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RESEARCH ARTICLE OPEN ACCESS

Development of a Conceptualized Automated Fruit Harvesting Machine

[1]Evbeifo N. O. [2]Suleiman, A. I., [2]Ibrahim, R.

[1]Department of Agricultural Technology, School of Applied Sciences, Auchi Polytechnic, Auchi, Edo State, Nigeria

[2]Department of Agricultural and Bioenvironmental Engineering Technology, School of Engineering, Auchi Polytechnic, Auchi, Edo State, Nigeria

Correspondence: geniusgodspeed@gmail.com

Abstract: The agricultural industry faces numerous challenges, including a shortage of field employees and rising fruit harvesting costs. In order to solve these issues, agribusiness must save labour and scale up. Agriculture automation has advanced in recent years, allowing for labour savings and large-scale farming. However, in the field of fruit harvesting, majority of the job is done by hand. This manual technique causes significant harm to sensitive fruits, lowering their market value. Mangoes, oranges, apples, and cashews for fresh markets are too delicate to be collected with harsh methods like shakers. If these methods were used, the fruits could be destroyed by being impacted by the tree's limbs during the fall or by the tree directly falling on the ground, resulting in a loss of quality and a reduction in fresh produce market trading profits. A feasible answer to these issues is the creation of an automated fruit harvesting equipment. Agriculture has recently necessitated automation and labour savings. Mechanization and robotics for fruit picking, on the other hand, have not progressed. This study suggests a suction arm-based system for automating fruit harvesting. The fruit is picked and passed via a chute using a Single Box Collector, which is a very rapid and accurate procedure. The findings of the trial revealed that over 90% of the fruits were successfully collected into the box. Furthermore, the automatic harvester may pick a fruit in as little as 12 seconds.
Keywords: Harvesting fruits, Manipulation, Automation, Suction arm

1. Introduction

Agriculture is the backbone of many emerging countries, and it aids in their economic, social, and individual development. Agriculture is also one of the key factors that has brought humanity together throughout the last 10,000 years, resulting in the foundation and growth of human civilizations all over the world. Today's high-tech, accurate, and qualitative large-scale modern agriculture industry is the outcome of several agricultural inventions over time. The current period of modern high-tech and environmentally controlled agriculture is generating high-quality food while also ensuring that fundamental nutritional demands for human health are met. Domestication of crops and animals, weed control techniques, water management, fertilizer/pesticide use, genetic engineering, and the large-scale mechanization that followed in the mid-1990s were all big advances in agriculture. These significant changes aided the agriculture sector's quick growth with mechanization and precise technologies, resulting in great inventions and revolutions around the world.

In recent decades, new technology and the most recent scientific research findings have been widely utilized in agriculture to improve product quality and productivity. The world's population is rapidly increasing, necessitating a steady supply of high-quality food. Farmers and agricultural labour populations are dwindling in Nigeria as a result of a variety of issues. As a result, researchers are working to find long-term and low-tech solutions to the problem of agricultural mechanization and automation by employing highly sophisticated systems that can replace manpower in tasks where a person may perform worse than an automatic device in terms of precision, consistency, and working cycle. Automation in greenhouses is becoming increasingly popular; in particular, modern high-tech greenhouses are outfitted with automatic equipment and control systems that are derived from numerically controlled machinery.

Fruit harvesting is an important horticultural application that reduces labor expenses and harvesting energy consumption while also increasing resource use [1–4]. Some agricultural items that are resistant to harm, such as olives and almonds, can be collected using trunk or branch shakers [5]. Mangoes, oranges, apples, and cashews for fresh markets, on the other hand, cannot be collected using harsh methods like shakers. If these methods were used, the fruits could be destroyed by being impacted by the tree's limbs during the fall or by the tree directly falling on the ground, resulting in a loss of quality and a reduction in fresh produce market trading profits. Shaking the trunk or branches of a tree also has the potential to remove unripe or small, immature fruits [6]. Manpower will be required to collect the fruits that fall to the ground after shaking, which will result in higher labour and harvesting expenses. Manual fruit harvesting, on the other hand, is labour-intensive and inefficient in terms of both economy and time.

