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REVIEW ARTICLE

LITERATURE REVIEW ON ENSET STARCH: PHYSICO-CHEMICAL PROPERTIES AND PHARMACEUTICAL APPLICATIONS

Abrham Wondimu[1*], Fantahun Molla[1], Subas Chandra Dinda[1], Naod Gebre-Samuel[1], Ebisa Tadese[1]

[1]Department of Pharmacy, College of Health Sciences, Mekelle University, P.O.Box 1871, Mekelle, Ethiopia.

ABSTRACT

Enset (Ensete Ventricosum, Family Musaceae) is a plant indigenous to Ethiopia, it is often called 'false banana" for its close resemblance to banana plant. The plant is the most important staple food for millions of people in the south and southwestern parts of Ethiopia. Enset plant contains starch as its major contents. The starch has been investigated for its physico-chemical properties including granule size, X-ray diffraction pattern, amylose content, gelatinization behavior, stability and various rhelogical properties of the gel. Based on its physico-chemical properties the starch was evaluated for various pharmaceutical applications such as in tablet binder and disintegrant. Several modifications were also attempted on the native enset starch so as to improve and modulate its physiochemical properties. Hence, this review aims to summarize the knowledge on the properties of enset starch and its pharmaceutical applications.
Key words: Enset Starch, Physico-Chemical Properties, Pharmaceutical Application

INTRODUCTION

Starch is the most abundant storage reserve carbohydrate in plants. It is found in many different plant organs, including seeds, fruits, tubers and roots, where it is used as a source of energy during periods of dormancy and re-growth[1]. A range of native starches from different sources with highly different functionalities are already on the market. Each starch is named according to its plant source, e.g. potato starch, maize starch, cassava starch, rice starch. These groups are distinctly different from each other with respect to chemical composition and physical properties [2].

Starch is made up of two polymers of D-glucose: amylose, an essentially unbranched α [1→ 4] linked glucan, and amylopectin, which has chains of α [1→ 4] linked glucoses arranged in a highly branched structure with α [1→ 6] branching links. Amylose and amylopectin make up 98–99% of the dry weight of native granules, with the remainder comprising small amounts of lipids, minerals, and phosphorus in the form of phosphates esterified to glucose hydroxyls. Starch granules range in size from 1 to 100 µm diameters and shape of polygonal, spherical, lenticular, and can vary greatly in content, structure and organization of the amylose and amylopectin molecules, the branching architecture of amylopectin, and the degree of crystallinity [3].

Amylose has a molecular weight ranging 10^5 – 10^6, corresponding to a degree of polymerization of 1000 – 10,000 glucose units. Less than 0.5% of the glucoses in amylose are in α [1→ 6] linkages, resulting in a low degree of branching. Amylopectin is a much larger polymer, with a molecular weight about 10^8 and a degree of polymerization that may exceed one million. Most starches contain 60 – 90% amylopectin, although high-amylose starches, with as little as 30% amylopectin, and waxy starches with essentially 100% amylopectin are well known. Amylopectin has about 5% of its glucoses in α [1→ 6] linkages, giving it a highly branched, treelike structure and a complex molecular architecture that can vary substantially between different starches with regard to placement and length of branches [2].

A great deal of attention has been devoted to starch and its derivatives mainly in the context of the food, plastics and pharmaceutical industries. This is not only because starch is readily available, inexpensive and inert material, but also because of the ease with which its physicochemical properties can be altered through chemical or enzymatic modification and/or physical treatment [4, 5].

Commercial starches are obtained from cereals (corn and wheat) and from tubers and roots (particularly potato and cassava) and they dominate the world markets for starches in the food and pharmaceutical industries. Recently more attention has been focused on the development of some of the starch from different botanical sources as excipients in pharmaceutical formulations [6].

*Corresponding author:
Abrham Wondimu,
Department of Pharmacy,
College of Health Sciences, Mekelle University,
Mekelle, Ethiopia.
E-mail: leabrham@gmail.com

Studies on enset starch have brought to light the possibility of using these starch as pharmaceutical excipients in substitution of other more common starches like corn and potato starch. Thus, the aim of this paper is to review the potential of enset starch as a pharmaceutical excipient.

