabilisation events that have an impact on the homogeneity of dispersions.(jaydeep M Barad etal)

1.9 OBJECTIVE OF THE STUDY

In Nigeria, most pharmaceutical industries depend heavily on importation of raw materials which are expensive and deplete our foreign reserves.Starch are readily available and have found wide applications as binders and emulsifying agents in pharmaceutical formulations.However a search in literature shows that starches from *zea mays* have been exploited in tablet and emulsion formulation but that of *Musa acuminata* and *Musa sapientum* as emulsifying agents have not been investigated.Hence the objectives of the study was to

- Extract the starch from *Musa acuminata* and *Musa sapientum*
- Evaluate it as an emulsifying agent in the formulation of emulsions.
- Compare the emulsifying properties of the starches with maize starch as the standard.

CHAPTER TWO

MATERIALS AND METHOD

2.0 MATERIALS USED

Unripe *Musa acuminata*, unripe *Musa sapientum*, viscometer, beakers, maize starch, measuring cylinders, arachis oil, distilled water, emulsion bottles, pipers, microscope, methylene blue, microscopic slide and covers, camera, water bath, weighing balance, seive, homogenizer, Arachis oil, chlorocresol, weighing balance .

2.1 MATERIALS

Musa acuminata unripe fruit



Fig 1 Fresh *musa acuminata* unripe fruit and its extracted starch

Musa acuminata family musaceae is a herbaceous perennial herb that can reach a height of around 20 feet and is occasionally wrongly referred to as a tree. Its "pseudostem," or stalk, is made up of a thick fibrous cylinder of closely spaced leaf bases or petioles that grows from a fibrous root system that is mostly made up of a fleshy rhizome (often referred to as a corm. There are typically dark or black blotches on the pseudostem, which is devoid of any woody structure.

Large, oblong or elliptic leaves that can be up to 10 feet long and 2 feet broad unfold from the pseudostem as it grows, usually one every week during warm weather. Around the pseudostem, the fragile leaves are grouped spirally and may be fully green.

Each row of female flowers develops into a cluster, called a “hand,” of 10-20 of the common fruit individually called “fingers”. These measure from 2½ to 12 inches long and ¾ to 2 inches wide at maturity and show a great variety in color, shape and texture. Up to 300 bananas, weighing over 100 pounds, can be produced on a single plant. Once the fruit, which is botanically considered a berry, ripens and is harvested the pseudostem dies. The plant reproduces and grows perennially by producing a new pseudostem the next season from the corm. In the wild, the plant reproduces both sexually by producing seeds and asexually by producing suckers. Cultivated varieties are almost exclusively produced asexually by cloning or tissue culture and have only vestiges of the ovules seen in the dark specks visible near the center of the fruit.

Each row of female flowers matures into a cluster of 10 to 20 common fruit, also known as “fingers” that are grouped together to form a “hand” (Valmayor R.V 2020).

These measure from 2½ to 12 inches long and ¾ to 2 inches wide at maturity and show a great variety in color, shape and texture. Up to 300 bananas, weighing over 100 pounds, can be produced on a single plant. Once the fruit, which is botanically considered a berry, ripens and is harvested the pseudostem dies. At maturity, they range in size from 2 ½ to 12 inches long and ¾ to 2 inches wide, and they exhibit a vast range of colour, shape, and texture. On a single plant, 300 bananas that weigh more than 100 pounds can be produced. The pseudostem decomposes when the fruit, which is a berry in botanical terms, ripens and is picked. One medium-sized banana (118g) provides 105 calories, 27g of carbohydrates, 14.4g of sugars, and 1.3g of protein. Bananas are a healthy source of fiber, potassium, vitamin B6, vitamin C, various antioxidants and phytonutrients. Its uses range from food to medicines. The bark has found applications to help relieve conditions like psoriasis and eczema, while soothing bug bites, wounds, sunburns and skin irritations.

The investigated and reported pharmacological activities of *M. acuminata* include antioxidant, antidiabetic, immunomodulatory, hypolipidemic, anticancer, and antimicrobial especially anti-HIV activities. *Musa acuminata* starch is used as a thickening stabilising and emulsifying agent in different systems.

The edible part of *M. acuminata* provides energy, vitamins and minerals. All other parts of the plant have been used in the treatment of many diseases in traditional medicine. The rich diversity of phytochemicals present in them probably contributes to their beneficial effects, and validates the role of *M. acuminata* plant parts used by various tribes and ethnic groups across the geographical areas of the world.

2.1.1 *Musa sapientum* unripe fruit



Fig 2 Fresh *Musa Sapientum* unripe fruit and its extracted starch

The herbaceous perennial banana, which belongs to the MUSACEAE family, has a height range of 5 to 9 metres. It has a tuberous underground rhizome, which is where the leaves grow. The lower leaves are folded over on themselves to form a "false stem" from which the long, narrow blades emerge and spread out. A developing point develops from the top of the rhizome in the centre of the folded leaf-sheaths, shoots up, and then appears as an overhanging inflorescence with a series of reddish brown bracts. From the base to the tip, the bracts spread out before falling off. 14–18 female flowers appear in double rows on the lowest 1–12 bracts.

