Technologies for Chilli Harvesting

Gowtham[1*], Sushilendra[2], Sunil Shirwal[3], Murali, M[4]., V. Raghavendra[5] and Abishek A.[6]

[1&6] Ph.D. Scholar, Department of Farm Machinery and Power Engineering, College of Agricultural Engineering, UAS, Raichur- 584 104, Karnataka, India.

[2] Professor, Department of Farm Machinery and Power Engineering, College of Agricultural Engineering, UAS, Raichur-584104, Karnataka, India.

[3]Associate Professor, Department of Farm Machinery and Power Engineering, College of Agricultural Engineering, UAS, Raichur-584104, Karnataka, India.

[4&5]Assistant Professor, Department of Farm Machinery and Power Engineering, College of Agricultural Engineering, UAS, Raichur-584104, Karnataka, India.

Corresponding Email: gowthambunny871@gmail.com

1. Introduction

Chili (*Capsicum annuum* L.) is an important spice cum vegetable crop cultivated throughout the world. There are more than 400 different varieties of chili found all over the world with different pungency, size, shape, colours and usage (DMII, 2009). India is the largest producer, consumer, and exporter of red dry chili which contributes about 40% of the World's production. In India, chili is cultivated about 0.78 Mha area with an annual production of 1.74 million tonnes with a productivity of 2.23 tonnes/ha (FAO, 2019). Chili is cultivated all over India and its sub-continent with Andhra Pradesh is leading in both the area (20%) and production (55%) followed by Karnataka, West Bengal, and Madhya Pradesh (SBOI, 2016). Berke *et al.* (2005) investigated that green chilies are harvested when the pepper has been reached its peak size, but are partial ripped stage which cannot be turned into chili pow der. However, red chilies are also harvested when pepper is moderately dried on the plants. Green chili pepper is either processed into a canned or frozen product or sold directly to the consumer, whereas red chili is mainly processed into chili powder (Bosland & walker, 2004).

Hand-picking is the most common traditionally harvesting method adopted by farmers to harvest chili peppers. A hand picking method is a time-consuming method and the unavail ability of labor during the picking season causes a delay in the harvesting period which directly impart poor-quality product. The labor crews miss some of the peppers because of shrub bery and they experience intense pain especially in the upper limbs, lower limbs, and the spine (Bernard, 1997). According to Hawkes and Libbin (2000), traditionally, harvesting meth od required 40–50 labors per day/ha which turns about 50% of the total cost of production. Mechanization for harvesting chili pepper reduced labor use by 51% (Hong *et al.*, 2006) and the harvesting cost of chili pepper can be reduced to 10% by using different mechanical harvesting techniques (Eastman et al., 1997). Hence, companies and researchers from Israel, China, and the USA had developed some prototype for pepper harvesting (Paul *et al.*, 2011 and Wall *et al.*, 2003).

The mechanical harvesting of chili pepper is a crucial task as the picking efficiency of harvester varies with fruit shape, size, moisture content, density, stem tenacity, and plant phys iology (Diemer et al., 2002). The chili peppers are widely dissimilar in their physical characteristics; therefore, it seems a highly difficult task for a single picking unit to pick pepper effectively. Even green and red chili from the same plant might require different picking units. The existing developed chili pepper harvester was developed using the chassis bases of the combine, which is suitable for large chili farms. However, combine type chili pepper harvester is not ideal for Indian condition, as about 86 % of farmers are in a category of small and marginal landholdings.

2. Methods of chilli harvesting

Chili harvesting is accomplished through both intensive manual labor and increasingly advanced mechanical methods, with the choice depending on factors like cultivar type (size, fragility), field size, and local labor costs. Manual harvesting is common for fresh market and specific dry varieties, while mechanical methods are used for large-scale production, particularly for processing.

2.1 Manual Chilli Harvesting

Fig 1. Manual Chilli Harvesting

Manual harvesting remains the predominant method in many regions, especially for varieties that require selective picking over a prolonged season. Manual chilli picking involves selectively harvesting mature green or red

fruits by hand, as chillies ripen non-uniformly and require careful handling to avoid damage. Workers detach the fruits by pinching the stem using their fingers and collect them in small baskets or waist bags, repeating the process across 3–5 pickings per season (Fig 1). A skilled labourer typically harvests 20–35 kg of green chilli or 15–25 kg of red chilli per day, making the operation labour-intensive and costly, especially during peak seasons.

Advantages

Selectivity: Allows for harvesting at the optimal maturity stage, which is critical for crops requiring multiple harvests and maintaining quality for the fresh market.

Minimal Damage: Properly trained workers can harvest with minimal mechanical injury to the fruit and plant.

Disadvantages

Labor Intensive and Costly: Harvesting accounts for a significant portion of the total labor required for chili cultivation, making it expensive.

Time-Consuming: The process is slow and may lead to missing the optimal harvesting window, which can affect product quality.

Health Concerns: Long-term contact with chili peppers during harvesting can cause harm to human eyes, skin, and respiratory system.

2.2 Mechanical Chilli Harvesting

Mechanization addresses the challenges of manual labor by using specialized equipment, offering increased efficiency and reduced costs for large-scale operations.