OVERVIEW OF ENSET PLANT (*Ensete ventricosum* (Welw.) Cheeseman)

Ensete ventricosum (Welw.) Cheeseman belongs to the family Musaceae, and the genus Enset. Enset looks like a large, thick, single-stemmed banana plant. Both enset and banana have an underground corm, a bundle of leaf sheaths that form the pseudostem, and large leaves (Figure 1). Enset, however, is usually larger than a banana, with the plant up to 10 m tall and pseudostem up to one meter in diameter[7]. Because of its resemblance to the banana plant, enset is often referred as "False Banana" as it does not bear edible fruit. Instead, it is used for the production of starchy foods [8].

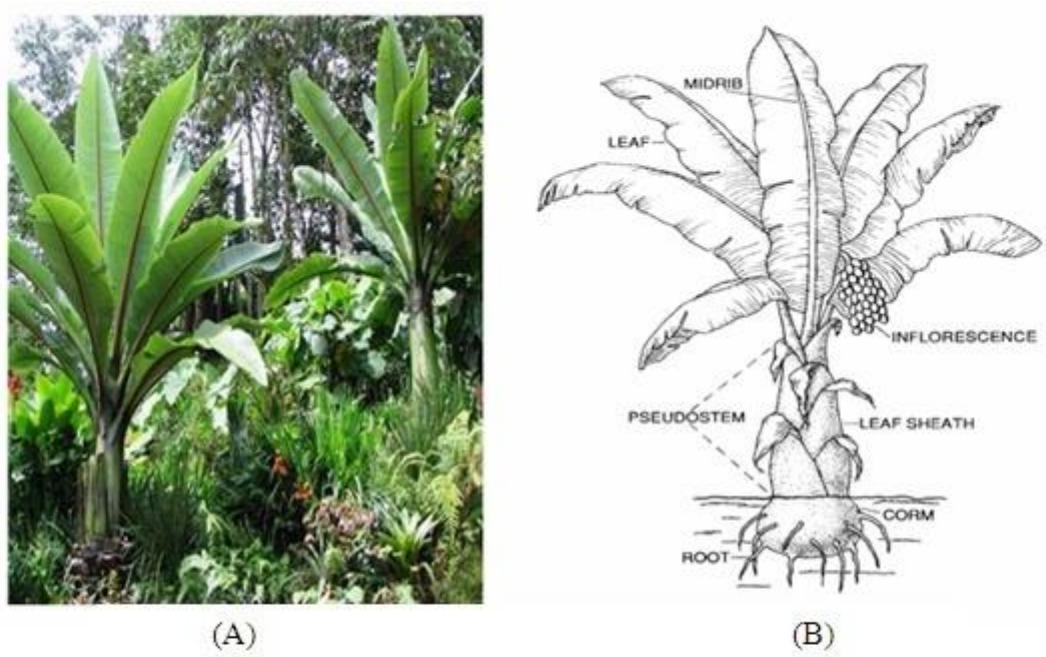


Figure 1: Enset plant in the garden (A) and its parts (B).

The plant is the most important staple food for 7 - 10 million people in the south and southwestern parts of Ethiopia. The plant is grown at altitudes ranging from 1500 - 3100 m above sea level, but scattered plants can also be found at lower altitudes. For optimum growth, the crop requires an average rainfall of 1100 - 1500 mm per year and average monthly temperature of 16 - 20 °C [9].

The major foodstuffs obtained from enset are locally known as *kocho*, *bulla* and *amicho*. In the preparation of kocho and bulla, the pseudostem and corms are cut and crushed and the exuding liquid containing starch is collected. Most of the water is allowed to drain away and bulla is collected, leaving the fibrous material, kocho, behind. Amicho is the boiled enset corm, usually of a young plant. Starch accounts for more than 90% of *bulla* (on dry weight basis) [7, 10].

