

**Utilization of Potato and Wheat Wastes
For Starch Synthesis Along With
Kinetic Study**



By

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Dedication

*I dedicate this thesis to all my Well Wishers for nursing me with love
and Affection Especially*

My Late Father

Muhammad Khushnood

My Mentor (Mother)

Nageena khatoon

My Siblings

Especially My Youngest Brother

Engr. Khayyam Khushnood

Nephews and Neices

Acknowledgments

As a matter of first importance all acclaim to **Almighty ALLAH**, Lord of the Creations, the Creator, for giving me the quality, ability and chance to attempt this exploration, persistent and to continue and finish it agreeably. May the harmony and favors upon the noblest of Prophets and Messengers, our **Prophet Muhammad(PBUH)** and on his Family and the majority of his Companions.

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Abstract

Mankind has explored the natural resources of earth without limits, including extraction of raw material for industry. The planet's capacity to absorb and convert the waste, resulting from modern life, seems to be inexhaustible. Situation has become a matter of great concern with the exponential increase in the population of planet. Consequently, waste production will increase by many folds. To counter this, alternatives such as substitution of conventional plastics for biodegradables are being studied. So, the main focus during the present work was the utilization of solid potato and wheat waste into biodegradable product such as starch, having various applications. For extraction of starch from waste potato and wheat, hydrothermal pretreatment was performed due to its high conversion efficiency and then compared it with the synthetic starch. Furthermore, kinetics of different starch were also carried out indicating that potato starch was the most suitable candidate and it follows the first order kinetics.

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Chapter 1: Introduction

1.1 Background

The natural resources of earth are being discovered by mankind deprived of constraints, and regarding this, extract raw material for industry. The planet's capacity to absorb and convert the waste, caused due to modernism appeared to be boundless. This alarming condition has become a piece of great attention, with the exponential increase in the population of planet[5].Consequently, waste production will increase by many folds. To counter this, alternatives such as replacement of conservative plastics to eco-friendly one are being studied[6].

The ecofriendly materials which can be easily degraded are being developed from recyclable resources to substitute unoriginal non-biodegradable materials has been encouraged because of the growing environmental awareness. Among these, substances like starches has the ability to replace synthetic polymer in plastic industries because of low cost, biodegradability ,non-toxicity and availably[7, 8].Corn being the main commercially available source of starch along with wheat, potato, and cassava[9].

1.2 Introduction of Starch

Edible and non-edible substances are largely composed of starch, which is a simple carbohydrate taken from the natural resources of agriculture. It has replaced the constituents of fossil fuel and is used as good natural resource because of it's biodegradable and renewable nature. All types of vegetables store energy in the of starch. It consist of enormous glucose units joined by glycosidic bonds. Furthermore, "amylose" (liner structure) and "amylopectin" (branched) being the two main component of starch. The molecular weight of amylose is 0.2-2 million, although that of highly branched amylopectin is as high as 100-400 million [10].



Figure 1.1 Powdered Form of Starch[11]

Starch can be degraded easily in diverse environments and is highly applicable in the advancement of completely degradable goods to meet definite market requirements. The breakdown of substances containing starch helps in recycling of atmospheric carbon di oxide which is being confined to starch-producing plants during their progress, thus closing biological carbon cycle[12].Consequently, reducing the risks of green house gases emissions that constitute greenhouse gases (GHG) like carbon di oxide, and oxides of sulphur and nitrogen.

1.3 Criteria for the selection of Starch

Following is the main criteria for the selection of starch as the starting material.

- Efficient utilization of agricultural wastes of potato and wheat.
- Biodegradable
- Reduced level of toxicity.
- Easy accessibility.
- Ecofriendly.
- Low cost.

1.4 Potato Starch

Potato is tuberous crop of Solanacea family. Roughly potato constitute about 18% starch [13], while peel wastes consists of 58% of dry weight as starch [14]. Statistics have shown that, Pakistan cultivated about 3,491,800 tons of potato in the year 2011[15].Approximately, about 5-20 % of the produce is likely to be wasted during cultivation of potato, while 18%of the potato waste is available in the form of peels from potato processing industries [14].Disposal of potato is a major issue of the food

industry. Hence, utilization of this agricultural waste will result in pollution control and a valuable carbon energy source in the form of starch[16].For the starch extraction from potato , hydrothermal pretreatment method was used[17]. Figure 1.2 shows the potato starch.



Figure 1.2 Potato Starch [1]

1.5 Wheat Starch

The foremost cereals in the human diet includes wheat. It is the cereal crop of Poaceae family[18]. Roughly wheat constitute about 58% of starch content. The annual production of wheat during 2011 was estimated to be 694 million metric tons and considered as second major cereal crop in the world after maize[19]. About 10 % of total wheat production was lost every year due to flood, fog, and heat stress. Utilization of this waste is an efficient strategy to reduce the stress of pollution. Regarding this, it can be used widely in the extraction of starch.



Figure 1.3 Wheat Starch

1.6 Different Pretreatment Methods for Starch Extraction

- Various pretreatment methods are used for the extraction of starch. These are “*Physical Pretreatment*” that includes milling and irradiation [20]. “*Physio Chemical Pretreatment*” such as steam explosion or auto hydrolysis, ammonia fiber eruption, carbon dioxide explosion and pyrolysis [21, 22]. “*Biological Pretreatment*” [20, 23] and “*Chemical Pretreatment*” that includes dilute acidic pretreatment, alkaline pretreatment, ozonolysis pretreatment, organosolv and oxidative delignification [24-26]. Table 1.1 summarizes the benefits and drawbacks of different pretreatment methods.

Table 1.1 Different Pretreatment Methods of Starch Extraction

	Frequently used pretreatment	Benefits	Drawbacks	Reference
Physical	Milling	Cost Effective	High energy demand for hard biomass	[20]
Chemical	Acid hydrolysis	Short reaction and residence time. Removal of lignin and hemicellulose content	Corrosion to reaction vessel Inhibitory sugar degradation byproduct is formed	[26, 27]
	Alkaline Hydrolysis	Reduction in the cellulose crystallinity Polymerization of carbohydrate is decreased.	Low digestibility enrichment in softwood.	
Physicochemical	Ammonia Fiber	Cellulose crystallinity is	Require ammonia reprocessing	[27, 28]

	Explosion	reduced . Short reaction time (15 min)	system. For hard wood, low digestibility is reported
	Steam Explosion	Cost effective for hardwood bio feedstock	Partial degradation of hemicellulose. fraction. Inhibitory sugar degradation byproduct is formed.
Biological	“White rot” and “soft rot fungi”	Less energy intensive Require mild conditions	Extended reaction [17, 20] time (2-4 weeks)

1.7 Motivation

To carry out the efficient conversion of agricultural wastes into useful products such as starch that can be further utilized in various applications like packaging and in motor fuels. The aim of my work is to extract wheat and potato starch from the rotten wheat and potato in order to reduce pollution caused by agricultural wastes. Value added of polysaccharide (starch) and agricultural products (wheat and potato) which is abundant in Pakistan and to carry out the maximum extraction possible from their rotten form .Furthermore, concepts of hybrid starch was first ever introduced that can be utilized in the most efficient way in the various applications to increase yield.

The objective of research is

1. To synthesize extracted (wheat ,potato) and hybrid starch and compare them with synthetic starch (analytical grade) donated by lab of SCME NUST.
2. To carry out the characterization techniques of starch in the following way

- “Scanning Electron Microscope” (SEM)
- “X-ray Diffraction “(XRD)
- “Fourier Infrared Spectroscopy”(FTIR)
- “Particle Size Analyzer”(PSA)
- “Energy Dispersive X-ray Spectroscopy” (EDS)
- “Ultra Violet Spectroscopy” (UV Visible)
- “Differential Scanning Calorimetry” (DSC)
- “Viscometer”
- “Thermaogravimetic Analysis” (TGA)

3. To study the kinetics of starch .

1.8 Layout of the Dissertation

Section 1 covers the outline of Starch ,diverse sorts of starch, blend technique and utilization of starch.

Part 2 covers enhanced applications and the outline of the examination work previously completed on starch blend and it's energy.

Section 3 incorporates materials and strategy did for various starch producing. Moreover, portrayal systems received to decide starch attributes are likewise discussed .

Section 4 establishes the Outcomes obtained from classification methods.

Fifth Chapter assess the energy investigation of starch.

Sixth Chapter comprises short synopsis of this examination work and future suggestions.

Chapter 2 Literature Review

2.1. Starch In General

2.1.1. Production and Application

Starch is charitable in all major agronomic products. In spite of being the fundamental vitality reinforcement for a huge decent variety of different plants like that of grains, vegetables ,roots and also tubers [29], oats contributes about progressively then 90 %of world starch [30].Maize (about 80%) is the biggest contributor of world starch creation, while wheat (>8%), potato (>5%) and cassava shares whatever is left of the generation [31]. Other starch sources like rice, grain, oats , sorghum , and so forth., additionally add to world starch generation to the slight degree.

Natural starch has various properties and has been employed in several food (54%) and non food (46%) applications[31].To improve the properties and to widen the scope of native and derived starch's applications , various physical and chemical modifications have been employed .Starch and it's derivatives have increasing demand in industry because of renewable and biodegradable source, easy availability, cost effective, versatile and due to ecofriendly nature. Presently , in order to have starch of improved functional properties various plant breeding techniques have been employed. Application of starch and starch derivative in foodstuff and non-food industry are précised in Table 2.1.

Table 2.1 Application of Starch in Different Industries

Nature of Industry	Purpose	Type of Starch
Food	Thickener, stabilizer, binder fat replacer, glaze, adhesive	Native and modified starch, maltodextrin, high fructose syrups
Beverage	Soft drinks, beer, alcohol, instant coffee	Sweeteners
Adhesives	Case sealing, laminating, tube winding, corrugated	Starch dextrans

	board	
Textile	Sizing, finishing, printing, fire resistance	Native and modified starches
Detergent	Surfactants, builders, bleach activators	Sucrose derivates
Pharmaceutical	Diluents, binders, drug delivery	Starch, malto- as well as cyclodextrins, polyols, glucose syrups
Plastics	Biodegradable filler	Starch
Biochemistry	Organic acids, amino acids, enzymes, alcohol	Starch hydrolysates
Other	Ceramics , coal, water treatment, oil drilling concrete, gypsum	Native and modified starches

Source: [32, 33]

2.1.2. Biosynthesis of Starch Granules

Endosperm(amyloplasts) of the seed has capacity starch, while fleeting starch is available in leaves (in chloroplast)[34]. Starch is a polysaccharide having semi crystalline granules ,consisting of “amylose” and “amylopectin” Amylose being straight polymer has α -(1,4) links, while amylopectin is extremely branched polyglucan having α - (1,4) and interconnected α -(1-6) links. There are two type of chemical linkages and only one type of sugar residue in the macromolecular components of starch granule [29] .However, biosynthesis of starch is more complicated than it give the impression[10].

2.1.3. Starch Granule Morphology

Starch granules exhibits different shapes, size and morphology depending on the biological origin, there by increasing its specificity in food applications[35, 36]. In nature, variously shaped starch granule for example, lenticular/oval, round/circular, polygonal and sporadic is being available with measurements extending from 1 to 100 μ m in distance across [10, 37].Grains from roots and tuber starches are relatively more prominent in size (2-100 μ m) having oval shape for the most part [35, 38]. Table 2.2 shows grain shapes and sizes of starch granules.The outer surface of starch grain has an important role in various applications[39]. In general , root and tuber starches have smooth surface[40].However, latest research studied by atomic force

microscope (AFM) shows that potato and tapioca have surface pores in contrast to the earlier reports[41]. Moreover, shape and sizes of these depressions depends on the source of starch[42].Table 2.2 summarizes the size and shapes of different starch granules.

