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Starch Extraction Machine for Banana

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Abstract: Starch is a biopolymer that finds immense applications in food industries, pharmaceutical industries, textile industries and paper industries because of its biodegradability, renewability and versatile functional characteristics. The traditional starch extraction methods used by small and rural industries are usually labour-intensive, water-intensive, energy-intensive, as well as inconsistent in crop and quality. These constraints limit productivity and put a barrier to sustainable processing. This report shows the design and development of an automated starch extraction system that is expected to enhance efficiency, yield and reliability of the processes and reduce the cost of operation and environmental impact. The proposed system measures mechanised washing, grinding, filtration, dewatering, and drying processes with automated control to provide even conditions of processing. The focus is put on energy-efficient functioning, maximal water use based on recycling systems, and the choice of the food-grade materials to address safety requirements. Scalability, portability and suitability of the system design to small and medium-scale agro-processing units are also taken into consideration. Even more sophisticated monitoring tools, such as sensor-based feedback and optional vision-assisted quality analysis, are used to increase process accuracy and consistency. Systematic mechanical design, choice of material, optimisation of the process, and evaluation of performance in terms of starch yield, purity, water consumption, and energy consumption is the methodology. Experimental outcomes prove the high level of extraction and manual intervention decreases in comparison with the conventional ones. The suggested system will contribute to the sustainable agro-industrial development, allowing the production of starch at low costs and an enhanced quality and lower ecological footprint. This will be useful to the rural entrepreneurs, farmers and the small scale industries in need of modernization without requiring to spend much in terms of capital.

Keywords - Starch extraction, Automated processingsystem, Agro-processing machinery, Sustainable starch production.

I. INTRODUCTION

Starch is also a useful natural carbohydrate polymer that has a wide application in food, pharmaceutical, textile, paper and bio-based materials [23]. It is mostly obtained in agricultural products like cassava, potato, maize, rice and other tubers [21]. In the developing nations, starch extraction is usually conducted through the use of traditional methods which are highly labor intensive, consume more water and have crude tools [16]. Such processes frequently lead to poor extraction rates, irregular quality of the products and high losses during post-processing [1].

As the demand of high-quality starch is increasing and sustainable production methods are necessary, the need to automate and use low-energy needs starch extraction system is growing [3]. The automation does not only enhance productivity but also provides uniformity to the processes, cleanliness, and safe operations [15]. The latest trends of mechanical design, sensor and optimization of the processes have led to the creation of small and smart extracting units that can fit into the decentralised agro-industrial systems [4].

The proposed project reduces these issues by recommending an automated starch extraction system that is meant to be used in small and medium-scale processes [1].The system is focused on modular building, low-energy use, maximum water use, and food safety regulations [6]. The proposed solution provides greater yields of starch, purity, and an overall efficiency of the process by combining mechanical automation with the optional features of smart monitoring [8].

A. OBJECTIVE:

- To design and fabricate a starch extraction machine.
- To evaluate the process parameters on starch yield, efficiency, and quality for various banana varieties
- To estimate the total cost of the developed starch extraction machine.

II. LITERATURE SURVEY

The field of starch extraction has been a crucial area of study because of its vast usage in food processing, pharmaceuticals, textile, paper making and biodegradable products. A number of researchers have aimed at enhancing the extraction process, product purity, energy use, and automation of the process in order to overcome the drawbacks of the traditional manual process [1]. The need to have cost-effective and scalable systems that can cater to small and medium-scale agro-processing industries has been highlighted by researchers [2].

Several scientists have come up with automated starch extracting machines that are aimed at minimizing human power as well as enhancing uniformity in operation [3]. These systems are usually combined with mechanical washing, grinding and filtration units to improve starch recovery without degrading hygienic processing environments [5]. This has been demonstrated to enhance the repeatability of a process and dependency on skilled labour has been reduced, and hence automated control mechanisms have become feasible in decentralized production units [4].