PHYSICO-CHEMICAL PROPERTIES OF ENSET STARCH

Amylose Content

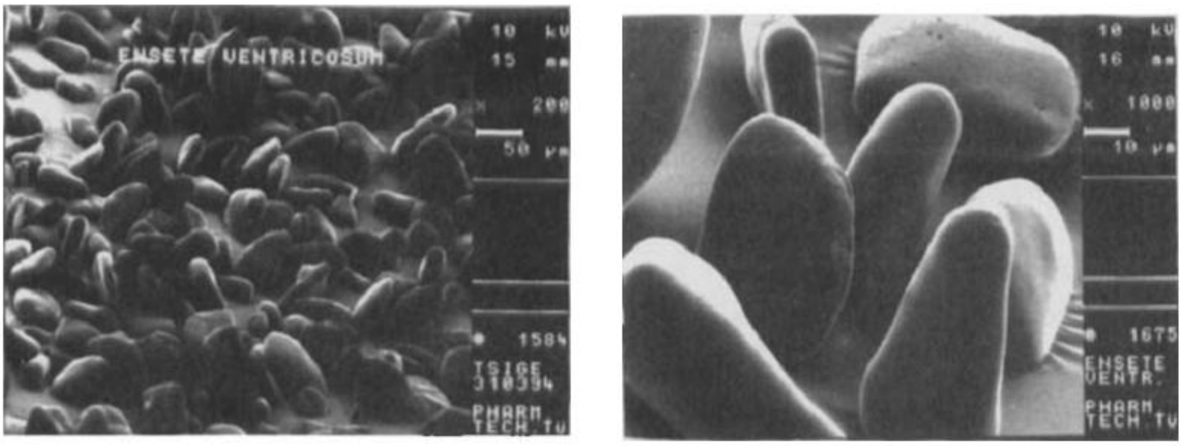
The linear component of starch, viz., amylose, imparts defining characteristics to starch. Amylose content varies considerably among different starches and genetic modifications have been carried out to obtain the starch of amylose contents varying from 0 to greater than 75% [11]. According to a study by Gebre-Mariam and Shimidt[10] the amylose content of enset starch was estimated to be 29.0%. Another study, however, indicated that the amylose content to be 21% [12]. The variation could arise from differences in the methodologies used for determination of the amylose content. Both of the studies showed that the amylose content of enset starch was comparable with that of potato starch[10, 12].

Other components in enset starch

The extracted starch is invariably accompanied by various other components viz., fiber, lipids, proteins and minerals, depending on a number of factors such as method of extraction, age of the crop, and environmental conditions. Some of these impart desirable qualities to the starch, while others affect the quality[11]. Proximate composition analysis of the enset starch showed 14.0% (w/w) moisture, 0.35% (w/w) protein, 0.25 % (w/w) fats, and 0.16% (w/w) ash[10]. A study also revealed that fat and protein content of enset starch was significantly higher than potato starch but lower than maize starch. Enset starch contained higher content of ash than maize starch, but lower than potato starch[10].

Granule Shape and Size

Gebre-Mariam and Schmidt[10] reported that a scanning electron micrograph shows enset starch is composed of entirely single entities of small and large grains with a characteristic shape that is somewhat angular and elliptical (Figure 2). The average granule size of enset starch was 37.7µm, which was comparable to that of potato starch (38.2 µm). The size distribution of the granules showed a normal distribution curve between 15 and 60 µm, sharper than that of potato starch, which was broadly distributed from 5 to 65µm[12]. But in another study the enset starch granule size was found to be 46 µm[10]. This variation could be due to difference in age of the crop used in the studies[13] and variation in collection season[14].



(A) (B)

Figure 2: Scanning electron micrographs of enset starch granules; (A) 200X; (B) 1000X[10]

X-ray diffraction pattern

Starch has a definite crystalline nature and the crystallinity has been assigned to the well ordered structure of the amylopectin molecules inside the granules. Different starches possess either ‘A’, ‘B’ or ‘C’ pattern (which has been suggested to be a mixture of ‘A’ and ‘B’ patterns). Enset starch possesses a typical B-type pattern as with potato starch with major peaks at 2θ= 5.5°, 14.5°, 17°, 22° and 24° (Figure 3)[10,12].