Table 2.2 Size and Shapes of Different Starch Granules

Source	Granular Shape	Granular Size (μm)	Distribution
Cereals	-	-	-
Barley (n)	Oval/lenticular	2-10 (s), 10-30(l)	Bimodal
Wheat (n)	Lenticular/Spherical	2-10 (s), 15-35 (l)	Bimodal
Rice (n)	Polygonal/Irregular	3-8	Bimodal
Maize (n)	Spherical/Polyhedral	2-30	Unimodal
Oat (n)	Polygonal/Irregular	2-15	Unimodal
Potato (n)	Round/Oval	12-75 & 12-37	-

[10, 35, 38, 43, 44]

2.1.4. Granule Composition

The starch mostly(98-99%) constitute amylose and amylopectin, as mentioned earlier. Even though, amylose to amylopectin ratio in native starch is (1:3), however, exact value depends on biological origin[29, 34, 43].Furthermore, breeding expertise have produced starches with low (waxy; <5%) and high (>35%) amylose[44]. Apart from that, starch also encompasses small amount of superficial and integrated proteins and lipids , along with small amount of minerals [45].Both exterior and interior lipids might exist in free state as well as bound to hydroxyl group of the starch component [46]. Generally, nitrogen is present as a protein in starch granule, but it may also be the part of starch lipid. For starch purity, protein content is less than .6%[47]Starch physicochemical properties such as swelling, digestibility, retrogradation and granule integrity might be influenced by both lipids and proteins[11, 48].Starch also contains trace amount of minerals (<.4%) such as Ca, Na, K, and P with only phosphorous having functional significance[44].Amylopectin from majority of plant sources have small amount of glucose moieties (.1-1%) with phosphate group[10]. In general , amylopectin of tuber and root starches have the maximum amount of phosphate group resulting in phosphorylation[40, 47].

2.1.5. Ultrastructure

2.1.5.1. Macromolecules

2.1.5.1.1. Amylose

At first amylose was found to have extensive straight chains of α -(1,4)- linkages of D-glucose (Figure 2.1). However, it is presently recognized that it additionally contains paltry segment of branches (1%) [10, 44, 49]. The atomic size and the degree of fanning rely upon the genomic wellspring of amylose and degree of spreading increments with the sub-atomic size of amylose [10, 44]. Usually sub-atomic load of amylose ranges from 105-106 Da [10]. The molar portion of stretched amyloses from various assortments, shifted from .3-.7 having 5-34 chains for every atom in the amylose division [49]. For the most part amylose of oats starches have littler sub-atomic load than that from tuber and root starches.

One of a kind capacity of amylose is capacity to frame helical consideration edifices having various natural and inorganic complexing specialists, for example, "lipids," "iodine", "dimethyl sulfoxide", "season mixes", and "aliphatic alcohols" likewise alluded to as V-amylose [1]. Furthermore, "temperature", "pH", and ionic quality of the framework, influences the arrangement of amylose-lipid incorporation complex (Vam,cpx).

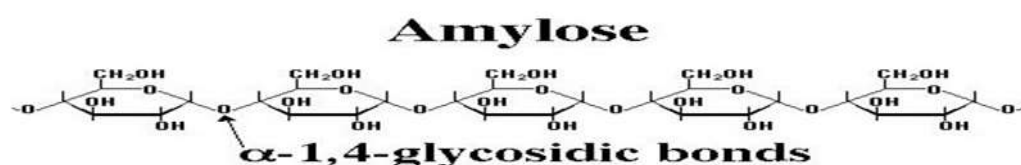


Figure 2.1 Structure of Amylose

2.1.5.2. Amylopectin

It is the primary segment of generally starches. It is among the main polymers in nature with a normal sub-atomic weigh of 107-109 Da [50, 51]. It comprise about 95% α -(1,4) and 5% α -(1-6)- linkages. The atomic size, shape and structure of

amylopectin differ with the botanic cause, like that of amylose [44, 52]. According to the length of amylopectin branches, three kinds of unit chains are available, alluded to as "A", "B", and "C" chains. Besides, the normal chain length of amylopectin in A-type starches is littler than B- and C-type starches [53, 54].

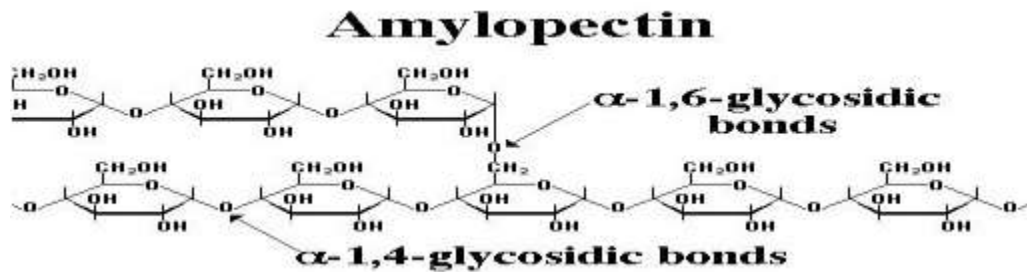


Figure 2.2 Structure of Amylopectin

2.1.6. Distribution of Amylose and Amylopectin within the Granule

Significant part of amylose is situated in the formless area of starch granules, yet its existence in reference to the amylopectin crystallite is as yet not clear yet. It was discovered later that amylose in ordinary starches is haphazardly intermixed as individual particle in formless and additionally crystalline districts of the granule [40, 55, 56]. Studies have appeared, the greater part of the amylose is available in fringe segment of these granules [57, 58]. However, contingent upon the amylose substance of starch, there was difference in the localization of amylose [59, 60]. Amylopectin chain length and branching pattern inside each cluster are different, in addition to different crystallite arrangement and water content [29, 58].

2.1.7. Starch Sources:

It includes

- cereal grain seeds like corn, wheat and rice
- Tuber and roots like potato and tapioca



Figure 2.3 Types of Starch Sources

2.1.8. Kinetics of Starch

Energy of hydrolysis of sorghum was inferred by Khan et al., 1980 from performing investigates hydrolysis rate consistent as the capacity of focus and temperature[61]. On the comparative premise, synthetically adjusted starches through the procedure of hydrolysis have additionally been reported[62]. The response conditions for hydrolysis were streamlined by utilizing thermo stable α -amylase. Moreover, microbial analysis are broadly utilized in starch hydrolysis in industries[63]. Starch energy is being learned at various temperature of 20°C, 27°C and 35°C by performing UV at theories temperature. It has been demonstrated that starch energy pursue first request response and is reliant on temperature .Furthermore, initiation vitality is additionally being determined for separated and half breed starch.

2.1.9. Significance of Research

Starch has huge impact on characteristics of the food products including texture, volume, moisture, consistency, shelf life and aesthetics[64-66]. These different properties are widely affected by the botanic origin of starch , it's configuration as well as it's structure. Several studies focus the correlation between starch configuration and it's functionality in food system[65, 67, 68]. However, still there is

gap between starch functionality in the food matrices and current knowledge of starch internal structure which need to be addressed.

Mankind has explored the natural resources of earth without limits, and regarding this, extract raw material for industry. The planet's capacity to absorb and convert the waste, resulting from modern life seemed to be inexhaustible. Situation has become a matter of great concern, with the exponential increase in the population of planet[5].Consequently, waste production will increase by many folds. To counter this, alternatives such as substitution of conventional plastics for biodegradable one are being studied [6].So, the main focus was the utilization of solid potato and wheat waste into biodegradable product such as starch, having various applications. For extraction of starch from waste potato and wheat, hydrothermal pretreatment was performed due to its high conversion efficiency and then compared it with the synthetic starch. Furthermore, kinetics of starch is also discussed in the subsequent chapters.

Chapter 3 Experimental

3.1. Materials Used

- Potassium Hydroxide as pellets, (M=56.11 g/Mol, additional unadulterated) acquired from Sigma-Aldrich.
- Iodine Solution , acquired from Science Center.
- Wheat Grains (500 grams) was acquired from neighborhood Market of Rawalpindi.
- Potato (500 grams) was acquired from neighborhood Market of Rawalpindi.
- Distilled Water .
- Other Utensils.

3.2. Synthesis Procedure of Wheat Starch

Wheat starch can be prepared by using hydrothermal pretreatment method. Hydrothermal pretreatment is preferred because of higher efficiency. Wheat grains were soaked in distilled water and provided with the anaerobic conditions for more than 15 days with the change in water on alternate days. After sufficient time of soaking, wheat grains were squeezed, separated, filtered and dried. The mother liquor left was then evaporated in an open atmosphere for almost 48 hours. After evaporation, the solid left behind was crushed uniformly to obtain starch. In this way wheat starch is extracted from the rotten wheat in the most economical and feasible way.

3.3. Synthesis Procedure of Potato Starch

Potato starch was also prepared by using hydrothermal pretreatment method. Potato tubers were soaked in distilled water, and provided with the anaerobic conditions for about 8 days with the change in water on alternate days. After sufficient time of soaking, potato tubers were squeezed, separated, filtered, and dried. The left over was evaporated in an open atmosphere for almost 72 hours. After evaporation, the solid left was crushed uniformly into obtain final form of potato starch. By this way potato starch was extracted from the rotten potato tubers.

3.4.Synthesis Procedure of Hybrid Starch

Hybrid starch was synthesized by taking an equal amount of wheat , potato and synthetic starch. The resulting starch obtained by the homogenized mixture of all the three starched have the similar properties like that of starch as confirmed by the characterization techniques.

3.5.Characterization Techniques

The characterization of synthetic, extracted and hybrid starch have been done by various techniques such as SEM, XRD,FTIR,EDS,PSA, U.VDSC,Viscosity and TGA.These procedures are talked about beneath.

3.5.1. Scanning Electron Microscopy (SEM)

SEM is a logical instrument used to contemplate the morphology and surface geography of the starch. Goals of this electron magnifying instrument is about 4nm with the amplification of 10-150,000X.

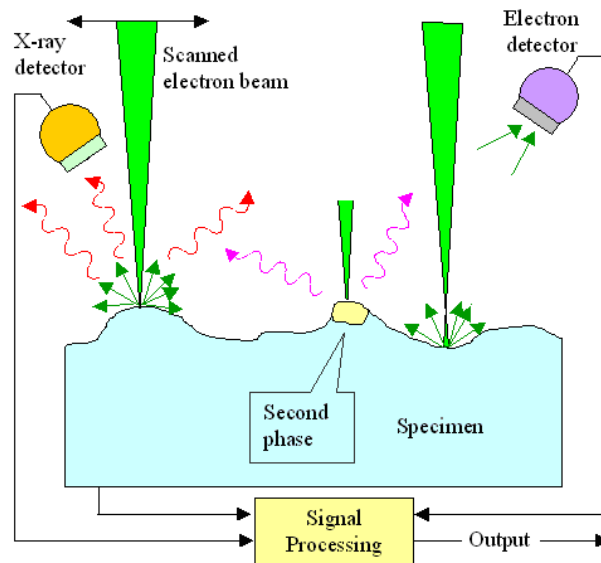


Figure 3.1 Working Principle of SEM

SEM provide finish filtered image of a sample when inspected under the arrangement of electron pillars .This happens when an electron associates with test's molecule, electronic signs are being produced ,subsequently giving data about morphology (measure and physical appearance) and geology (surface attributes) of the example

Starch was analyzed under JEOL (JSM-6490A) SEM instrument. Starch was layered with gold with the help of sputter coater to make it conductive.