Musa sapientum (*M. sapientum*) commonly known as 'banana' is widely used folk medicine for the treatment of various ailments including diarrhea, wounds, stomach ulcer, diabetes, heart burn, inflammation and others

2.1.2 MAIZE STARCH

Maize starch is obtained from the caryopsis of *Zea mays*.L

- An extremely fine, white or slightly yellowish powder, or irregular white lumps that are easily reduced to powder, that creaks when squeezed between the fingers and has no taste or odour. It is insoluble in water and ethanol. Starch has taken the top spot among polymers used as pharmaceutical excipients due to its benign and nonirritating qualities, low cost, simplicity of modification, and variety of uses. Starch is frequently used as a diluent, disintegrant, binder, and lubricant in traditional tablets and capsules. Starch has essential inherent qualities that have enabled its use in pharmaceuticals. It has also been utilised for a variety of specialised drug delivery applications, including the delivery of difficult compounds and the targeting of particular body areas. With a few unique traits, such as non-foaming & non-thinning qualities of boiling solution, maize starch exhibits all the characteristics of native starch. Therefore, maize starch has a negligible impact on the productivity of the paper and weaving industries. When high viscosity starch is employed, the fibre gains a higher tensile strength, which enhances sizing (Obaro. M et. al 2022).

Maize starch is used for its gelling or thickening properties in many sectors of agro-food applications (soups, delicatessen meats, sauces, pastas, creams). Used in Pastry, cream, Desserts, coating, etc. It is used as an anti-sticking agent in medical products using latex-like surgical gloves, condoms and diaphragms. Furthermore, it also acts as a source of energy and its intake helps prevent low blood sugar. Certain cosmetic products also use dry starch powder as a filler.

2.2 METHOD

2.2.1 Extraction of Starch

Fresh unripe banana species were purchased from the new Benin market in Edo state. The plants were identified by Dr. Akinnibosun Henry Adewale. The extraction of the starch from the unripe banana fruits was carried out using an already established method (Martha. H. et al 2022)

The unripe fruits of the banana species were measured before and after being peeled, the peeled unripe banana was cut into smaller pieces, grinded with a blender. The slurry obtained was passed through a mesh sieve and the filtrate was extracted. The extracted filtrate was left to settle for 48 hours in order to extract the starch from it. Water was decanted in order to obtain the settled starch from the filtrate, the extracted starch was allowed to sun dry for 2-3 days until it was properly dried and the yield was calculated. The powder was then passed through a 125mm Sieve in order to homogenize it. The powder was then stored in an airtight container until use.

2.2.2 Calculation of Percentage Yield

The peeled unripe banana fruits were weighed with a weighing balance and the starch extracted from it was dried and also weighed.

Musa acuminata

UNPEELED-4545g

Peeled -3060g

Starch gotten -311

Percentage (%) yield $-311/3060 \times 100 = 10.17\%$ w/w

Musa sapientum

Unpeeled unripe fruit -6565g

Peeled fruit-3575

Starch gotten -512.1g

Percentage (%) yield $-512.1/3575 \times 100 = 14.21\%$ w/w

Musa Sapientum showed to have a greater starch yield than the *Musa acuminata*

2.2.3 Properties of The Extracted Starch

- **Organoleptic properties:**

The test for appearance, odour, color, taste, texture and smell of the various starch powder were carried out in replicates and the observations were recorded.

physicochemical properties

- **Iodine test for the presence of starch**

100mg of the various starches were added to a test tube and few drops of iodine solution was added and a blue-black colouration was observed.

- **Solubility:** 2g of starch was out in about 10ml of water and shaken vigorously it was filtered and weighed, the weight was compared to the initial weight Iodine test for the presence of starch .

2.3 PREPARATION OF STARCH MUCILAGE

Using an already established method (Nakajima. S et al 2023) Varying concentrations (5-30%w/v) of the starches were prepared by dispensing the appropriate weights of the starches in 20ml of distilled water at room temperature (28°C) to form a suspension. The extracted starch was passed through a sieve to remove any impurities. Different concentrations of 5%, 10%, 15%, 20%, 25%, 30% starch mucilage was prepared from the extracted starch of the banana species by dispensing the appropriate weights of the starches in 20ml of distilled water at room temperature (28°C), dissolving and stirring the calculated amount of the extracted starch in the required amount of hot water until a clear paste was formed and the viscosities, the resulting suspension was made up to a final volume of 50ml by the addition of boiled distilled water to form the mucilage. For the various concentrations were determined using the viscometer apparatus. The time of flow of each concentration through the capillary of a suspended viscometre was determined. The viscosities were determined in replicates and mean values were calculated and the results documented using standard deviation.

2.4 DETERMINATION OF VISCOSITY OF VARIOUS CONCENTRATIONS OF FRESHLY PREPARED STARCH MUCILAGE

Viscosity was measured using the Ostwald U-tube viscometre shown below.(Pratumwal, Y. et.Al 2017)