A summary of research conducted to understand the extraction of starch by using other sources of agriculture has indicated that mechanical extraction is among the most viable method to be used in small scale extraction [7]. Although enzymatic and chemical methods are more purifying, they add extra expenses and complexity of the process [6]. Mechanical grinding with selective filtration has been greatly adopted as a perfect equilibrium between efficacy, low-cost, and ease of operation [9].

Recent studies have given a lot of attention to energy efficiency especially in the process of drying and dewatering [10]. Scholars have contrasted various drying methods and have found out that, after optimization of the mechanical de watering method, the controlled drying process can significantly lead to a decrease in the usage of energy [11]. The effective choice of the motors and optimization of the process have also been listed as the major consideration in the reduction of the operational costs.

There is a lot of concern over usage of water that has made water optimization to be a central issue because of growing environmental issues. A number of studies have suggested the use of closed-loop water recycling system that minimizes the freshwater intake without jeopardizing the yield of starch or its quality [8]. They have also used advanced filtration, such as membrane-based separation, in order to extract starch in wastewater streams, and this has enhanced sustainable processing practices [13].

Starch extraction systems have also been improved by automation and intelligent monitoring. On-line methods of quality monitoring of starch purity and particle uniformity have been proposed using vision-based quality assessment [12]. Monitoring and smart control systems that employ sensors have allowed precise control of the parameters of the process flow rate, temperature, and moisture content [19]. Moreover, there are efforts to predictive maintenance methods based on vibration and sensor data to minimize the machine downtime and enhance their reliability [15].

The recent studies have also focused on the sustainability and life cycle evaluation of the starch extraction technologies [16]. Ecology studies have pointed out water usage and energy consumption as the key causes of processes inefficiency. These papers suggest the use of integrated systems design, use of renewable energy, and reduction of waste in order to improve sustainability [14].

In general, it can be stated that the research on the automation and optimization of starch extraction systems has reached a high level [17]. Nevertheless, there are numerous high-end solutions that cannot be used by small-scale users due to their expensive or complicated nature. The gap that still exists in research is the development of a simplified, low cost, and energy efficient automated system of starch extraction that can sustain high yield and quality but at the same time allow agro-industrial development to be sustainable [18]. The suggested system seeks to fill these loopholes by incorporating established mechanical concepts and lean automation coupled with efficiency of resources [20].

III. SCOPE OF THE PROJECT

A. Small and Medium-Scale Industries Applicability:

The main reason why the automated starch extraction system is being developed is to cater to those small and medium-sized agro-processing industries that continue to apply the manual methods[16].The problems that are common in these industries are low processing efficiency, periodic quality of the product and shortage of manpower[5].

The proposed system offers a practical approach by introducing mechanized and automated processing without complexities and expensive nature of large industrial plants[16].The small size of it allows fitting into small spaces and it can also be run with minimum technical skills.

The system is able to handle the starch rich raw materials that are readily available such as banana, cassava, potato and other tubers, making it very flexible to regional farming methods[21]

B. Improvement of Process Automation and Consistency:

In the extraction of starch, automation is important to bring about uniformity and repeatability[15].This project scope also involves the replacement of manual process by automated processes of washing, grinding, filtration and dewatering[1].

Automated control guarantees the steady processing environment including water flow, grinding strength, and filtration rate, all of which have direct effects on starch yield and quality. The system minimizes operational errors, batch variability and contamination risks by minimizing human intervention[4].

C. Energy Saving and Low Operation Cost:

One of the key areas of concern in the starch processing is its energy consumption, especially in the grinding, dewatering and drying phases[3].

The extent of this project will involve optimization of energy consumption by effective selection of motors, mechanical transmission, and sequence of processes.

The system minimizes energy use without interfering with the extraction efficiency by minimizing power loss and also by maintaining optimal operating conditions.

Less energy consumption means less cost of running the system, and the system is economically practical even when used by small-scale users[20].

