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Enhancing Aesthetics and Prolonging Lifespan of Cut Flowers with an Innovative Water Circulation Filtration System

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An innovative vase integrates a water circulation filtration system and an artistic design, aiming to prolong the lifespan of cut flowers while enhancing their aesthetics. Its cylindrical shape, featuring inlet and outlet water holes at the base, connects seamlessly to the filtration system, ensuring continual water filtration and recirculation. The frosted ceramic surface of the vase conceals stems, visually enhancing floral arrangements and harmonizing with the flowers and the vase itself. With a removable base facilitating easy cartridge replacement and maintenance, two separate water channels supply the internal filtration system. Its unidirectional piston controls water reservoirs and manages water flow. Experimentally, this vase significantly prolongs the longevity of diverse types of flowers. Lilies and carnations exhibit elevated aperture, water content, and antioxidant capacity, with reduced bacterial counts and ethylene content compared with the cases of using other methods. Chrysanthemums display slightly lower bacterial counts and ethylene content, albeit with similar aperture, water content, and antioxidant capacity to those when using traditional methods. Proven benefits include equivalence or superiority to traditional water replacement methods for all flowers, minimizing preservative use, reducing water consumption and bacterial growth, fostering living water, and ensuring the survival of larvae. This interdisciplinary design serves as a practical example for education and exemplifies innovation in extending the lifespan of cut flower and enriching floral aesthetics.

1. Introduction

With the development of technology, global environmental conservation awareness is rising. In daily life, flowers are used to convey emotions at weddings, funerals, celebrations, and other occasions. Cut flowers refer to flowers or inflorescences that are cut from plants and are usually

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used as decorations, gifts, or sacrifices. The cut flower industry is a high-value-added industry. According to statistics, the global cut flower market reached approximately US$40 billion in 2020. However, the lifespan of cut flowers is limited and it is not easy to keep flowers fresh in daily life. Once they are cut from plants, problems such as water loss, cell aging, ethylene release, and microbial infections begin to occur. The sludge in municipal wastewater and industrial wastewater contains a huge amount of organic matter and must be treated through engineering so that the sludge can be decomposed and rendered friendly to the environment.[1–3] Contaminated water in vases can also reduce the quality and longevity of cut flowers. Therefore, how to extend the lifespan of cut flowers and reduce the negative impact of flower arrangements on the environment is particularly important.

It is the wish of many scientists to make people's lives more pleasing and blissful through technology. Flower arrangements require the regular maintenance of cut flowers, water changes, and preservatives; otherwise, they can lead to bacterial growth, larval breeding, unpleasant odors, and even a reduction in the lifespan of flowers. These tedious steps required to maintain flowers deter many people from keeping flower arrangements. Internet of Things and information and communication technology are integrated to build a smart farm watering system to reduce manpower, save water, and improve the quality of agricultural products.[4] An environmental control system for a smart household is proposed to provide people with a comfortable and protective environment at work and home.[5] The tedious household chores of flower arrangement can also be accomplished through cross-domain integration design, making the aesthetics of flower arrangement easier to achieve at home.

In this study, we integrate interdisciplinary expertise to rapidly propose solutions and verify their feasibility. We design an automatically timed water circulation and filtration flower vase based on the concept of water cultivation. Water purification is achieved by filtering and treating the water in the vase. In the experiment, we compare the outcomes of no water change, traditional water change, and using the water circulation filtration system. The experimental results show that the water circulation device extends the lifespan of cut flowers, saves water resources without changing water, and reduces the burden of using preservatives on the environment. In this study, we demonstrate how to integrate interdisciplinary knowledge in engineering, biology, and aesthetics, and hope to positively promote education in academia and contribute to a good environment.

2. Literature Review

Cut flowers are popular decorations and gifts, but their lifespan is short, usually lasting only a few days to a few weeks. The lifespan of cut flowers is affected by many factors, including the type and variety of flowers, the cutting time and method, water quality and quantity, temperature and light, nutrients and preservatives, and the presence of bacteria and ethylene. Therefore, how to extend the lifespan of cut flowers and improve their quality and value is an important issue for the cut flower industry and consumers.[6]

Bacterial presence can lead to xylem occlusion in cut flowers, impacting their longevity.[7] Currently, the life of cut flowers in a vase can be extended by adding various additives. Among the additives, sugar water is the most accessible to ordinary people. Sugar water can be used to improve the water absorption efficiency and quality of cut flowers.(8) Innovative methods that combine sugar water and plant hormones also help cut flowers to absorb water more efficiently and inhibit flower development to extend the vase life.(9) Other methods retard bloom development through various techniques, enhance water uptake, and reduce microbial activity in vase water.(10) However, untreated preservatives can adversely affect human health and the environment.(6) Some natural plant extracts have shown promise in maintaining postharvest flower quality and longevity,(11) yet a detailed cost analysis regarding this aspect remains unexplored.(12) Hence, it is urgently needed to develop a more environmentally friendly, convenient, and effective method to extend the lifespan of cut flowers.

