

Engineering-based development of a manual comb and conceptual design of a portable chamomile picking machine

Wael A. Mahmoud^{1*}, Mahmoud A. M. Abd El-Moulaa¹, Ashraf K. Zaalouk²

(1. Agricultural Machinery and Power Engineering Department, Faculty of Agricultural Engineering (Assiut Branch), Al-Azhar University, Assiut, 71524, Egypt;

2. Agricultural Machinery and Power Engineering Department, Faculty of Agricultural Engineering, Al-Azhar University, Cairo, 11651, Egypt)

Abstract: Chamomile (*Matricaria chamomilla* L.) cultivation is of significant economic importance; however, traditional manual harvesting remains a primary bottleneck due to high labor costs and low productivity. Large-scale mechanical harvesters are often unsuitable for the small agricultural holdings prevalent in many regions due to their complexity and cost. This study establishes a technical framework for a small-scale harvesting solution, starting with the evaluation of a manual picking comb designed based on the plant's physical-mechanical properties. Experimental results indicated that the optimal comb configuration (100 mm tooth length, 5 mm gap width) achieved a peak productivity of 14.88 kg h⁻¹ and a picking efficiency of 95.33%, significantly outperforming manual picking (4.68 kg h⁻¹). Based on these empirical findings, a conceptual design for a portable, battery-powered chamomile harvester was developed. The proposed design features a lightweight structure (under 7 kg without batteries) incorporating a synchronized harvesting mechanism consisting of a picking comb, a reciprocating cutting blade, and a rotary collecting brush. This conceptual framework provides a cost-effective and ergonomically efficient solution specifically tailored to enhance harvesting productivity for small-scale chamomile farmers.

Keywords: *Matricaria chamomilla* L., conceptual design, mechanical harvesting, picking efficiency, small-scale farming.

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1 Introduction

German chamomile (*Matricaria chamomilla* L.), an annual plant belonging to the Asteraceae family, is globally recognized as a widely used medicinal herb. Its easily identifiable small flowers, characterized by white petals surrounding a bright yellow core, are cultivated and grow wild across the world (Zadeh et al., 2014). This versatile plant finds extensive applications

in dried teas, pharmaceuticals, and essential oils (Franke and Schilcher, 2007). The precise dimensions of chamomile flowers, with diameters ranging from 18-28 mm and a mass between 30-50 mg (Mühlbauer and Müller, 2020), highlight their delicate nature and sensitivity. Beyond their physical attributes, the flowers are rich in polyphenolic compounds and flavonoid aglycones (Qureshi et al., 2019), and their essential oil components, notably those with important

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***Corresponding author: Wael A. Mahmoud, Associate professor.** Agricultural Machinery and Power Engineering Department, Faculty of Agricultural Engineering (Assiut Branch), Al-Azhar University, Assiut, 71524, Egypt. E-mail address: waelshaban.50@azhar.edu.eg.

anti-inflammatory activities, underscore chamomile's significant importance in both classical and folk medicine (Szóke and Lemberkovics, 2021). Chamomile flowers appear in flushes, with 4-5 flushes typically obtained. The importance of medicinal and aromatic plants lies in their being a rich source of natural active substances such as alkaloids, flavonoids, terpenes, and others, which can be extracted (Ibrahim, 2020). Economically, chamomile cultivation holds significant prominence. In Egypt, for instance, it ranks first among medicinal and aromatic plants, with a cultivated area of 16,567 Feddans (approximately 6,958 ha) yielding 23,035 tons (MALR, 2022). Globally, over one million cups of chamomile tea are consumed daily (Raal et al., 2012), underscoring its high economic value and substantial demand, particularly in European markets, owing to its diverse pharmacological and pharmaceutical properties (Mahgoub et al., 2020).

The commercial success of chamomile cultivation heavily depends on the efficient collection of flowers at their optimal stage. Flowers emerge in 4-5 distinct flushes, with the second, third, and fourth flushes contributing most significantly to the total yield (Singh et al., 2011). The critical window for effective flower collection extends over a period of 3–6 weeks, typically during March–April, making timely and efficient picking paramount for maximizing both yield and quality. Chamomile flowers are inherently delicate and fragile, necessitating a precise picking process. Mechanical characterization reveals that breaking force values range from 6.36 N for top flowers to 2.79 N for lower-level flowers (Pajic et al., 2007), with the general breaking point in the range of 3–4 N (Ehlert et al., 2011). Consequently, manual picking remains the predominant method; this traditional approach is characterized by high labor costs, significant time consumption, and reduced production efficiency, yielding low picking rates of only 3–5 kg h⁻¹ manually (Zimmer and Mueller, 2004). Furthermore, manual picking techniques require approximately 25–30

working days per hectare when using a manually pushed picking cart (Franke and Schilcher, 2007). Moreover, mechanical damage resulting from inappropriate harvesting, handling, and transport techniques is one of the most common and severe defects, leading to considerable economic repercussions primarily due to negative changes in the flowers' organoleptic attributes (Martinez-Romero et al., 2004).