D. Sustainable Processing and Water Conservation:

Water Conservation:

Uncontrolled washing and separation processes tend to make water consumption excessively high in the process of traditional starch extraction[6].

The proposed system will resolve this problem through the use of managed flow of water and effective separation systems.

The scope goes to the possibility of including water recycling and filtration units to recycle process water, and therefore cutting down the use of freshwater by a large margin[17].

E. Food Safety, Hygiene and Quality Assurance:

Food safety and hygiene is a highly significant requirement in the manufacture of starch, particularly food and pharmaceutical uses[25].

Contamination is prevented by taking into consideration food-grade materials and closed processing units in the scope of this project.

The automated processing minimises direct interaction of humans with the raw materials and intermediate products, enhancing the hygiene and safety of the product[15]

F. Scalability and Future Technological Integration:

The automated starch extraction system has a modular design that allows the scale-up and upgrade possibilities to be quite high[5].The component sizes and configurations can be changed to suit an alternative capacity of the system.

This enables users to scale production with the increase in demand without having to change the entire setup.

IV. METHODOLOGY

A. Selection and Preprocessing of Raw Materials:

Samples of bananas are bought from the local markets of Coimbatore.Five varieties of banana are selected they are: Nendran,Montham, Robusta, Poovan, and Karpuravalli.For starch extraction, only raw (unripe) bananas are selected based on their physical characteristics. The selected bananas should be Green in colour, firm in texture and unripe with high starch content.

B. Starch Liberation and Mechanical Grinding:

The cleaned bananas are cut and fed into the mechanical grinding unit. The grinding process is set in such a way that it tears the starch-containing cells effectively and does not produce so much heat. Rotational speed(rpm) of 10,000 to 12,000 rpmand grinding pressure are kept controlled to make sure that the size distribution of the particles is uniform, and this is very important in the separation of starch. The solid raw banana is then turned into a slurry, and starch granules can be discharged into a liquid medium. The grininding blade of 4 to 5 inch is fitted with overload protection and safety enclosures so as to allow it to operate safely.

This step is important in ensuring that the maximum amount of starch is liberated whilst using minimal energy. Optimized grinding parameters would help in enhancing starch yield and enable easy downstream separation and filtration.

C. Slurry Preparation:

Around 650-850 ml of water is added to the ground material to make a homogeneous slurry. Washing is done with control in order to isolate starch grains and fibrous matter. A ratio between water and solid is strictly maintained to provide good suspension of starch and reduce the use of water. The homogeneity of the slurry is ensured by the agitation mechanisms, which helps to avoid the settling of starch during the processing. This process will make sure that the starch granules will be suspended in the liquid phase so that they can be efficiently separated in the following filtration units. The process lowers the loss of starch in the washing process and is more effective in extracting. Also, the system design can be adjusted to the changing of washing parameters depending on the aspect of raw materials. The methodology guarantees a uniform slurry generation and sustainability in the water consumption in the process by taking care of accurate control of the formation of the slurry.

D. Separating Filtration and Starch:

Filtration is an important step in starch extraction, where the mixture of banana slurry is separated into liquid and solid parts. After grinding banana with water, the slurry contains both starch and fibrous materials. This slurry is passed through a sieve, where the liquid starch passes through while the larger fibrous particles are retained. This process mainly works based on the difference in particle size.

In this project, a rotating paddle is used along with the sieve to improve filtration. The paddle helps in continuously mixing and pushing the slurry across the sieve, preventing clogging and ensuring better separation. As a result, more starch-rich liquid is collected efficiently, while the waste fibers are removed. This makes the process faster, cleaner, and more effective compared to manual filtration

E. Dewatering of Slurry:

The starch suspension is then dewatered after filtration with an aim of lowering the content of excess moisture. The separation of the water and the starch slurry is done by means of mechanical dewatering like pressing or centrifugation. This step saves energy since the load on the later drying processes is very minimal. A uniform moisture removal is ensured by controlling dewatering without breaking starch granules. The water extracted can be filtered, and it can be used in the system again, which is in favour of sustainable processes. This stage lowers moisture, which enhances the stability and storage life of starch. Drying efficiency is also increased with proper dewatering and a variety of processing times is also minimized. This is necessary in ensuring the desired physical properties of starch are obtained without compromising on the quality of the product and operational efficiency.