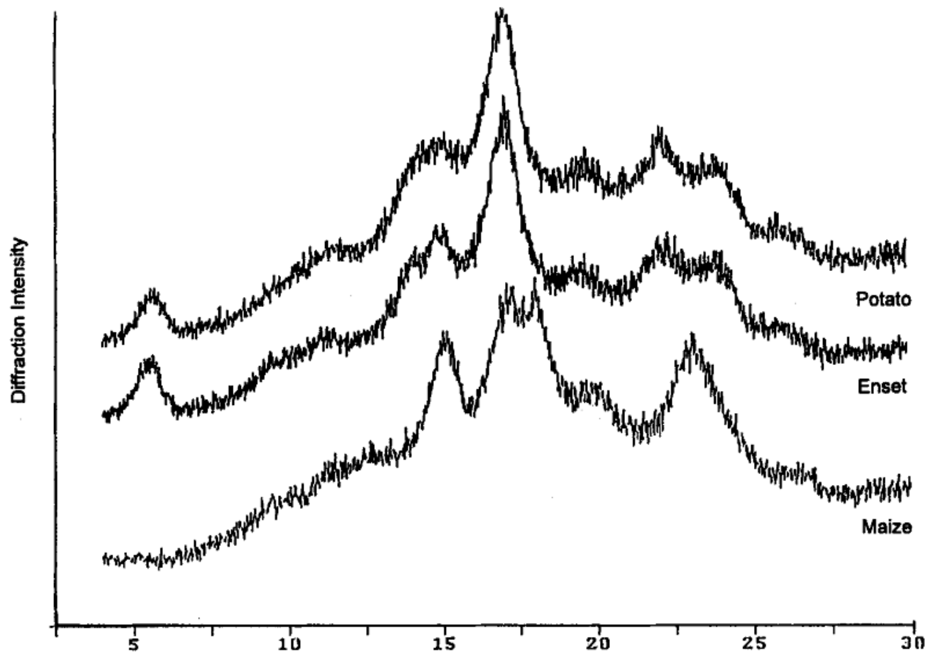


Figure 3: X-ray powder diffractograms of potato, enset and maize starches[10].

Gelatinization behavior

When starch granules are heated in water to progressively higher temperatures, a point is reached where the polarization cross starts to disappear and the granules begin to swell irreversibly. This phenomenon, associated with the disruption of granular structure, is called ‘gelatinization’ [15,16].

The gelatinization temperature, which is indicative of the temperature at which the starch granules gelatinizing, can be measured by using different methods.

Gebremariam and Schimt measured it using DSC. DSC thermograms of enset starch at a starch water ratio of 1:2 showed that the onset temperature (T_o), the peak temperature (T_p) and endset temperature (T_e) of gelatinization of enset starch to be 61.8, 65.2 and 71.7°C, respectively (Figure 4). The values reported are higher than that of potato starch[10]. On the other hand, Hirose *et al*.[12], examined the gelatinization behavior of enset starch by determining the viscosity and the light transmittance change of starch suspension during continuous heating. In both methods, the authors found that enset starch had a higher gelatinization temperature than potato starch. As the gelatinization temperature reflects the degree of orderly arrangement of the molecules in the starch granules, it may be assumed that enset starch is sturdier than potato starch. The enthalpy (ΔH) of gelatinization of enset starch reported was 21.6mJmg^{-1} [10].

