ADDIS ABABA UNIVERSITY

COLLEGE OF HEALTH SCIENCES

SCHOOL OF PHARMACY

DEPARTMENT OF PHARMACEUTICS AND SOCIAL PHARMACY

ISOLATION AND PHYSICOCHEMICAL CHARACTERIZATION OF STARCHES FROM THREE VARIETIES OF ETHIOPIAN SWEET POTATO [*IPOMOEA BATATAS* (L.) LAM.]

BY

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Isolation and Physicochemical Characterization of Starches from Three Varieties of Ethiopian Sweet Potato [*Ipomoea batatas* (L.) Lam.]

By

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This is to certify that the thesis studied by Kebede Wondu Tilayeneh, entitled: "Isolation and Physicochemical Characterization of Starches from Three Varieties of Ethiopian Sweet Potato [*Ipomoea batatas* (L.) Lam.]" and submitted in partial fulfillment of the requirements for the Degree of Master of Science in Pharmaceutics complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Chair of the Department

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA:	Analysis Of Variance
AOAC :	Association of Official Analytical Chemist
BDV:	Breakdown Viscosity
BVA:	Brabender Amyloviscograph
CSA:	Central Statistical Agency
CV:	Cold Paste Viscosity
DSC:	Differential Scanning Calorimetry
ΔH:	Enthalpy
FTIR:	Fourier Transform Infrared
HV:	Hot Paste Viscosity
PV:	Peak Viscosity
RH:	Relative Humidity
RS:	Resistant Starch
RVA:	Rapid Visco Analyzer
SDS:	Slowly Digestible Starch
SEM:	Scanning Electron Microscopy
SP:	Swelling Power
USP/NF:	United States Pharmacopoeia /National Formulary
UV/VIS:	Ultraviolet-visible
XRD:	X-Ray Diffraction

ABSTRACT

Starch is a polysaccharide that has important role in pharmaceutical, food and other industries. Although there are a number of commercial sources of starch, it is important to evaluate the potential applications of starch from local sources. Despite the presence of different varieties of sweet potatoes in Ethiopia, the physicochemical properties of their starches have not been previously studied. Thus, the aim of this study was to isolate, characterize starches from three varieties of Ethiopian sweet potatoes, namely Awassa83, Kulfo and Tulla. Starches were isolated using 0.075% (w/v) sodium metabisulphite solution. The starches were studied for the amylose, lipid, protein, fiber, moisture content, granule size, morphology, X-ray diffraction pattern, swelling power and solubility, thermal properties, and pasting properties. Moisture, protein, ash, lipid and fiber content of the starches varied from 12.41 to 13.72%, 0.05 to 0.22%, 0.22 to 0.4%, 0.16 to 0.41% and 0.37 to 0.43%, respectively. Scanning electron microscopy showed polygonal, round and cupoliform/bell shaped granules and the starch from the sweet potato varieties differed in their mean granule size, particle size distribution and amylose content. While Kulfo starch showed highest amylose content (18.15%), starch from Awassa83 revealed the largest mean particle size (20.9 µm). Swelling power and solubility ranged from 14.5 g/g to 21.7 g/g and 3.05% to 9.8%, respectively. X-ray diffractions pattern of the starch was C-type with maximum characteristic peaks at 15^o, 17^o, and 23^o 2θ. Gelatinization temperatures, namely, onset temperature ($T_{o:}$ 61.82-65.27 ^oC), peak temperature ($T_{p:}$ 65.60-69.09 ^oC), endset temperature ($T_{e:}$ 72.13-73.69 ^oC) and the enthalpy of gelatinization (5.45 mJ/mg to 6.85 mJ/mg) were obtained. Variations in pasting properties were observed among the sweet potato starches comprising peak viscosity (787 mPa.s to 873 mPa.s), hot paste viscosity (652 mPa.s to 723 mPa.s), breakdown viscosity (135 mPa.s to 158 mPa.s), cold paste viscosity (898 mPa.s to 997 mPa.s), setback viscosity (111 mPa.s to 127 mPa.s), peak time (4 min to 4.53 min) and pasting temperature (71.85 ^oC to 74.3 ^oC). Awassa83 starch depicted relatively high Peak and breakdown viscosities and low setback viscosity, and it may be suitable as a thickening and gelling agent. In conclusion, the results indicate that the sweet potato starches may be alternative source for use in the food, pharmaceutical and other industries.

Keywords: Awassa83, *Ipomoea batatas*, Kulfo, Starch, Sweet potato, Tulla

1. INTRODUCTION

1.1. Starch

Starch, a polysaccharide composed exclusively of D-glucose, is one of the most abundant organic compounds found on earth (Jane, 1995; Manek *et al.*, 2012). Starch can be isolated from leaves, stems, tubers, seeds, and roots of higher plants stored as an energy reserve. Chemically, starch is a carbohydrate polymer consisting of anhydro glucose units linked by α-D-(1, 4) and α-D-(1, 6) at the branch, glycosidic bonds (Bertolini, 2010). It consists of two inherently incompatible molecules (illustrated in Figure 1): amylose, a linear polymer, and amylopectin, a branched chain polymer (Manek *et al.*, 2012). Starch is used in a variety of industries including food, textiles, cosmetics, plastics, adhesives, paper, and pharmaceuticals (Adeboye and Emmambux, 2017; Yin and Wang, 2016). The various industrial usage of the starch materials is prefaced on its availability at low cost, high caloric value, inherent exceptional physicochemical properties and the ease of its modification to other derivatives (Gebre-Mariam and Schmidt, 1996).

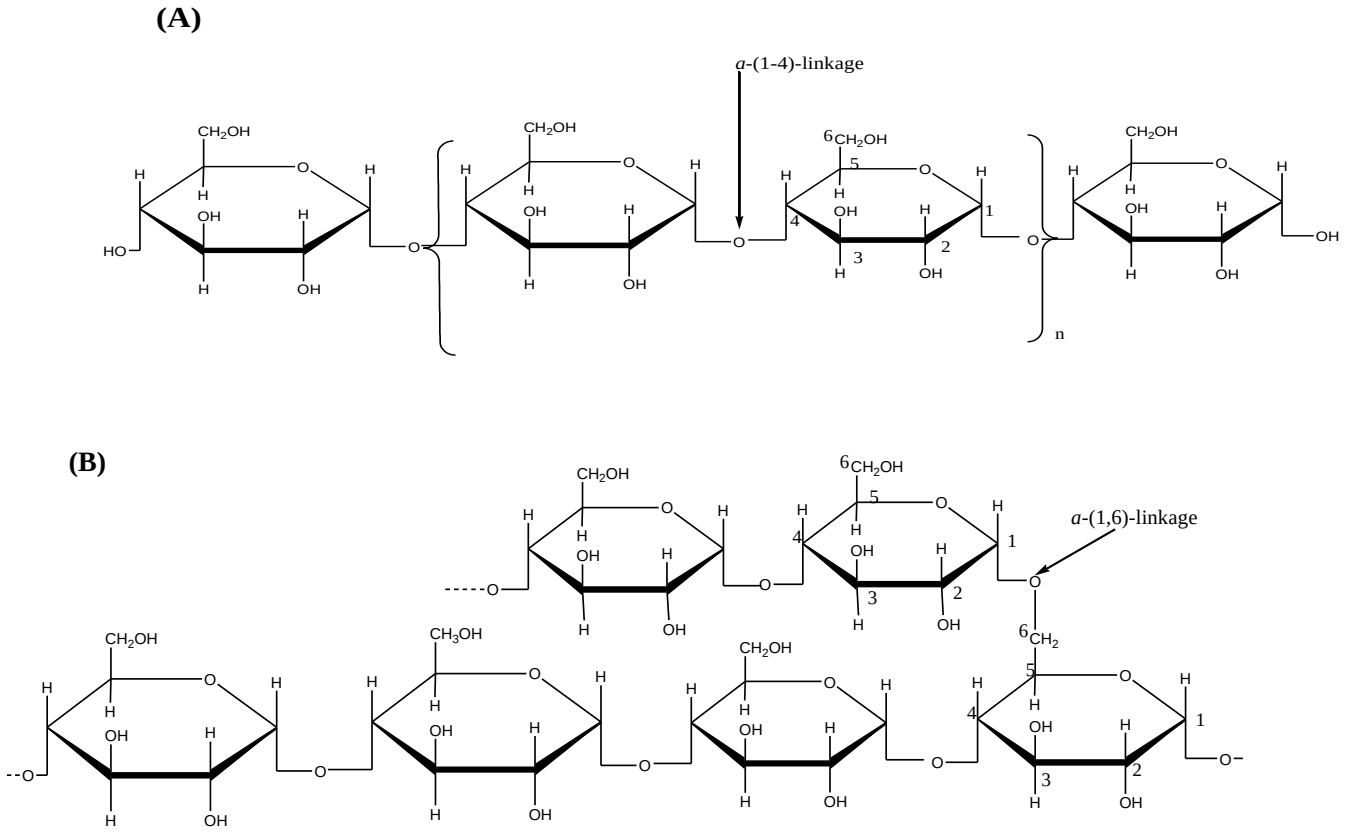


Figure 1: Linear amylose starch molecule (A) and branched amylopectin starch molecule (B).

Modified and unmodified starches are commonly used in products for personal care, cosmetic appeal, and food additives (Maneka *et al.*, 2005). From a pharmaceutical outlook, starch finds its value in solid-oral dosage forms, where it has been used as a binder, diluent, and disintegrant (Adedokun and Itiola, 2010).

Nevertheless, such diversified applicability demands specific physicochemical and functional characteristics that a single starch source is unlikely to be able to supply. Thus, in order to provide market growth, the starch industry has been looking at alternatives that could satisfy actual demands. Meanwhile the functional properties of starch are clearly reflected by the physicochemical features, thus a comprehensive physicochemical and structural characterization of the starch sample is indispensable.

1.2. Sweet potato [*Ipomoea batatas* (L.) Lam.]

Sweet potato (*Ipomoea batatas*) is a dicotyledonous plant that belongs to the family Convolvuceae (Wang *et al.,* 2011). It is believed to have its center of origin in South America and it was brought to Europe by Columbus and afterwards introduced to Africa and Asia by the Portuguese and Spanish merchants (Abegunde *et al.,* 2013). It is a tuberous and starchy root crop important for food security and cultivated in over 100 developing countries and ranks among the five most important food crops in over 50 of those countries. Further, above 95% of the global sweet potato production is in developing countries (Ali *et al*., 2015). This crop is known for its resistance to drought, vigorous early growth and low input requirements. It also does well in areas of high rainfall and it requires very little labor and care compared to other crops (Tigabu and Tilahun, 2015).

Sweet potato plant (Figure 2) is cultivated in Ethiopia mostly for human consumption and as animal feed (Belehu, 2003). It is the major crop among the root crops in the country with a yield of 359.10 quantal per hectare (CSA, 2017). During the 2016/17 main season, sweet potato, potato and taro covered about 88.09 % of the total area cultivated with root crops in the country (CSA, 2017). There are about eighteen white fleshed and six orange fleshed sweet potato varieties released in Ethiopia (Gurmu and Mekonen, 2017). Nevertheless, most of these varieties are obsolete and are not under production. Currently, only three varieties, namely Awassa 83, Kulfo and Tulla are being produced by agrarians. These varieties give relatively better root yield

in areas where sweet potato virus diseases pressure is low (Gurmu and Mekonen, 2017). Approximately 20 million Ethiopians are dependent on sweet potato as a staple food, reflecting the importance of the crop for food security and the livelihoods of rural communities (Tofu *et al.*, 2007).

It is grown in all parts of the country; predominantly in the eastern, southern and south western parts of the country (Gurmu and Mekonen, 2017).

a) **b)**

Figure 2: Sweet potato plant (a) and its tuber (b) (Pictures taken by Wondu.K).

Currently, sweet potato is being distributed to drought affected areas of the country where maize and other crops regularly fail due to recurrent droughts. Thus, the importance of the crop is increasing in terms of cultivated area, production and number of sweet potato growing households (Gurmu, 2015). The government is also giving due attention for root crops production due to the prevailing drought condition in the country (Gurmu, 2015).

Although it is widely utilized for combating food shortage and malnutrition, literature review indicates no report on the physicochemical and structural properties of starches from the widely available sweet potato (Ethiopian varieties) plants for potential industrial applications.

1.3. The Physicochemical properties of starch

1.3.1. Density

The density of starch plays an important role for technological and engineering purposes. Several trends have been proposed that relate the bulk density of excipients to functional properties like compactibility and powder flow (Manek *et al*., 2012). A low bulk density is an indication for poor flowability of a powder, which might delay or even prevent the formation of a lubricant film during the mixing process (Celik, 2011). The Carr's index and the Hausner ratio are simple methods that use density values to predict the flow properties of powders. Carr's index, also known as percent compressibility, describes the flow properties of powders as excellent (5-15%), good (12-16%), fair (18-21%), and poor (23-28%). Similarly, a Hausner ratio value of less than 1.20 is indicative of good flow while a value greater than 1.50 indicates poor flow properties (USP 30/NF 25, 2007). The compressibility index has also been used as measures of interparticulate friction (Manek *et al.*, 2012**).**

1.3.2. Crystallinity

Starch has a definite crystalline nature and the crystallinity has been assigned to the well-ordered structure of the amylopectin molecules inside the granules (Blanshard, 1987; Hong *et al.*, 2016; Moorthy, 2002). According to X- ray diffraction spectra, there are usually A-, B-, and C-type starches (Manek *et al.*, 2012). A-type starch has strong diffraction peaks at about 15^o and 23^o 2θ and an unresolved doublet at around 17^o and 18^o2θ. B-type starch gives the strongest diffraction peak at around 17^o 2θ, a few small peaks at around 15^o, 20^o, 22^o, and 24^o 2θ, and a characteristic peak at about 5.6^o 2θ. C-type starch is a mixture of both A and B-type polymorphs. It shows strong diffraction peaks at about 17^o and 23^o 2θ and a few small peaks at around 5.6^o and 15^o 2θ (Cai and Wei, 2013; Guo *et al.*, 2014).

The crystal structure of starch is studied with an X-ray diffractometer. The traditional view is that cereal starches generate A-type diffraction patterns; tubers, and high amylose starches generate B- type patterns; and legume, roots, and some fruit and stem starches show C-type patterns (a mixture of A- and B-type) (Builders and Arhewoh, 2016). Type-A starches tend to have higher levels of crystallinity and higher gelatinization temperatures whereas type-B starches tend to have lower levels of crystallinity and lower gelatinization temperatures. While the gelatinization

temperatures increase with increasing amylose content in type-A starch, the amylose content appears to have no effect on gelatinization temperature of type-B starches (Tian *et al.*, 1991).