F. Dryingand Quality Assessment:

Drying of the dewatered starch is controlled to produce the required moisture content in making the starch safe to store and use. Drying is done under controlled temperature to ensure starch is not destroyed or discoloured. Standardized drying tests of consistency of product and increases shelf life. The starch is then dried and packed in a hygienic environment to ensure no contamination takes place. The quality assessment processes are done to measure the levels of moisture content, color, texture and purity. Process adjustments are used to deal with any deviations. This last step is used to determine that the extracted starch is of the required industry standard and is capable of application in various areas. The methodology will end with appropriate storage instructions to ensure that the products remain intact even after some time.

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V. PROPOSED SYSTEM

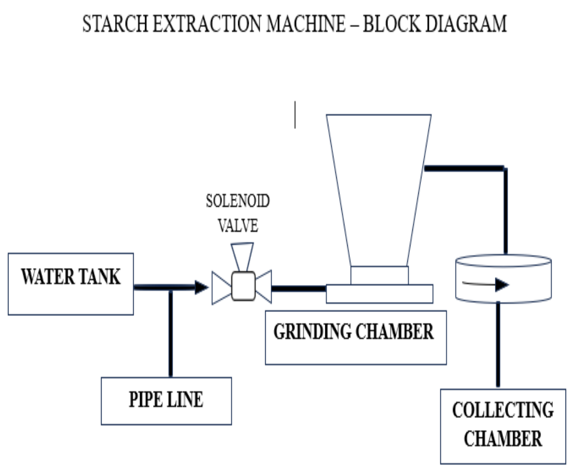


Fig 1: Block Diagram

Fig2: Starch Extraction Machine Setup

The proposed system is a computerized starch extraction unit that aims at enhancing efficiency, consistency, and hygiene and eliminating the use of manual energy and resources wastage. The system focuses on combining mechanical processing with the control of water usage and high-efficiency filtration in order to obtain high-quality starch extraction that may be used in medium and small-scale processes. The entire design is focused on simplicity, cost-effectiveness and sustainability, which suits the decentralised Agro-processing setting.

It starts with the controlled supply of water by the water storage unit into the starch extraction chamber. Water is very important in supporting the formation of pulp and starch suspension. The amount of water is controlled in such a way that there is maximum uniformity of mixture, which does not over-dilute, yet is able to release the starch. This is managed water inflow, and it increases the efficiency of extraction and reduces unwarranted water usage.

The primary component of the system is the starch-extraction chamber. Its content is prepared raw material, which is put in this chamber, where mechanical grinding occurs. The motor's rotational speed is 17,000-22,000 rpm. This process helps in the extraction mechanism, which breaks down the raw material, breaks up the cellular structures, and releases starch granules into the liquid medium. The closed construction of the extraction chamber avoids contamination and makes the working of the extraction chamber safe. Even mixing of the starch granules in the liquid is necessary to ensure that the separation of the granules in the downstream can occur effectively.

The slurry containing the starch goes down the strainer filter unit after the extraction process has been done. The strainer filter serves as a primary separation technique, in which fibrous solids and coarse solid residues are held. The gratified net structure of 100 to 120 µm enables both starch granules and liquid to be filtered through, and the effect is that unwanted solids are filtered out. This filtration stage aims to enhance the level of purity in starch and avoid clogging in later units. The solid waste that is retained can be withdrawn individually, and recycled or disposed of in the form of by-products, which will help in the reduction of waste.