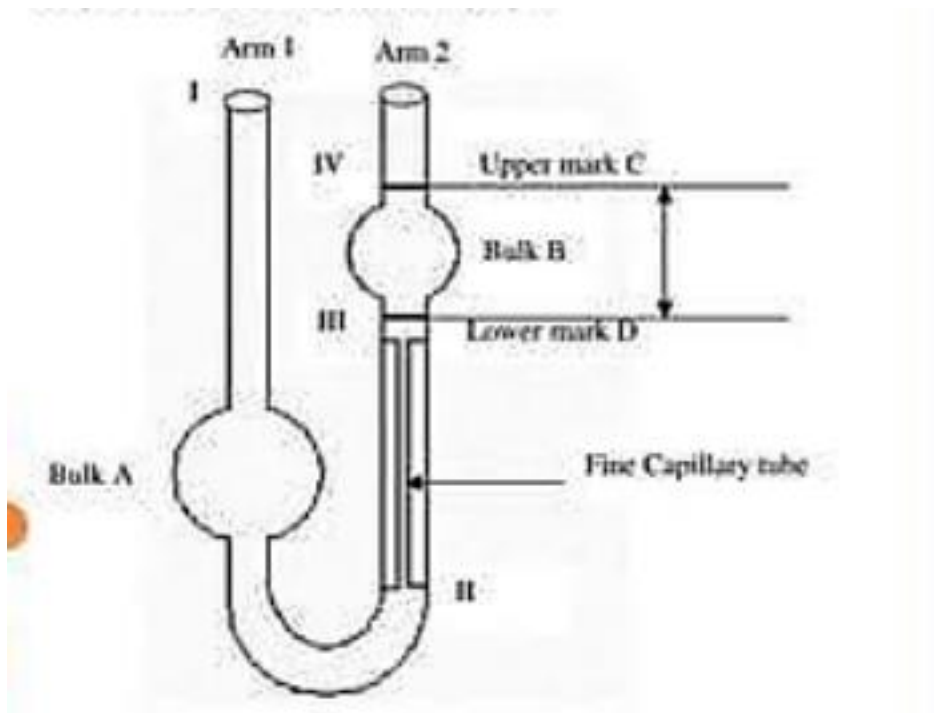


Figure 3: Ostwald U-tube Viscometer

The viscosity was determined by the time it takes for the varying concentration of the starch mucilage to flow from the upper mark C to the lower mark D.

2.5 PREPARATION OF EMULSION

Table 1: Formular of emulsions prepared with the varying concentrations of starches showing the ingredients and corresponding quantities for each formulation.

Ingredients	Quantity used in <i>Musa sapientum</i> emulsion			Quantity used in <i>Musa acuminata</i> emulsion			Quantity used in Maize starch emulsion		
	10%	20%	30%	10%	20%	30%	10%	20%	30%
Percentage of starch in preparation									
Extracted starch	10g	20g	30g	10g	20g	30g	10g	20g	30g
Arachis oil	40ml v/v	40ml v/v	40ml v/v	40ml v/v	40ml v/v	40ml v/v	40ml v/v	40ml v/v	40ml v/v
Water	20ml	20ml	20ml	20ml	20ml	20ml	20ml	20ml	20ml
2g chlorocresol (5%) w/v	1ml w/v	1ml w/v	1ml w/v	1ml w/v	1ml w/v	1ml w/v	1ml w/v	1ml w/v	1ml w/v
Distilled water to	100ml	100ml	100ml	100ml	100ml	100ml	100ml	100ml	100ml

The emulsion was prepared from the extracted starch from the banana species and the analytical maize starch. The method used was the wet gum method; using the wet gum method, 10%, 20% and 30% of the Starch mucilage from the various starches provided was prepared ...which was 10g in 10ml of water, 20g in 20ml of water, 30g in 30ml of water until a clear paste was made The various concentrations of the prepared starch mucilage were then used to prepare the emulsion by using a general formulation of adding 40ml of arachis oil, 1ml of 5% of chlorocresol was added as a preservative and using water to make the total preparation to 100ml in a beaker. The beaker was placed in a homogenizer for 10 minutes in order to homogenize the preparation. After complete homogenization, the preparation was poured into 100ml calibrated emulsion bottles and the bottles were labeled appropriately.

Microscopic evaluation of emulsion globules was carried out using the microscope for globule characterisation and the effect of aging on the storage of the emulsion for two weeks was observed.

2.6 MICROSCOPIC EVALUATION OF EMULSION GLOBULES

A microscopic slide and cover and the microscope, one drop of the preparation was added to a microscopic slide ,one drop of 10% methylene blue preparation was added both of them were mixed appropriately with a stirrer and was covered with the microscopic slide cover,and using the microscope on a 40X magnification,it was viewed under the light microscope.The globule structure and sizes were determined as there was a distinct difference between the globules and the field of view.Dilution tests were also Carried out using the Emulsion,here, small amount of various concentrations of the emulsion was added to a large amount of water and oil...The observations were written. All the emulsion formulations were tested for stability at room temperature, and their stability was evaluated at various time intervals for up to 4 weeks.

CHAPTER THREE

3.0 RESULTS AND DISCUSSION

3.1 RESULT OF PERCENTAGE YIELD OF STARCHES EXTRACTED FROM BANANA SPECIES

The study shows that the starch obtained from *Musa acuminata* was 10.17%w/w while the starch obtained from *Musa sapientum* was 14.21 %w/w.

Hence *Musa Sapientum* showed greater yield than *Musa acuminata*.

Table 2: Organoleptic properties

PARAMETERS	<i>MUSA ACUMINATA</i>	<i>MUSA SAPIENTUM</i>	MAIZE STARCH
Colour	Dark brown	Light brown	White
Odour	Characteristic	Characteristic	Characteristic
Texture	slightly coarse	Smooth	Smooth
Taste	Yeast like taste	Yeast like taste	Flour like taste

The Organoleptic properties results in table above shows the colour of *Musa acuminata* and *Musa sapientum* were seen to be dark-brown and light-brown respectively, this can be as a result of oxidation as banana is high in iron and the starch after being extracted were sun dried for days .