Analysis of different starches were performed at 20 kV accelerated electron voltage and 12-20 Pa chamber pressure on samples, obtaining images on fracture surfaces with secondary electron signals.

3.5.1. Fourier Transform Infrared (FTIR) Spectroscopy

FTIR is a diagnostic system that gives data about the vibration qualities of useful gatherings or the ID of synthetic bonds present in an atom. It is utilized for both subjective and quantitative examination of tests.

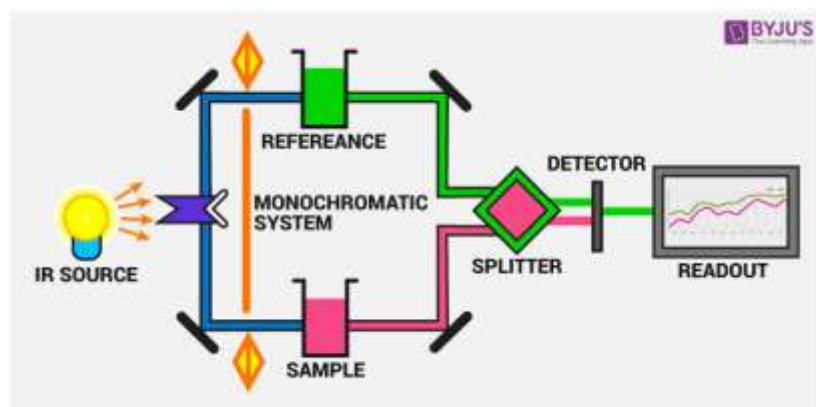


Figure 3.2 Working Principle of FTIR

Essential rule of IR spectroscopy is the connection of electromagnetic radiation with species that have a perpetual or instigated dipole moment and the excitation of various vibrational states. Along these lines material moves and becomes IR active.

Covalent bonds are adaptable or in condition of vibration. Vibrations are either extending or twisting (symmetric, awry). Dipole minute must change amid a vibration to be IR dynamic. Oxygen, hydrogen are IR idle as they don't results in change of dipole minute with connection of electromagnetic radiation. IR range got is plot among %transmittance and recurrence in wave number(cm^{-1}). FTIR instrument (Perkin Elmer, range 100) was accessible for the investigation of starch with the wave number scope of 450cm^{-1} to 4000cm^{-1} . Starch was put into the FTIR machine in pellet shape. Examination was done at room temperature [69] with the investigation time of under 10 minutes.

3.5.2. X-Ray Diffraction (XRD)

Expository procedures used to quantify the normal dividing among layers and columns of molecules and to delineate the stage or crystalline structures of powdered examples. The extent of crystallites, stage immaculateness, stage personality, grid parameter, crystallinity and gem structure can be acquired by XRD design results. X-beams are the EM (electromagnetic radiations) with the wavelength (1\AA), shorter than bright however longer than gamma beams. There are three principle parts of XRD: X-beam tube, an example holder and identifier.

XRD procedure depends on the obstruction of monochromatic X-beams and an example. Cathode beam tube frame the X-beams by the communication of high vitality charged electron on target (typically copper). Collaboration of these high vitality electrons, results in the dislodging of the inward shell of electrons of the example material. Because of this ionization procedure , qualities X-beams spectra are created. The starch test (fine and homogenized) were inspected utilizing X-beam diffractometer.

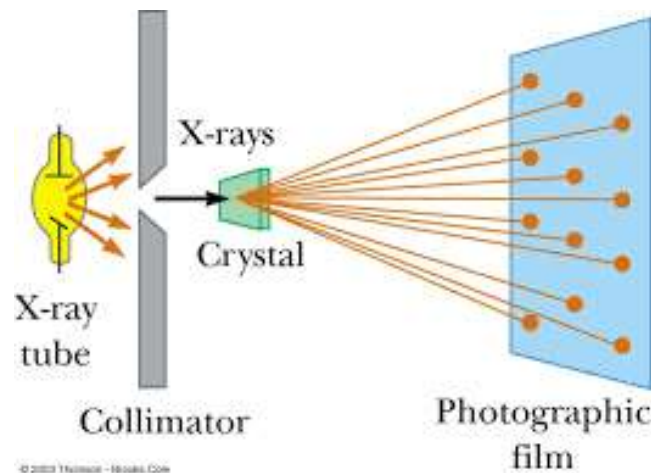


Figure 3.3 Working Principle of X-Ray Diffraction Analysis[2]

Bragg's law was utilized to distinguish the d-dividing between structure layers at an explicit edge.

$$n\lambda = 2d \sin\theta$$

It is easy to comprehend the Bragg's law ,utilized for the procedure of diffraction. Crystallite size of the gems can be found by utilizing Debye-Scherrer condition. All

crystalline material has the remarkable X-beam design ,utilized as a unique mark for its ID

3.5.3. Energy-Dispersive X-ray Spectroscopy (EDS)

It is a logical method utilized for the essential examination or compound portrayal of the sample.EDS procedure depends on association of some wellspring of excitation of X-beams and an example. Rendering abilities of EDS is because of the major rule that every component has an exceptional nuclear structure ,bringing about one of a kind arrangement of crests on its electromagnetic discharge range. Parts of EDS gear are :excitation source, the X-beam finder, the beat processor and the analyzer.

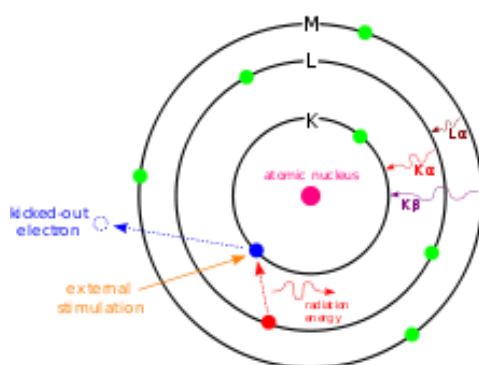


Figure 3.4 Principle of EDX

Starch samples were analyzed using model JEOL (JSM-6490A). EDS is carried out by the interaction of high energy beam of X-rays with that of sample. Sample was first sputtered with gold to make it conductive. Characteristics peaks of carbon , and oxygen were analyzed during EDS of starch sample. Hydrogen was unable to analyzed by the facility of the equipment found.

3.5.4. Particle Size Analyzer (PSA)

It is an analytical technique used to find the average particle size of the sample. PSD is important in assessing effectiveness of treatment processes.

Commonly used method for particle size analysis are:

- Serial Filtration
- Electronic Particle Counting
- Microscopic Observations

Method employed for PSA in the lab is Electronic Particle Counting. Principle of PSA is that the diluted sample in the specific dispersing solvent passes through calibrated orifice or past laser beam. As particle pass through orifice, conductivity of fluid changes owing to the presence of particle. Change in conductivity is co related to the size of equivalent sphere. In the same way, reduce intensity is correlated to the diameter of particle. Particles counted are grouped into particle size ranges. In turn ,volume fraction corresponding to each particle size range is computed.



Figure 3.5 Particle Size Analyzer

Average particle size of wheat grains and potato are analyzed by using model Horiba LA 920. Samples were diluted in the dispersion solvent which was water. Amount of sample and dispersing solvent was in the ratio of 1:4. Sonication is carried out for about an hour before passing the diluted sample through the equipment designed for PSA. Principle was followed in the same way as mentioned before. In this way, average particle size of wheat and potato was analyzed successfully which comes out to be about 1 μ m.

3.5.5. Viscosity:

Viscosity is the measure of resistance of fluid measured in centipoise and poise. Viscosity of starches were analyzed using DV-11+Pro Viscometer of Brookfield. Starch solution were prepared by dissolving 5g of starch in 95ml of water. The solution were first heated to about 97°C ,and then analyzed in viscometer with spindle speed of about 50rpm with the analysis time of less than 2 minutes.



Figure 3.6 Viscometer

3.5.6. Ultraviolet-Visible Spectroscopy (UV-Vis)

UV-Vis refers to absorption spectroscopy in the ultraviolet-visible spectral region.

UV Range: 180-400 nm

Visible Range: 400-780 nm

The UV spectrum is a plot between wavelength λ_{\max} and some concentration factor (Absorbance or molar absorptivity coefficient ϵ).

The principle of UV spectrum is the energy difference between the ground state and the excited state. Ground state has low energy, while excited state has high energy. This energy difference depends on the location of the electron.

UV of the starch tests was dissected through JENWAY 7315 Spectrophotometer. Diluted test of starch was made in water. Moreover, HCl was added to look after pH (3) of the arrangement. Water was utilized as blank to adjust the equipment. Then the diverse sort of starch tests were analyzed at three distinctive Temperature (20°C, 28°C, and 35°C). At lower Temperature λ_{\max} was moved to higher wavelength, contrasted with higher temperature. Figure 3.7 demonstrates the schematic display of UV Spectroscopy.

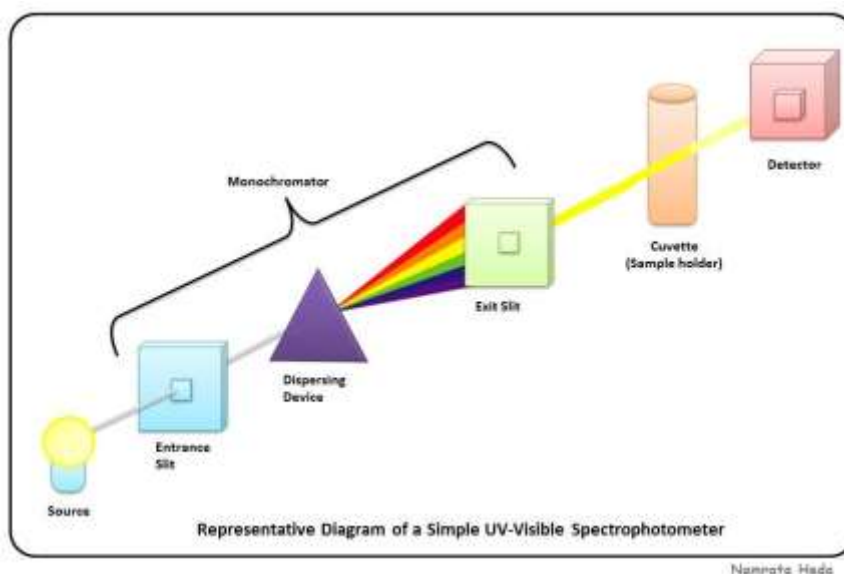


Figure 3.7 Schematic Diagram of UV-Visible Spectrophotometer

3.5.7. Differential Scanning Calorimetry (DSC)

It is an expository system used to gauge the measure of warmth required to build the temperature of an example, and reference is estimated as an element of temperature. Thereference test has the all around characterized warm limit over the scope of temperature to be filtered.

The term DSC was utilized as it quantifies vitality straightforwardly and permits exact masurments of warmth limit [70]. Starch tests were broke down through DSC gear. Temperature assurance [$T_p(^{\circ}\text{C})$] and gelatinization enthalpy [$\Delta H_p(\text{J.g}^{-1})$] was completed in nearness of nitrogen air for a range from encompassing tempearure to about 130°C , with the warming rate of about $10^{\circ}\text{C.min}^{-1}$ in the example of $12.00 \pm .5\text{mg}$ of various unique, extricated and cross breed starch.