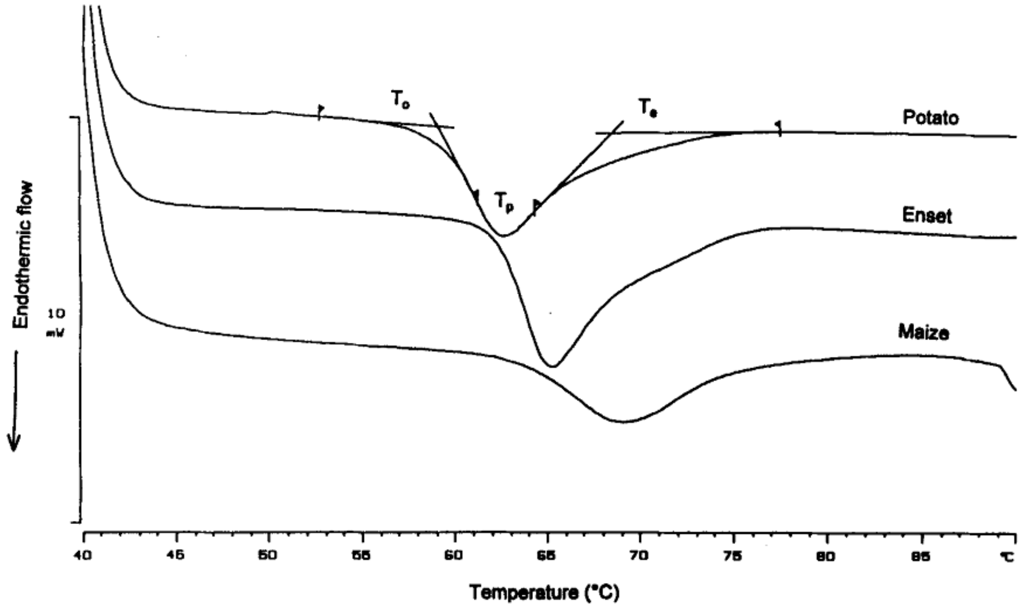


Figure 4 : DSC thermograms of enset, potato and maize starches at water-to-starch ratio of 2:1[10].

Pasting Behavior

Use of starch in textile, paper, adhesive and food industries depends on the viscosity of the starch paste. Among the different equipment, the Brabender Viscograph and Rapid Visco Analyzer are most commonly used[11]. Pasting property of enset starch determined by Brabender Viscograph showed a peak viscosity of 884 Barbender unit (BU); which was between potato starch (1668 BU) and maize starch (302 BU). Enset starch attained its maximum viscosity after a heating period of 33min. It is also stated that the maximum viscosities of enset and maize starch were attained at higher temperature (95°C) as compared to potato starch (72°C). The cold paste viscosity (CV) of enset starch was greater than its corresponding peak viscosity, indicating the high retrogradation tendency of the amylose fraction of enset starch[10].

Characteristic properties of enset starch gel

Physical properties such as firmness, stickiness, adhesiveness and cohesiveness of enset, potato, sago and corn starch gels were determined by Hirose *et al*.[12]. It was reported that rheological properties represented by cohesiveness, adhesiveness and firmness of enset starch gel were comparable with those of corn starch. The enset starch paste quickly formed a fragile gel during storage, which was similar to the behavior observed of corn starch[12].

Swelling and Solubility

Swelling power provides evidence of non-covalent bonding between starch molecules. Factors like amylose-amylopectin ratio, chain length and molecular weight distribution, degree/length of branching and conformation determine the degree of swelling and solubility[17].

A study indicated that the swelling power and solubility of enset starch increased with temperature. It was also revealed that the swelling power of enset starch was much lower than potato starch and much higher than that of maize starch. According to similar study both enset and maize starches showed lower solubility values than potato starch[10].

PHARMACEUTICAL APPLICATION OF ENSET STARCH

Tablet binder and disintegrant

The binding and disintegrant properties of enset starch have been evaluated in chloroquine phosphate, dipyrone, and paracetamol tablet formulations and compared with tablets prepared with potato starch[18]. The results showed that enset starch had a better binding ability giving tablets of lower porosity and friability, but higher crushing strength than potato starch [18]. On the other hand, Enset starch exhibited poor disintegrant property than potato starch[19]. The authors concluded that although enset starch is a less effective disintegrant than potato starch, it can be used as a disintegrant at optimum

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concentration, suggesting that enset plant could be used as an alternative source of starch in tablet formulations[19]. In another study, the binding and disintegrant properties of pregelatinized enset starch was investigated[20]. The result of the study revealed that pregelatinized enset starch demonstrated comparable binding and disintegrant property with that of Starch 1500® (commercially available partially pregelatinized corn starch) [20].