Table 3: Physicochemical properties

Solubility			
Acetone	Insoluble	Insoluble	Insoluble
Chloroform	Insoluble	Insoluble	Insoluble
Ethanol	Insoluble	Insoluble	Insoluble
Hot water	Insoluble	Insoluble	Insoluble
Iodine	Blue black colour	Blue black color	Blue black color
Percentage yield	14.21%	10.17%	

The solubility profile of the various starches were also checked and they were seen to be insoluble. Generally, starches are insoluble.

Using iodine to test for the presence of starch is a common experiment because iodine in combination with starch forms an easy to see dark blue complex. The various starches turned blue black on the addition of few drops of iodine which indicated the presence of starch.

Table 4: Viscosities of different concentrations of freshly prepared starch mucilage with banana species (in seconds) ± SD using maize as the standard (in seconds) ± SD

Starches evaluated	Concentration used	Viscosity (in seconds) ± SD
<i>Musa sapientum</i>	5%	114±20.29
	10%	304.6±49.22
	15%	914±156.43
	20%	1521.6±43.21
	25%	3336±143.14
	30%	5618±299.83
<i>Musa acuminata</i>	5%	466±27.45
	10%	810±89.14
	15%	1160±78.74
	20%	3252±252.86
	25%	5562±412.08
	30%	7204.8±82.12
Maize starch	5%	760±89.14
	10%	1294± 196.45
	15%	2815.8±34.29
	20%	6210±153.17
	25%	8492±450.3
	30%	10728±171.06

The result above showed that the Viscosity of Analytical maize starch, starch extracted from *musa acuminata* and *musa sapientum* increases with increase in their concentration. There was a marked increase in the Viscosity of Analytical maize starch, followed by starch extracted from *musa acuminata* and then starch extracted from *musa sapientum* showed an increase in viscosity with an increase in the concentration of the emulsifying agent (5-30%w/v) with the range (760±89.14-10728±171.06) for maize starch, (466±27.45-7204.±82.12) for *Musa acuminata* and (114±20.29-5618±299.83) for *Musa sapientum*. The study showed that *Musa acuminata* is more

favorable as an emulsifying agent than *Musa sapientum* when compared to maize starch. This is because the freshly prepared starch mucilage had a higher time of flow compared to *Musa sapientum* because it had more viscous preparations. Increasing the concentration of starches in emulsions generally leads to increased viscosity, which can impact the stability, texture, and overall performance of the emulsion.

Higher concentrations of starch can enhance the stability of emulsions. The starch molecules can form a protective barrier around the dispersed oil droplets, preventing coalescence and separation. The increased viscosity from starches can alter the texture of the emulsion.

Viscosity plays a crucial role in emulsions for several reasons:

Emulsion Stability: Viscosity helps to maintain the stability of emulsions by resisting the coalescence of dispersed droplets. In emulsions, higher viscosity prevents the oil droplets from merging and separating from the aqueous phase, ensuring a stable and homogeneous product.

Viscosity can influence the ease of emulsion formation. In some cases, increasing viscosity can make it easier to create stable emulsions because it reduces the mobility of the dispersed droplets, making them less likely to coalesce or separate.

Control of Ingredient Release: In pharmaceutical and cosmetic emulsions, viscosity can control the release of active ingredients. A higher viscosity may slow down the release of a drug from a topical cream, allowing for prolonged therapeutic effects.

Rheological Behavior: Viscosity is part of the overall rheological behavior of emulsions. Understanding the rheological properties, such as shear-thinning or shear-thickening behavior, is crucial for optimizing emulsion formulations for specific applications.

Flow Properties: Viscosity affects how emulsions flow and can impact their ease of handling and dispensing. For instance, a more viscous preparation flows more slowly from the bottle, making it easier to control the amount dispensed (Singh, M. et al. 2020)

In summary, viscosity is a fundamental property in emulsions that influences their stability, texture, flow, and overall performance.

DILUTION TEST

Using water and oil dilution test was carried out for all the concentrations of emulsions that were prepared and it was soluble in oil and water but more soluble in water

- It is an oil in water emulsion, water is the external phase
- *MUSA ACUMINATA* SHOWED TO BE MORE VISCOUS THAN *MUSA SAPIENTUM*
- The emulsions were observed for 2weeks for the effect of aging and the observations were recorded in the table below ;

Table 5: showing results of change in Globule sizes of freshly prepared and aged emulsions emulsified with maize starch and different banana species starch

Starches evaluated	Concentration used (%w/v)	1 st day Globule sizes (mm) ± SD	7 th day Globule sizes (mm) ± SD
<i>Musa sapientum</i>	10%	1.125±0.375	2.51±0.37
	20%	1.57±0.39	2.51±0.37
	30%	1.57±0.8	3.0±0.71
<i>Musa acuminata</i>	10%	2.0±0.35	3.2±0.96
	20%	1.04±0.21	2.65±0.43
	30%	1.75±0.18	3.9±1.37
Maize starch	10%	1.6±0.23	2.57±0.37
	20%	1.87±0.3	2.51±0.37
	30%	2.25±0.82	3.0±0.71

From the table above it can be seen that as the emulsion aged it showed that there was a decrease in the globule number of the emulsion and an increase in the globule size after 7days which showed ((1.75±-3.94±1.37) for *Musa acuminata* ,(1.57±-3.0±0.71) for *Musa sapientum* and (2.25±-3.0±0.71) for maize starch which is the standard.