Figure 3.8 Differetial Scanning Calorimeter Equipment

3.5.8. Thermogravimetric Analysis (TGA)

This investigation was performed on TA instrument TGA Q500 hardware in nearness of nitrogen environment for a range from encompassing temperature to about 600°C , with the warming rate of about $10^{\circ}\text{C.min}^{-1}$ in the sample of 5mg starch [3]. Figure 3.9 demonstrates the TGA analyzer.

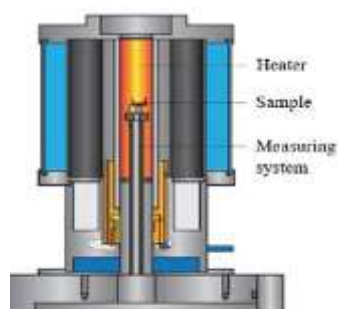


Figure 3.9 Thermogravimetic Analyzer [3]

Chapter 4 Results Of Thesis

4.1. Energy Dispersive X-Ray Spectroscopy

EDX of extracted, hybrid and synthesized starch was performed using equipment present in CASE-N department of NUST. Table 4.1 shows the weight and atomic percent of different type of starches.

Table 4.1 Weight & Atomic % of (a):Wheat (b) (c) : Potato (d) Hybrid Starch

Element	Weight %	Atomic %
CK	55.64	62.55
OK	44.36	37.45
TOTAL	100	

(a)

Element	Weight %	Atomic %
CK	58.64	65.55
OK	41.36	34.45
TOTAL	100	

(b)

Element	Weight %	Atomic %
CK	53.64	60.55
OK	46.36	39.45
TOTAL	100	

(c)

Element	Weight %	Atomic %
CK	55.64	63.55
OK	43.36	36.45
TOTAL	100	

(d)

Weight and atomic percent of an element present in the sample can easily be analyzed through the EDX. Different types of starch when analyzed through EDX confirms the elemental and relative proportion of both carbon and oxygen. Hydrogen can not be analyzed as it is the lightest element and beyond the resolution capacity of equipment present. Some impurities might also be there in starches as they are extracted. Furthermore, pictorial display of EDS is shown in Fig 4.1.

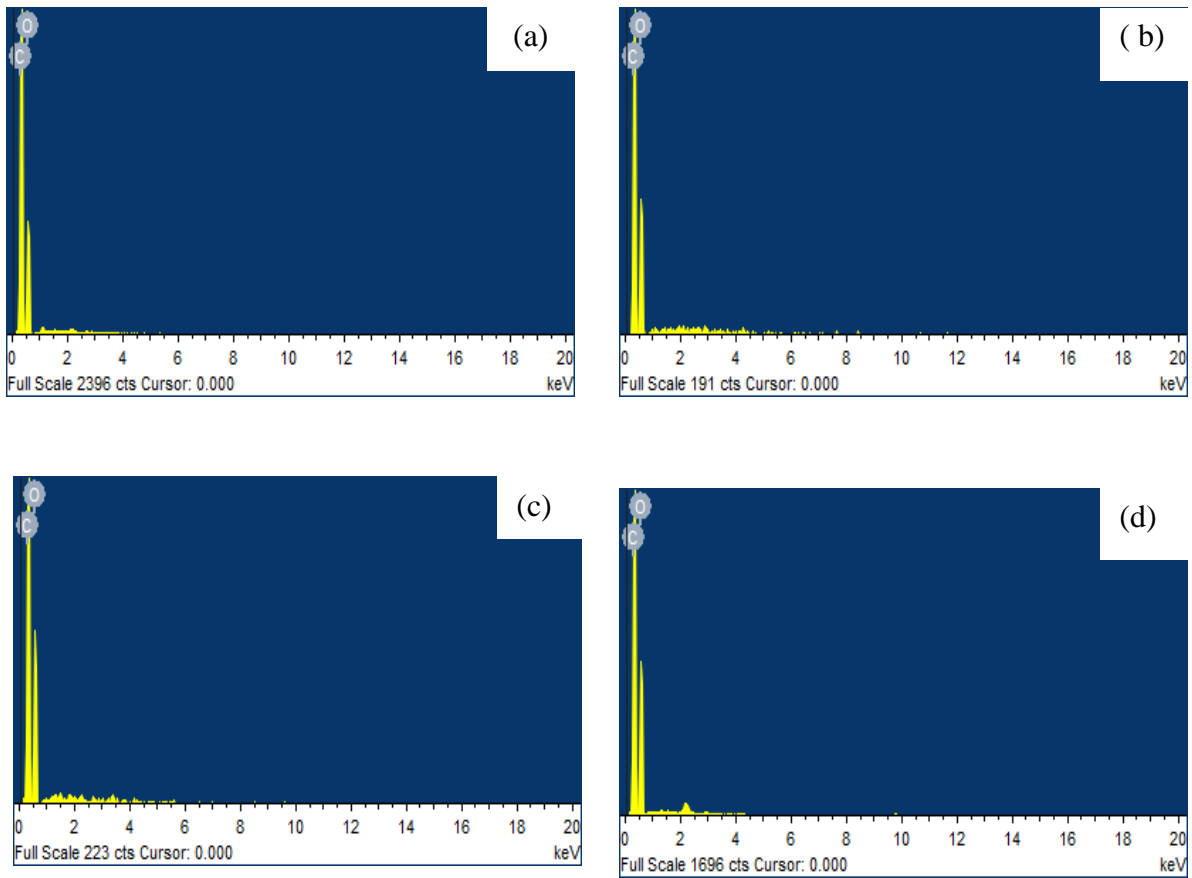


Figure 4.1 EDX of Starches (a) Wheat, (b) Original, (c) Potato, (d) Hybrid

4.2. Scanning Electron Microscopy(SEM)

SEM images shows the morphology and topography of extracted ,original and hybrid starch using (JEOL – Japan), model JSM-6490A. Figure 4.2 shows the SEM images of each of them.

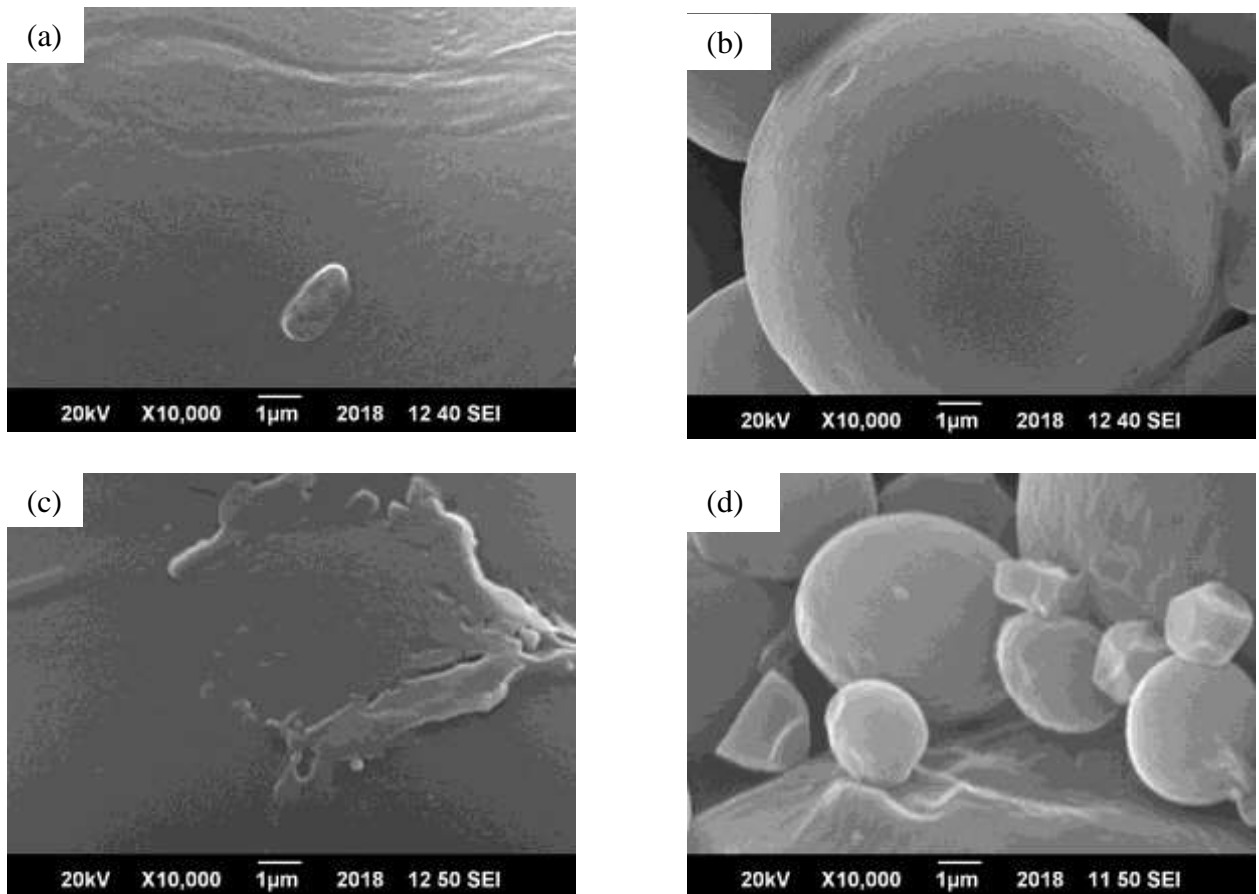


Figure 4.2 SEM images of (a) Hybrid ,(b) Synthetic, (c), Potato (d) Wheat Starch

SEM images indicate the morphology of various starches. Original starch shows the smooth surface of starch molecules because of the crystalline amylopectin structure, as indicated in (b). Potato starch shows the crystalline structure, but owing to the extraction of potato, certain impurities were present, as indicated in (c). Wheat starch has a smooth crystalline structure with small oval granules of wheat as indicated in (d). Hybrid starch shows different starch characteristics as indicated in (a). All images show that starch has a smooth surface and a round shape.

4.3. Viscosity

Viscosity is being measured by using equipment Visco meter of model DV-E, DV 11+Pr0 of Brook Field present in SCME lab. Table 4.2 shows the viscosity of different extracted and hybrid starch.

Table 4.2 Viscosity (Cp) of Synthetic Starch, Wheat Starch, Potato Starch, and Hybrid Starch

S. No	Material	Viscosity (Cp)
1	Synthetic Starch	118.4
2	Wheat Starch	32.39
3	Potato Starch	95.46
4	Hybrid Starch	75.24

The table shows the viscosity of different starches. Viscosity of wheat starch is much lower compared to potato starch. This is because of the presence of phosphorous linkages, present in tuber unlike that of cereals[71]. Hybrid starch has the viscosity comparable to each of the wheat, potato and synthetic starch.

4.4. Particle Size Analyzer (PSA)

Particle size analysis of each of the extracted wheat and potato waste were being performed using the PSA equipment of model Horiba LA 920. Average particle size obtained after grinding was about 1 μ m. Table 4.3 shows the PSA results.

Table 4.3 PSA of Wheat and Potato Starch

Samples	Median (μm)	Mean (μm)	Variance (μm)	Standard Deviation (μm)
Wheat Starch	24.5367	78.5998	9041.3	95.0859
Potato Starch	278.7085	349.7440	1.037E ⁺⁵	329.9457

4.5. X-Ray Power Diffraction (XRD)

XRD is a valuable technique for the analysis of crystalline structure of synthesized and extracted starches. Figure 4.3 shows the XRD of, wheat, hybrid, potato and original starch.