When designing any mechanical machine, understanding the physical properties of the materials the machine will handle or be made from is crucial. These properties are the foundation for determining the machine's efficiency and performance (Elkaoud et al., 2025). While some mechanical chamomile picking machines exist, they are often technologically advanced and large-scale, rendering them prohibitively expensive and unsuitable for the prevalent small-sized agricultural holdings in countries like Egypt, where land fragmentation poses a significant challenge (Abdelmoula et al., 2024). This notable lack of appropriate small-scale mechanical solutions directly hinders the development of chamomile cultivation and inflates its production costs. Therefore, this research presents a unique methodology aimed at bridging this gap. First, a comprehensive study of the engineering and physical properties of chamomile flowers and their stems was conducted to provide the necessary scientific foundation for designing any harvesting machine (Abdelmoulaa et al., 2024). Building upon these properties and the extracted data, a preliminary manual picking comb was then developed and evaluated to determine the optimal dimensions and parameters for the picking process, as well as to identify the mechanical and operational challenges that any future design might encounter.

This study aims to develop a manual picking comb based on the physical and mechanical properties of chamomile (*Matricaria chamomilla* L.) and evaluate its performance as a primary step toward mechanization. Specifically, the research focuses on

determining the optimal comb parameters through field testing to achieve high picking efficiency and productivity. These empirical results are then utilized to establish a comprehensive conceptual design for a portable, battery-powered picking machine. The goal is to provide a technical framework for a lightweight, cost-effective harvesting solution tailored for small-scale agricultural holdings, bridging the gap between manual labor and full-scale mechanization.

2 Materials and methods

This section outlines the systematic engineering methodology employed to develop the conceptual design of a portable chamomile picking machine. The design process was executed in four sequential stages to ensure that the final concept is both scientifically grounded and practically viable.

2.1 Methodological framework

Stage 1: Defining requirements and operational goals

The process began by identifying the operational challenges in Egyptian smallholdings. A set of design criteria was established to guide the design process:

High picking efficiency: Aiming to exceed traditional manual rates ($3 - 5 \text{ kg h}^{-1}$) while maintaining a high recovery percentage.

Minimizing mechanical damage: Keeping the picking force within the safe threshold (mean: $3.02 \pm 0.12 \text{ N}$) to preserve flower quality.

Portability and ease of use: Designing a lightweight, handheld unit for single-operator maneuverability in fragmented fields.

Low-voltage power source: Utilizing DC motors and rechargeable batteries for environmental sustainability.

Stage 2: Data collection and engineering characterization

To provide a quantitative basis for the design, the physical and mechanical properties of chamomile were utilized as established in the preliminary study by Abdelmoulaa et al. (2024). These physical properties (summarized in Table 1) and mechanical properties

(summarized in Table 2) served as the primary inputs for calculating the machine's dimensions, optimizing its picking mechanism.

Stage 3: Design analysis and mathematical modeling

The data collected were translated into specific engineering requirements using the following design equations:

Comb clearance optimization (G): To ensure stems pass through while heads are retained, the gap width was constrained by:

$$d_{s(max)} < G < D_{f(min)} \quad (1)$$

Where,

$$d_{s(max)} = 1.40 \text{ mm};$$

$$D_{f(min)} = 17.00 \text{ mm}.$$

This justifies the selection of gaps (4, 5, 6, and 7 mm).

Number of teeth (N): Determined by the frame width ($W=200 \text{ mm}$) and tooth thickness ($t=2 \text{ mm}$):

$$N = \frac{W-G}{G+t} \quad (2)$$

Theoretical field capacity (C_t): Modeled to ensure the efficiency of the goal:

$$C_t = \frac{W \times V \times \eta \times \rho}{10} \quad (3)$$

Stage 4: Evaluation and preliminary prototype (Manual Picking Comb)

To validate these theoretical parameters, a manual picking aid was fabricated and tested. This prototype served as the bridge between theory and the final conceptual design.

2.2 Description of the developed manual picking comb

The preliminary manual device was fabricated to optimize the picking principles identified in Stage 3. The components, as illustrated in Fig. 1, include:

Frame: Steel sections (20 mm wide, 2 mm thick) with dimensions of $200 \times 20 \times 110 \text{ mm}$ ($W \times L \times H$).

Comb: Fabricated from iron (200 mm wide, 2 mm thick) with 5 mm teeth and variable gaps (4, 5, 6, and 7 mm).

Cutting unit: A 1 mm thick iron cutter blade moving underneath the comb.

Transmission system: Powered by manual tensile

force with a return spring.

Collecting basket: A galvanized steel chassis (0.3 mm thick) with dimensions of $200 \times 120 \times 140$ mm.

2.3 Iterative design and development process

The development of the chamomile harvester followed an iterative engineering design approach, structured into three functional stages. Each stage was conducted to ensure a transition from theoretical concepts to a viable prototype under clear experimental conditions.

Stage 1: Functional analysis and requirement specification

Tasks: Analyzing the mechanical interaction and shearing process between the cutting unit blades, the comb teeth, and the chamomile stalks (*Matricaria chamomilla* L.).

Importance: This stage defines the mechanical energy required for stem detachment without causing excessive vibration that could lead to flower loss or plant uprooting.

Results: The "Mechanical Shearing" principle was identified as the core detachment mechanism. Based on the engineering properties in Table 2, the design Shear Force was established within a range of 0.74 N to 1.48 N (depending on the cutting angle from 30° to 60°). Additionally, the operational height range was defined as 120 and 766 mm.

Stage 2: Concept generation and experimental screening

Tasks: Testing various comb geometries integrated with the shearing unit to ensure a clean cut. This included testing gap widths (4, 5, 6, and 7 mm) and tooth lengths (50, 100, 150, and 200 mm).

Experimental conditions: Trials were conducted on fresh chamomile samples with a moisture content of $77.81\% \pm 2.96\%$. The manual stroke speed was maintained at approximately 0.5 m s^{-1} to simulate actual field harvesting conditions.