1.3.3. Thermal characteristics

Although starch granules are insoluble in cold water, they can swell slightly and become hydrated, resulting in an increase in the diameter of the granules. This process is reversible. When heat is applied to such a system, nevertheless, irreversible changes occur. As the granules are heated, they reach a specific temperature at which they swell more. With continued heating, the viscosity of the suspension increases dramatically (Douzals *et al.*, 1996). The starch then absorbs more water and the granules swell more or continue to expand above the melting temperature (Ratnayake and Jackson, 2006). This overall sequence of change from dispersion to paste is known as starch gelatinization (Gebre-Mariam and Schmidt, 1996).

Gelatinization of starch is the loss of crystalline structure of starch granule, which is mainly from crystalline amylopectin; on the other hand, the enthalpy value reflects the loss of the ordered double helices more than the crystallinity loss (Sanchez-Rivera *et al.*, 2010). Gelatinization temperature is indicative of the temperature at which the starch granules begin gelatinizing. The gelatinization temperature is controlled not only by the water content but also by the presence of various minor chemicals, salts, sugars and other small molecules (Moorthy *et al.*, 2012). Differential Scanning Calorimetry is an important tool to study starch gelatinization (Bertolini, 2010).

1.3.4. Morphological characteristics

Starch occurs naturally as discrete particles, called granules (Liu, 2013; Wani *et al.*, 2012**).** Granule size and shape of starch are reported to be primarily affected by the germplasm from which the starch is isolated. The other factors affecting starch granule morphology include climatic conditions and agronomic practices. Generally, granule size refers to the average diameter of the starch granule. Granules of tuber and root starches, for example, are oval, although round, spherical, polygonal, and irregular shaped granules also exist (Yoo *et al.*, 2009). Granule size can be determined by various techniques like microscopy (light microscopy, scanning electron microscopy), sieving, electrical resistance, laser light scattering, and field flow fractionation (Lindeboom *et al*., 2004)**.** However, SEM is frequently used to determine granule

size. It also provides a more detailed perspective on granule surface characteristics and granule morphology (Chmelik *et al.,* 2001)**.**

1.3.5. Rheological characteristics

Rheological characteristics describe the behavior of materials subjected to shearing forces and deformation, which are considered viscoelastic complexes. The basic feature of starch rheology is its viscosity. Other rheological characteristics involve texture, transparency or clarity, shear strength and the tendency for retrogradation. All of these features play important roles in the commercial applications of starch. Rheological starch properties are studied through the behavior of viscosity curves, which are influenced by temperature, concentration and shear stress (Alcázar-Alay and Meireles, 2015; Martínez-Preciado, 2014).

Pasting refers specifically to change the starch upon further heating after gelatinization has occurred, including further swelling and leaching of polysaccharides from the starch granule, and increased viscosity which occurs with application of shear forces (Christianson *et al.*, 1981; Ratnaningsih *et al.*, 2016).

Instruments like the Rapid Visco Analyzer (RVA) and Brabender Viscoamylograph (BVA) describe the viscosity parameter as functions of temperature and time. The RVA and BVA describe paste behavior in three periods: (i) a controlled heating period, increasing the temperature of the suspension from room temperature to a maximum that is generally determined at 95 °C; (ii) an isothermal period, maintaining the suspension at the maximum temperature for analysis; and (iii) a cooling period, decreasing the temperature to approximately 50 °C (Alcázar-Alay and Meireles, 2015; Deffenbaugh and Walker, 1989).

During the analysis, the suspension is subjected to shear forces. Suspensions typically show a peak in viscosity that starts after gelatinization and increases as the granules swell, followed by a decrease in viscosity due to granule disintegration and polymer realignment. A Breakdown viscosity is defined by a difference between the viscosity peak and the minimum viscosity at the maximum analysis temperature. During the cooling period, amylose leaching forms a gel or three-dimensional network. Gel formation further increases the viscosity, called the cold paste viscosity. The difference between the paste viscosity at the end of the cooling period and the minimum viscosity at 95 °C is termed the setback (Karim *et al.*, 2000; Sun *et al.*, 2014).

1.3.6. Swelling and solubility

Swelling and solubility indices provide the evidence of interactions between the water molecules and the starch chains in the crystalline and amorphous regions (Ali *et al.*, 2014**;** Claver *et al.*, 2010)**.** The swelling behavior of starch depends mainly on the amylose content, structure of amylose and amylopectin, and presence of non-carbohydrate substances, especially in the presence of lipids acting as inhibitor of swelling. Solubility of starch is an indicator of the degree of starch granules dispersion after cooking (Bhupender *et al.*, 2013)**.** The solubility could imply the amount of amylose leaching out from starch granule when swelling, therefore the higher the solubility the higher will be the amylose leaching (Sanchez-Rivera *et al.*, 2010; Wani *et al.*, 2015).

1.3.7. Moisture sorption pattern

Moisture sorption pattern is used in determining the measure of moisture sensitivity of the starch and it reflects the relative physical stability of the end product formulated with the starch when stored under humid conditions (Oladayo *et al*., 2016).

Starch has been classified as a moderately hygroscopic material. Moisture is known to modify the flow and mechanical properties of many powders including starch (Crouter and Briens, 2014). Thus, knowledge of moisture sorption properties of starch is necessary where controlled powder flow or compaction is critical (Gebre-Mariam and Schmidt, 1998). The moisture content of dry starch varies from 6-16%, depending on the process used for drying the starch. Higher levels of moisture can lead to microbial damage and subsequent deterioration in quality. The maximum moisture content prescribed for safe storage by most of the starch producing countries is 13% (Emenike *et al.*, 2017; Moorthy, 2002). Estimation of moisture sorption is needed to establish moisture activity and moisture content relationship for materials (Moorthy, 2002).

1.4. Applications of starch

1.4.1. Food industry

Starch is used in a wide array of industrial applications (Bertolini, 2010; Van Der Maarel *et al.*, 2002). Native starch is by far the most consumed polysaccharide in the human diet; traditional staple foods such as cereals, roots, and tubers are the main sources of starch. Uses of starch after

disruption of the native starch granules, such as gelatinized, hydrolyzed, or modified starches, led to ingredients and foods, either homemade or manufactured. These modifications also affect sensorial properties (texture, viscosity, visual aspect, flavor) as well as nutritional ones (Bertolini, 2010). Starch is a very important biopolymer in the food industry, where it performs various functions as thickener, binder, disintegrant, stabilizer, texture modifier, gelling and bulking agent (Aina *et al.*, 2012; Otegbayo *et al.*, 2014). Modified starch enhance paste consistency, thickening, smoothness and clarity, and to impart cold storage stability and freeze thaw stability in comparison to its native complement. Starches are also used in different food types like baked food, baby foods, snacks, confectionaries (Singh *et al*., 2010) dairy products and meat products (Taggart, 2004). Starch is a major component and plays an important role in texture and quality of dough and bread as well (Miyazaki *et al.*, 2006). The contribution of starch to bread making is related to its water absorption property during dough development; gelatinization and pasting behavior during baking; and crystallization and retrogradation behavior on cooling and storage (Calvin, 2016; Goesaert *et al.*, 2005). In addition, the swollen, intact starch granule has a role in the thermal-setting stage of layer cake baking (Howard *et al.*, 1968). Starches are also found in a wide range of confectionery products, contributing from soft to hard gels, and from brittle to chewy textures as the structure builder in coatings and even as the molding medium to support the shaping of confections due to their ease of cooking in high-sugar environments, and their ease of handling during production (Taggart, 2004; Phillips and Williams, 2009).

Modified starches are used in dairy products; they provide variety of attributes, including enhanced viscosity, cutability, mouthfeel and stability. Starches are used in yogurts and sour cream to control syneresis and enhance thickness. Furthermore, starch is used to enhance viscosity and smoothness of puddings (Phillips and Williams, 2009; Singh *et al.*, 2010).

Starches are also used in meat industry for water retention and texture improving characteristics. They are added to meat product formulations as water binders to reduce formulation costs, increase yields, reduce cooking losses, improve texture, sliceability and succulence, besides increasing fat and water binding (Taggart, 2004).

Since starch varies greatly in form and functionality between and within botanical species, and even from the same plant cultivar grown under different conditions. Its different properties are useful for making diverse food products (Ellouzi *et al.*, 2015; Otegbayo *et al.,* 2014).

1.4.2. Pharmaceutical applications

Excipients are increasingly being known as important components of conventional and novel drug products, providing specific functions in helping the formulation of optimally stable, elegant, safe, and active drug products (Boonme *et al.*, 2012; Shirwaikar *et al.,* 2008). Starches in its native and modified forms are widely employed as versatile excipients in various solid dosage forms, especially as diluents, disintegrants, and binding agents in tablet formulations (Hong *et al*., 2016), due to their suitable physicochemical properties as well as their relative low cost and inertness (Gebre-Mariam and Schmidt, 1996). It also finds applications as a thickener, colloidal stabilizer, gelling agent, bulking agent, water retention agent, adhesive (Builders and Arhewoh, 2016; Singh *et al*., 2003), filler, superdisintegrant and matrix former in capsules and tablet formulations (Vishwanadha *et al.,* 2015). Starch has also been investigated as an excipient in novel drug delivery systems for nasal, oral, periodontal, and other site-specific delivery systems (Builders and Arhewoh, 2016; Hartesi *et al.*, 2016).

Rahman et al. (2008) studied that starch1500 performed as an excellent binder producing a granulation that was not only compressible but produced tablets of improved hardness and friability compared to those prepared with povidone (Rahman *et al.*, 2008). Similarly, Bayor et al. (2013) evaluated starch from sweet potato genotypes and confirmed their poor flow properties which make it possible to be used as a stronger pharmaceutical diluents (Bayor *et al.* 2013).

Starch due to their biocompatible, biodegradable, safe, cheap, natural, sustainability, chemical flexibility, and eco-friendliness are promising in the pharmaceutical sector. Its will continue to function as a versatile polymer in drug delivery due to their novel applications as well as commercially viable, and continue to emerge with the spate of attention and research into this material (Adedokun and Itiola, 2010**;** Builders and Arhewoh, 2016**;** Ngwuluka *et al.*, 2014**).**

1.4.3. Other applications

Starch has also various applications in paper, plastic and textile industries (Bertolini, 2010). It is one of the most important ingredients in paper industries. It is added to replace the natural binding agents the wood pulp loses during processing. Starch has the ability to fill in the cavities on the sheet, giving a smoother, more resistant surface, to improve the printing and optical properties of paper in coating formulations and used as the adhesive for paper coating colors. Starch is even more important in making recycled paper products (Conner, 2001). For instance, cationic starch with higher degree of substitution has been used to increase the retention and strength properties of paper (Liu *et al.*, 2010). Furthermore, a starch modified through chemical cross-linking with citric acid and using altered starch structures with longer chains, which reduces the water sensitivity of starch to enhance film formation, has been used in production of packaging materials (Menzel, 2014). In plastic industry, the starch granule has been used as filling agent for polyolefin and as a component in synthetic polymer blends (Vilpoux and Averous, 2002). In the textile industry, starch films are also used during textile production as fiber coatings (Alcázar-Alay and Meireles, 2015). Starch octenylsuccinylation had been performed to improve the quality of sized polyester containing warp yarns and for sizing polyester/cotton yarns (Zhang *et al.* 2014).

1.5.The present study

Many plant species found in Ethiopia which some of them can be used as a source of starch for pharmaceutical, food and other industrial applications. Some of the Ethiopian plants which have been shown to possess starch, include *Ensete ventricosum* (Gebre-Mariam and Schmidt, 1996); *Dioscorea abyssinica* (Gebre-Mariam and Schmidt, 1998); *Colocasia esculenta* (Adane *et al.*, 2004); *Coccinia abyssinica* (Nigussie *et al.*, 2006); *Manihot esculenta* (Paulos *et al.*, 2007); *Dioscorea bulbifera* (Mohammed *et al.*, 2007), *Triticum decocum* (Mosisa *et al.*,2014), *Plectranthus edulis* (Assefa *et.al.*,2015). Ethiopia is also rich in sweet potato plants with high food value, nutrient content, and starch as well. However, the isolation, the physicochemical properties of sweet potato starches, and its possible industrial applications have not been exploited well so far.

The reason to do this research is that the need for starch from local source as it will save foreign currency expenditure, and the fact that the chemical composition and physicochemical

characteristics of starch affected by many factors that in turn affect the potential application of starch from a given source. Since, the genetic differences in the varieties would translate into physical and biochemical changes in the respective starch granules; which would ultimately influence their functional properties as food and non-food applications. Moreover, starches have been became a prime choice of material in the industry of biotechnology and nanotechnology. For instance, among others, large amounts of starches are demand in fermentation processes. Accordingly, in order to provide market growth, the starch industry has been looking at alternatives that could satisfy actual demands. Meanwhile the functional properties of starch are clearly reflected by the physicochemical features, thus a comprehensive physicochemical and structural characterization of the starch sample is vital.

The purpose of this study was to isolate and compare the physicochemical properties of starches from three Ethiopian sweet potato varieties (Awassa83, Tulla and Kulfo), and assess the feasibility of their industrial production.

1.6. Research questions

The research questions for this study were:-

- Are the Ethiopian sweet potato varieties promising plants as alternative source of starches (economically feasible)?
- Does the proximate composition of the starches (amylose-amylopectin ratio) lie within the normal range?
- What do their physicochemical properties look like (granule size, gelatinization, viscosity etc.) in view of their envisaged applications in pharmaceutical, food and other industries?

1.7. Objectives of the study

1.7.1. General objective

- To isolate and characterize the physicochemical properties of native starches from three Ethiopian sweet potato varieties for possible applications in pharmaceutical, food and other industries.

1.7.2. Specific objectives

- To isolate starches from tubers of three Ethiopian sweet potato varieties and determine their percent yield;
- To determine the chemical compositions of the sweet potato starches and;
- To study the physicochemical properties of sweet potato starches.

2. EXPERIMENTAL

2.1. Materials

2.1.1. Plant materials

Ethiopian sweet potato tubers (Awassa 83, Kulfo, and Tulla) were obtained from Hawassa Agricultural Research Center, Wondogenet town, Southern Nations and Nationalities People's Region, Ethiopia.

2.1.2. Chemicals and solvents

Sodium metabisulphite (FINKEM, Laboratory Reagent), sulphuric acid (H_2SO_4) (Avonchem Ltd,UK), potassium sulfate (K_2SO_4) (Fisher Scientific, USA), sodium hydroxide (NaOH), potassium chloride (KCl), sodium chloride (NaCl) (Sörensen, Leuren, Denmark), hydrochloric acid 37% (HCl) (Riedel-deHaën®, Germany), potassium iodide (KI) (UNI-CHEM Chemical Reagents, USA), iodine resublimed (Reagent Chemicals Services Ltd., UK), potato starch (BDH Poole Co, UK), amylose and amylopectin (Merck, Germany) were used as received. All chemicals used were either of reagent or analytical grade.