Super-disintegrants

Although the native starch has been widely used as a tablet disintegrant, the softening effects it has on a tablet at an effective concentration along with the increasing demand for faster disintegration, dissolution and improved bioavailability of drugs administered by conventional oral tablets has resulted to some extent in its replacement by more active disintegrants, such as "super-disintegrants". These super-disintegrants include sodium starch glycolates, cross-linked polyvinyl pyrolidone and cross-linked carboxymethyl cellulose. Sodium starch glycolate is the sodium salt of a relatively low substituted carboxymethylether of a native starch prepared by both crosslinking and substitutions. The disintegration efficiency of a sodium starch glycolate prepared from enset starch was evaluated in α-lactose monohydrate and dicalcium phospahe dehydrate tablets by comparing similar tablets containing sodium starch glycolate from potato starch (Primojel®) or croscarmellose sodium, NF (Ac-Di-Sol®)[21]. The finding showed that the disintegration efficiency of sodium starch glycolate prepared from enset starch is as efficient as Primijel® [21].

Sustained release agent

Different polymers have been used for the development of sustained release dosage forms. Recently, various species of modified starch were evaluated for the formulation of sustained release dosage forms and they have shown a promising result in sustaining drug action. Enset starch, cross-linked using sodium hexametaphosphate (SHMP) in solid phase systems under different microwave powers and reaction times, has been used for the preparation of starch microspheres as sustained release agent. It was found that the cross-linked enset starch sustained the release of the drug for nearly a day[22]. Comparative study of the physicochemical, drug loading and releasing properties of cross-linked cassava, enset and potato starches, using sodium hexametaphosphate (SHMP) as cross-linking agent also showed that cross-linked enset starch loaded higher amount of drug in 0.1 N HCl, 0.9% NaCl and pH 7.4 phosphate buffered saline media as compared to cross-linked cassava and potato starches. After 12 h, cross-linked enset starch matrix released about 90% of the drug, indicating its ability to sustain drug release and their potential to be used as drug-release-sustaining pharmaceutical excipient[23].

In another study, enset starch acetate with degrees of substitution of 2.142 and 0.672 were evaluated for direct compressibility and drug release sustaining properties. The result showed that high degree of acetylation renders enset starch to sustain the drug release for more than 12h and highly compressible[24].

Pharmaceutical gelling agent

The application of native starch as the pharmaceutical gelling agent has been reported, but discouraging mainly because of the need for a high concentration and heating to obtain a viscous gel, the opacity of the formed gel, and its poor stability compared to other gelling agents[11]. Several reports indicate that carboxymethylation improves aqueous dispersibility and cold storage stability of starch pastes. These improved properties suggest the potential application of CMS as a pharmaceutical gelling agent. A study was conducted by Gabriel and his co-workers to investigate carboxymethylated enset starch as pharmaceutical gelling agents[25]. Accordingly, nine different topical gel formulations of ibuprofen were prepared. All formulations were evaluated with respect to cosmetic qualities, pH, drug content, viscosity, spreadability, extrudability, *in vitro* drug release, anti-inflammatory activity and stability. The ibuprofen gels exhibited significantly higher anti-inflammatory activity in mice compared to the standard 1% indomethacin gel and they were found to be non-irritant and physicochemically stable. Indicating the potential use of carboxymethylated enset starch as effective gelling agents in topical preparations.

CONCLUSIONS

Numerous study revealed that Enset starch has amylose content, granule size, X-ray diffraction pattern and gelatinization temperature which is comparable to potato starch. However, the swelling power and solubility properties are lower than that of potato starch. The granules of the enset starch are angular and elliptical in shape, different from potato starch. Enset starch demonstrated numerous pharmaceutical applications, including binder, disintegrant, super disintegrant, and gelling agent. The cross-linked and acetylated form of enset starch showed their potential use as a novel drug delivery system. Hence it can be concluded that enset starch can be used as alternative starches in pharmaceutical industries, especially in Ethiopia, where almost all of the starch used are imported from abroad.

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