Importance: To determine the optimal geometric configuration that balances shearing efficiency with minimal trash content (stems and leaves).

Results: The 5 mm tooth gap was selected as the

optimal "Design Point." This width effectively captures and guides the stalks (mean diameter 1.16 mm) toward the shear blades while preventing flower heads from passing through.

Stage 3: Design evaluation and final concept selection

Tasks: Evaluating generated concepts based on four weighted criteria: (1) Shearing efficiency, (2) Ease of local manufacturing, (3) Power consumption (compatibility with DC batteries), and (4) Ergonomic handling. CAD software was utilized in this stage to refine the 3D components and ensure precise alignment of the shearing mechanism before physical fabrication.

Importance: Ensuring the machine's suitability for smallholdings where maintenance resources and power access are limited.

Results: The final conceptual design was defined as a handheld, battery-powered unit featuring a rotating picking reel with integrated shear blades and a lightweight galvanized collecting box.

2.4 Experimental prototype of the manual picking comb

To evaluate the conceptual design under field conditions, an experimental manual prototype was developed. This stage focused on validating the mechanical interaction between the plant and the machine components before finalizing the electrical design. Design Specifications and Component Integration. The manual comb was fabricated to test the efficiency of the "Shearing" principle. The technical specifications, based on the engineering properties of chamomile (Table 2), are as follows:

Frame structure: Fabricated from steel sections (20 mm wide, 2 mm thick) with dimensions of $200 \times 20 \times 110$ mm (W $\times$ L $\times$ H) to support the assembly of the picking components.

Comb geometry: The comb was made from iron (200 mm width, 2 mm thickness) featuring 5 mm teeth. It was tested with four different gap widths (4, 5, 6, and 7 mm) to accommodate the stem diameter ($d_{s(\text{mean})} = 1.16$ mm) and ensure flower head retention. **Cutting**

unit and shearing mechanism: A 1 mm thick iron cutter blade was positioned underneath the comb. This unit was designed to apply the necessary Shear Force, which ranges from 0.74 N to 1.48 N depending on the cutting angle (30° to 60°) as identified in the mechanical analysis.

Transmission and power: The cutting action was powered by a manual tensile force, with a spring installed at the cutter end to return the blade to its original position.

Collection system: A galvanized steel basket (0.3 mm thick) was integrated with dimensions of 200 × 120 × 140 mm to collect the harvested flowers.

Key outcomes from prototype evaluation

Table 1 Physical properties of chamomile flowers (Abdelmoulaa et al., 2024)

Properties		Min.	Max.	Mean	SD	CV %
Moisture content (%)	Flowers	74.42	79.82	77.81	2.96	3.80
	Stalks	80.77	84.62	82.51	1.95	2.36
	Stems	75.47	79.63	78.22	2.38	3.04
	Composite (Di)	17.00	27.00	21.89	2.32	10.59
Flowers dimensions (mm)	Disc (Di)	9.50	14.00	11.53	0.90	7.81
	Stalk (Di)	0.80	1.40	1.16	0.13	11.08
	Lower	120	160	135.7	10.7	7.90
Flowers height (mm)	Higher	505	766	593	65.7	11.07
	Single (g)	0.26	0.35	0.30	0.02	5.98
Fresh flowers mass (g)	Thousand (g)	280	370	318.5	31.10	9.76
	Bulk	0.30	0.32	0.31	0.01	4.72
Wet flower density (g.cm ⁻³)	True	0.84	0.88	0.85	0.02	2.31
	Bulk	0.13	0.15	0.14	0.01	6.35
Dry flower density (g.cm ⁻³)	True	0.26	0.29	0.28	0.01	4.82
	Wet	31.67	35.56	33.52	1.95	5.82
Porosity (%)	Dry	45.56	52.17	48.52	3.36	6.92

Table 2 Mechanical properties of chamomile flowers (Abdelmoulaa et al., 2024)

Properties		Min.	Max.	Mean	S. D	CV %
Coefficient of static friction (μ) for wet flower	Galvanized sheet	0.24	0.29	0.27	0.01	4.89
	Stainless steel	0.24	0.28	0.26	0.01	4.57
	Rubber	0.25	0.30	0.28	0.02	4.71
	Plywood	0.30	0.34	0.32	0.01	3.17
Coefficient of static friction (μ) for dry flower	Galvanized sheet	0.31	0.38	0.36	0.02	5.89
	Stainless steel	0.32	0.37	0.34	0.02	5.39
	Rubber	0.34	0.39	0.37	0.02	4.05
	Plywood	0.43	0.54	0.47	0.03	6.51
Repose angle (Degree)	Wet flower	33.75	36.87	35.20	1.57	4.46
	Dry flower	24.45	27.13	25.78	1.34	5.20
Picking force (N)	Flowers	2.87	3.26	3.02	0.12	4.12
	Angle (30°)	0.68	0.80	0.74	0.04	5.12
Shear force (N)	Angle (45°)	0.95	1.10	1.02	0.04	4.18
	Angle (60°)	1.38	1.60	1.48	0.07	4.76

2.5 Description of the manual picking comb

A portable manual picking machine was designed and fabricated as a preliminary step to explore and optimize picking principles. The machine was characterized by its lightweight and ease of manual

The testing of this prototype provided specific data for the current research:

Gap optimization: The 5 mm gap was found to be the most effective for the current chamomile variety, balancing flow and picking efficiency.