2.2. Methods

2.2.1. Starch isolation

Starch was isolated according to the method described by Gebre-Mariam and Schmidt (1996). First, fresh sweet potato tubers (Awassa 83, Kulfo and Tulla) were thoroughly washed to remove surface soil. Then, the cleaned tubers were immersed in water, peeled and cut up into small pieces and soaked with distilled water containing 0.075% w/v of sodium metabisulphite, and then crushed with a local blender machine. The starch slurry materials were then passed through fine muslin to remove cell debris and the translucent suspension collected, and allowed to settle and the supernatant decanted. The sedimented starch was washed several times with distilled water until the wash water was clear and free of suspended impurities. Finally, the starch was dried at room temperature, milled to fine powder using grinder machine (Pulberisette 2, Fritsch, Germany), sieved through 224 µm mesh size, and kept in tightly sealed containers (Gebre-Mariam and Schmidt, 1996).

2.2.2. Determination of yield

For determination of percent yield on dry mass basis of starch from sweet potato tubers, the method stipulated in Association of Official Analytical Chemist (AOAC, 2000) was employed. About one kilogram of fresh sweet potato tubers were cleaned, peeled and cut into small pieces and milled to fine powder. The milled mass (starch flour) was then dried at room temperature and weighed accurately and extracted using distilled water containing sodium metabisulphite (by straining the wet mass through muslin cloth and washing with distilled water several times). The starch sediment was sieved, dried at room temperature and weighed from which the percent yield was calculated.

2.2.3. Determination of chemical composition

2.2.3.1. Estimation of amylose content

Amylose content of sweet potato starches was determined by a colorimetric assay method (Gebre-Mariam and Schmidt, 1996). A stock solution of each of amylose and amylopectin was prepared by dissolving 50 mg of the respective substance in 10 ml of 1.8% HCl. Two ml of each of the stock solutions were taken and diluted to 10 ml using 1.8% HCl. From the resulting solutions appropriate aliquots were taken and diluted with 1.8% HCl. Mixtures of amylose and amylopectin solutions were prepared to provide a starch concentration of 50 μg in 10 ml in any mixture. Various mixtures were prepared to contain 100, 80, 60, 40, 20, or 0% amylose or amylopectin, respectively. The absorbance reading of the resulting solutions were taken at 600 nm (for amylose) and 540 nm (for amylopectin) using UV/Visible Scanning Spectrophotometer (UV-1800, SHIMADZU, Japan) equipped with a program recording several wavelengths, immediately after staining with Lugol's solution (diluted 1:3). 100 μl of the diluted Lugol's solution were used for staining 2 ml of the mixture. Similarly, absorbance readings of each of the pure amylose and amylopectin solutions of the same concentrations and solutions of starch were taken at the same wavelengths. Blanks were run with stained 1.8% HCl. The amylose content of starch was estimated from the relationship between concentrations and absorbance of known mixtures of amylose and amylopectin at 600 nm as the interference from amylopectin at the concentration used was negligible. The results are the average of 5 determinations.

2.2.3.2. Protein content

Protein content was analyzed by employing Kjeldahl method as described in the Association of Official Analytical Chemist (AOAC) method 979.09 (2016). Kjeldahl method involves destruction of sample by sulphuric acid, whereby, all nitrogenous contents are converted into ammonium by the action of conc. H_2SO_4, H_2O_2 [as oxidizing agent] and catalyst comprising (mixture of 7.0 g K_2SO_4+ 0.8 g $CuSO_4$). Nitrogen is liberated as ammonia, distilled, collected and titrated. In the current study, starch sample (0.5 g) was placed in 500 ml digestion flask. 6 ml of acid mixture (2 parts of conc. sulphuric acid and 1 part of conc. orthophosphoric acid) were added. The flask was placed on a heater and allowed to react and digested at 420 ^oC for 1 hour. As soon as the violent reaction ceased, heat was increased and the destruction was continued until the content appeared light green (~1 h). It was then cooled and diluted with distilled water. After cooling, the material was distilled by steam distillation with 40% of sodium hydroxide and the ammonium (NH_4^+) was released in the form of ammonia (NH_3). Finally, the condensed NH_3 is trapped by 1% boric acid and titrated against 0.1M standard HCl and the analyte is referred to as a crude protein, (since the method determines the nitrogen in the components of all protein). The protein content was determined as a mean of three measurements, and reported by multiplying percent nitrogen by 6.25.

2.2.3.3. Fat content

Fat content was determined according to the method stipulated in the AOAC method 2003.06 (2016). A clean aluminum cup with boiling chips that has been dried at 92 ^oC for an hour was weighed and then kept in desiccator for 30 min to cool. 3.5 g of sample was weighed accurately and cover with fat free cotton and was attached with magnetic ring to hang the thimble to the extraction chamber. 70 ml of diethyl ether were added to the aluminum cup and the extraction was allowed to happen for 4 hours. Then the aluminum cup was removed from the extraction unit and placed on a drying oven at 92 ^oC for 30 min and then kept on desiccator to cool for 1 h. The aluminum cup was weighed immediately after withdrawn from the desiccator. The % fat content of the starch sample was calculated according to Eq.2.1.

$$\text{Fat}\,\% = \text{Wf} \times \frac{100}{\text{SW}} \quad \ldots\ldots 2.1$$

Where; Weight of fat (Wf) = Weight of aluminum cup after extraction-Weight of aluminum cup before extraction, SW is weight of sample.

2.2.3.4. Fiber content

The fiber content was analyzed through the procedures stipulated in the AOAC 962.09 (2016).Two g of the sample (W_3) was poured into a 600 ml beaker and to this 200 ml of 1.25 % H_2SO_4 were added, boiled for 30 min placing a watch glass over the mouth of the beaker; and keeping the level constant with distilled water. After 30 min, 20 ml of 28% KOH were added to the mixture and boiled gently for 30 min while stirring occasionally. The sample was then filtered through vacuum filtration which had been coupled with the sintered glass crucible. Then the solution from the beaker was poured into the sintered glass crucible. The beaker walls were rinsed with hot distilled water several times and then finally washed with 1% H_2SO_4 and 1% NaOH. The filtrate were then dried using dry crucible (W_1) for 2 hours in oven at 130 ^oC and cooled for 30 min in a desiccator and then weighed (W_2) and the same crucible was transferred to muffle furnace for 30 min at 550-600 ^oC, afterwards, it was withdrawn, and cooled in a desiccator and weighed (W_2).). Fiber content was estimated as shown in Eq.2.2.

$$Fiber\ content\ (\%) = \frac{(W_2 - W_1\ )x100}{W_3} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..\ldots\ldots 2.2$$

Where; W_1 is crucible weight before drying, W_2 is crucible weight after drying, W_3 is sample dry weight.

2.2.3.5. Ash value

Ash value of the study material was obtained according to AOAC (2016), official method 923.03. 2.5 g (W_1) of the material were weighed, and transferred to relatively broad ashing dish that has been ignited in an oven for 30 min at 100 ^oC, cooled in desiccator for 1 hour to reach ambient temperature, and weighed (W_2). The sample was then ashed in a muffle furnace at 550 ^oC for 1 hour, withdrawn from the furnace and allowed to cool and moisten with a few drops of deionized water and the water was evaporated on a hot plate. Thereafter, it was ashed once more for 30 min at 550 ^oC and cooled and some drops of deionized water and 5 drops of concentrated nitric acid (HNO_3) were added and evaporated on hot plate. And finally, the ashed in the muffle

furnace was kept for 30 min at the same temperature and cooled in a desiccator for 45-60 minutes and weighed (W_3). Percent ash was determined from Eq. 2.3.

$$\%\ \text{Ash} = (W_3 - W_2) * \frac{100}{W_1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.3$$

Where; W_3 is weight of ashed sample and crucible, W_2 is weight of crucible, and W_1 is weight of pre-ashed sample.

2.2.3.6. Moisture content

Moisture content of the study material was determined by following the method described in the AOAC 930.15 (2016). A known amount of sample in a clean and parched drying box was dried at 92 ^{o}C overnight in oven, cooled for 30 min in a desiccator and weighed. The sample was once more kept at 92 ^{o}C in oven for 1 hour and finally cooled and weighed (W_2). Drying is considered to be complete if two successive weightings show a negligible loss in weight ≤ 2mg for a 5g sample at 1 h intervals. Moisture content was determined from Eq. 2.4 below.

$$\%\ \text{Moisture} = (W_1 - W_2)\text{x}\frac{100}{\text{SW}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.4.$$

Where; W_1 is weight of box and fresh sample, W_2 is weight of dry sample and box, and SW is sample weight.

2.2.4. Physicochemical characterization of starch

2.2.4.1. Fourier transform infrared (FTIR) spectra

The FTIR spectra of starch from the three sweet potato varieties and potato were determined using FTIR spectrophotometer (FTIR-8400S, SHIMADZU, Japan) as described elsewhere (Assefa *et al.*, 2015). Scanning was carried out between wave numbers 4000 and 400 cm^{-1}. Each IR spectrum was performed with 20 scans and spectral resolution of 8 cm^{-1}.

2.2.4.2. X-ray diffraction patterns (XRD)

The X-ray diffraction patterns of the starches were obtained with copper, nickel foil filtered, K$^{\alpha}$ radiation using a diffractometer (Miniflex 600, Rigaku, Germany). The diffractometer was

operated at 15 mA and 40 kV. The scanning region of the diffraction angle (2θ) was from 3 to 35 as described elsewhere (Gebre-Mariam and Schmidt, 1996).

2.2.4.3. Scanning electron microscope (SEM)

Scanning electron microscopy (SEM) was used for morphological study of native sweet potato starch granules as described elsewhere (Gebre-Mariam and Schmidt, 1996). The shape and surface features of isolated sweet potato starches were observed using environmental scanning electron microscopy, Philips XL30 ESEM FEG (Leuven, Belgium).

2.2.4.4. Differential scanning calorimetry (DSC)

The DSC measurements of the starch-water mixture (starch/water ratio of 1:1 w/w, on dry basis) were carried out using a Mettler DSC thermal analyzer (Mettler-Toledo GmbH, Giessen, Germany) from which gelatinization temperatures were obtained. Sealed pans containing the samples were heated from 20 °C to 120 °C at a rate of 10 k min^{-1}. An empty sealed pan was used as a reference. The enthalpy of gelatinization (ΔH), the onset temperature (T_o), the peak temperature (Tp) and the end set temperature (Te) of each sample were determined as described elsewhere (Gebre-Mariam and Schmidt, 1996).

2.2.4.5. Granule size and distribution

Starch granule size distribution analyses were carried out using a Malvern Mastersizer 2000 Laser Diffraction Particle Size Analyzer (Malvern Instruments Ltd, U.K) as described elsewhere (Gebre-Mariam and Schmidt, 1998). The operational conditions were fixed to be: Range (0.05-900 µm, 300RF); active beam length (2.4 mm); sample unit (MS1: Small Volume Sample Dispersion Unit); Polydisperse; Standard-wet, Presentation (30HD). A small amount of starch was dispersed in 400 ml of distilled water till an obscuration of 10-30% was recorded, and measuring time was 5 sec. The mean volume particle size distribution, mean particle size and specific surface area were obtained with the Mastersizer S, PSS0003-01 software (2002). All determinations were done in triplicates.

2.2.4.6. Density measurements

Bulk density

Bulk density of sweet potato starches and potato starch were determined by weighing 60 g of starch powder and transferred into calibrated glass cylinder through a short stemmed glass funnel and the volume occupied by the powder was noted, and the resulting volumes were used for

calculation of bulk density (g/ml) by using Eq.2.5. All measurements were obtained in triplicates.

$$\text{Bulk density } (\rho b) = \frac{m}{Vb} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots 2.5$$

Where; m is weight of the powder and; Vb is bulk volume.

Tapped density

Tapped densities of starch samples were performed by using a tapped densitometer (ERWEKA, Germany). 60 g of starches samples were measured and subjected to 500 taps for 8 minutes. The tapped volume was noted which was used to calculate the tapped densities following Eq.2.6. The measurements were performed in triplicates.

$$\text{Tapped density}(\rho t) = \frac{m}{Vt} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots 2.6$$

Where; m is weight of the powder and; Vt is tapped volume.

The Carr's index and Hausner ratio were calculated based on the information from the bulk density and tapped density using Eq.2.7 and Eq.2.8, respectively.

$$\text{Carr's index (\% Compressibility)} = \left[\frac{\rho t - \rho b}{\rho t}\right] * 100 \ldots \ldots \ldots \ldots \ldots \ldots 2.7$$

$$\text{Hausner ratio (HR)} = \frac{\rho t}{\rho b} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots 2.8$$

Where; ρb is bulk density and; ρt is tapped density.

True density

True density was determined by liquid displacement method using benzene as immersion flued, the method mentioned in Gonzalez and Peret (2002). A 25 ml volumetric flask filled with benzene was weighed. Two g of starch was transferred into the volumetric flask that had been closely adjusted with benzene. The starch's true density (ρ) was calculated using Eq.2.9. The measurements were performed in triplicates and the average was taken.

$$\text{True density } (\rho) = \frac{[Ws*Sg]}{[(Ws+Wx)-Wy]} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.9$$

Where; Ws is weight of starch, Sg is Specific gravity of benzene (0.876), Wx is weight of volumetric flask filled with benzene, and Wy is weight of volumetric flask filled with benzene and starch powder.

2.2.4.7. Moisture sorption pattern

Moisture sorption behavior was determined by using the methods described elsewhere (Greenspan, 1977; Paulos *et al.*, 2009). Saturated salt solutions of NaOH with relative humidity (RH %; 8.24%, 20% and 40%), NaCl, KCl and distilled water were prepared which provided relative RH % of 75.5%, 85% and 100%, respectively. Two g of sweet potato starch was placed on a petri dish and dried in an oven (Kottermann® 2711, Germany) for 4 h at 120 ^{0}C and weighed. Then, the petri dishes were placed in the Pyrex desiccators and left for 4 weeks. Finally, the weight increments as percentage of initial starch weight were taken as moisture sorption. The results are the mean of three parallel determinations.

2.2.4.8. Swelling power and solubility

Swelling power (SP) and solubility of starches were determined using the method described elsewhere (Manek *et al.*, 2012). Starch samples (0.5 g each) were dispersed in distilled water (10 ml) in pre-weighed centrifuge tubes. Aqueous dispersions of starch samples were heated at reasonable intervals between 20 °C and 85 °C for 30 min, with shaking every 5 min and then left to cool to room temperature. Each sample was then centrifuged at 3000 rpm for 15 min and analyzed for the weight of sediment per gram of starch dry weight basis. The supernatant liquid obtained at each point was dried in a hot air oven for 2 h at 130 ^{0}C and weighed after cooling in a desiccator. All determinations were done in triplicate. The percent solubility (%S) and SP were determined according to Eq.2.10 and 2.11, respectively.

$$\%S = \left[\frac{W_1}{W_2}\right] * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.10$$

$$SP = W_2 * \frac{100}{W_3} * (100 - S) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.11$$

Where; W_1 is weight (g) of soluble material in the supernatant, W_2 is Weight (g) of precipitate and; W_3 is Weight (g) of starch sample.