Table 6: Effect of aging on the storage of emulsion prepared from 30%w/v starch of *Musa acuminata*, *Musa sapientum* and maize starch

Days	30% maize starch	30% <i>Musa acuminata</i>	30% <i>Musa sapientum</i>
0	Freshly prepared and stable	Freshly prepared and stable	Freshly prepared and stable
1-4days	No change observed	Slight cracking observed	Cracked lines
5 th day	Cracking observed	4cm separation	No changes
6 th	Cracking increased	6cm separation	More cracks ,12cm separation
8 th	No change from previous observation	Reduction in the viscosity of the preparation.	Oil separation at the top and water separation at the bottom .
12 th	No change from previous observation	Slight foul smell observed and surface of the preparation turned dark brown	No growth ,swelling of preparation I.e reduction in viscosity of the preparation.
14 th	Greenish growth observed,oil phase separation from the preparation.	Foul smell observed	No growth observed observed

From the table above it can be seen that cracks were observed in the emulsion preparations of *Musa acuminata* and *Musa sapientum* from the 4th day and observed in that of maize starch from the 5th Day . The study also showed phase separation in the emulsion from the 7th day and it was observed that there was a reduction in the viscosity of the preparation with time .

The cracking increased as the emulsion aged and there was a reduction in the viscosity of the preparation I.e increased fluidity .it was also recorded that there was a slight foul smell that can be attributed to the fermentation of the banana starch and after over a week, there was growth observed in the preparation.

The results also showed that there were changes in the preparation when observed for two weeks ,there was cracking and phase separate which showed instability and there was also mucous formation and growth despite the use of 1ml of 5%w/v chlorocresol ,hence maybe a higher concentration of the anti microbial agent should be used or another type of anti microbial

agent should be used .The study of aged emulsions is essential for improving product quality,optimizing formulations,ensuring stability,and advancing scientific knowledge in multiple fields.

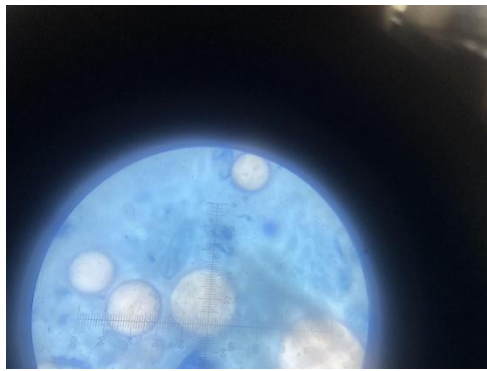
The cracking might be due to the complete separation of the oil and water phases.This can be as a result of the emulsifying agent losing its viscosity or if the emulsion is thermodynamically unstable.Changes in temperature,pH,or the presence of incompatible ingredients can trigger phase separation.

GLOBULE STRUCTURE

Using the light microscope in a magnification of X40, placing a drop of the various concentration of the emulsions on a slide and being stained with a water soluble dye(methylene blue) and covered with a slide cover...it was ensured that there was a distinct difference between the globule and the field of view in order to ensure there was appropriate measurement of the number of globules, the globule size and diameter in a given field of view .

MICROSCOPY The pictures below show the various globule sizes of the various preparation when viewed under the microscope on the first day and seventh day. Photomicrographs of 30% freshly made emulsions from the various starches from the 1st day to the 7th day are shown below and are labelled 1-7 after a period of seven days the globules were found to increase in the three preparations indicating a drop in stability with time.

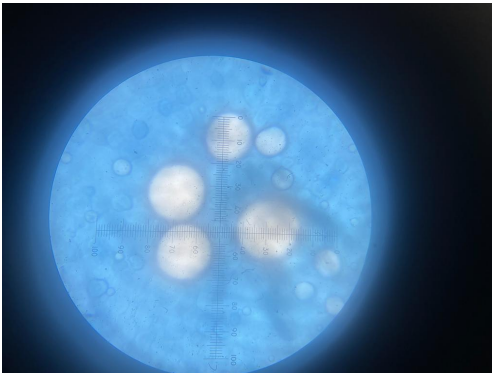
1ST – 7TH Day Microscopic analysis of emulsion prepared with 30%w/v *Musa Acuminata*