Force requirements: The manual trials confirmed that the shear force required is significantly lower than the picking force (detachment force), justifying the transition to a low-power electrical shearing system.

Structural integrity: Steel and iron sections of 2 mm thickness provided sufficient rigidity to handle the cumulative shearing forces during continuous operation.

operation. The main components of the manual picking comb are included as shown in Figure 1:

Frame: The frame was fabricated from steel sections 20 mm wide and 2 mm thick. Its dimensions were 200 mm wide, 20 mm in length, and 110 mm in

height, allowing for the assembly of the picking comb components.

Comb: The comb was fabricated from iron sections 200 mm in width and 2 mm in thickness, with 5 mm teeth and four different types of gaps (4, 5, 6, and 7 mm). It was made with four different lengths (50, 100, 150, and 200 mm). It was fixed below the frame by four screws.

Cutting Unit: The cutting unit consisted of one cutter blade moving underneath the comb. The cutter blade was made from iron sections, 200 mm in width

and 1 mm in thickness, with 5 mm teeth and four different types of gaps (4, 5, 6, and 7 mm). It was made with a length of 50 mm.

Tensile Force Transmission System: The cutting unit was powered by a manual tensile force; it returned to its previous position using a spring installed at the cutter end.

Collecting Basket: The collecting basket chassis was made of galvanized steel 0.3 mm in thickness, with dimensions of 200 mm in width, 120 mm in length, and 140 mm in height.

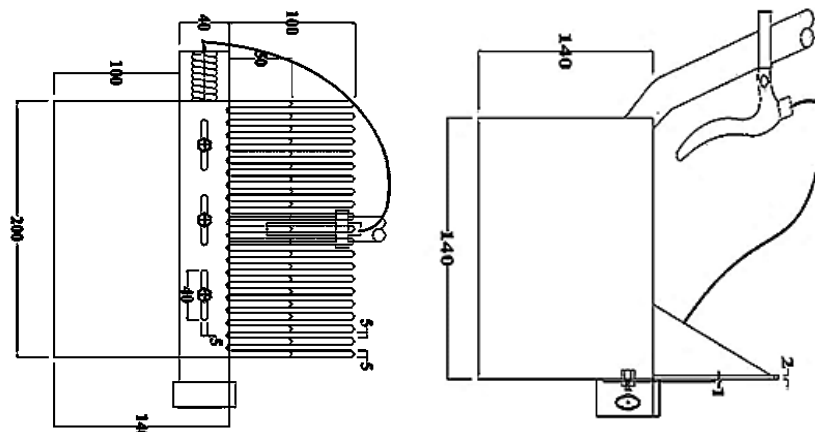


Figure 1 Geometric drawing of the developed picking comb (Dim. In mm.)

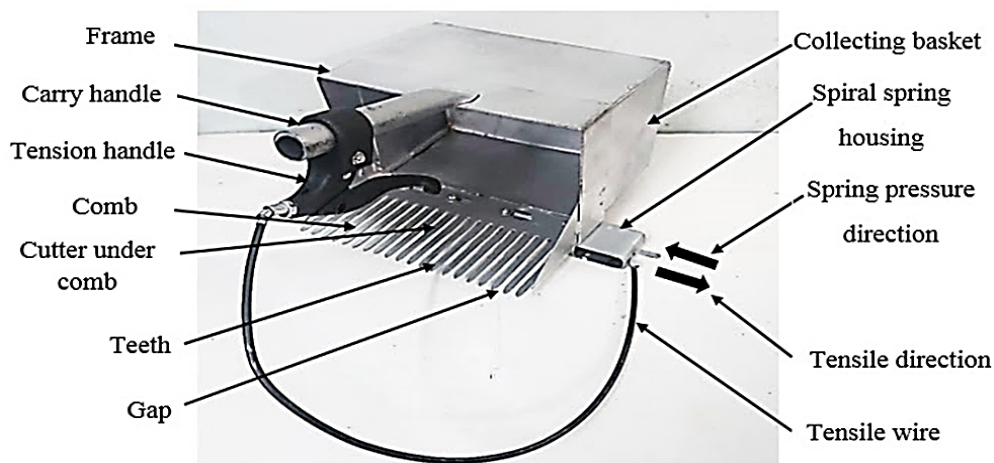


Figure 2 The developed comb for picking chamomile flowers

2.6 Experimental variables and performance parameters

Preliminary experiments were designed to evaluate the performance of the manual picking machine, focusing on two main variables:

Four different types of comb gap widths: 4, 5, 6, and 7 mm.

Four different comb lengths: 50, 100, 150, and 200 mm. These experiments aimed to compare productivity and production costs between manual and

comb picking. Each experiment was repeated 10 times to measure the effect of the picking comb length and the comb gap width on the following metrics.

Figure 3 shows a picture from the field trial to evaluate the performance of the handheld chamomile picker, illustrating realistic harvesting conditions in the field and the machine's operation. The picture shows the realistic harvesting conditions in the field and how to operate the machine.



Figure 3 Performance evaluation of the manual chamomile picking machine

2.7 Evaluation criteria and equations

To assess the performance of the manual picking machine, the following criteria and equations were used:

Percentage of Damage (DF%): The percentage of damage (DF%) was evaluated using the equation by Agbetoye (2009):

$$DF (\%) = (md / mc) \times 100 \quad (4)$$

Where,

DF is damage percentage (%);

md is mass of the damaged flowers (kg);

mc is total mass of cut flowers (kg).