2.2.4.9. Pasting properties

Pasting properties were analyzed by with rapid viscoanalyzer (RVA, Model Super 4, Sweden). A pasting curve of starch was obtained for starch-water suspensions (5% w/w, dry starch basis). The suspension was analyzed as follows: heating from 50 to 90 ^{o}C at 12 ^{o}C/min (after an equilibration time of 1 min at 50 ^{o}C), a holding period of 2.5 min at 95 ^{o}C, cooling from 95 to 50 ^{o}C at 12 ^{o}C/min and holding at 50 ^{o}C for 2 min. The rotating speed of the paddle was kept constant at 160 rpm. The analysis was performed at Cargill, Germany.

2.2.5. Statistical analysis

Data was subjected to analysis of variance (ANOVA) using statistical software OriginPro 8.5.1 (Origin Lab TM Corporation, USA). Tukey multiple comparison test was used to compare the individual difference in the characteristics of the starches. At 95% confidence interval ($P<0.05$) were considered statistically significant. The results are reported as mean and standard deviation (SD).

3. RESULTS AND DISCUSSION

3.1. Yield and chemical composition of starch

The proximate composition of a starch material has to be within the optimum range in order to find different industrial applications. This requires knowledge of the chemical and physical characteristics of the starch material. Table 1 shows the chemical composition of native sweet potato and potato starches.

The yields of isolated sweet potato starch from Awassa83, Kulfo and Tulla varieties were 75.1 %, 63.7 % and 66.6%, respectively on dry weight basis. Among the three Ethiopian sweet potato varieties studied, Awassa83 gave the highest percentage yield of starch on dry weight basis. The results indicate that the three Ethiopian sweet potato varieties are promising plants as an alternative source of starch. These yields are relatively lower compared to that of potato tuber at 87% (Gebre-Mariam and Schmidt, 1996) starch yield.

The protein content of Tulla starch was much lower than that of Awassa83 and Kulfo starches ($P<0.05$).Whereas, protein content of Awassa83 and Kulfo starches were higher than that of potato starch ($P<0.05$). This indicates that the removal of protein present in the starting material is less complete for sweet potato compared with potato tuber (Chen *et al*.,2003). The lipid content of Kulfo starch was much lower than that of Awassa83 and Tulla starches ($P<0.05$), but much higher than that of potato starch ($P<0.05$). The lipid contents of the three sweet potato starches were much higher than that found in potato starch ($P<0.05$). The protein and lipid content significantly inhibit the swelling power and pasting viscosity of starch and hinder the enzymatic hydrolysis (Hu *et al.*, 2017). Accordingly, the swelling power and paste viscosity of the three sweet potato starches are much lower than that of potato starch.

Ash value is important in determining the purity and quality of substances in powder form (for instance starch), and to eliminate all unnecessary organic matter (WHO, 2011). The ash values of Awassa83 and Tulla starches were much higher than that of Kulfo and potato starches ($P<0.05$). These ash values of the sweet potato starch are in good agreement with those obtained by Aina et al. (2012) for Caribbean sweet potato starch.

Fiber presence in natural polymer influences degradation in the body. The fiber degrades faster than the polymeric matrix due to an effective increase in the surface accessible to

microorganisms. Thus, the fiber content accelerates the material disintegration (Keller *et al.*, 2000). As presented in Table 1, the fiber content of Awassa83 starch is slightly higher than that of Tulla, Kulfo and potato starches, however it is not significant (P>0.05).

As shown in Table 1, the moisture content of Kulfo starch (12.41%) almost similar with that of potato starch (12.40 %). Lower moisture contents were observed in potato and Kulfo starches than in Awassa83 and Tulla starches (P<0.05). Moisture content of the starch that falls within the moisture level (<20%) is recommended for commercial starches (Soni *et al*., 1993). The moisture level of the sweet potato starches are 12.40-13.72% as recommended for safe storage in most starch producing countries.

Table 1: Proximate composition and some selected physicochemical properties of native sweet potatoes and potato starch granules (w/w, %).

Content %	**Awassa83**	**Tulla**	**Kulfo**	**Potato**
Amylose	13.32±0.30	11.13±0.26	18.15±1.36	28.13±0.41
Ash	0.40±0.02	0.36±0.02	0.22±0.03	0.20±0.03
Fiber	0.43±0.04	0.40±00	0.37±0.03	0.38±0.01
Lipid	0.33±00	0.41±0.03	0.16±0.01	0.08±00
Protein	0.22±0.02	0.05±00	0.16±0.02	0.11±0.01
Moisture	13.72±0.29	13.65±0.17	12.41±0.03	12.40±0.02
Yield	75.10	66.60	63.70	87.00*****

***** Adopted from the report by Gebre-Mariam and Schmidt (1996)**.**

Depending on the source and genotype, the relative quantities of amylose and amylopectin that comprise a given starch vary (Nuwamanya *et al.*, 2013). Amylose, in aqueous solution, strongly interacts with iodine (I^3-) to form a blue colored helical complex (λmax 600-610 nm). Whereas, amylopectin weakly interacts with iodine (I^3-) to form a violet colored complex (λmax 530-540 nm). Thus difference in the "iodine binding capacity" of the two starch molecules make the colorimetric assays method most preferred in the determination of amylose content in starches (Gebre-Mariam and Schmidt, 1996). Amylose and amylopectin solutions as well as their mixtures stained with Lugol's solution showed linear relationship between absorption and

concentration at 600 nm and 540 nm, respectively. Accordingly, the amylose content of the starch was estimated at 600 nm without significant interference from the amylopectin (Figure 3).

Therefore, the amylose contents of Awassa83, Kulfo, Tulla and potato starches were estimated to be 13.32 %; 18.15 %; 11.13 % and 28.13 %, respectively (Table 1), which are significantly different ($P<0.05$). It has been reported elsewhere that the amylose content of different varieties of sweet potato starches vary from 8.5 % to 37.4 % (Takeda *et al.*, 1986). Figure 3 shows the standard linear curve for amylose content determination ($A = 0.013C + 0.147$; $R^2 = 0.997$; where A is absorbance (dimensionless), C is concentration of amylose (µg/ml)).

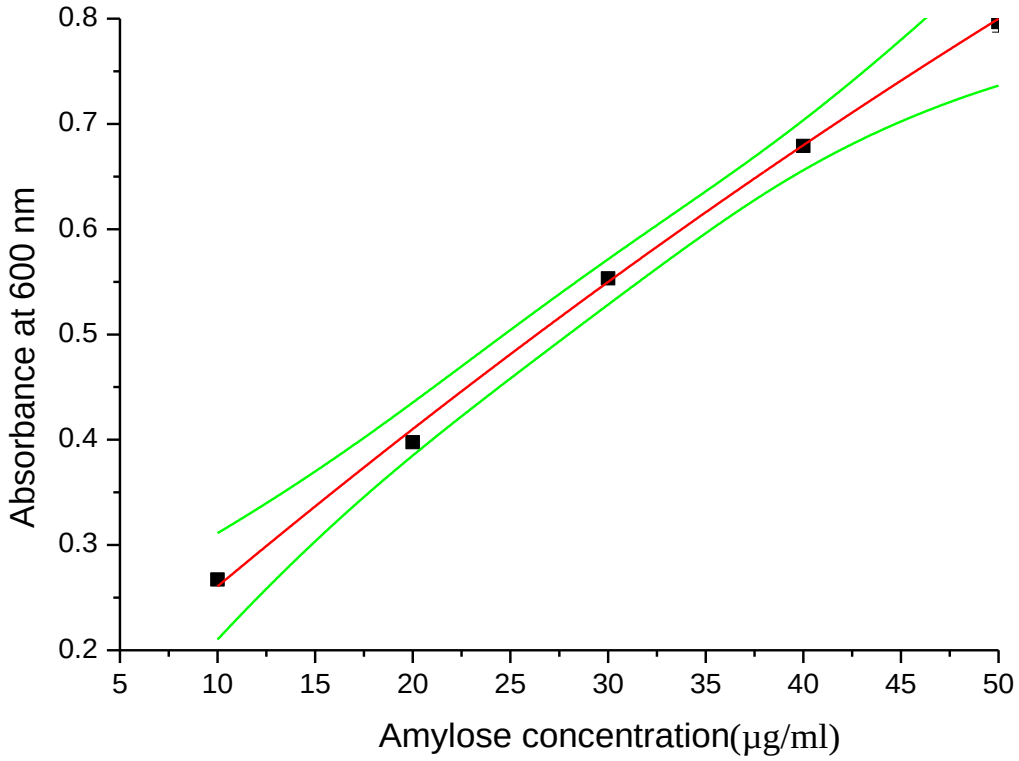


Figure 3: Standard linear curve for amylose content determination by colorimetry.

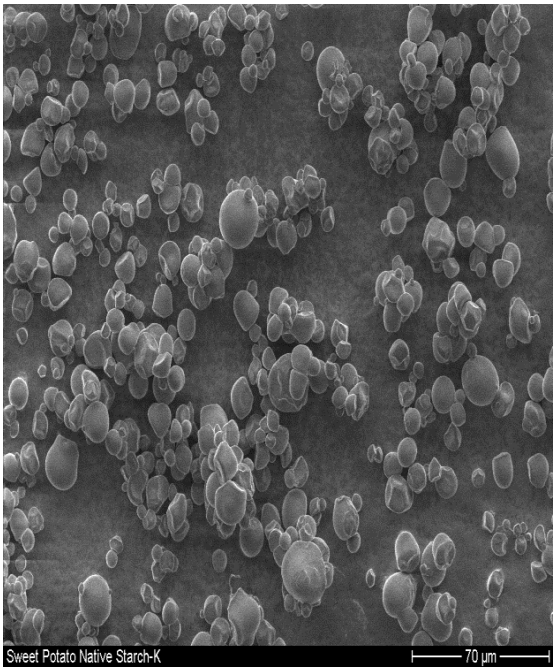
In this study, as the sweet potato starches possess low amylose content they may be appropriate for use in applications requiring relatively low amylose content. Nevertheless, it should be noted that amylose is not the only determinant factor in starch functionality (Nuwamanya *et al.*, 2013).

3.2. Physicochemical characterization of starch

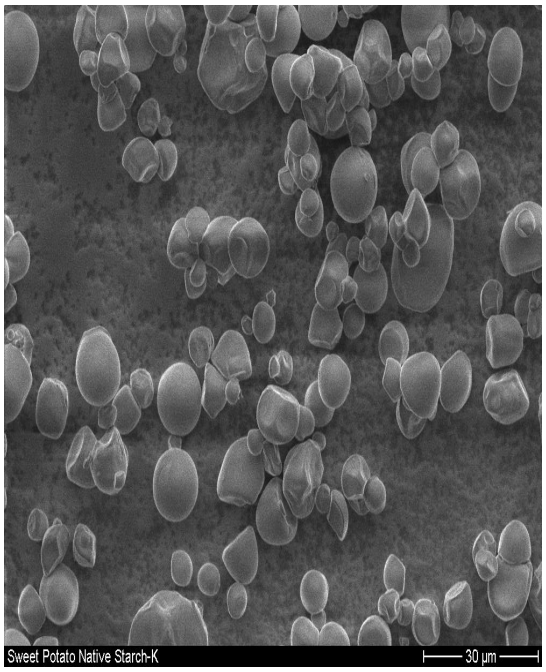
3.2.1. Morphological characteristics

Particle morphology is an important property in the characterization and identification of especially powdered pharmaceutical excipients. It can also be used to envisage certain functional properties that relate particularly to the powder compaction and flow (Builders *et al.*, 2013).

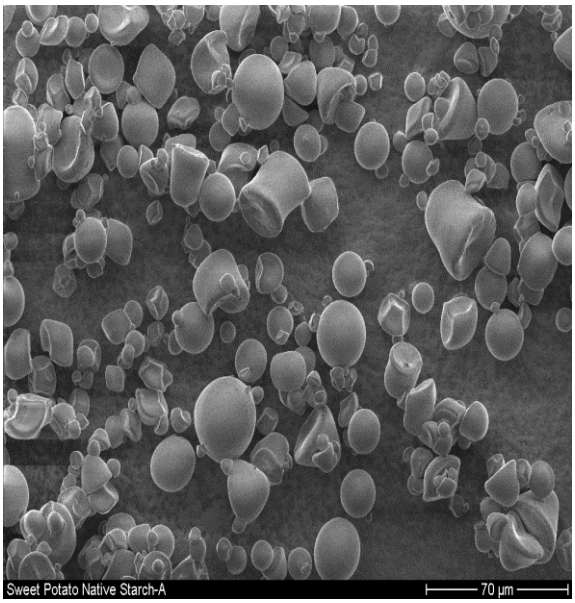
The micrographs of the granules of the sweet potato starch granules (Awassa83, Kulfo and Tulla) are shown on Figure 4. The shapes varied from polygonal, round to cupoliform/bell shaped. This is in agreement with previous reports on sweet potato starch granules (Abegunde *et al.*, 2013; Chen *et al.*, 2003). Regarding the surface of starch, amylose-rich starch granules have rough surface with different particle shapes; whereas amylopectin-rich granules have smoother granule surface (Niazi and Antonius, 2012). As illustrated in Figure 4, the granule surface of starch appeared to be smooth with no sign of any crack. Other researcher also observed smooth granule surface of sweet potato starch without fissures (Babu *et al.*, 2015).