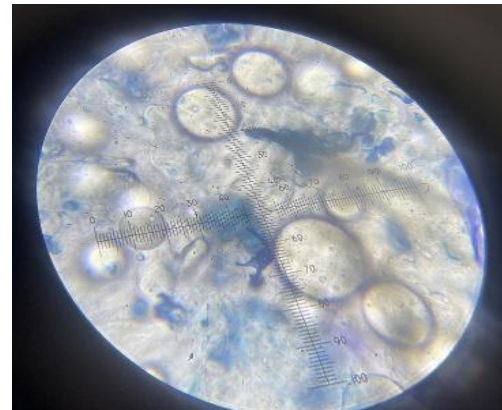
1



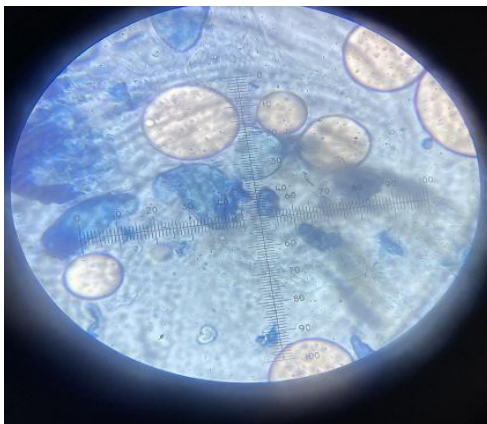
5



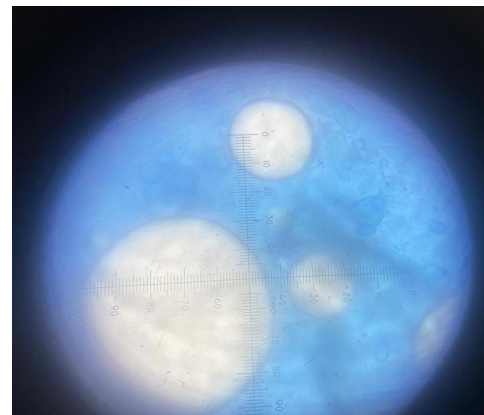
2



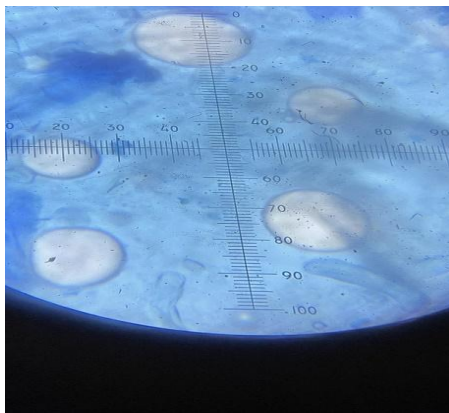
6



3



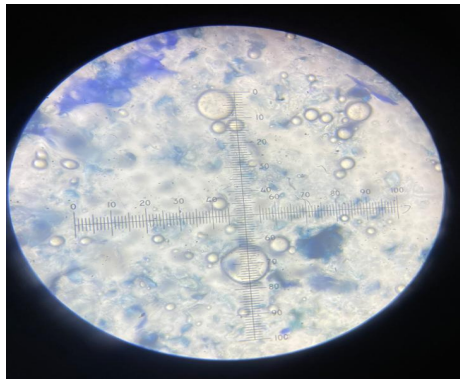
7



4

Figure 4: Showing photomicrographs of freshly prepared and aged emulsion emulsified with 30% *Musa acuminata* using a magnitude of 40x microscope lens with image dimension of 768x1024.

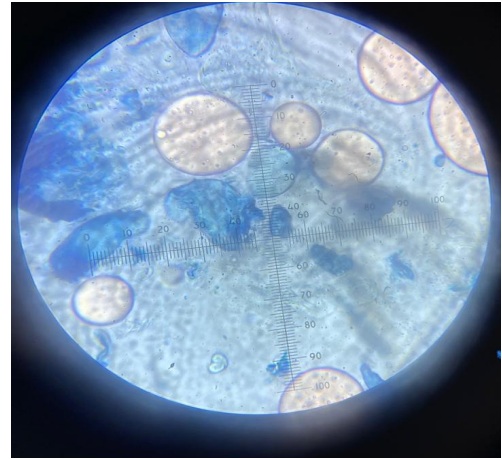
1ST – 7TH Day microscopic analysis of emulsion prepared with 30%w/v *Musa sapientum*



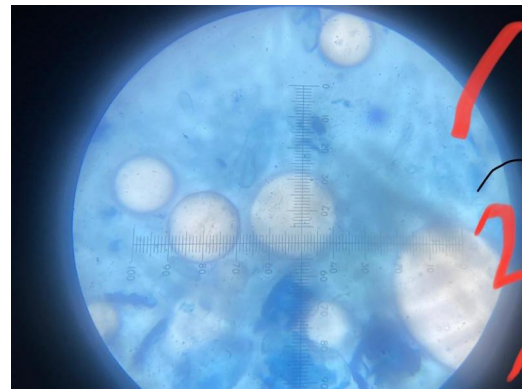
1



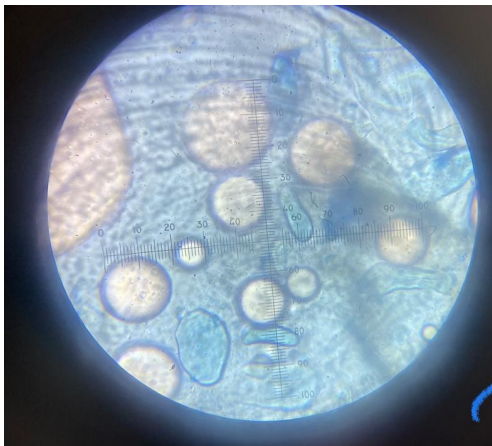
2



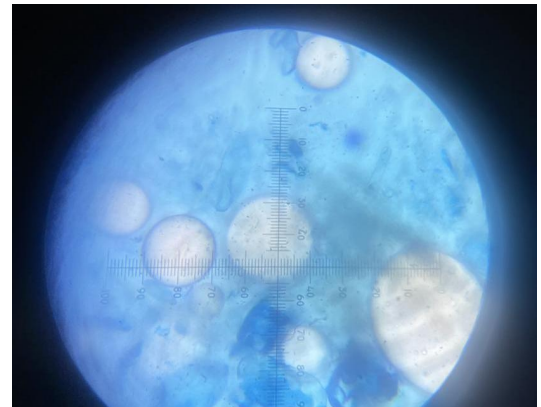
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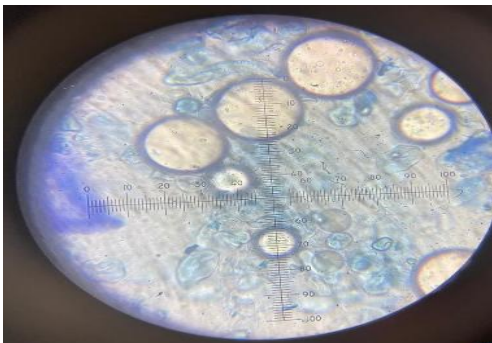
6