Picking Efficiency (η_p , %): The following equation was used to estimate the picking efficiency according to Agbetoye (2009):

$$\eta_p = ((mc - md) / mc) \times 100 \quad (5)$$

Where,

η_p is the picking efficiency of chamomile flowers (%);

md is mass of the damaged flowers.

Comb Productivity (*Pc*): Comb productivity (*Pc*) was determined using the following equation according to Mahmoud et al. (2021) and El-Sabaei et al. (2025):

$$Pc = mp / T \quad (6)$$

Where,

Pc is the output capacity (kg h^{-1});

Mp is total mass of the picked flowers (kg);

T is time taken (h).

Manually Productivity (*Pm*): Manually productivity was determined using the following equation (Abou El-Magd et al., 2023):

$$Pm = mp / T \quad (7)$$

Where,

Pm is manual productivity by one laborer (kg h^{-1});

Mp is total mass of the picked flowers (kg);

T is time taken (h).

2.8 Cost estimation

Depreciation rate (*D*): Depreciation rate was estimated using the following equation according to $D = (Pm - S) / Lm$, where: *D*: depreciation rate (L.E./year). *Pm*: Picking purchase price (estimated price = 150 L.E). *S*: salvage price (L.E) = 10% purchase price. *Lm*: Life-expectancy of the machine (10 years). Assumed that yearly operating days = 90 days/year and daily operating hours of 8 h.

Interest in Investment (*I*): Investment interest was estimated using the following equation:

$$I = ((Pm + S) \times i) / 2 \quad (8)$$

Where,

I is interest in investment (L.E. /year);

i is interest is compounded annually (rate/year).

Shelter, taxes, and insurance: These were assumed to be 5% of the machine purchase price.

Repair and maintenance: Costs were assumed to be 100% of depreciation costs.

Labor cost: This is defined as payment for an operator who operates the machine (L.E. h^{-1}). Labor wage (One laborer) = 10 L.E h^{-1} .

Production cost: This was calculated according to Abu-Elmaaty (2023): Production cost (L.E kg^{-1}) = Operation cost (L.E h^{-1}) / comb productivity (kg h^{-1}).

3 Results and discussion

This section analyzes the results obtained from field experiments conducted to evaluate the performance of the developed manual chamomile picking prototype. The evaluation assessed key operational parameters, including productivity, picking efficiency, and flower damage, alongside a cost-benefit analysis compared to traditional manual harvesting.

3.1 Comb productivity (P_c , kg h^{-1}) analysis

The productivity of the manual picking comb (P_c , kg h^{-1}) was evaluated across varying tooth lengths (50, 100, 150, and 200 mm) and gap widths (4, 5, 6, and 7 mm). Field trials identified a peak productivity of 14.88 kg h^{-1} , achieved with a 100 mm tooth length and a 5 mm gap width.

This performance peak is attributed to the 5 mm gap providing an optimal clearance that facilitates stem entry while preventing head slippage. Furthermore, the

100 mm length optimized the "collection volume" per stroke; it captured a maximum number of flowers while avoiding the branch entanglement and mechanical congestion observed with longer teeth (150-200 mm), which typically hinder the shearing process (Figure 4).

3.2 Percentage of flower damage (D_f , %)

Experimental results indicated a proportional relationship between the comb's geometric parameters and the percentage of flower damage. It was observed that increasing both tooth length and gap width led to a higher incidence of damage. The minimum damage recorded was 1.33%, achieved with a 5 mm gap width and the shortest tooth length of 50 mm.

This trend is attributed to the fact that longer teeth or wider gaps increase the intake of vegetative mass (branches and leaves) along with the flowers. This accumulation creates internal friction and mechanical pressure within the comb assembly, resulting in bruising before the shearing action is completed. Conversely, the smaller dimensions (50 mm length and 5 mm gap) facilitated selective picking, minimizing interaction with non-target plant parts and ensuring a cleaner cut (Figure 5).

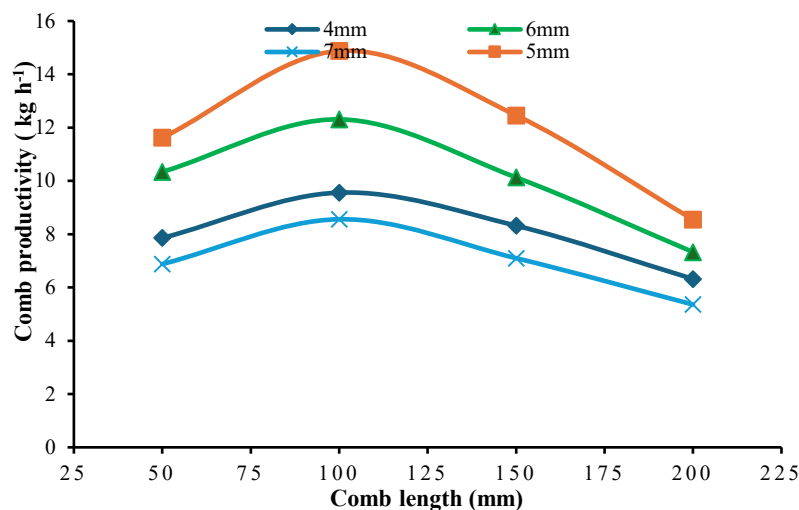


Figure 4 Picking comb productivity as affected by comb length and gap width

3.3 Picking efficiency (η_p , %)

Picking efficiency is a decisive parameter in validating the functional performance of the comb's geometry. The experimental results indicated that an increase in both tooth length and gap width beyond

certain limits led to a decline in picking efficiency, coupled with an increase in flower damage. The peak picking efficiency of 95.33% was achieved using a 100 mm tooth length and a 5 mm gap width.