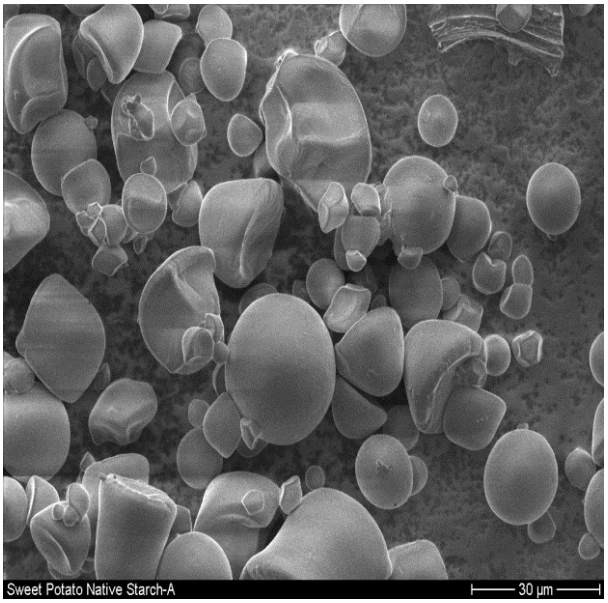


a)

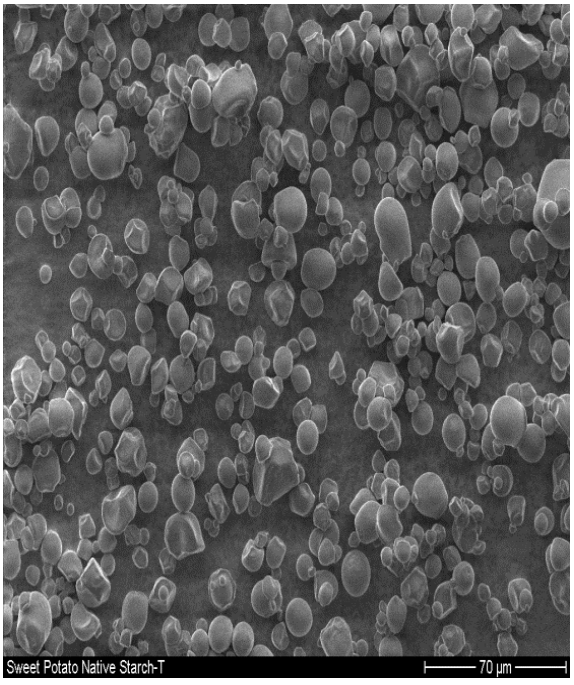


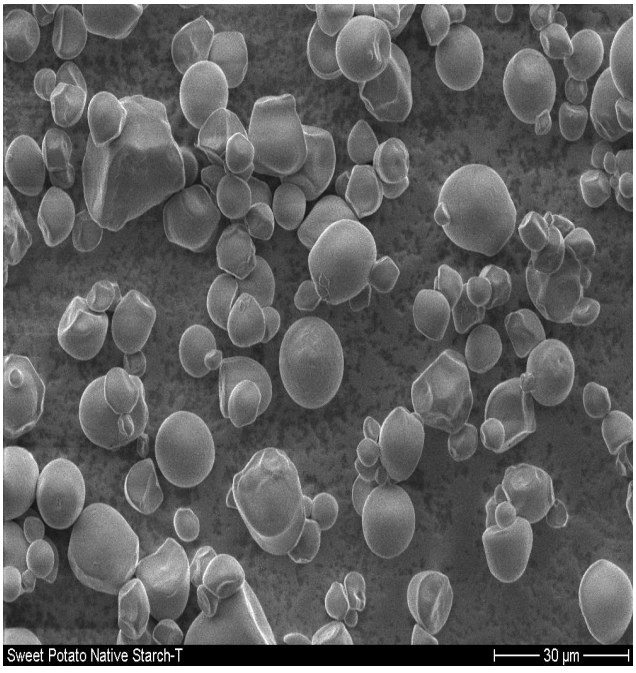
b)





c) **d)**





e) **f)**

Figure 4: Scanning electron micrographs with magnifications of 2000x; a) native Kulfo starch granules (70µm), b) native Kulfo starch granules (30µm), c) native Awassa83 starch granules (70µm), d) native Awassa83 starch granules (30µm), e) native Tulla starch granules (70µm), f) native Tulla starch granules(30µm).

3.2.2. Granule size and distribution

The particle size and distribution of sweet potato and potato starches are shown in Table 2 and Figure 5. The granule size range of Awassa83 starch (4.88-38.43µm) was slightly broader than that of the Tulla (0.92-22.22µm) and Kulfo (1.56-22.22µm) starches. The mean dimension of starch granule size of Awassa83 starch (20.9µm) was higher than that of Tulla (12.11µm) and Kulfo (12.12µm) starches. The mean particle size and dimensions for Tulla and Kulfo starches are almost similar.

Particle size and particle size distribution are among the characteristics that most significantly affect the behavior of starch granules. Together with the shape of the granules, they are also among the most important factors to distinguish between the starches of different origin (Rasper, 1971). The differences in the granule size of the starches are seemingly attributed to variety differences, growing conditions and plant physiology. Furthermore, starch granule size plays a significant role in influencing the pasting parameters of starches (Abegunde *et al.*, 2013). The size ranges of the sweet potato starches are noticeably different from that of potato starch (10 - 100 µm). The mean dimensions of starch granule sizes of the sweet potato starch are also lower than that of potato starch (40.64 ± 1.35 µm). Due to this smaller particle size compared to potato starch, the sweet potato starch has a higher specific surface area. Thus, sweet potato starches are anticipated to have poor flowability as compared to potato starch. Nevertheless, particle size is not the sole factor affecting the flow of powders; other like, moisture content, shape and surface charge of particles are known to impede flow properties of powders. Sweet potato starches were more homogeneous than potato starch, which has the broadest particle size distribution in native starch. Although granules size and particle size distribution obviously influence the functional properties of starch granule, others like moisture content coupled with shape of the granules have influence on the functional properties of the starch granules. Fine starch granules could be used as fat substitutes in high fat foods (Ma *et al.*, 2006)). Nevertheless, starch with larger proportion of small starch granules like Kulfo and Tulla will find use in applications requiring relatively small starch granules. The granule size and size distribution of sweet potato starch was in good agreement to the result of (Soison *et al.*, 2015) who studied characterization of starch in relation to flesh colors of sweet potato varieties.

Table 2: Particle size and distribution of three sweet potato and potato starches.

	Size (µm)	
Starch	**Range**	**Mean ± SD**
Awassa 83	4.88-38.43	20.9 ± 0.25
Tulla	0.92-22.22	12.11 ± 0.74
Kulfo	1.56-22.22	12.12 ± 0.50
Potato	10-100	40.64 ± 1.35

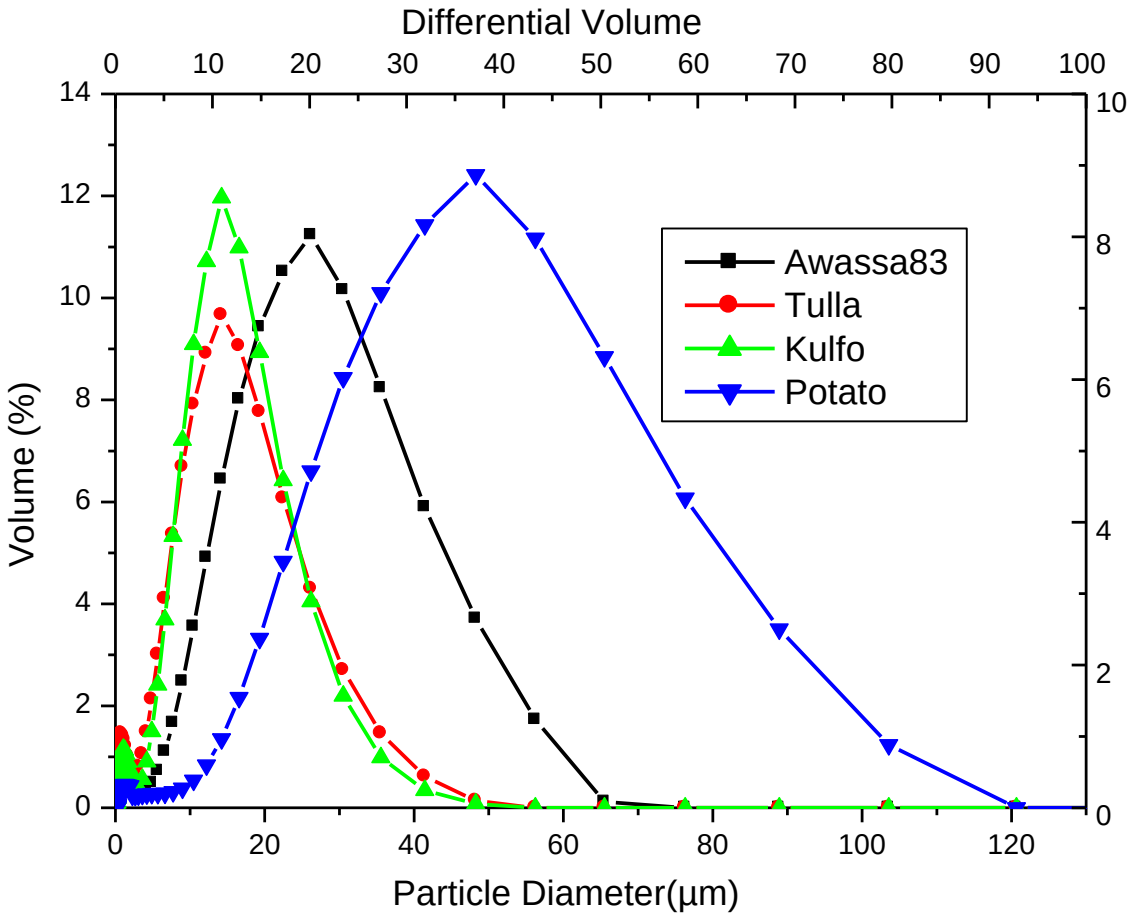


Figure 5: Particle size distribution of three varieties of sweet potato starches (Awassa83, Tulla and Kulfo) and potato starch.

3.2.3. Density and related properties

All industrial operations in handling powders depend on flow characteristics. Flow plays a role in industrial operations like mixing, transportation, and packaging (Shah *et al*., 2008). Particularly for pharmaceutical solid dosage forms, the absolute and relative densities play important role in determining their performance (e.g. flow and compaction properties) in tablet dosage forms. Moreover, knowledge of density is useful to avoid risk of segregation by avoiding mixing of powders of significantly with difference in densities. Densities and related properties of sweet potato and potato starches are shown in Table 3.

Table 3: Density and related properties of three sweet potato and potato starches.

Starch	Bulk density (g/ml)	True density (g/ml)	Tapped density (g/ml)	Carr's index (%)	Hausner ratio
Awassa83	0.61±0.01	1.44±0.10	0.74±0.01	17.29±1.53	1.21±0.02
Tulla	0.58±0.03	1.43±0.01	0.73±0.01	19.84±3.32	1.25±0.05
Kulfo	0.58±0.03	1.43 ± 0.05	0.73±00	19.52±6.93	1.27±0.07
Potato	0.66±0.01	1.43±0.06	0.73±00	10.04±0.67	1.13±0.04

Bulk density relates to the morphology and crystallinity of powders. A higher bulk density is connected with better powder flow (Niazi and Antonius, 2012). Kulfo and Tulla starches exhibited lower bulk densities than potato starch ($P<0.05$). The bulk density of Awassa83 starch is also lower than potato starch but higher than Kulfo and Tulla starches; however the difference is not significant. The difference observed in the bulk density values could be due to the different particle size, moisture content and shape which affect the packing arrangement of the powder particles. The sweet potato and potato starches have comparable tapped and true densities ($P>0.05$).

The Carr's index and the Hausner ratio utilize density values to predict the flow properties of powders. Carr's index, describes the flow properties of powders as excellent (5-15%), good (12-

16%), fair (18-21%), and poor (23-28%). Likewise, a Hausner ratio value of less than 1.20 is indicative of good flow while a value greater than 1.50 indicates poor flow properties (USP 30/NF 25, 2007). The Carr's index has also been used as a measure of interparticulate friction (Manek *et al.*, 2012). Accordingly, Carr's index of the three sweet potato starches are comparable with that of potato starch ($P>0.05$), and their Hausner ratio values for Awassa83 and Tulla starches are almost comparable ($P>0.05$). Kulfo starch has significantly different Hausner ratio values compare with that of potato starch ($P<0.05$) (Table 3). In general, the sweet potato starches are anticipated to have fair followability and compressibility properties compared with that of potato starch.

3.2.4. Swelling power and solubility

Swelling power reflects to the water absorbing capacity of starch granules, and solubility indicates the dissolution of starch granules during heating in water (Yu *et al.*, 2015). When aqueous dispersions of starch granules are heated, the starch molecules hydrate and swell with a consequent leaching of some soluble starch into the liquid. Swelling power provides evidence of non-covalent bonding between starch molecules. Bonding forces within the granules of a starch affect the degree of swelling and the amount of leaching. Accordingly, highly associated starch granules with an extensive and strongly bonded micellar structure should demonstrate relatively greater resistance towards swelling (Chen *et al*., 2003). Both swelling and solubility parameters can be influenced by a series of factors: (i) amylose content, (ii) content of amylose-lipid complex, (iii) percentage of amylopectin molecules and the degree of polymerization, and (iv) degree of interaction between amylose and amylopectin chains inside crystalline and amorphous regions(Yu *et al.*, 2015).

The swelling power and solubility profiles of the sweet potato and potato starches are shown in Figure 6 and Table 4, respectively. As anticipated, the swelling power and solubility of the starches increased with temperature (the increase is higher for potato starch).

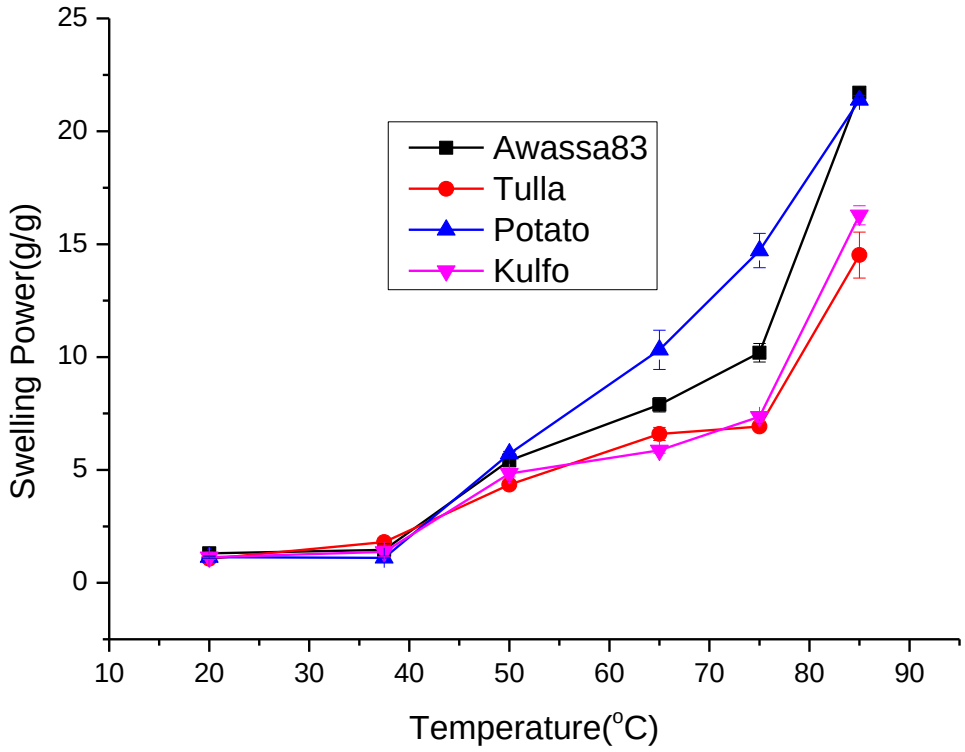


Figure 6: Swelling power of sweet potato starches and potato starch at different temperatures.