Large amounts of labour are necessary to accomplish intense hand harvesting, and labour wages are constantly growing. The only method to keep or lower labour expenses per unit of output is to raise labour productivity or increase production volume. Given world trade regulations and living costs, competing on cheap labour costs is impossible. As a result, mechanization is the sole solution, as it is the only way to reduce harvesting labour costs, allowing growers to remain competitive in the future and even expanding markets [7]. In addition, mechanization is critical to the future of fruit growers in developed countries. Harvest machinery also increases farmers' ability to conduct operations in a timely way, in addition to decreasing the drudgery of harvest labour and as the only solution to preserving harvest productivity. It also eliminates the hazards of relying on huge volumes of seasonal hand labour for short periods of time, as well as the social issues that come with an inflow of low-wage workers. Machine harvesting systems are a partial solution to these problems because they efficiently remove fruits from trees, lowering harvesting costs to about 35–45 percent of total production costs [2] and reducing labour costs and harvesting energy consumption, as well as improving resource utilization in agricultural activities [8].

By considering the above-mentioned issues and the necessity for, and potential of, fruit harvesting robotics in agriculture, this paper was presented to with the following objectives:

i. developments of an automated fruit harvesting machine.
ii. Evaluating the design strategies in recognition and picking systems, and developments in fruit harvesting.

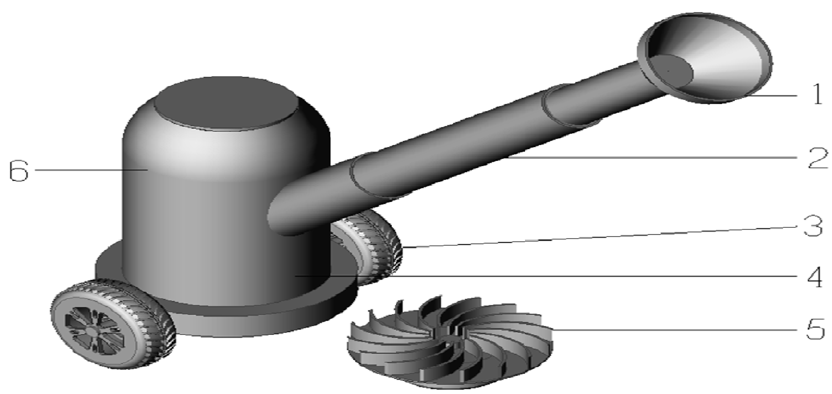
2. Materials and Methods

2.1 Design Concepts

The methodology adopted included:

a. Design and fabrication of the automated fruit harvesting machine concept consisted of three main units; the first unit is the gripping system in which identification and location of fruits are confirmed, the second unit is a picking system in which grasping and cutting operations are performed; and the third unit is a moving the fruits into sub-unit(chute) of the machine inside the fruit collection tank. Depending on the agricultural application and on the workspace in which the machine is operated, a rotational joint, linear joint, twisting joint, revolving joint and orthogonal joint or a combination of these joints are used to connect the links which form a revolute, spherical, cylindrical, structure. The diagram in Figure 1, elaborate on the mechanism of operation of the fruit harvesting machine.

b. The theoretical design was then translated into a real-world design for the pilot-scale automated fruit harvesting machine. To achieve fast and robust operation in the complex anddynamic fruit harvesting environment the machine must be equippedwith systematicgripping, picking and collection capabilities.Gripping is needed for the detection and classification of fruits, the assessment of the state of the fruits (readiness orripeness of fruits and flowers) as well as the localization of materials of construction.Complex actions are required to reach the fruits within a highly occluded environment, to perform theoperation on the object (e.g., grasp, cut from stem, spray)and to transport the object to a container. These actions mustbe performed delicately ensuring no damage is caused to theobject or crop environment.