This high efficiency confirms that these specific dimensions (100 mm and 5 mm) provide the optimal mechanical interaction; they allow for the maximum capture of flower heads per stroke while ensuring a

clean detachment without slippage. This balance effectively preserves the physical integrity of the flowers and enhances the overall quality of the harvested crop, as illustrated in Figure 6.

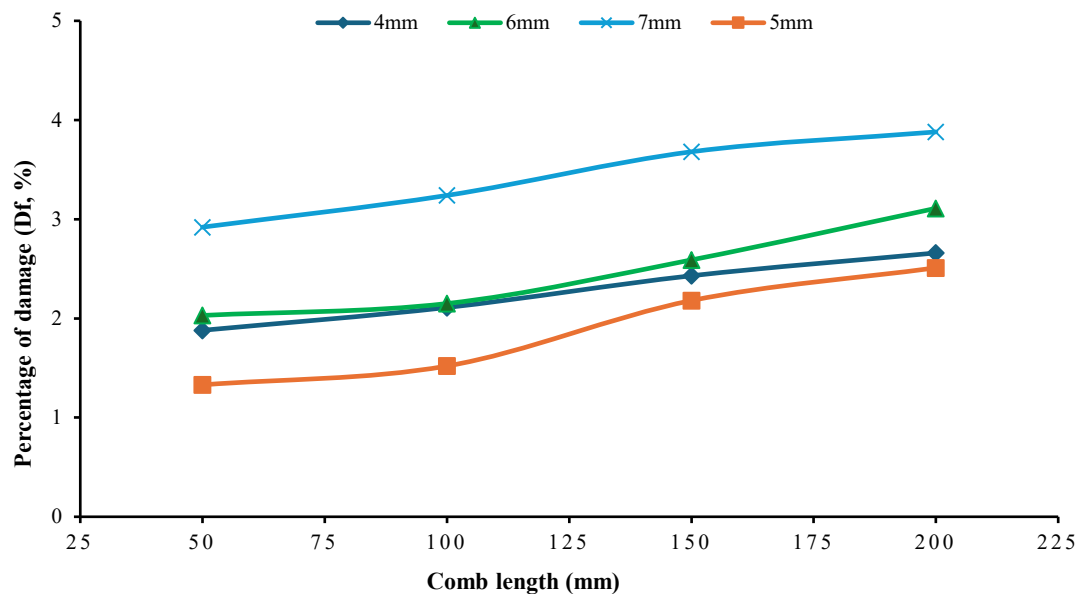


Figure 5 Average percentage of damage according to comb length and gap width

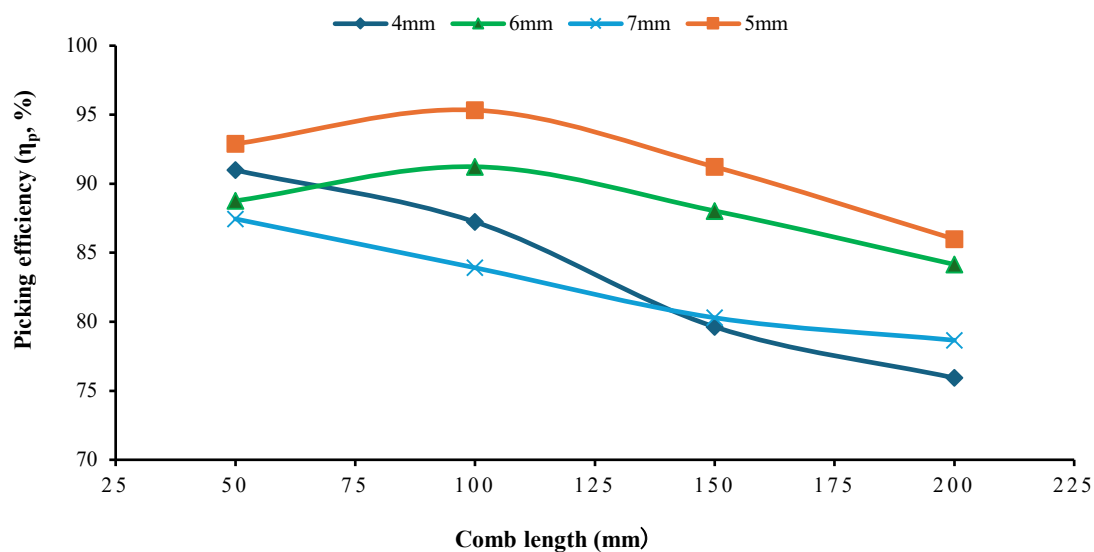


Figure 6 Average percentage of picking efficiency via comb length and gap width

3.4 Cost estimation

Following the technical evaluation, the economic feasibility of the manual picking comb was assessed. The costs of operating the chamomile picking comb were estimated. The costs of operating the manual chamomile picking comb were estimated, with total fixed costs amounting to 0.041 (L.E h⁻¹) and total variable costs amounting to 10.019 (L.E h⁻¹). Accordingly, the total cost for operating the machine under the same operating conditions was 10.060 (L.E

h⁻¹).