The swelling power increased with increasing (20-85 °C) temperature. The swelling power of starches were low at 20-50 °C, and started to rise rapidly at 50 °C, which indicated that an increase in swelling power occurred when temperature approached the gelatinization temperature (Man *et al.*, 2012). The greatest swelling power was observed at 85°C. Significant differences in swelling power were found at 75 and 85 °C. Higher values were observed for the Awassa83 and potato starches. For instance, the swelling power of Tulla (6.9 g/g), Kulfo (7.4 g/g) and Awassa83 (10.2 g/g) were observed as compared to that of potato starch (14.7 g/g), at 75 ^{o}C. Awassa83 and potato starches swelled to a greater extent than those of Kulfo and Tulla starches at temperatures higher than 75 °C. Higher swelling powers imply a lesser degree of intermolecular associative forces in the granules. Studies have shown that there is relatively high resistance towards swelling between highly linked starch granules with extensive and strongly bonded micellar structures (Chen *et al*., 2003).

The water solubility of the sweet potato starches also increased with increasing temperatures (Table 4). The increase in solubility was highest at 85°C for potato (20±2.95 %) starch followed by Kulfo (9.8±0.31 %), Tulla (3.25±0.76 %) and Awassa83 (3.05±0.37 %) starches, respectively. Potato starch has shown higher solubility than the sweet potato starches at all temperatures studied. Various factors contribute to this difference in solubility of the starch: the source, inter-associative forces within starch granules, the difference in swelling power and chemical composition (lipid-amylose complex), etc. of the starch.

Swelling power and solubility measurements have been used to reflect the arrangement of molecules within starch granules. The differences among the starch samples appeared to be the basis for the differences in their functional properties, consequently, making them usable for the various applications in the food and pharmaceutical industries. The increment of swelling power is an indicative of suitability of a starch being used as a disintegrant in the pharmaceutical industry. Accordingly, there is a comparable swelling power property between Awassa83 and potato starches; and among the three sweet potato starches, Awassa83 starch may be expected to show comparable disintegration profile to potato starch in tablet formulation.

Table 4: Solubility (% S) of three sweet potato starches and potato starch at various temperatures.

Temperature (^{o}C)	**Awassa83 (% S)**	**Tulla (% S)**	**Potato (% S)**	**Kulfo (% S)**
20	0.02±0.0	0.82±0.35	0.20±0.02	0.56±0.01
37.5	0.15±0.0	1.20±0.21	0.70±0.01	2.50±0.00
50	0.31±0.01	1.23±0.12	5.30±0.03	4.60±0.02
65	0.46±0.12	2.03±0.042	7.66±1.60	7.00±0.12
75	2.49±0.55	2.93±0.20	9.64±1.50	8.00±0.43
85	3.05±0.37	3.25±0.76	20.00±2.95	9.80±0.31

3.2.5. Moisture sorption pattern analysis

An understanding of the moisture sorption characteristics of pharmaceutical excipients is imperative since most of physicochemical and functional properties of these materials either

depend or are affected by it. Moisture may also induce unpredicted phase transitions in excipients which may also be imparted to the active pharmaceutical ingredients when used for formulation. Mostly, when starch is exposed to a moisture rich environment, the water molecules interact strongly with the polar groups of the amylose and amylopectin units, forming a monomolecular layer (Builders *et al.*, 2013). Knowledge of moisture sorption profiles of starch is necessary where controlled powder flow or compaction is critical. Moisture modifies the flow and mechanical properties of many powders including starches (Gebre-Mariam and Schmidt, 1996).

The moisture sorption profiles of the sweet potato starches and potato starch equilibrated at various humidity levels are presented in Figure 7. Awassa83, Kulfo and Tulla starches showed similar moisture sorption profiles. Potato starch exhibited slightly higher moisture sorption profile than the sweet potato starches particularly at 85 % and 100 % RH (Figure 7). This slightly higher moisture uptake of potato starch can be related to the disruption of the polymer chain network of the starch resulting in the exposure of numerous polar functional groups, which interact with water molecules. Nevertheless, this difference is not statistically significant ($P>0.05$).

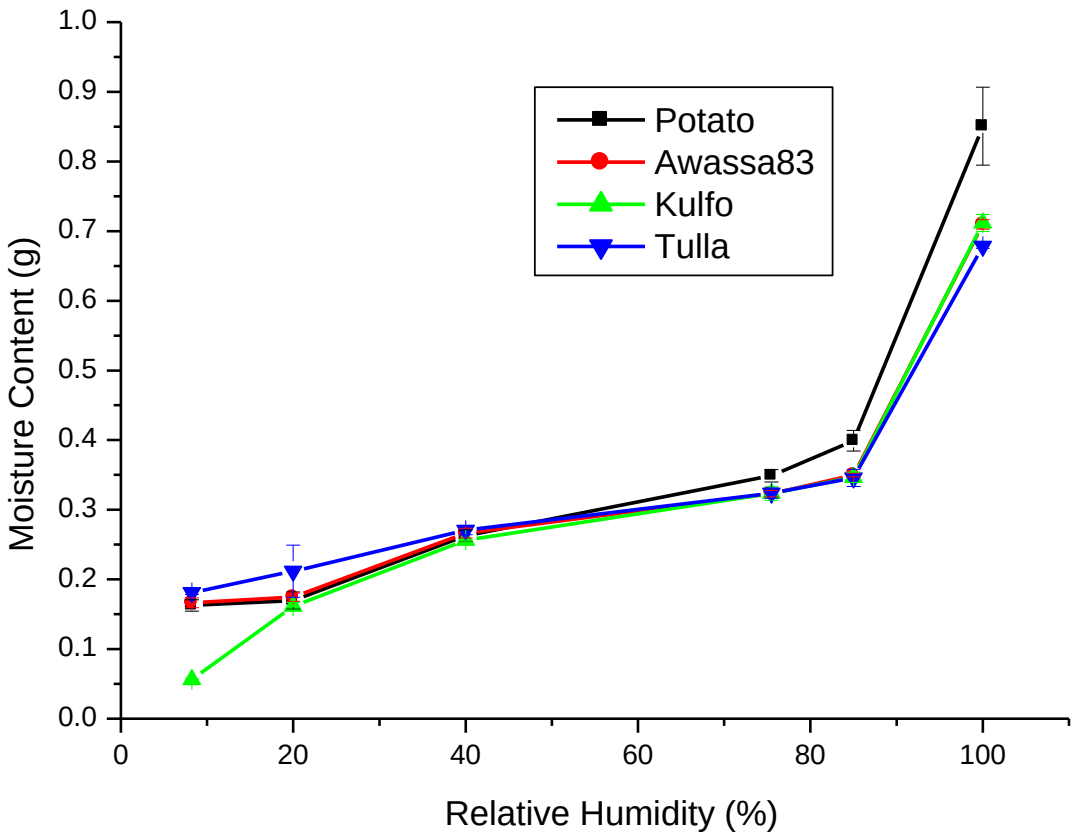


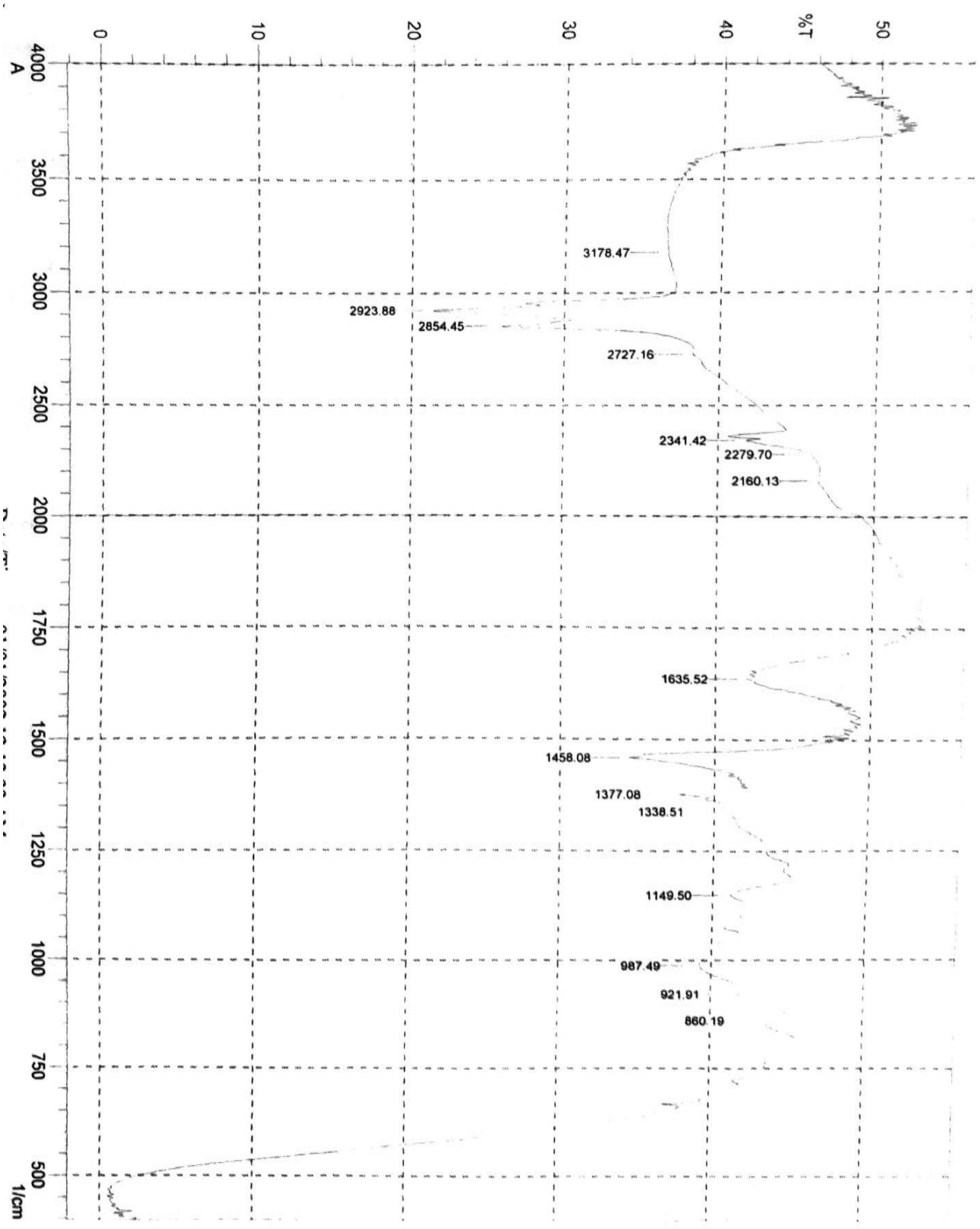
Figure 7: Moisture sorption patterns of sweet potato (Awassa83, Kulfo and Tulla) starches and potato starch.

3.2.6. FTIR spectra analysis

The FTIR spectra of the sweet potato starches and potato starch are shown in Figure 8. The absorbance in starch corresponds to the vibrational modes of the chemical bonds and the structures of starch molecules in numerous studies.

The broad absorption bands observed in the range of 3300 cm^{-1} to 3100cm^{-1} due to O-H stretching vibration. Generally, the absorption range for O-H vibration is in the range of 3400-3200 cm^{-1}, but in sweet potato starches and potato starch, the O-H stretching peak shifts to lower frequency. Because the intermolecular hydrogen bonds in the cyclic ring weaken the O-H bond (Pavia *et al.*, 2001), thus shifting the band absorption region to 3100cm^{-1} frequency. The peaks at