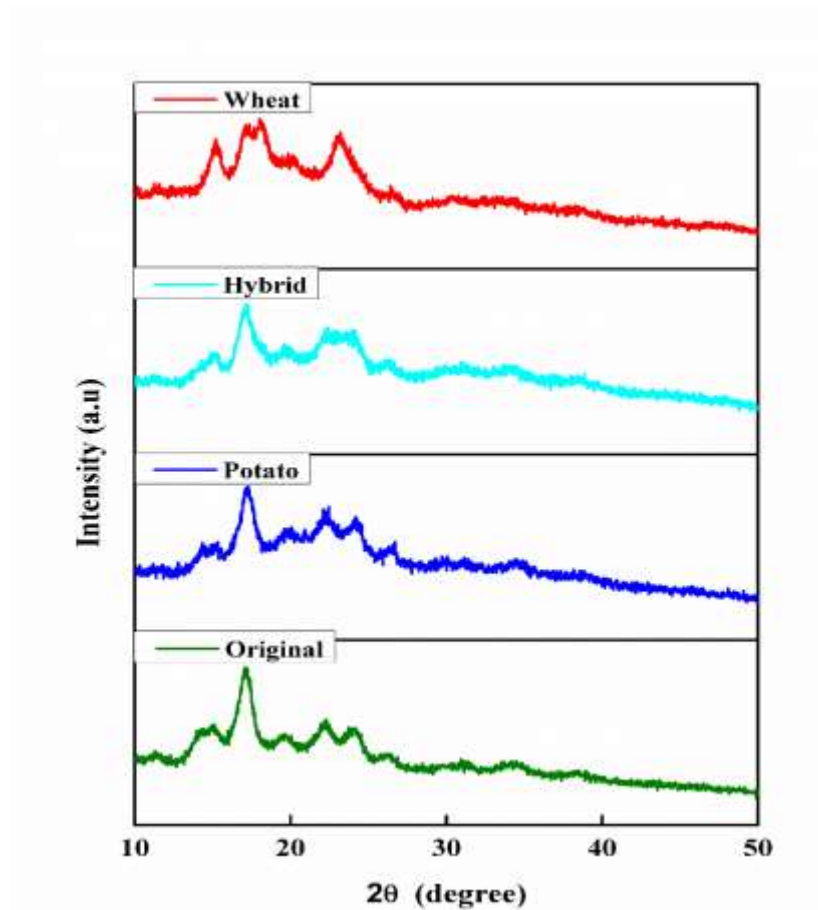


Figure 4.3 XRD pattern of Wheat, Hybrid, Potato and Original Starch

Starch is the crystalline structure with amylopectin (branched) responsible for crystalline region of the starch and amylose (linear) responsible for amorphous phase of the starch[37, 72]. The presence of two phases is confirmed by the aspect of the XRD spectrum. This spectrum was characterized by a broad region between 10° and 50° with some distinctive peaks.

The main peaks were observed at $2\theta=11.4^\circ$, 17.4° , 18.5° and 23.1° . A broad peak with low intensity were observed between 19.3° and 20.7° . An additional peak is observed at about 19.8° in case of wheat starch that might be due to presence of impurity as it was extracted. Peak in case of potato starch was observed at 18° and 22° respectively[37]. Peaks of higher intensity is because of the crystalline structure of amylopectin while that of lower intensity is due to amorphous structure of amylose. Similar results were obtained in the literature cited [19, 44, 73, 74].

4.6. Fourier Transform Infrared Spectroscopy(FTIR)

FTIR of potato, wheat, hybrid and original starch are given in Figure 4.4 performed by FTIR equipment model Spectrum 100 (Perkin Elmer)

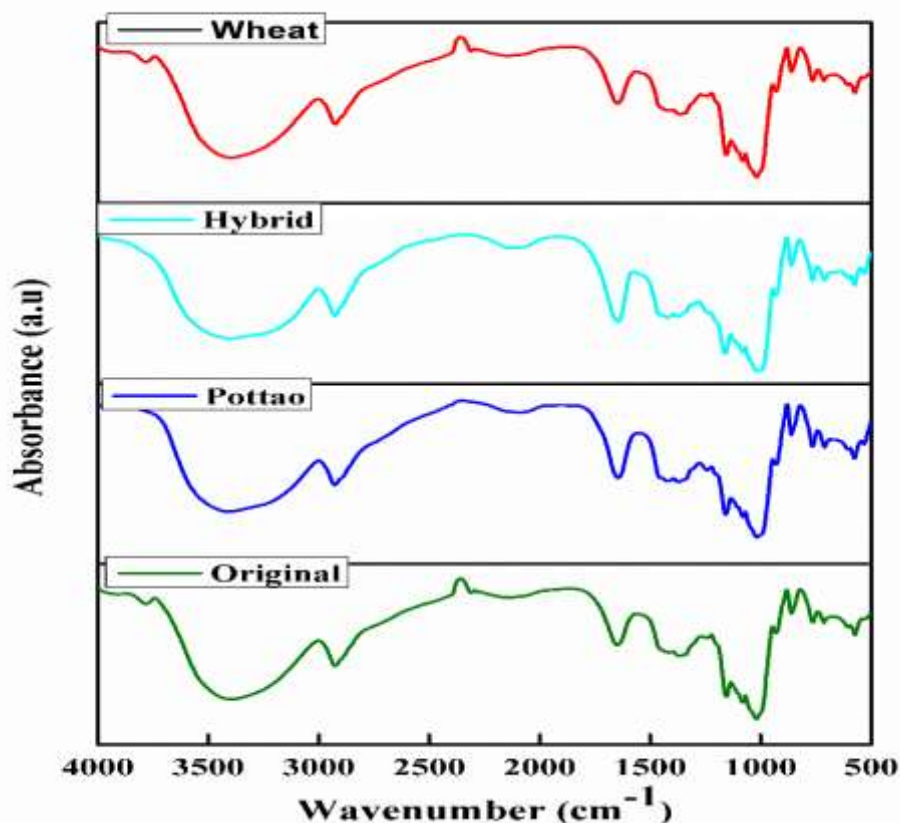


Figure 4.4 FTIR pattern of Wheat, Hybrid, Potato and Original Starch

Strong and broad FTIR peaks of starches were observed at 3400cm^{-1} owing to the presence of OH group in the amylose chain. Peak intensity at 2931cm^{-1} and 1600cm^{-1} is because of the presence of methyl and carbonyl groups in the starch chain. Peaks at 1430cm^{-1} and 900cm^{-1} is attributed to “crystalline” and “amorphous” structure of starch, respectively. The intensity of peak at 1157cm^{-1} is due to the presence of C-O-C bond in starch molecule. Moreover, the splitting of band at 996cm^{-1} and 1017cm^{-1} is correlated to a change from native to gelatinized form of the starch. The results were very much similar to the literature cited [10, 75].

4.7. Ultra Violet Results (UV):

4.7.1. At Room Temperature

UV spectroscopy is being measured at room temperature of 27°C using the equipment UV visible spectrophotometer model,UV-1900 present in SCME lab. Figure 4.5 shows the UV spectrum of different starches at room temperature.

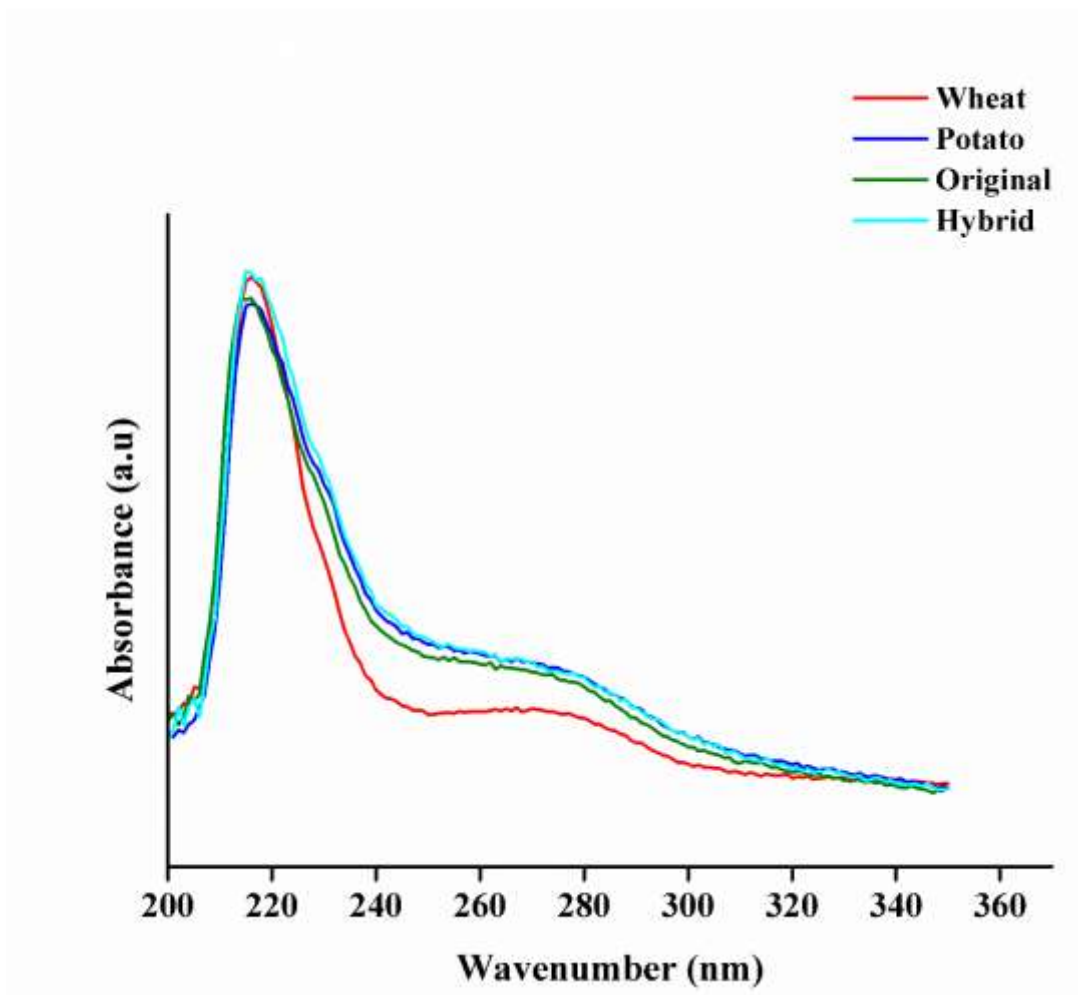


Figure 4.5 UV Spectra of Wheat, Potato, Original and Hybrid starch at 27°C

UV of extracted, hybrid and original starches at room temperature show the absorbance peak at λ_{\max} of about 215°C[76].Slight variation is there in case of potato and wheat .This might be the presence of impurities as they are extracted. Furthermore, at room temperature, energy of molecule and their collision frequency

is less compared to that of molecule at higher temperature of 35°C but higher than 20°C[77].This was further confirmed by performing UV at 35°C and 20°C.

4.7.2. At Higher Temperature of 35°C

UV spectroscopy was also being measured at higher temperature of 35°C. Figure 4.6 shows the UV spectrum of different starches at higher temperature of 35°C.