3.5 Comparison between manual picking and developed picking comb

A comparative analysis between traditional manual harvesting and the developed picking comb demonstrates a significant improvement in field performance. At its optimal configuration (100 mm length and 5 mm gap), the comb achieved a productivity of 14.88 kg h⁻¹, whereas the average productivity for a manual laborer was recorded at 4.68

kg h⁻¹. This indicates that the developed comb increases harvesting capacity by approximately 318% (or 3.18 times) compared to traditional methods. These findings confirm that the prototype offers high operational efficiency and lower production costs, providing a viable technological solution for chamomile growers.

3.6 Conceptual design of the portable chamomile picking machine

Based on the quantitative results obtained from the evaluation of the preliminary manual prototype, this section presents the conceptual design for a portable electric chamomile harvester. The experimental phase established that a 100 mm comb length and a 5 mm gap width represent the optimal configuration for balancing high productivity (14.88 kg h⁻¹) with maximum picking efficiency (95.33%) and minimal crop damage.

By integrating these validated dimensions with the comprehensive analysis of chamomile's physical properties specifically the mean stem diameter (1.16 mm) and required shearing force the proposed design aims to transition from manual operation to a synchronized, power-driven system. This conceptual model is engineered to enhance ergonomics, reduce operator fatigue, and maintain the high harvest quality achieved during preliminary testing.

3.7 General description and main components

The conceptual design of the portable chamomile harvester integrates several functional units engineered to operate in synchronization, ensuring high picking efficiency while minimizing flower damage. The detailed engineering layout, including elevation, plan, and side views, is presented in Figure 7, while the overall three-dimensional assembly is shown in the isometric drawing in Figure 8.

The machine's architecture consists of the following primary components:

The main frame: A lightweight structure designed to provide rigid support for all integrated units.

The picking and shearing mechanism: This assembly includes the optimized comb, the reciprocating cutting blade, and the rotating collecting brush.

The power transmission system: Comprising the drive shafts (axes) and gear reduction units required to convert motor torque into mechanical action.

The collection system: An integrated basket designed for easy detachment and crop storage.

Power source: A portable electric unit (rechargeable battery) to ensure field mobility and operational autonomy.

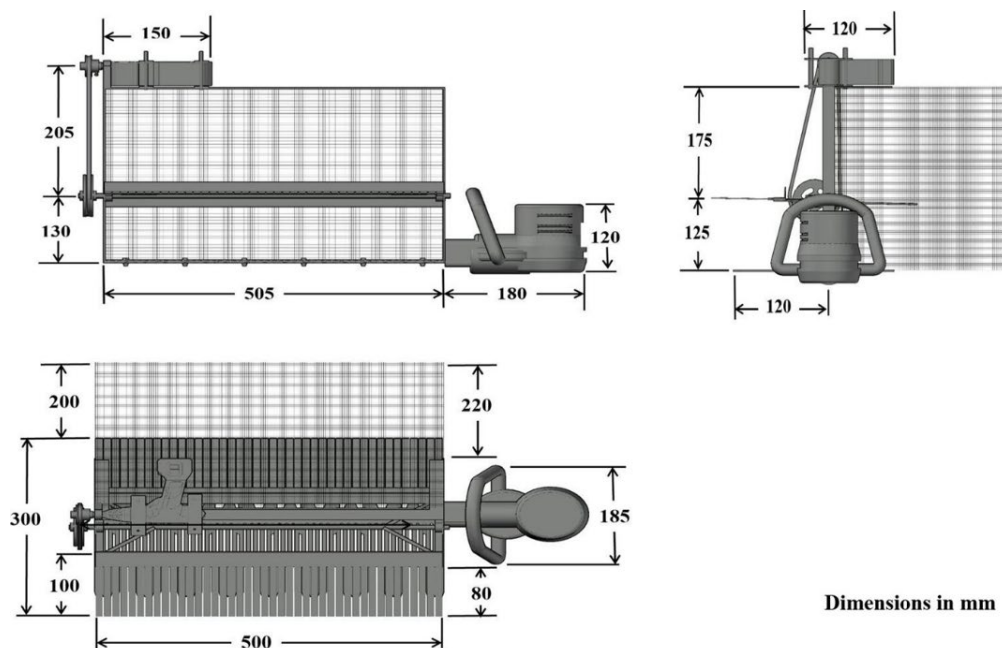


Figure 7 proposed design dimensions of the proposed chamomile flower picking machine