2923 and 2854 cm^{-1} are due to C-H stretching vibrations (absorption bands for C-H stretching ranges from 3000cm^{-1} to 2850cm^{-1}). Broad absorption bands in the range of 1350-1000 cm^{-1}, are characteristics of C-O stretching in C-O-C and C-O-H in the glycosidic ring of sweet potato and potato starches. The region between 1200 and 400 cm^{-1} is claimed as the finger print region for carbohydrate.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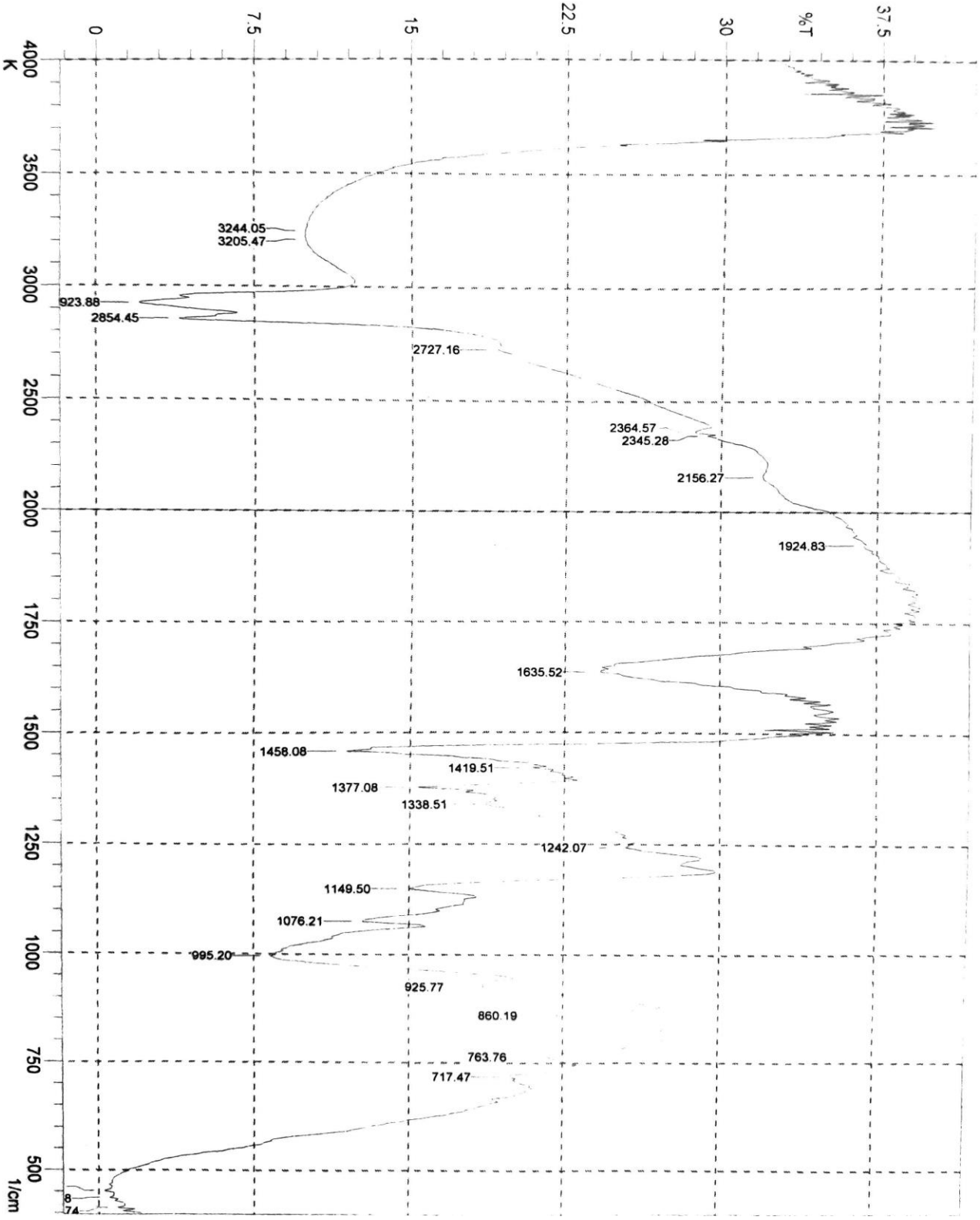
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2364.57
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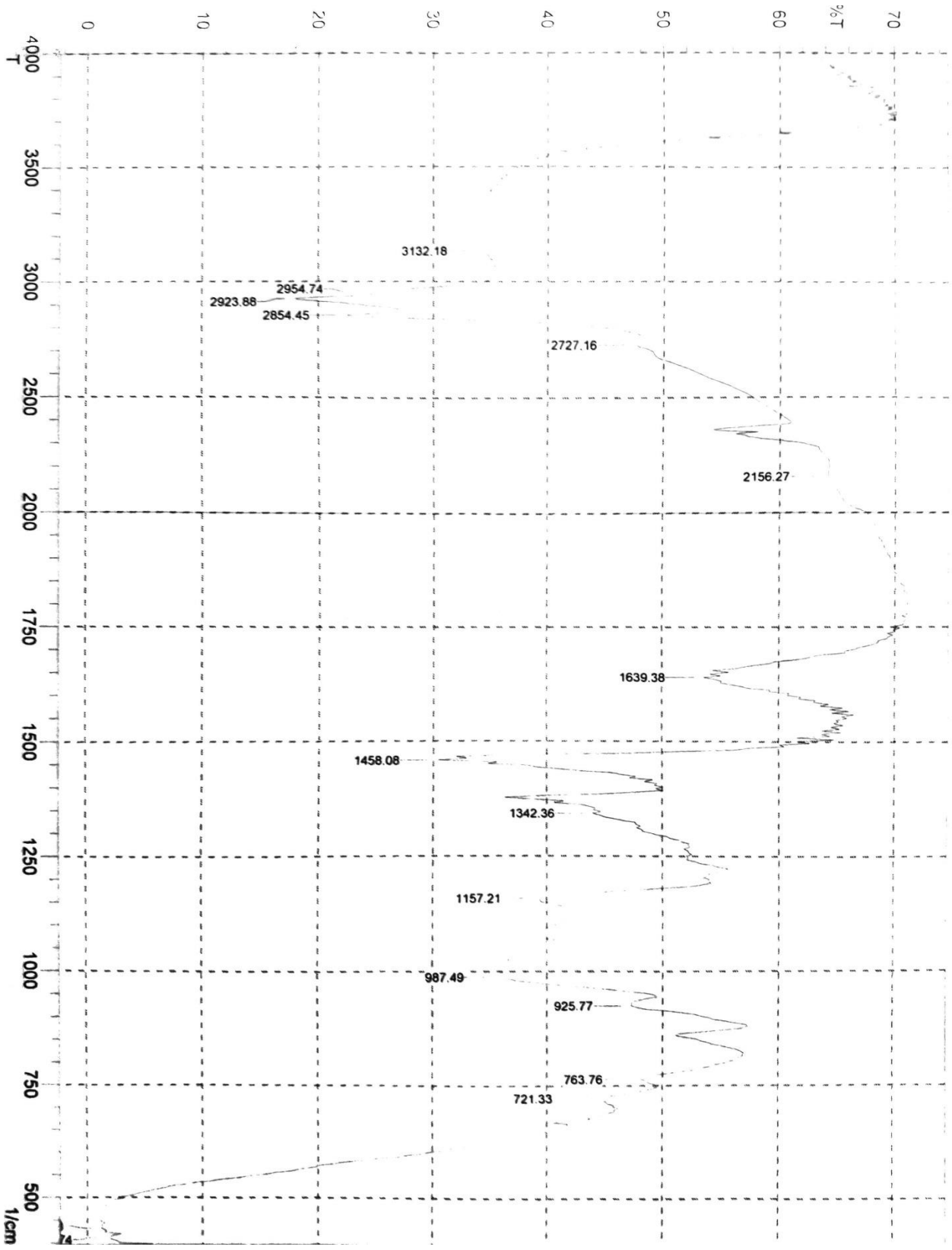
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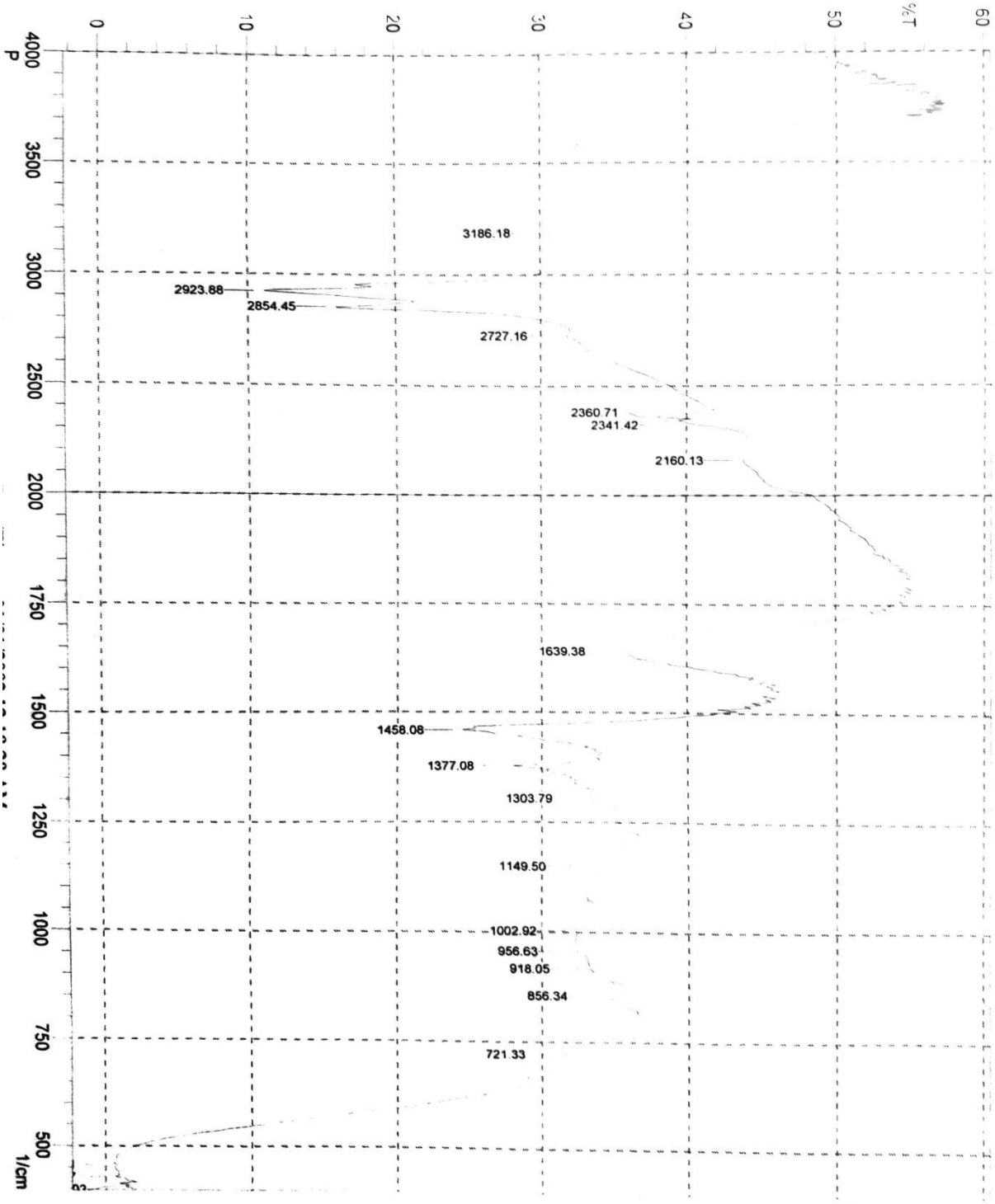

(P)

Figure 8: FTIR spectra of Awassa83 (A) starch; Kulfo starch (K); Tulla starch (T); Potato starch (P).

3.2.7. X-ray diffraction pattern analysis

The XRD pattern is the fingerprint of the crystal structure within starch granules (Zeng *et al.*, 2011). The X-ray diffraction patterns of the starches are shown in Figure 9. The sweet potato starches exhibited typical C-type XRD patterns with the first peak around 15° 2θ, the second around 17° 2θ and the third peak around 23° 2θ . Potato starch displayed maximum peaks at 17^{o} 2θ, and the other significant peaks were at, 15^{o} 2θ, 22^{o} 2θ and 24^{o} 2θ confirming typical B-type patterns. The diffraction patterns of sweet potato starches are in good agreement with that reported elsewhere for sweet potato starch (Noda *et al.*,1996). In general, the XRD intensities of the three varieties of sweet potato starches were almost identical to each other.

C-type starch is an important source of high levels of resistant starch (RS) and slowly digestible starch (SDS). RS means all starch and starch degradation products resist small intestinal digestion and enter the large bowel in normal humans. RS in colon appears to play an important role in preventing colon cancer, diverticulitis and hemorrhoids through production of short chain fatty acids. The other beneficial physiological effects of RS include decreased serum cholesterol and triglycerides level, increased fecal bulk and prebiotic effects (Guo *et al.*, 2014b). RS and SDS could decrease the *in vivo* hydrolysis rate of starch and can be considered dietary fiber. Meanwhile, RS contributes to a modulation of glycemic response and promotes the proliferation of gut microflora. Nevertheless, immediate application of starches is not possible owing to such drawbacks as vulnerability to retrogradation of starch paste and poor freeze-thaw and shear stabilities. Providentially, modification provides native starch with expandability, making it a multifunctional material. Modifications of starch are frequently accompanied by transformation of crystallinity that results from crystal formation or destruction. The C-type starches mainly change from C- to A-type, C- to B-type, and C-type to amorphous structure (Buléon, 1997; Guo *et al.*, 2017). In the present study, the sweet potato starch showed C-type and, this type of starch has been claimed to have more quantity of resistant starch.

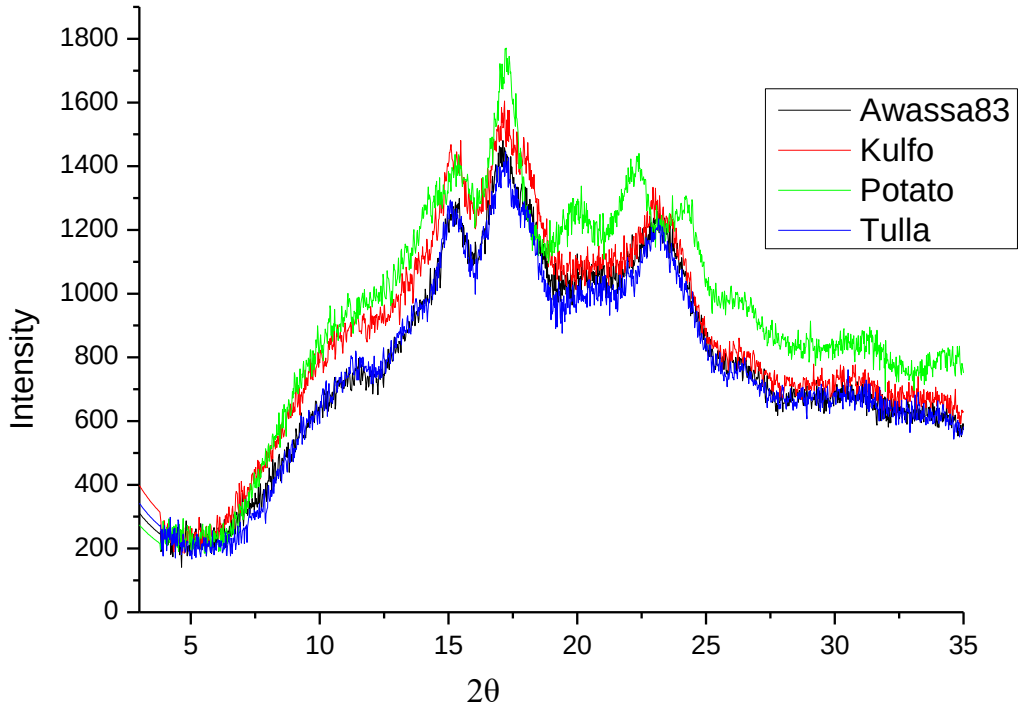

Figure 9: XRD patterns of native sweet potato (Awassa83, Kulfo and Tulla) and potato starches.

3.2.8. DSC study of gelatinization

Starch gelatinization is an important phenomenon occurring in various food and non-food processing operations. Processes such as baking of bread and cakes, extrusion of cereal based products, thickening, and gelling of sauces and pie fillings are all dependent on proper starch gelatinization (Biliaderis *et al.*,1980). The cooking, textural and digestive properties of food products containing starch can be significantly affected by the physical transformation known as gelatinization. This refers to the process by which a starch/water system undergoes an order-disorder transition during heating (Sichina, 2000). DSC is predominantly well suited to investigate the phase transitions of starch/water systems because it allows: (i) study of starch gelatinization over a wide range of starch/water ratio; (ii) determination of gelatinization temperatures above 100 ^{o}C; and (iii) estimation of transition enthalpies (Biliaderis *et al*., 1980).

The DSC thermograms of native sweet potato starches are presented in Figure 10. Data from the thermograms scans are provided in Table 5. The gelatinization temperatures (T_o, Tp, Te) of Kulfo and Tulla starches were nearly similar, but they were higher than those of Awassa83 and potato starches. The onset temperature reflects the first measurable swelling of the starch granules as reflected by the appearance of an increasing viscosity, and the gelatinization temperature reflects the beginning of the granule distortion or disruption after the granular structure can no longer support the continuing swelling (Herceg *et al.*, 2010).

The gelatinization temperature reflects the degree of crystallinity of the molecules in the starch granules (Gebre-Mariam and Schmidt, 1996). The granules disruption of Tulla and Kulfo starches were less than that of Awassa83 and potato starches. The nature of the starch (e.g., amylose/ amylopectin ratio),the specific constituent (e.g., stearic acid), lipids and nonionic constituents can have a significant effect on starch gelatinization characteristics (Lund, 1984). Awassa83 starch displayed the lowest gelatinization temperature compared to Kulfo and Tulla starches indicating easy cooking. These may suggest that the amylose lipid complex, crystallinity and crystalline arrangement of Awassa83 starch granules were lower than Kulfo and Tulla starches. Besides, Awassa83 has larger ΔT (10.31). The results observed that the increase of gelatinization temperatures affected the increase of ΔH. Therefore, these may indicate that the arrangement of crystalline structure and the amylose lipid complexes of Tulla and Kulfo starches were more similar than those of Awassa83 and potato starches. Kulfo starch, nevertheless, showed lower ΔH values (5.45mJ/mg) despite its higher gelatinization temperature. This indicates that once T_o is reached the granules require lower energy of gelatinization (Gebre-Mariam and Schmidt, 1996). From the data, it was also found that transitional ΔH of sweet potato starches are significantly less than that of potato starch. Starch that differ in gelatinization temperature and enthalpy have different cooking characteristics that affect industrial processes (Lund, 1984). Gelatinization properties of these starches are in good agreement to those reported by Collado et al. 1999, who studied the genetic variation in the physical properties of sweet potato starch.