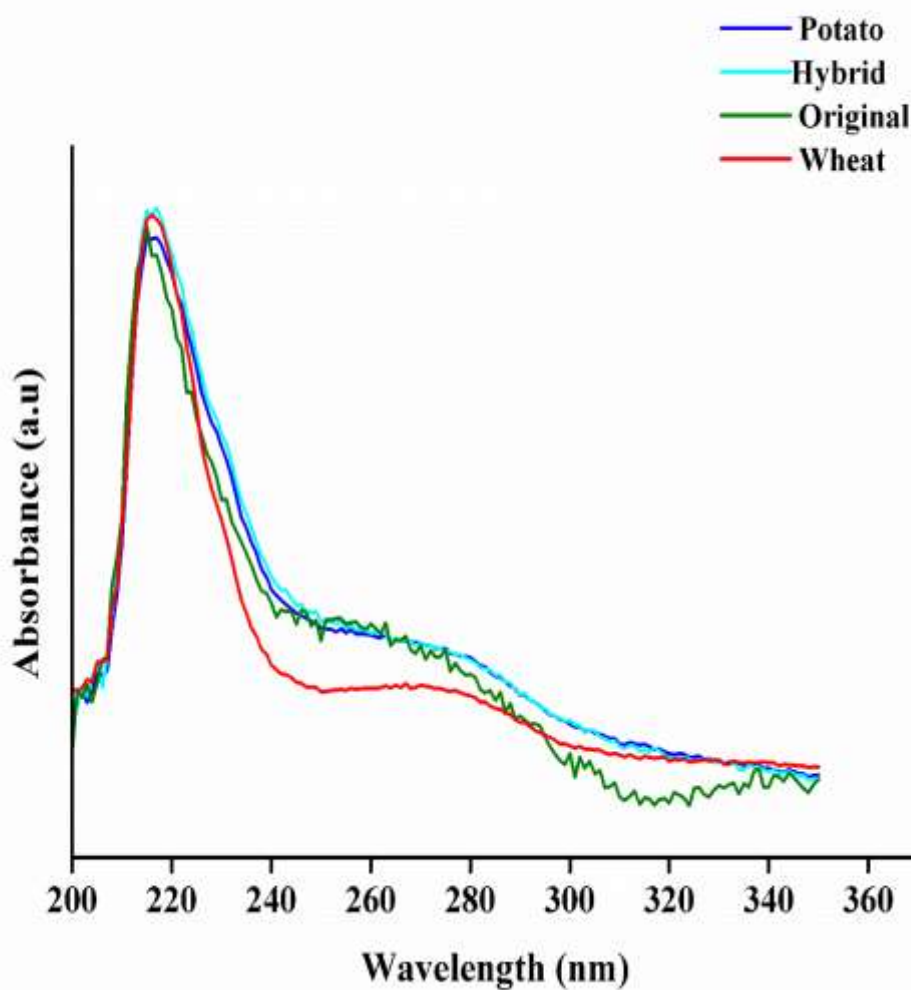


Figure4.6 UV Spectra of Wheat, Potato, Original and Hybrid starch at 35°C

UV of extracted, hybrid and original starches at high temperature show the absorbance peak at λ_{\max} of about 210°C[77]. In this case, at high temperature, energy of molecule and their collision frequency is high compared to that of molecule at room temperature of 27°C and 20°C, resulting in the lower λ_{\max} as confirmed by analysis.

4.7.3. At Lower Temperature of 20°C

UV spectroscopy was also being measured at lower temperature of 20°C. UV of extracted, hybrid and original starches at lower temperature show the absorbance peak at λ_{\max} of about 218°C[76]. Furthermore, in this case, energy of molecule and their collision frequency is lowest compared to that of molecule at room temperature of 27°C and high temperature of 35°C, resulting in the higher λ_{\max} as confirmed by analysis. Figure 4.7 shows the UV spectrum of different starches at lower temperature of 20°C.

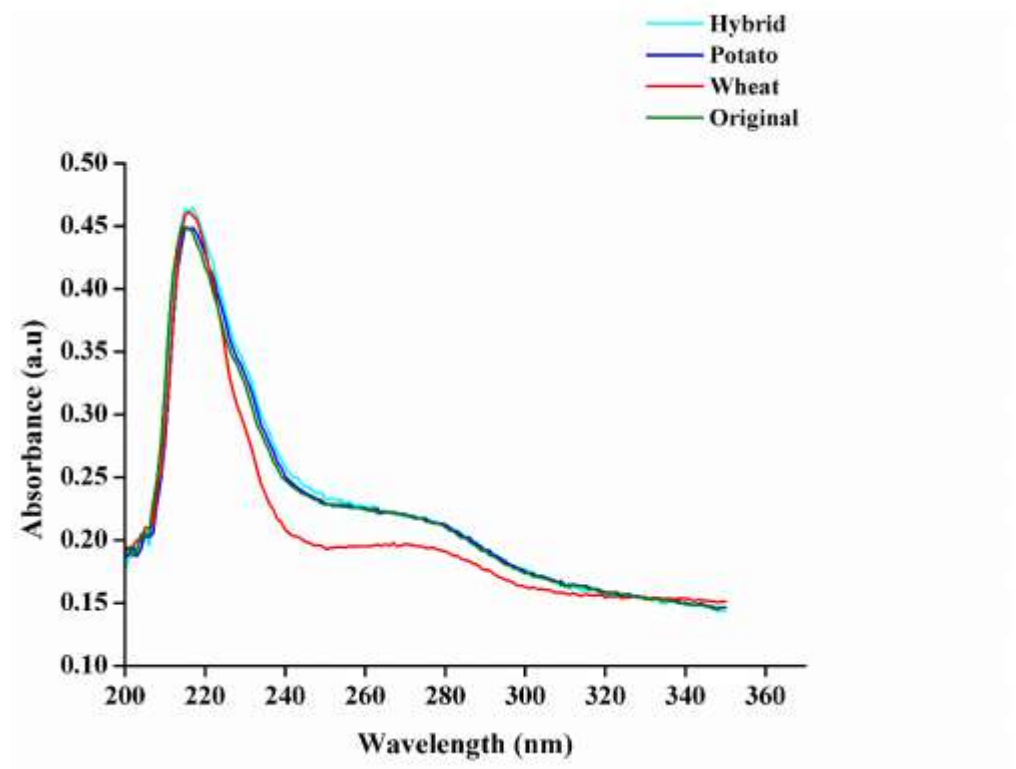


Figure 4.7 UV Spectra of Wheat, Potato, Original and Hybrid Starh at 20°C

4.8. Thermal Gravimetric Analysis (TGA)

TGA is an analytical technique to determine the moisture and ash content of the active ingredients [78]. Furthermore, TGA inflection temperature and the melting point helps in the identification of different carbohydrates [54]. Figure 4.6 shows TGA of extracted, original and hybrid starch.

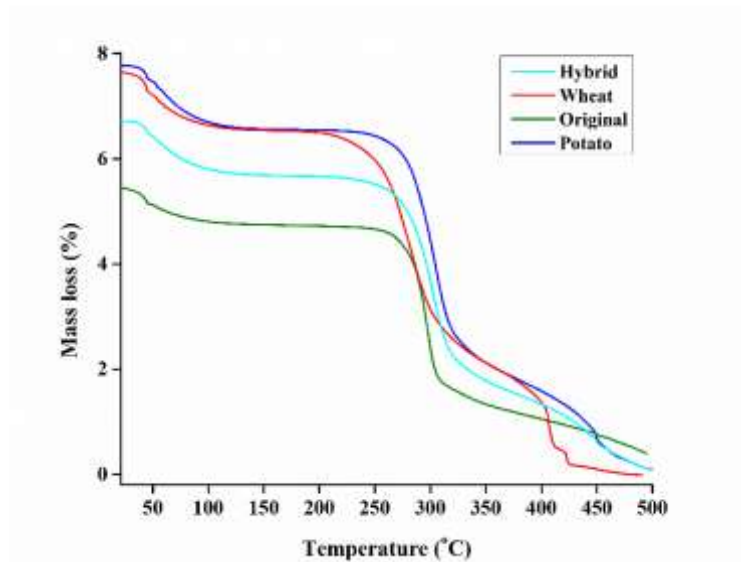


Figure 4.8 TGA of Hybrid, Wheat, Original and Potato Starch

The first curve at 40°C indicates the dehydration step. At about 290°C there is exothermically burning of the carbon black formed. Finally the residue at about 430°C is the mineral ash content. The results are similar to the literature cited [78].

4.9. Differential Scanning Calorimetry:

The figure 4.9 shows the DSC of different extracted and hybrid starches.

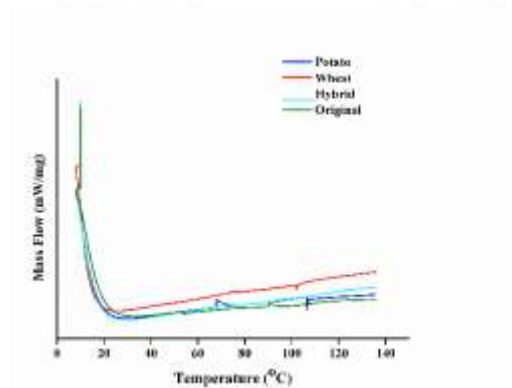


Figure 4.9 DSC of Potato, Wheat hybrid and Synthetic Starch

DSC was being carried out for extracted and hybrid starches to find out the enthalpy of starches. DSC shows the gelatinization temperature of starch of different biological origin. Potato starch shows the complete phase transition indicating the gelatinization temperature of 55-60°C. In case of wheat starch, first endothermic transition corresponds to the melting of crystalline lamellae, while the second endothermic peak shows the dissociation of amylose-lipid complexes [79]. Hybrid and native starch shows the same results that corresponds to the potato starch.

Chapter 5 Kinetic Study

Kinetic study of various starches were being carried out at different temperature of 20°C , 27°C and 35°C with pH=3.3. When controlled conditions were being applied , kinetics of the starch follow first order kinetics with the concentration dependent variable with respect to time. It was further confirmed by the straight line equation of the first order kinetics. So the integrated form of kinetic equation is :

$$\ln \frac{C_0}{C} = kt$$

Where C_0 = Initial concentration of starch, g/m³

C = Concentration of starch at time t ,g/m³

k = Rate Constant , min⁻¹

t = Time , min

In order to study kinetics, UV results were utilized. Beer- Lambert Law was employed to have concentration at different times. According to Beer- Lambert Law absorbance is directly proportional to the concentration, with molar absorptivity as the proportionality constant.

$$A \propto Cl$$

$$A = \epsilon Cl$$

Where

A = Absorbance

C = Concentration (ppm)

l = Path Length (1 cm)

ϵ = Molar Absorptivity(L mol⁻¹ cm⁻¹)

5.1. Standardization Curve

Standardization curve was used to have the molar absorptivity. To have this, graph was drawn between concentration in ppm at x-axis, and absorbance at y-axis. A straight line was obtained, slope of which is equal to molar absorptivity (ϵ).

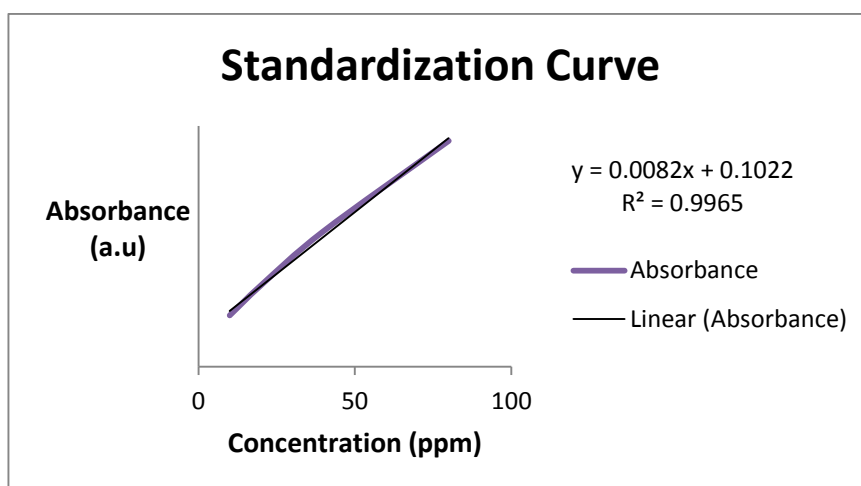


Figure 5.1 Standardization Curve

This value of slope was utilized to calculate concentration at different time by using Beer-Lambert Law as follows.

$$A = \epsilon Cl$$

$$C = A/\epsilon l$$

In this way concentration at different time interval and the temperature was calculated.