The filtered liquid is then passed onto the starch collection unit. The starch-rich liquid is temporarily stored in this unit, which is processed further to be sedimented, dewatered, dried. The collection unit will help to avoid contamination and make the extracted starch simple to handle. It is maintained in proper storage conditions so as to keep the starch in the right quality before further processing procedures can be done.

The flexibility and ease of the design is one of the strengths of the suggested system. All the parts are put in a logical order to promote the easy flow of materials and operation. The system will have reduced labour and operation errors as it will need minimal human intervention. Hygienic processing and long-term reliability is provided by easy cleaning and maintenance of smooth internal surfaces and accessible components

Component	Description	Function
Water Reservoir	Storage unit for process water	Supplies controlled water for pulp formation
Starch Extraction Chamber	Enclosed mixing and grinding unit	Crushes raw material and releases starch granules
Mixing Blades	Motor-driven rotating blades	Ensures uniform grinding and slurry formation
Strainer Filter	Fine mesh filtration unit	Separates fibrous residues from starch slurry.

Liquid Collection Unit	Storage tank for filtered starch liquid	Collects starch-rich liquid for further processing
Waste Outlet	Solid discharge path	Removes fibrous and solid waste after filtration
Control Unit	Automated control mechanism	Regulates water flow and motor operation

Table 1: Major Components of the Proposed Starch Extraction System

VI. RESULTS & DISCUSSION

Banana starch is expensive compared to starches available in the market, but it is a healthier alternative because it helps position health (digestive health, low-gi, gluten-free) and niche. value-added products made from banana: our health bar, gluten-free mix, and banana starch have higher profit margins in the market, and banana starch has high resistance starch and is a good source of low-glycemic foods, diabetic-friendly products, and gut-health-focused foods.

In this experiment, the workflow and machine working are explained, as there are five banana varieties being selected for the experiment.

A research was carried out in finding out which banana variety could have and higher starch yield and the results the genome group of AAA or ABB has the highest touch yield because they are triploids and a lower starch yield from the genome varieties AA or AB that is diploied and in certain cases the dessert varieties that is Robusta variety has an lower starch yield even though it is a triploid genome variety.

The experiment is based on the previous works carried out, and based on this, the experiment was conducted on the above-mentioned varieties to determine the starch yield. Based on the experiment carried out, Nendran and Monthan have higher starch yields, while the other varieties have lower starch yields.

The starch and starch yield are compared, and the tabulation and graph are mentioned below:

S. No	Banana Variety	Banana Wt. (g)	Water Required (ml)	Starch Yield (g)	Time Taken (min)	Efficiency (%)
1	Karpuravalli	250	700	193	12	77
2	Poovan	250	700	185	11	74
3	Robusta	250	700	201	10	80
4	Monthan	250	700	235	11	94
5	Nendran	250	700	240	10	96

Table :3 Higher Efficiency from all the Varity.

S. No	Banana Wt. (g)	Water Required (ml)	Wet Starch Yield(g)	Starch Yield (g)	Time Required (min)	Efficiency (%)
1	250	600	170	26	11	68
2	250	650	179	32	12	71
3	250	700	182	36	13	72
4	250	750	201	45	12	80
5	250	800	190	40	11	76

Table 4: Banana Variety: Karpuravalli

S.No	Banana Wt. (g)	Water Required (ml)	Wet Starch Yield(g)	Starch Yield (g)	Time Required (min)	Efficiency (%)
1	250	600	160	22	10	64
2	250	650	165	25	13	66
3	250	700	170	30	12	68
4	250	750	185	39	10	74
5	250	800	173	34	12	69
6	250	850	176	28	11	70

Table 5: Banana Variety: Poovan

S. No	Banana Wt. (g)	Water Required (ml)	Wet Starch Yield(g)	Starch Yield (g)	Time Required (min)	Efficiency (%)
1	250	600	170	26	11	68
2	250	650	179	32	12	71
3	250	700	182	36	13	72
4	250	750	201	45	12	80
5	250	800	190	40	11	76