Table 5: Gelatinization properties of native sweet potato starches.

Starch	Parameters				
	T_0 (^oC)	T_p (^oC)	T_e (^oC)	ΔHgel (mJ/mg)	ΔT (T_e-T_o)
Awassa83	61.82	65.60	72.13	6.76	10.31
Kulfo	65.27	69.09	73.69	5.45	8.42
Tulla	63.94	68.08	73.35	6.85	9.41
Potato*	58.70	62.60	68.10	19.80	9.40

*Value adopted from the report by Gebre-Mariam and Schmidt (1996).

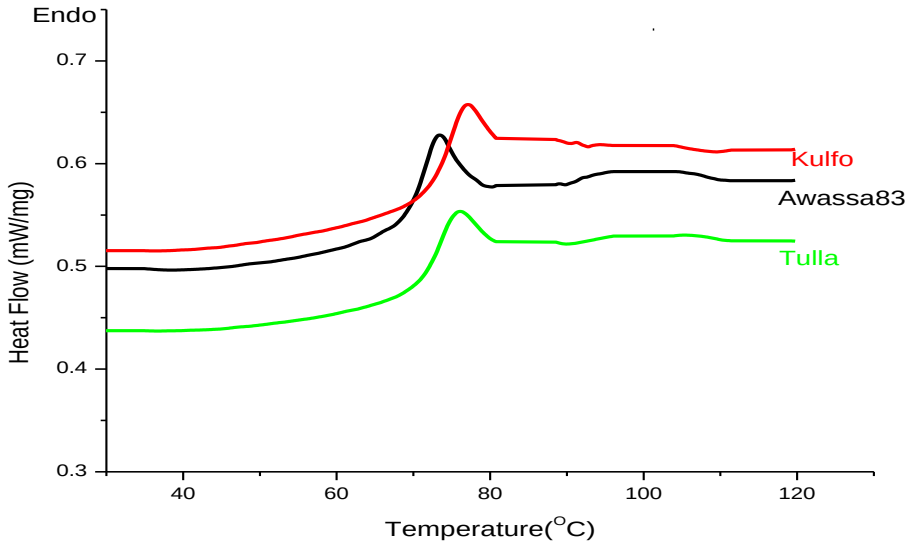

Figure 10: DSC thermograms of native sweet potato (Awassa83, Kulfo and Tulla) starches.

3.2.9. Pasting properties

When starch is heated in the presence of enough water, starch granules swell by absorbing water. As the heating temperature is increased the gelatinization temperature is reached after which a paste is formed (Gebre-Mariam and Schmidt, 1996). Pasting properties represent changes in viscosity of starch suspensions during heating, holding and cooling (Singh *et al.*, 2017). The pasting properties of starch are influenced by the size and shape of granules, amylose content, branch chain-length distribution of amylopectin, phosphate-monoester derivatives, and lipids. The amylopectin contributes to the swelling of starch granules, and amylose-lipid complexes

inhibit swelling (Kim *et al*., 2013). The pasting characteristics of Awassa83 starch, Kulfo starch, Tulla starch and potato starch are compared in Table 6 and Figure 11. The pasting temperature, the temperature at which viscosity of starch suspensions began to increase steeply during heating due to the absorption of water and loss of starch structure, varied between 66.05 and 74.30 °C. Accordingly, the pasting temperature of a 5 % of starch paste of the Awassa83 (71.85 ^{o}C), Tulla (73.65 ^{o}C) and Kulfo (74.30 ^{o}C) starches are much higher than potato (66.05 ^{o}C). The potato lower pasting temperature, potato starch indicates lower resistance to swelling and rupturing. Whereas the high pasting temperature of Kulfo and Tulla starches indicates higher resistance to swelling and rupture. The latter relates to smaller granule size, which is also related to the higher of Tp.

According to Schoch and Maywald (1968), the starch pasting viscosity patterns can be roughly classified into four types: Type A: high swelling starches, for instance, potato, tapioca, the waxy cereals, and ionic starches derivatives. The granules of these starches swell immensely when cooked in water, and the internal bonding forces become weak and fragile toward shear. Hence a high pasting peak followed by major thinning during cooking is observed. Type B: Moderate swelling starches, for example, normal cereal starches. Because the granules do not swell excessively to become fragile, these starches show a lower pasting peak and much less thinning during cooking. Type C: Restricted swelling starches, especially chemically cross-bonded products. Cross linkages within the granule markedly reduce swelling and stabilize the swollen granule mechanical fragmentation. Hence the pasting curves show no pasting peak, but rather a very high viscosity which remains constant or increasing during cooking. Type D: starches with highly restricted swelling, particularly “high amylose” corn starches containing 55-70% linear fraction. Because of the internal rigidity imparted by the high content of associated linear molecules, the granules of these starches do not swell sufficiently to give a viscous past when cooked in water at normal concentrations. Hence, the amount of starch must be increased two or three fold to give a significant hot past viscosity of type-C. However, such high amylose starches give a type A or B viscosity pattern when cooked in media (0.1N sodium hydroxide) which cause greater granule swelling (Schoch and Maywald, 1968). Thus, the RVA curves for the sweet potato starch showed type-B behaviors while potato starch showed type-A behavior (Figure 11).

Peak viscosity (PV) is the maximum viscosity attained by starch during gelatinization. It indicates the water binding capacity of the starch granule (Mohd Hanim *et al.*,2014). PV at any concentration is an important distinguishing feature of a starch from other species (Gebre-Mariam and Schmidt, 1996). Awassa83 starch shows a peak viscosity value (873 mPa.s) which is higher than Kulfo (787 mPa.s) and Tulla (829 mPa.s) starches but much lower than potato starch. High viscosity is desirable for industrial uses in which a high thickening power is required (Kim *et al.*, 1995). In contrast to Kulfo and Tulla starches, the high peak viscosity observed in Awassa83 starch implies that it may be suitable for products requiring high gel strength, thick paste and elasticity. Potato starch displays unrestricted granules swelling, displaying maximum viscosity at a relatively shorter period of heating (3.25 min). Kulfo starch attains its maximum viscosity after a heating period of 4.53 min which was slightly longer than for Tulla (4.33 min) and Awassa83 (4 min) starches. In spite of longer pasting time (4.53 min), Kulfo possesses lower viscosity (787 mPa.s) than potato, Awassa83 and Tulla starches (Table 6).

With regards to viscosity at 95°C, the viscosity of the sweet potato and potato starches goes down, at a relatively lower rate for Awassa83, Tulla and Kulfo starches as compared to potato starch. The hot paste viscosity (HV) has been attributed to the mixed effect of swollen starch granules, granule fragments, colloidally and molecularly dispersed starch molecules, rate of amylose exudation, competition between exuded amylose and the remaining granules for free water (Gebre-Mariam and Schmidt, 1996). After holding time of 2.5 min at 95°C, the HV observed were 1447 mPa.s (potato); 723 mPa.s (Awassa83); 671 mPa.s (Tulla); and 652 mPa.s (Kulfo) starches. Compared to Awassa83, Tulla and Kulfo starches, a significant disruption in HV is observable in potato starch. Thus, the sweet potato starches seemed to maintain their structural integrity more than potato starch.

There was a general increase in viscosity in the sweet potato starches when the paste was cooled to 50 °C. End viscosity formed at the end of cooling at 50°C is named as cold paste viscosity (CV). The CVs were 1725mPa.s (potato); 997 mPa.s (Awassa83); 898 mPa.s (Kulfo); and 956 mPa.s (Tulla). CV is an important property if the extruded starch is to be used as an ingredient in foods that require cold thickening capacity, like instant soups, creams or sauces (Alves *et al*., 1999). The observed increase in CV of the sweet potato starches than their corresponding PV might be attributed to the high retrogradation property of the starches during cooling.

Furthermore; differences amongst varieties in CV could be associated with differences in amylose contents. Hence it might be assumed that on cooling the viscosities of the sweet potato starches rise due to the high retrogradation tendency of the amylose fraction. In this study, the sweet potato starches exhibited increase in CV than their corresponding PV, but the values are much lower than that of potato starch CV.

The break down viscosity (BDV) of starch measures the starch paste resistance to shear and heat. The BDVs of the sweet potato starches were 135 mPa.s, 150 mPa.s, and 158 mPa.s for Kulfo, Awassa83 and Tulla starches, respectively. The lowest BDV observed in Kulfo starch suggests its greater resistance to shear as compared to Awassa83 and Tulla starches. The sweet potato starches showed much lower BDV values than potato (2495 mPa.s) starch, suggesting greater resistances to shear and heat as in sweet potato starch compared to potato starch.

Table 6: Pasting characteristics of the three sweet potatoes and potato starches at 5% w/w concentration.

	Viscosity (mPa.s)						
Starch	**PV**	**HV**	**BDV**	**CV**	**Setback**	**Peak time (min)**	**Pasting temp.(°C)**
Potato	3942	1447	2495	1725	-2217	3. 25	66. 05
Awassa83	873	723	150	997	124	4. 00	71. 85
Kulfo	787	652	135	898	111	4. 53	74. 30
Tulla	829	671	158	956	127	4. 33	73. 65

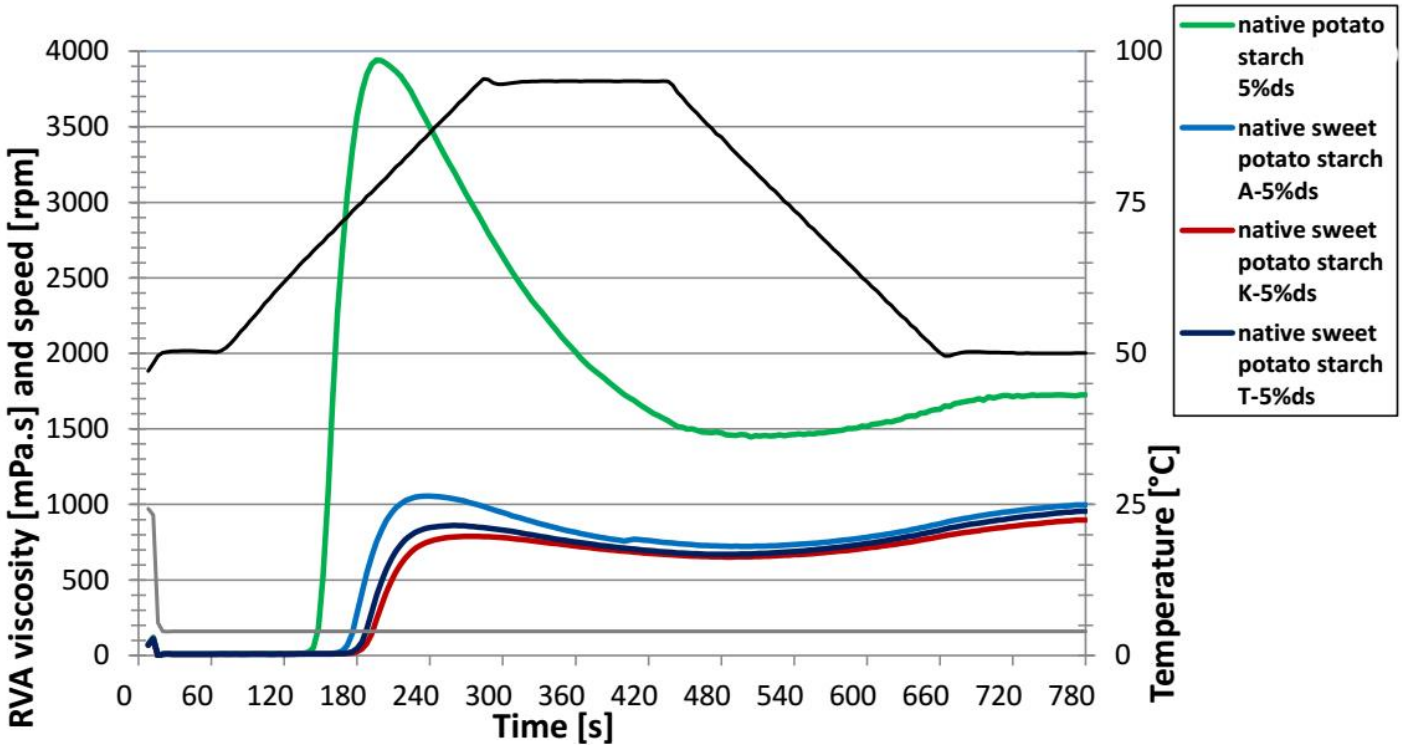

Figure 11: RVA viscosity curves of sweet potato [Awassa83 (A), Kulfo (K) and Tulla (T)] and potato starches.

The setback viscosities (Cv-Pv) for Awassa83 (124 mPa.s), Kulfo (111 mPa.s) and Tulla (127mPa.s) starches were positive while negative for the potato starch (Table 6). For the sweet potato starches, slightly higher setback viscosity was observed for Tulla than that of Awassa83

and Kulfo starches. Moreover, Awassa83 starch presented with slightly lower setback viscosity suggesting lower retrogradation tendency than that of Tulla starch. On the other hand, potato starch showed much lower setback viscosity suggesting lower retrogradation tendency.

Generally, pasting and thermal properties are the most important properties when considering starches for use as gelling and thickening agents. Starch having relatively high PV, high BDV and low setback viscosity could be considered for use as thickening (Abegunde *et al.*, 2013). Thus, among the sweet potato starches, Awassa83 starch has depicted relatively high PV and BDV, and low setback viscosities and it may be suitable as a thickening.

4. CONCLUSION

Sweet potato starches were isolated from three Ethiopian sweet potato varieties, namely Awassa83, Kulfo and Tulla. The yield was in the range of 63.7 % to 75.1 % on dry weight basis. Protein content of Awassa83 and Kulfo starches were higher than that of potato starch. The lipid content of the sweet potato starch was much higher than found in potato starch. The moisture content of the sweet potato starches fall within the optimum range for commercial utilization. The shapes of the sweet potato starch granules varied from polygonal, round to cupoliform/bell shaped. The swelling power and solubility of the starches increased with temperature but were lower than those of potato starch. The XRD patterns of the sweet potato starches displayed C-type starch at 2θ. Sweet potato starches exhibited higher gelatinization temperatures and lower enthalpy than that of potato starch. The RVA pasting curves showed type-B behavior. In conclusion, the results indicate that the sweet potato starches may be alternative sources for use in the pharmaceutical and other industries.

5. SUGGESTIONS FOR FURTHER WORK

As the follow up, the following further studies are suggested;

- Phosphorus content determination of the starches;
- Stability study of the starches;
- Microbial loads determination of the starches and;
- Physical and chemical modifications to enhance the application in pharmaceutical, food, and other industries.

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