5.2. Calculation of Concentration at 20°C

Concentration at 20°C for different starch samples were analyzed using Beer-Lambert Law as mentioned above. Tabulated values of each of the extracted, synthetic and hybrid starch at 20°C is shown as mentioned below.

5.2.1. For Hybrid Starch

Table 5.1 Calculation of Concentration for Hybrid Starch at 20°C

time	ϵ	L	A	C	Co	Co/Co-C	ln Co/Co-C
0	.00821	1	1.86	226.5529	226.5529	1	1.516 ⁻¹⁰
10	.00821	1	1.76	215.654	226.5529	1.0505	0.0493
20	.00821	1	1.53	199.345	226.5529	1.1364	0.1279
30	.00821	1	1.42	187.345	226.5529	1.2092	0.1900
40	.00821	1	1.22	154.765	226.5529	1.4638	0.3810

5.2.2. For Synthetic Starch

Table 5.2 Calculation of Concentration for Synthetic Starch at 20 °C

time	ϵ	l	A	C	Co	Co/ Co-C	ln Co/Co- C
0	.00821	1	0.95	115.7125	115.7125	1	-3.94 ⁻⁷
10	.00821	1	0.92	112.0585	115.7125	1.032608	0.0350
20	.00821	1	0.9	109.6224	115.7125	1.055555	0.0456
30	.00821	1	0.87	105.9683	115.7125	1.091954	0.0879
40	.00821	1	0.85	103.5323	115.7125	1.117647	0.147

5.2.3. For Wheat Starch

Table 5.3 Calculation of Concentration for Wheat Starch at 20 °C

time	ϵ	l	A	C	Co	Co/ Co-C	ln Co/Co- C
0	.00821	1	1.88	228.9890	228.989	1	1.797 ⁻¹⁰
10	.00821	1	1.74	211.9366	228.989	1.0804	0.0773
20	.00821	1	1.72	209.5006	228.989	1.0930	0.0889
30	.00821	1	1.63	198.5383	228.989	1.1533	0.1426
40	.00821	1	1.48	180.2679	228.989038	1.27027	0.2392

5.2.4. For Potato Starch

Table 5.4 Calculation of Concentration for Potato Starch at 20 °C

time	ϵ	l	A	C	Co	Co/ Co-C	ln Co/Co- C
0	.00821	1	1.45	176.613	176.613	1	-3.10 ⁻¹¹
10	.00821	1	1.43	174.177	176.613	1.0139	0.01388
20	.00821	1	1.41	172.345	176.613	1.0247	0.02446
30	.00821	1	0.99	170.432	176.613	1.0362	0.035629
40	.00821	1	0.97	165.656	176.613	1.0664	0.064048

5.2.5. Kinetic Study at 20°C

Kinetics study at lower temperature was carried out by using UV. Spectrophotometer by interpreting UV data. After interpretation, it was confirmed that different starches almost follow first order kinetics.

Table 5.5 First Order Kinetics Values of Different Starches at 20°C

Serial No	Samples	K Values (min ⁻¹)	R ²
1	Synthetic Starch	.0237	.951
2	Potato Starch	.0015	.954
3	Wheat Starch	.0054	.942
4	Hybrid Starch	.009	.925

Figure 5.1 shows the graphical view of calculated and linearized form of first order kinetics of extracted, synthetic and hybrid starches at 20°C. Calculation of Concentration at 27°C

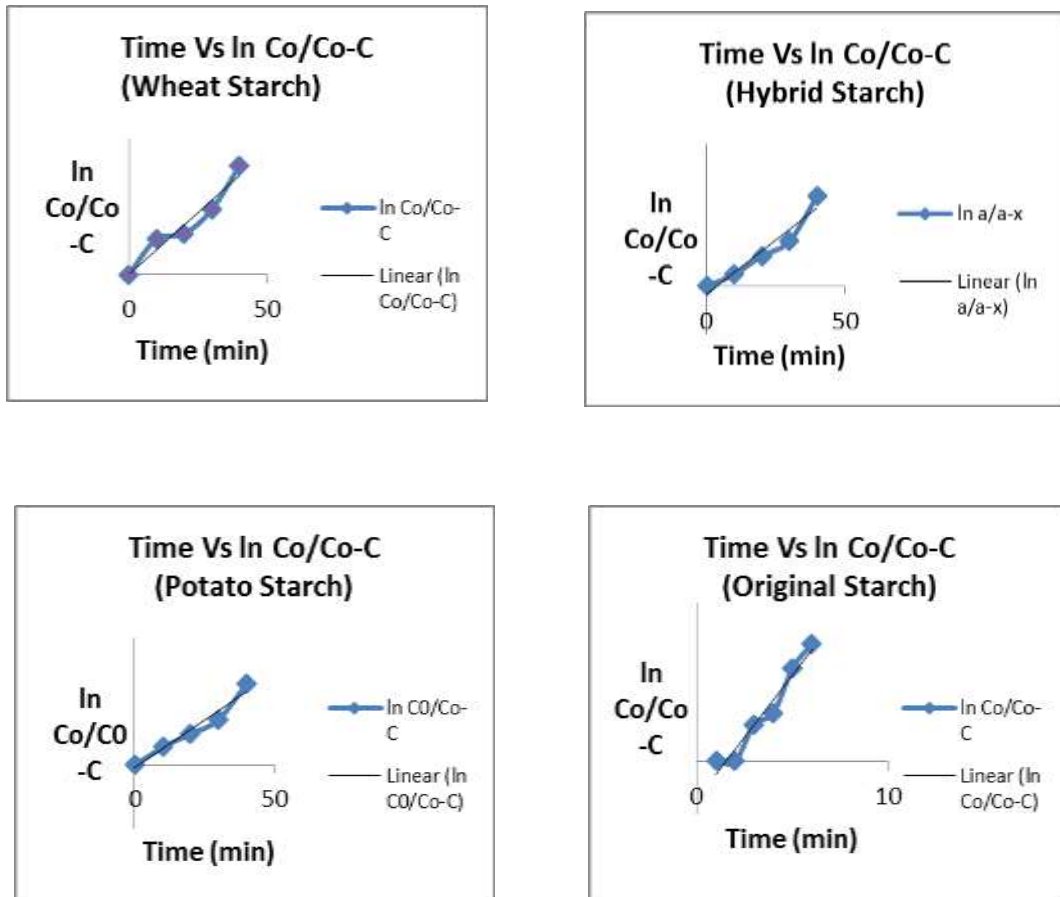


Figure 5.2 Linearized and Calculated form of First Order Kinetics of Different Starches at 20°C

Concentration at 27°C for different starch samples were analyzed using Beer-Lambert law. Tabulated values of each of the extracted, synthetic and hybrid starch at 27°C is shown.

5.2.6. For Synthetic Starch

Table 5.6 Calculation of Concentration for Synthetic Starch at 27°C

time	ϵ	I	A	C	Co	Co/ Co-C	ln Co/Co- C
0	.00821	1	0.215	26.1875	26.1875	1	1.269 ⁻¹⁰
10	.00821	1	0.213	25.9439	26.1875	1.0093	0.0093
20	.00821	1	0.211	25.7003	26.1875	1.018	0.0187
30	.00821	1	0.181	22.0462	26.1875	1.1876	0.1721
40	.00821	1	0.159	19.3666	26.1875	1.3522	0.3017

5.2.7. For Hybrid Starch

Table 5.7 Calculation of Concentration for Hybrid Starch at 27°C

time	ϵ	I	A	C	Co	Co/ Co-C	ln Co/Co- C
0	.00821	1	1.88	228.9890	228.9890	1	1.797 ⁻¹⁰
10	.00821	1	1.74	211.9366	228.9890	1.0804	0.0773
20	.00821	1	1.72	209.5006	228.9890	1.0930	0.0889
30	.00821	1	1.63	198.5383	228.9890	1.1533	0.1426
40	.00821	1	1.48	180.2679	228.9890	1.2702	0.2392

5.2.8. For Wheat Starch

Table 5.8 Calculation of Concentration for Wheat Starch at 27°C

time	ϵ	I	A	C	Co	Co/ Co-C	ln Co/Co- C
0	.00821	1	0.215	26.1875	26.1875	1	1.264 ⁻¹⁰
10	.00821	1	0.213	25.344	26.1875	1.0332	0.0327
20	.00821	1	0.211	22.1232	26.1875	1.1837	0.1686
30	.00821	1	0.181	21.345	26.1875	1.2268	0.2044
40	.00821	1	0.159	17.9875	26.1875	1.4559	0.3756

5.2.9. For Potato Starch

Table 5.9 Calculation of Concentration for Potato Starch at 27°C

time	ϵ	I	A	C	Co	Co/ Co-C	ln Co/Co- C
0	.00821	1	.245	29.8416	29.8416	1	1.165 ⁻⁰⁷
10	.00821	1	.236	28.7454	29.8414	1.0381	0.03742
20	.00821	1	.215	26.1875	29.8416	1.1395	0.1306
30	.00821	1	.192	23.3861	29.8416	1.2760	0.2437
40	.00821	1	.147	17.9049	29.8416	1.6666	0.5108

5.2.10. Kinetic Study at 27°C

Kinetics study at room temperature was carried out by using UV. Spectrophotometer by interpreting UV data. After interpretation, results are summarized in table 5.2.

Table 5.10 First Order Kinetics Values of Different Starches at 27°C

Serial No	Samples	K Values (min ⁻¹)	R ²
1	Synthetic Starch	.0688	.95
2	Potato Starch	.0014	.93
3	Wheat Starch	.0092	.94
4	Hybrid Starch	.0054	.94

Figure 5.2 shows the graphical view of calculated and linearized form of first order kinetics of extracted, synthetic and hybrid starches at 27°C.