3



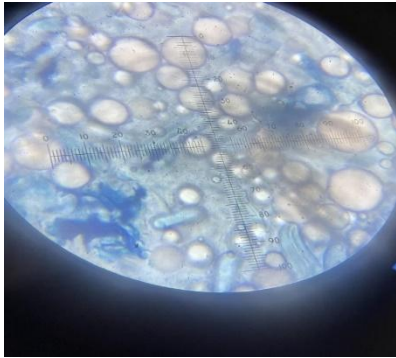
7



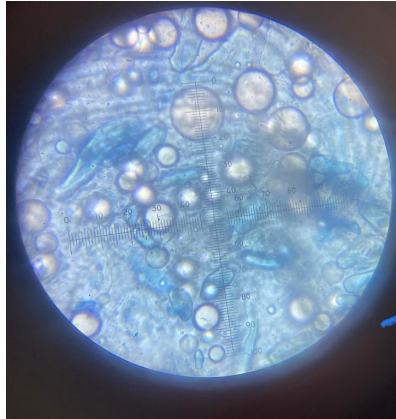
4

Figure 5: Showing photomicrographs of freshly prepared and aged emulsion emulsified with 30% *Musa sapientum* using a magnitude of 40x microscope lens with image dimension of 768x1024.

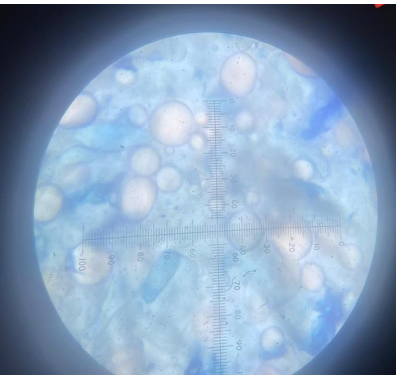
1ST – 7TH Day microscopic analysis of emulsion prepared with 30%w/v Maize starch



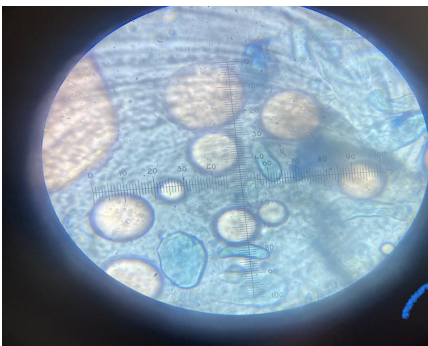
1



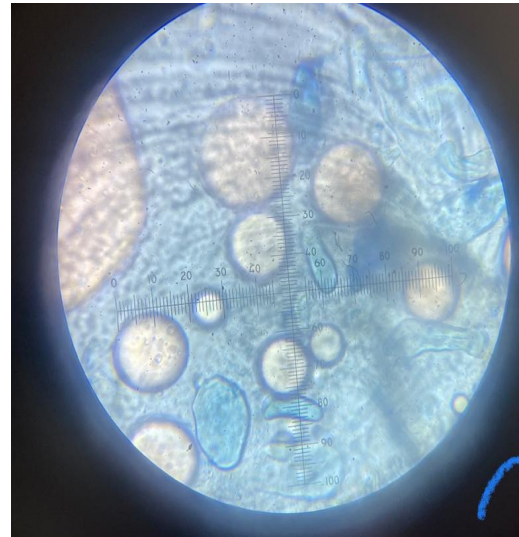
2



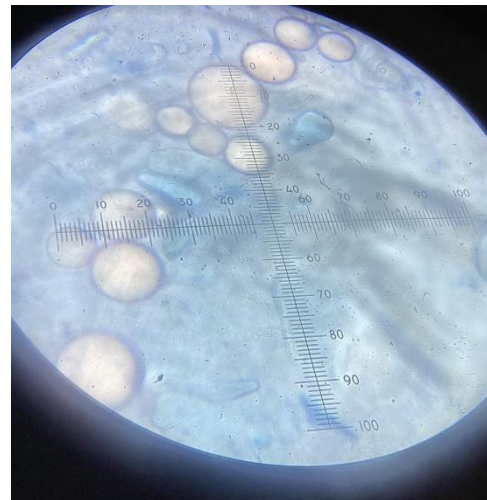
3



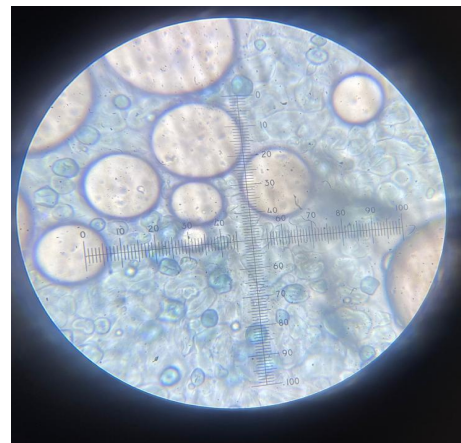
4



5



6



7

Figure 6: Showing photomicrographs of freshly prepared and aged emulsion emulsified with 30% Maize starch using a magnitude of 40x microscope lens with image dimension of 768x1024.