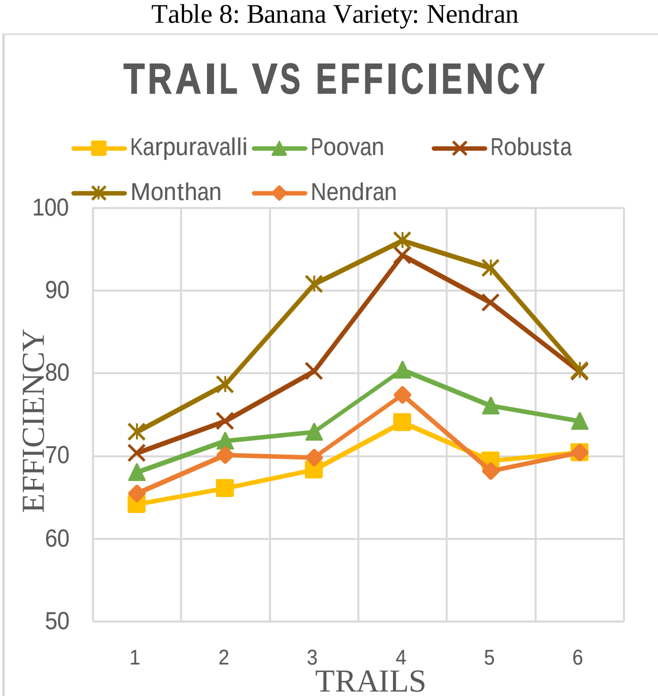
Table 6: Banana Variety: Robusta

S.No	Banana Wt (g)	Water Required (ml)	Wet Starch Yield (g)	Starch Yield (g)	Time Required (min)	Efficiency (%)
1	250	600	175	35	13	70
2	250	650	185	42	12	74
3	250	700	200	50	10	80
4	250	750	235	58	11	94
5	250	800	221	40	12	88
6	250	850	200	43	13	80

Table 7: Banana Variety: Monthan

S.No	Banana Wt(g)	Water Required (ml)	Wet Starch Yield(g)	Starch Yield (g)	Time Required(min)	Efficiency (%)
1	250	600	182	45	11	72
2	250	650	196	50	12	78
3	250	700	227	56	11	90
4	250	750	240	64	10	96
5	250	800	231	52	12	92
6	250	850	200	48	13	80

Table 8: Banana Variety: Nendran



Graph 1: Efficiency Vs Trail

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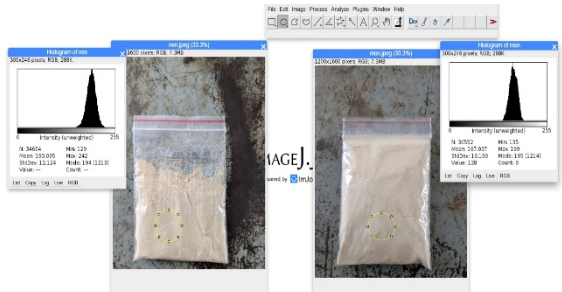
As already mentioned, the results from the starch extraction machine also help us understand that Nendran and Monthan have the highest starch yield, and that the starch from 250 grams of banana is 50-60 grams of starch powder after drying.

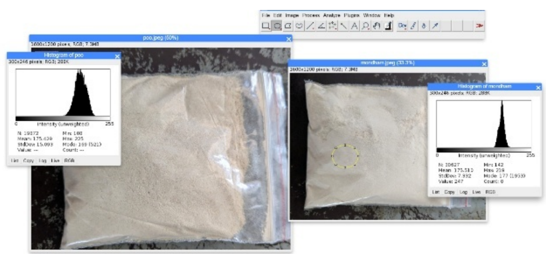
A. Image-Based Analysis of Starch Samples Using ImageJ Histogram

- Nendran vs Mondhan



- Karpuravalli vs Robusta

- Poovan vs Mondham



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