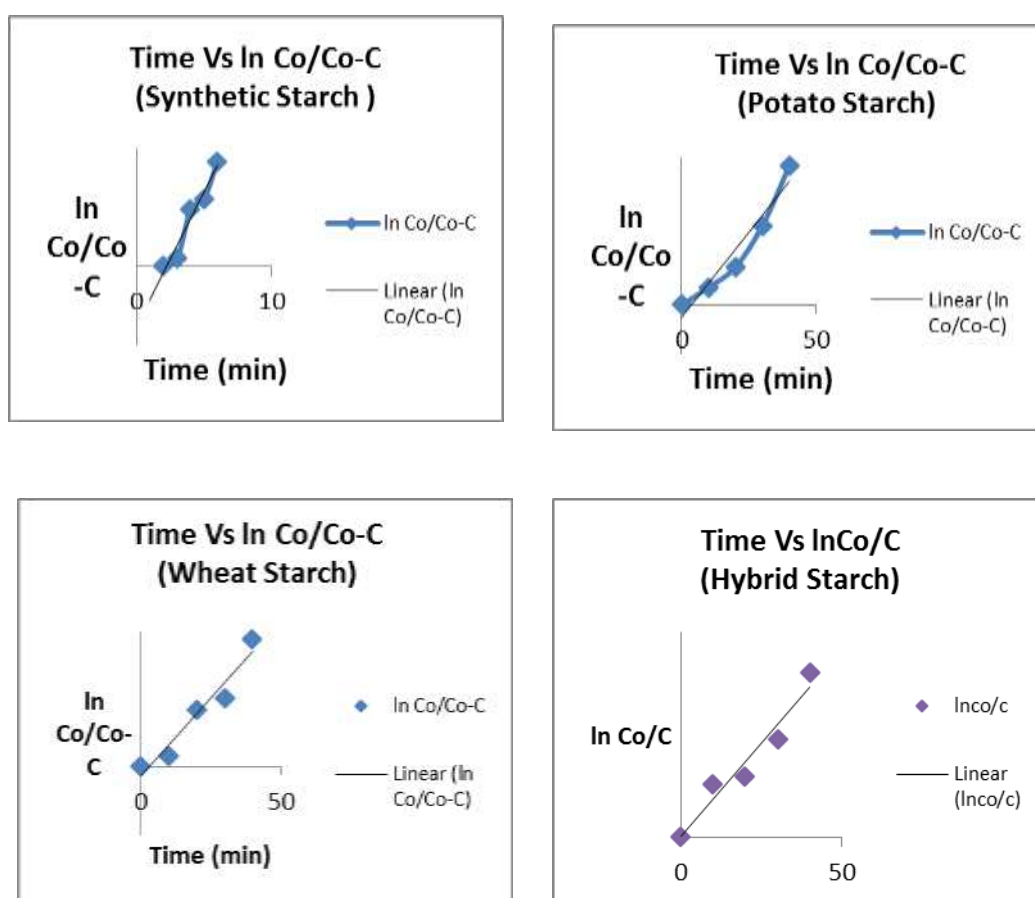


Figure 5.3 Linearized and Calculated form of First Order Kinetics of Different Starches at 27°C

5.3. Calculation of Concentration at 35°C

Concentration at 35°C for different starch samples were analyzed using Beer-Lambert law. Tabulated values of each of the extracted, synthetic and hybrid starch at 35°C is shown.

5.3.1. For Synthetic Starch

Table 5.11 Calculation of Concentration for Synthetic Starch at 35 °C

time	ϵ	l	A	C	Co	Co/ Co-C	ln Co/Co- C
0	.00821	1	0.45	54.8112	54.8112	1	6.333^-11
10	.00821	1	0.44	53.5931	54.8112	1.0227	0.0224
20	.00821	1	0.42	51.1571	54.8112	1.0714	0.0689
30	.00821	1	0.4	48.7210	54.8112	1.1256	0.1177
40	.00821	1	0.38	46.2850	54.8112	1.1842	0.1690

5.3.2. For Hybrid Starch

Table 5.12 Calculation of Concentration for Hybrid Starch at 35 °C

time	ϵ	l	A	C	Co	Co/ Co-C	ln Co/Co-C
0	.00821	1	.45	54.8112	54.8112	1	6.333E- 11
10	.00821	1	.44	53.5931	54.8112	1.0227	.02247
20	.00821	1	.42	52.3456	54.8112	1.0471	.06899
30	.00821	1	.4	48.7210	54.8112	1.1254	.11778
40	.00821	1	.38	46.2850	54.8112	1.18421	.16907

5.3.3. For Wheat Starch

Table 5.13 Calculation of Concentration for Whea Starch at 35 °C

time	ϵ	l	A	C	Co	Co/ Co-C	ln Co/Co-C
0	.00821	1	2.53	308.16077	308.106	1	-1.20 ⁻ 10
10	.00821	1	2.48	302.0706	308.106	1.0199	0.01978
20	.00821	1	2.41	293.5444	308.106	1.0496	0.04841
30	.00821	1	2.39	291.1084	308.106	1.0583	0.05674
40	.00821	1	2.35	286.2362	308.106	1.0764	0.07369

5.3.4. For Potato Starch

Table 5.14 Calculation of Concentration for Potato Starch at 35 °C

time	ϵ	l	A	C	Co	Co/ Co-C	ln Co/Co-C
0	.00821	1	0.56	68.2095	68.2095	1	1.446 ⁻ 11
10	.00821	1	0.54	65.7734	68.2095	1.0370	0.0363
20	.00821	1	0.52	63.3373	68.2095	1.0769	0.0782
30	.00821	1	0.5	60.9013	68.2095	1.1234	0.1133
40	.00821	1	0.48	56.2345	68.2095	1.2180	0.19723

5.3.5. Kinetic Study at 35°C

Kinetics study at higher temperature was carried out by using UV. Spectrophotometer by interpreting UV data. After interpretation, results are summarized in table 5.3

Table 5.15 First Order Kinetics Values of Different Starches at 35°C

Serial No	Samples	K Values (min ⁻¹)	R ²
1	Synthetic Starch	.0043	.98
2	Potato Starch	8.5714	.96
3	Wheat Starch	.0018	.97
4	Hybrid Starch	.0043	.94

Figure 5.3 shows the graphical view of calculated and linearized form of first order kinetics of extracted, synthetic and hybrid starches at 35°C.

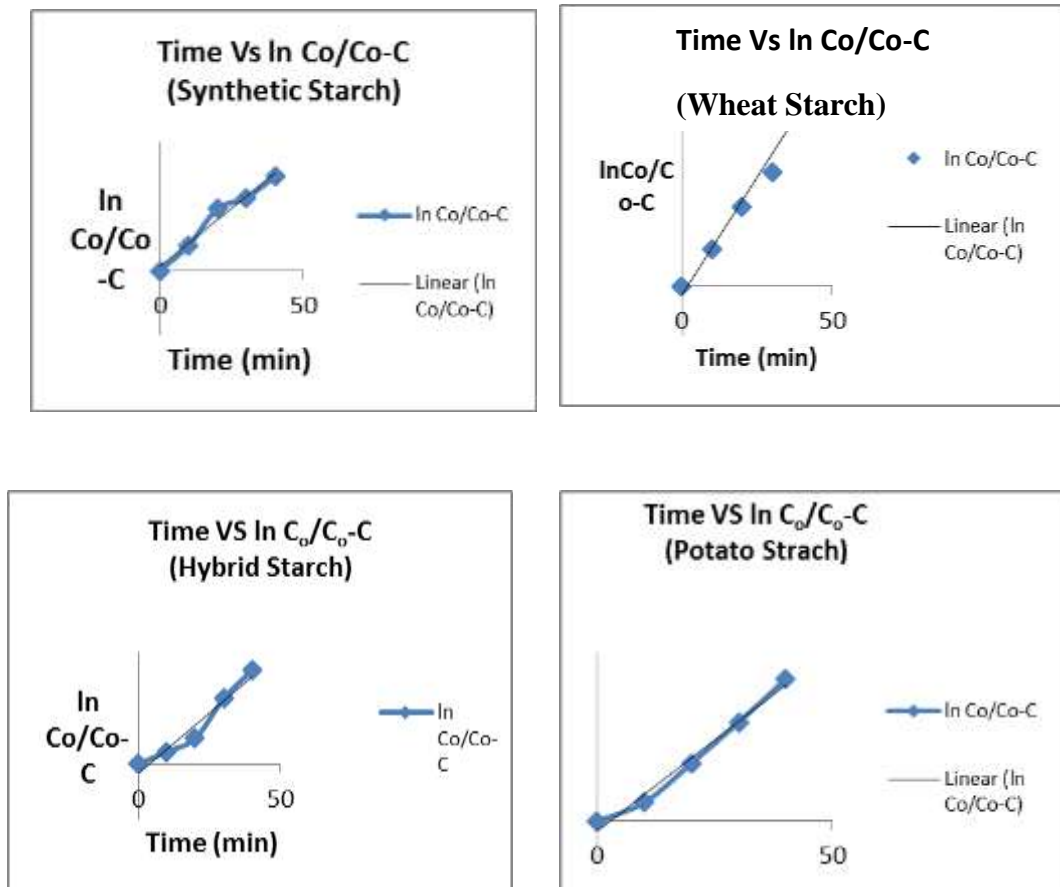


Figure 5.4 Linearized and Calculated form of First Order Kinetics of Different Starches at 35°C

5.4. Concentration VS Time Variation

There is variation of concentration with time. As time passes , concentration of substrate available decreases ,subsequently graph profile also show decreasing trend. Figure 5.4 shows the decreasing trend of concentration of reactant with respect to time.

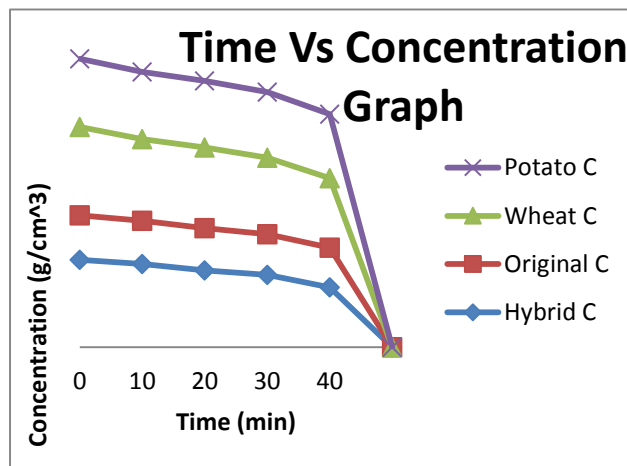


Figure 5.5 Decreasing Trend of Concentration with Time

5.5. Calculation of Activation Energy

Activation energy was being calculated by employing Arrhenius equation.

$$K = Ae^{-E/RT}$$

where

K = Rate Constant

A = Pre exponential Factor

E = Activation Energy (KJ/mol)

R = Gas Constant (8.314 atm m³/mol K)

T = Temperature (K)

Integrating form of Arrhenius equation is

$$\ln k = \ln \frac{R}{T} + \ln k_0$$

When the graph was drawn between $1/T$ and $\ln k$, straight line was obtained, with the slope $=E/RT$, from where Activation Energy(E) is being calculated.

Table 5.16 Activation Energies of Different Starches

Material	Slope	E_a (kJ/mol)	Adjusted R² value
Synthetic Starch	-1386.3	11.5	.965
Potato Starch	-4300.4	35.75	.925
Wheat Starch	-3188.8	26.5	.952
Hybrid Starch	-4417.4	33	.942

When calculation of activation energy is being carried out, it was found that, energy required for the potato starch is highest among all other starches. This indicates that, potato starch required greater amount of energy to proceed the reaction and to form the activation energy complex. All other starches required comparatively less amount of energy.

Conclusion and Recommendation

Conclusion

It is concluded through research work being carried out that agricultural wastes can be utilized effectively and efficiently for the starch synthesis. Hydrothermal pretreatment method was being employed for starch extraction because of higher yield as previously reported. Furthermore, hybrid starch is an added material and has the great potential to be used for starch applications in energy sector as well as a biodegradable material. However, composition of hybrid starch must be controlled, otherwise it might produced negative results. UV results has shown that at higher temperature , absorbance will be shifted towards lower wavelength and vice versa. Kinetics being studied through UV results, indicated that potato starch approaches the first order kinetics in the most appropriate way.

Future Recommendation

- Waste utilization ,must be there at commercial scale.
- Different combination of starches can be used for diversified application of starch.

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