The images above showed that there was a difference between the globules sizes of the emulsion in day 1 and day 7. An increase in the globule size of an emulsion typically decreases its stability. Emulsions consist of two immiscible liquids, such as oil and water, where one is dispersed in the other. The stability of an emulsion is influenced by several factors, including the size of the dispersed droplets or globules.

From the result above it can be seen that the number of globules Decreased and the size of the globules increased. The increase in globule size can be said to be coalescence. An increase in the globule size of an emulsion typically decreases its stability(Jafari S.M et.al 2008).Emulsions consist of two immiscible liquids, such as oil and water, where one is dispersed in the other.The stability of an emulsion is influenced by several factors, including the size of the dispersed droplets or globules (Fleming. A. et al 2017)

When the globule size is increased:

Reduced Surface Area:Larger globules have a smaller surface area relative to their volume compared to smaller globules. This decreased surface area makes it more challenging for emulsifying agents (like surfactants) to effectively coat and stabilize the globules.

Increased Coalescence: Larger globules are more prone to coalescence or merging together. This results in the formation of bigger droplets, which can lead to phase separation and the breakdown of the emulsion.

Enhanced Creaming: Larger globules are more susceptible to gravitational settling or creaming. As a result, the dispersed phase (e.g., oil) tends to rise or fall more quickly in the continuous phase (e.g., water), causing instability.

Greater Kinetic Energy: Larger globules have higher kinetic energy requirements for diffusion and Brownian motion. This makes them more likely to collide and coalesce, further destabilizing the emulsion(Lefebvre, A.H., 1992)

In summary,increasing the globule size in an emulsion decreases its stability by reducing the surface area for emulsifier action, promoting coalescence,increasing susceptibility to creaming, and raising kinetic energy requirements for dispersion.Maintaining small globule sizes is often essential for ensuring the stability of emulsions(.Postelmans, A. et. al 2020)This is an important instability term in emulsion preparations.Increase in globule size distorts the preparation as larger globule size will sediment. this also shows that the viscosity of the starches reduced daily

because it was unable to suspend the smaller globules individually help causing them to move and coalesce with each other to form a larger globule which will sediment in the preparation. In pharmaceutical practice, it is important that the dispersion phase is viscous enough to suspend the dispersed phase uniformly, in cases where the active pharmaceutical ingredient of the preparation is dissolved or carried in the dispersed phase, this can bring about lack of dose uniformity. Coalescence of globules in emulsions can affect the dose uniformity of the emulsion. Here's how:

Dose Variability: When emulsion globules coalesce (combine or merge), they can create regions within the emulsion with varying concentrations of the dispersed phase (e.g., oil droplets in water). This can lead to dose variability because different portions of the emulsion may contain different amounts of the active ingredient or substance.

Loss of Homogeneity: Coalescence disrupts the homogeneity of the emulsion. It can result in some parts of the emulsion having higher concentrations of the dispersed phase, while others have lower concentrations. This non-uniformity can lead to inconsistent dosing when portions of the emulsion with higher or lower concentrations are dispensed.

Stability Issues: Coalescence can also be an indicator of poor emulsion stability. Emulsions are typically designed to be stable, preventing the coalescence of globules. When coalescence occurs, it may be a sign of instability in the product, which can further affect its ability to maintain dose uniformity over time.

To maintain dose uniformity in emulsions, it is important to control and minimize coalescence during formulation, manufacturing, and storage. This is achieved through the selection of appropriate emulsifying agents, mixing methods, and storage conditions to ensure that the emulsion remains stable and maintains a consistent distribution of the dispersed phase.

CHAPTER FOUR

4.0

CONCLUSION AND RECOMMENDATION

4.1 Findings

The study showed that the starch extract obtained from *Musa acuminata* and *Musa sapientum* unripe fruits were 10.17% and 14.21% respectively. However the yields are poor and not economical, this calls for a better method of extraction of starch from the unripe fruit. The starch from *Musa acuminata* compares more favourably with maize starch and the starch from *Musa sapientum* is less comparable as emulsifying agents in the formulation of pharmaceutical emulsions and hence they can be used as an emulsifying agent in pharmaceutical emulsions.

4.2 CONCLUSION

The extracted starch from *Musa acuminata* and *Musa sapientum* unripe fruit can be used as an emulsifying agent in the formulation and stabilisation of emulsion and will serve as substitute to imported chemicals and polymeric colloids used in the formation of emulsion.

Musa acuminata starch compared more favourably with Analytical maize starch composed to *Musa sapientum* starch used in emulsion formulation.

4.3 RECOMMENDATION

From the study, research should be carried out on

- The method of extraction of starch from the unripe fruits.
- The emulsifying properties of modified *Musa sapientum* starch
- The yield and emulsifying properties of modified *Musa sapientum* starch, *Musa acuminata* starch and *Musa paradisiaca* starch should be compared.

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