Process: Mechanical harvesters use various mechanisms to detach fruit from the plant, including rotating brushes, helical spiral-type rollers or comb-type devices. These machines are often self-propelled or tractor-drawn and can harvest several acres in a fraction of the time compared to manual picking.

Techniques: Common picking mechanisms include:

1. **Double-helix type:** Uses counter-rotating helical rods to clamp and comb plants, suitable for larger varieties.
2. **Drum-finger type:** Employs flexible fingers on a rotating drum to "pluck" fruits, suitable for long, fragile varieties.
3. **Comb-type:** Uses rigid or flexible comb elements to comb through the foliage and dislodge peppers.

1. Double-Helix Type Picking Mechanism (Counter-Rotating Helical Rods)

The double-helix mechanism consists of two helical rods or spirals that rotate in opposite directions, creating a clamping and pulling action while moving through the chilli canopy. As the rotating helices pass between the plant rows, they gently grip the stems and branches, guiding them upward while simultaneously "combing" through the foliage (Fig 2). This action loosens mature fruits and detaches them through controlled pulling forces. The design reduces direct impact on fruits and minimizes breakage of branches. Because the spacing between helices can be adjusted, this mechanism works best for larger, sturdier chilli varieties and plants with stronger stems that can withstand mechanical contact. Its smooth, continuous motion allows higher picking efficiency but may not perform as well on delicate varieties with fine branching.

Fig 2. Double-Helix Type Picking Mechanism

2. Drum-Finger Type Picking Mechanism (Rotating Drum with Flexible Fingers)

Fig 3. Drum-Finger Type Picking Mechanism

This mechanism uses a cylindrical drum fitted with multiple flexible rubber or silicone fingers around its surface. As the drum rotates, the fingers move in sweeping motions that mimic human hand-plucking, reaching into the plant canopy and hooking around the pedicels of ripe fruits. The flexibility of the fingers allows them to bend around branches without breaking them, making this system particularly suitable for long, slender, and fragile chilli varieties that require gentle handling. The rotating fingers apply just enough impact and pulling force to detach mature fruits while leaving immature chillies intact. This mechanism is widely studied in robotic harvesting prototypes because its soft interaction reduces bruising and fruit damage (Fig 3).

3. Comb-Type Picking Mechanism (Rigid or Flexible Comb Elements)

The comb-type picker includes one or more rows of comb-like teeth—either rigid plastic/metal or flexible polymer strips—positioned to penetrate the plant canopy. As the mechanism moves through the crop, the comb teeth separate branches and sweep through the foliage, causing ripe chillies to be dislodged by tension or light impact. The spacing and depth of the comb can be adjusted based on plant height and density. This system is simpler and lighter compared to drum or helix types and provides good coverage across bushy plants. However, because the comb applies uniform force across the plant, it is more suited for robust varieties and uniform fields, as delicate fruits may experience higher mechanical stress (Fig 4). Its low cost and simple operation make it common in experimental or small-scale mechanical pickers.

Fig 4. Comb-Type Picking

Advantages

Increased Efficiency: Machines can harvest large quantities quickly, significantly reducing time and labor costs (e.g., mechanical harvesting costs can be a fraction of manual costs).

Reduced Drudgery: Alleviates the labor intensity and physical stress associated with manual work in hot conditions.

Scalability: Essential for commercial, large-scale farms to handle high yields efficiently.

Disadvantages & Considerations

Cultivar Specificity: Most machines are developed for specific chili varieties (e.g., bold varieties in the US, slender varieties in India) and may not be universally adoptable. Plant characteristics like structure, fruit position (erect vs. pendent), and detachment force significantly impact efficiency.

Potential Damage: Mechanical methods can cause more damage to the fruit and plants compared to careful hand-picking, which is a concern for fresh market produce.

Incomplete Harvesting: Machines can have lower picking efficiency (sometimes leaving some fruit behind) or pick up foreign material (leaves, stems), requiring additional cleaning and sorting post-harvest.

Initial Investment: The machinery is costly and primarily suited for large farms to be economically viable.

3. Components of a Mechanical Chilli Harvester

Mechanical chilli harvesters—whether walk-behind, tractor-mounted, or self-propelled—generally contain a combination of fruit-detaching mechanisms, plant-guiding structures, and collection systems. Each component plays a specific role in ensuring effective harvesting with minimal fruit damage.

1. Picking / Detaching Mechanism (Core Unit): This is the main component of a mechanical chilli harvester responsible for removing fruits from the plant. The common types of picking mechanisms are:

a) Helical Roller / Double-Helix Unit: This mechanism consists of two counter-rotating helical rods that gently grip and comb the plant canopy. As they rotate, they create a rubbing and pulling force that detaches ripe fruits effectively. It is best suited for chilli varieties with stronger stems.

b) Drum-Finger Mechanism: This mechanism uses a cylindrical drum fitted with flexible rubber or silicone fingers. The fingers sweep through the plants, hooking and plucking ripe chillies with minimal force, making it suitable for fragile or long-pod varieties.

c) Comb-Type Mechanism: This mechanism uses combs with rigid or flexible teeth that sweep through the foliage to dislodge fruits through brushing and light impact. It is simpler and lighter in design but requires careful adjustment to avoid plant or fruit damage.