S/N	DESCRIPTION
1	FRU:T SUCTION COLLECTOR
2	ADJUSTABLE COLLECTOR CHANEL
3	ROLLER
4	VACUUM MOTOR/BATTERY CHAMBER
5	ELECTRIC MOTOR FAN
6	FRU:T COLLECTOR CHAMBER

Figure 1: A projectionof the automated fruit harvesting machine

2.1.1 Fabrication and Testing of the Automated Fruit Harvesting Machine

This included: (a) allocating a fabricator to construct the Automated Fruit Harvesting Chambers and accessories; and (b)Some of the selected materials for the construction and fabrication of the machine comprised: Stainless Steel plates, stainless steel Pipes, PVC Pipes,suction system, mild Steel plates, pressure hoses(flexible) and foams. The robot grippers in horticulture applications for fresh fruit and vegetable manipulation have to fulfil special requirements such as high speed activation, adaptation to a variety of shapes, maximum adherence and minimal pressure, no damage to the product, low maintenance, high reliability, low weight, be approved for contact with foodstuffs, low energy consumption, required positional precision for both gripping and releasing of the product, ease of cleaning, and easy and fast ejection of the product (important for products of low weight).

c:**Testing the System**

1. Evaluation of thedevelopedcutting system for the harvesting machine was based on gripping and suction potentials (Figure 1). These systems assist to avoid virus transformation, reduce the fungal vulnerability and increase the shelf life of fruits by adopting a smooth and thermal cutting approach. The design consists of conical gripper mounted on a frame connected by a specially designed notch plate and operated by a vacuum motor. Based on voltage and current from the battery bank and microcontroller unit, cutting system prototype—picking and collection— were developed.
2. The post-harvest inspection of harvested fruits confirmed an increase in the shelf life of fruits and prevention of fungal and virus transformation. The fruits harvested by the system can be preserved more than 15 days under normal room conditions.
3. We tested whether different fruits like oranges, mangoes, cashew can be picked by the gripper using suction force.

The main goals of testing were to determine how wellthe fruit harvesting machine met the design requirements. Complete automation was not physically possible given the costs of the detection and harvesting algorithm mechanism that runs a robotic harvester.

3.0 **Results and Discussion**

3.1. **Performanceand Commercial Case**

Automation, mechanization, and enterprise management are inextricably linked. To begin with, the requirements of the technology to be developed are dictated by enterprise management and the related business case. Second, and alternatively, the technology should be integrated into the enterprise's process flow, product flow, and usage of human and equipment resources [9-11]. In the Nigerian agricultural engineering literature, neither aspect has gotten significant attention. These scenarios can be used to produce appropriate requirements for fruit harvesting technology that has yet to be developed, such as cycle times and success rates. Alternatively, it enables a company-wide assessment of the influence of existing technology on work and product flow.

In most circumstances, business cases believe that human labour can completely replace it. Despite being a noble goal, given present technology, this appears to be a step too far. For the time being, it may be preferable to create scenarios that use a combination of human and robotic work. At this moment, there are two possibilities. In the strictest sense, technology progress can be aimed toward human-robot collaboration, which means that robots can be used to replace human work whenever possible. If technology cannot totally replace human labour, human supervision and intervention can be used [12]. Human-robot collaboration is a technical topic with numerous possibilities that has yet to be fully explored in the agricultural environment [12-15]. Alternatively, robots can be utilized to accomplish the majority of a work, such as harvesting, while humans are used to handle the more challenging cases[16].

4. **Conclusion**

In this work, we built an automated fruit harvesting machine with a capacity for picking fruits in 12 seconds. We performed automatic fruit harvesting through the method of fruit position gripping and harvesting using an automated manipulator with a harvesting hand that does not damage the fruit and its tree. Using the system, we showed that the fruit position of 90% or more can be detected in 2 s. The proposed fruit harvesting algorithm also showed that one fruit can be harvested in approximately 12s.Though fruit harvesting technology is growing at a considerablepace at a world-wide scale, the market for robotic systems and its application in Nigeria is small and very scattered. So far, for this technology has proven that with adequate funding and logistics, one can fabricate a fruit harvesting machine.

Acknowledgements: This research was funded by grants from the Tertiary Education Trust Fund (TETFUND) the researchersappreciateTETFUND, Nigeria, for providing the grant in carrying out this research and Auchi Polytechnic Management for its kind approval.

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