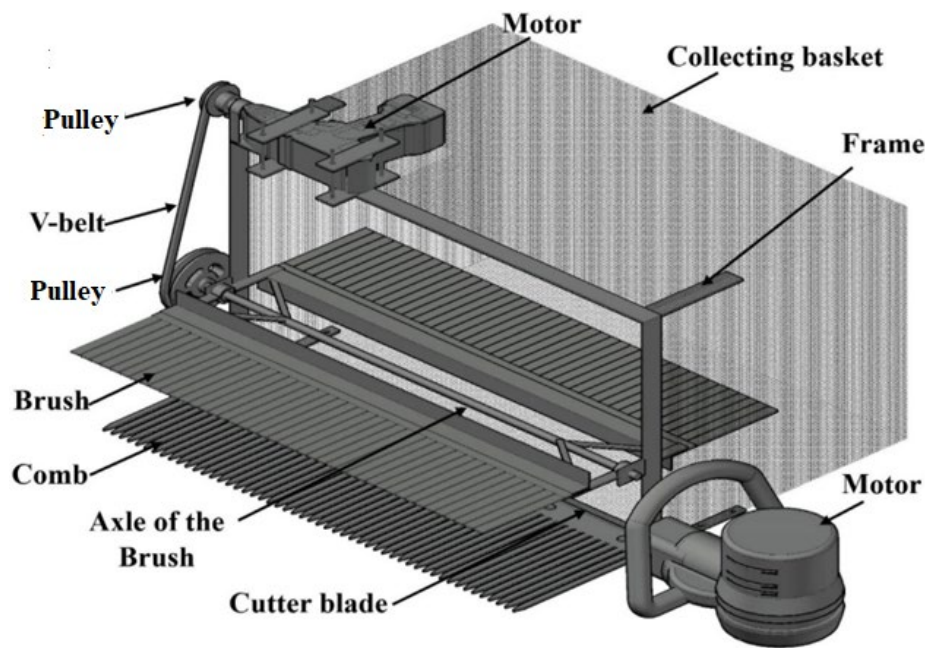


Figure 8 shows the proposed final design of the chamomile flower picking machine

3.8 Component details and operating principles

3.8.1 main frame

The frame of the picking machine is proposed to be constructed from rectangular flat steel strips (2×20 mm). Its main dimensions are estimated at approximately 505 mm in width and 305 mm in height. These dimensions are selected to provide a compact and lightweight platform capable of stably accommodating all components while ensuring ergonomic ease for the operator.

3.8.2 Picking mechanism

As the functional core of the machine, the picking mechanism is designed to align flower stems vertically and guide them toward the shearing zone.

Comb: The primary function of the comb is to gather the plant branches and secure the flowers at the top to facilitate shearing from below. It is proposed that the comb be fabricated from steel sections with a length of 500 mm and a thickness not exceeding 2 mm to balance durability with low weight. To allow for performance comparison, the design may include teeth with lengths ranging from 50 to 200 mm. While the tooth width is assumed to be constant at 5 mm, the gap between teeth is proposed to be variable within a range of 3 to 9 mm; these dimensions were determined based on preliminary experimental results to optimize picking efficiency and minimize damage. Furthermore,

the edge of each tooth is envisioned to be chamfered into an isosceles triangle (10 mm side length) to facilitate penetration through dense foliage. For maintenance and testing flexibility, the comb is designed to be easily detachable, fastened directly to the lower frame using a bolt assembly.

Cutting Blade: A dual reciprocating cutting blade (500 × 70 × 1 mm) is proposed to shear the aligned stems. The blade gaps are designed to align perfectly with the comb's teeth for precise cutting. Each blade is specified to be sharpened at a 30° angle. Power is intended to be derived from a 20V DC motor via a gear reduction system.

Collecting Brush: It is proposed that a rotary brush, composed of rubber fingers (100 mm long, 10 mm wide, and 2 mm thick), be integrated to guide the flowers and sweep them into the collection box after shearing.

3.8.3 Supporting units

Axis and Bearings: The horizontal brush axis is envisioned as a steel shaft (8 mm diameter, 550 mm length) mounted on a pair of bearings. It is preferred to be positioned 125 mm vertically above the comb to ensure effective flower collection.

Collecting Basket: The structure is proposed to be made of metal rods covered with a replaceable mesh fabric bag, with an estimated capacity of

approximately 5 kg.

Power Source: The design aims for the machine to rely on a shoulder-slung, rechargeable battery pack to ensure operational independence and mobility in the field.

3.9 Limitations and future work

While this study establishes a robust technical foundation for chamomile harvesting mechanization, certain limitations should be addressed in future research. First, the current performance data is based on a manual comb prototype; although it provides critical design parameters, the dynamic effects of a motorized system—such as high-frequency vibrations and their impact on flower damage—require further empirical investigation. Second, the conceptual design assumes a continuous power supply; future work should focus on optimizing battery endurance and weight distribution to ensure ergonomic safety for prolonged field use. Additionally, the influence of varying environmental factors, such as dew and stem moisture content, on picking efficiency remains to be tested. Subsequent research phases will involve the fabrication of the physical prototype and field testing under diverse agro-climatic conditions to refine the synchronization between the reciprocating blade and the rotary brush.

4 Conclusion

This research developed an integrated methodology for the conceptual design of a portable, low-voltage chamomile harvester, specifically engineered to bridge the gap between inefficient manual labor and costly large-scale machinery. The design criteria were fundamentally established based on a comprehensive analysis of the physical and mechanical properties of chamomile flowers and stems.

The performance evaluation of the preliminary prototype demonstrated a peak productivity of 14.88 kg h⁻¹, representing a 3.18-fold increase compared to traditional manual harvesting. Furthermore, the optimal configuration (100 mm tooth length and 5 mm gap) achieved a high picking efficiency of 95.33% with minimal crop damage, confirming the system's

technical and economic viability.

Integrating these experimental findings, the proposed conceptual design features a synchronized mechanism—comprising an optimized comb, reciprocating blade, and rotary brush—within a lightweight structure estimated at no more than 7 kg. Powered by a portable DC source, this harvester offers a flexible and ergonomically efficient solution, ensuring operational independence for small-scale chamomile farmers while maintaining high harvest quality.

5 Recommendation

Based on the performance evaluation of the manual prototype and the established conceptual design, this study recommends transitioning to the fabrication phase of a functional physical prototype. It is essential to conduct a comprehensive field evaluation of the electric harvester under diverse environmental conditions. Furthermore, the performance data should be rigorously analyzed and compared against the preliminary manual results to validate tangible improvements in harvesting efficiency. Such development will finalize a practical, high-efficiency solution tailored specifically for the operational needs of small-scale chamomile farms.

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