2. Plant Dividers / Row Separators: Plant dividers are positioned at the front of the harvester and are used to split crop rows and guide plants smoothly into the picking mechanism. They help prevent plant entanglement, ensure uniform feeding of plants, and maintain harvesting efficiency. These dividers are commonly available in V-shaped, cone-shaped, or plate-type designs depending on field conditions and crop spacing.

3. Picking Guides / Feed Guides: Picking or feed guides are structures designed to direct chilli branches toward the detaching mechanism in a controlled manner. They ensure proper alignment of plants, reduce the chances of stem breakage, and position the plant at an optimal height and angle, thereby enabling smooth and efficient harvesting.

4. Power Transmission System: The power transmission system supplies the necessary motion to operate the harvesting components such as rollers, drums, or combs. It typically consists of an engine or motor (petrol, diesel, or electric), a gearbox, and transmission elements like chains, belts, pulleys, or shafts. This system ensures stable operation

and allows adjustment of rotational speed to match crop conditions and harvesting requirements.

5. Conveying System: The conveying system is responsible for transporting detached chilli fruits from the picking area to the collection unit. It usually includes belt conveyors, screw or auger conveyors, and sometimes vibrating sieves that help separate leaves and small debris. This system is designed to minimize drop height and impact, thereby preserving fruit quality during handling.

6. Cleaning & Separation Unit (Optional in Advanced Models): In advanced harvesters, a cleaning and separation unit is included to remove unwanted materials such as leaves, twigs, and soil particles. This is achieved using airflow systems, vibration mechanisms, or mesh sieves. The unit enhances the quality of harvested chillies before they are stored or packed.

7. Collection System

The collection system gathers the harvested chillies into bins, trays, or bags. It is designed for easy removal and handling while preventing bruising or damage to the fruits. In some cases, cushioned or padded collection bins are used, especially for delicate chilli varieties.

8. Adjustable Height & Support Frame: The support frame forms the structural base of the harvester, holding all components together. It includes height adjustment features to accommodate different plant heights and field conditions. Walk-behind models are equipped with wheels and handles for maneuverability, while larger systems are typically tractor-mounted for higher efficiency.

9. Control System: The control system allows the operator to regulate machine functions such as the speed of the picking mechanism and conveyor. It may include throttle control, RPM regulators, gearshift options, and safety shut-off switches. These controls enable efficient operation and adaptability under varying field conditions.

4. Conclusion

Mechanical chilli harvesters offer a promising solution to the challenges of labour-intensive harvesting by improving efficiency, reducing costs, and minimizing drudgery. The integration of advanced picking mechanisms such as double-helix, drum-finger, and comb-type systems, along with supporting components like conveyors and cleaning units, ensures effective fruit detachment with minimal damage. However, performance depends on crop characteristics and machine design optimization. Studies indicate that well-designed harvesters can achieve high picking efficiency and low losses, making them suitable for large-scale adoption. With further refinement and adaptation to smallholder conditions, mechanical harvesting can significantly enhance productivity and sustainability in chilli cultivation.

5. References

Berke, T., Black, L. L., Talekar, N. S., WangJ, F., Gniffke, P. and Morris, R. 2005, Suggested cultural practices for chili pepper. AVRDC Pub., 05-620.

Bernard, B. P., 1997, Musculoskeletal disorders and work place factors: a critical review of epidemiological evidence for work-related musculoskeletal disorders of the neck, upper extremity, and low back, DHHS (NIOSH), 97-141.

Boasland, P. W., and Walker, S. 2004, Growing chiles in Mexico. New Mexico State University, cooperative extension service guide, 230.

Diemer, J. A., Phillips, R. and Hillon, M. 2002, An industry–university response to global competition. New Mexico Chile Task Force Report 1.

Eastman, C., McClellan, F. and Bagwell, T. 1997, Impact of increasing wages on New Mexico chili production. New Mexico Agricultural Experiment Station Research Report No., 71.

FAO (2019). *FAOSTAT Database*. Food and Agriculture Organization of the United Nations, Rome, Italy.

Hawkes, J. and Libbin, J. D., 2000, Crop cost and return estimator in New Mexico, 1998. New Mexico Agricultural Experiment Station. Las Cruces.

Hong, J. T., Jo, K. H, Jo, N. H., Hong, J. K., Choi, Y., Shin, S. Y., and Choi, C. K. 2006, Study on integrated mechanization system for harvest and postharvest operation of once-over-harvest pepper. Symposium of Korean Society or Agricultural Machinery, 11(2), 184-189.

Paul, A. F., Walker, S. J. and Herbon, R. P. 2011, A system approach to chile harvest mechanization. International Journal of Vegetable Science, 17:296–309.

Wall, M. M., Walker, S. J., Wall, A. D., Hughs, E. and Phillips, R. 2003, Yield and quality of machine harvested red chile peppers. Horttechnology, 13(2).

* * * * * *