The technology of water circulation filtration is mature but has not yet been used for the maintenance of cut flowers in a vase. Currently, water circulation filtration devices are mainly designed for aquaculture, aquariums, and ornamental fish breeding.(13,14) Therefore, there is still great space for the development of and potential for water circulation filtration technology, especially in the field of cut flowers. We designed an automatically timed water circulation filtration vase that uses the mature technology of the aquatic cultivation water filtration system to extend the lifespan of cut flowers in vases. The device uses the principle of water circulation to filter and disinfect the water in the vase before its return to the vase to improve the growth status of cut flowers.

In recent years, the principle of water circulation has been applied in fields such as aquaculture, aquariums, and ornamental fish breeding for tasks such as filtering, disinfecting, and heating the water before returning it to containers to improve water quality. This method is called water circulation filtration, the principle of which is similar to biological filtration.(15)

Biological filtration is a method in which microorganisms are used to form a biofilm on the filter medium to remove organic and inorganic substances from water through physical separation, adsorption, and biodegradation. This method has been widely used in drinking water and wastewater treatment.(6) This principle was adopted in an automatically timed water circulation vase designed to effectively solve the problems of frequent water changes and environmental damage. The study is aimed at further exploring the application of water circulation filtration devices in the field of cut flowers and attempts are made to solve the following problems: (1) the design and optimization of water circulation filtration devices; (2) the elucidation of the effects of water circulation filtration devices on different types and varieties of cut flowers; (3) the evaluation of the benefits of water circulation filtration devices; (4) the integration of water circulation filtration devices with cross-domain integration design. We hope that the findings of this study will benefit the cut flower industry and consumers.

3. Process of Cross-domain Integration Design

Research on applying water circulation systems to vases must first examine design requirements from an engineering perspective. After completing a prototype of an automatically water circulation and filtration vase, biological technology experiments and records should be planned to prove that the benefits to cut flowers are better than those of traditional water replacement methods. Then, through aesthetic considerations and craftsmanship, the product can be developed for commercialization or replication. This is both practical and aesthetically valuable, as it extends the lifespan of cut flowers. The overall experiment involves a comparison of traditional water replacement with automatic water circulation methods to verify whether such circulation methods can improve the maintenance of cut flowers.

The impurities and bacteria in vases can cause cut flowers to rot and wither. Therefore, to keep cut flowers fresh and beautiful for a longer period of time, the amounts of impurities and bacteria in the water must be reduced to extend the lifespan of cut flowers. In addition, the device should also reduce the frequency of water replacement, thereby saving water resources and manpower while reducing the survival environment for mosquitoes.

3.1 Design of water circulation filtration vase

We investigate a method of using a water circulation system to filter and clean the water in the vase to extend the lifespan of cut flowers. The device includes a water pump to extract water from the vase and return it to the vase after passing through a filtration system. Various filtering materials can be used in the filtration system, such as activated carbon, ceramic filters, or other materials that can remove impurities from the water.[6] The first step is to screen the vase function by the Kawakita Jiro method with experts, evaluate the general direction by 3D modeling, and finally evaluate the electronic circuit engineering.[16] Then, the relevant modeling parts, filter materials, motors, chipsets and other electronic parts are assembled into the finished device after testing. The developed water circulation filtration device is shown in Fig. 1.

To enhance the freshness of flowers, this vase integrates a water filtration system. It employs Arduino Nano and a 5 V relay to power the pumping motor, facilitating water circulation

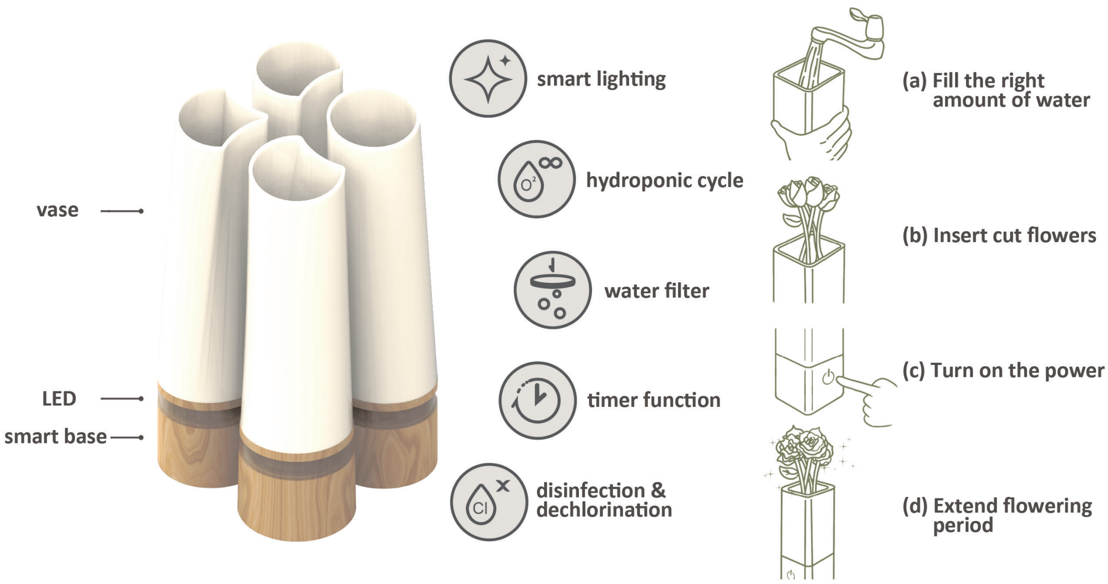

Fig. 1. (Color online) Form and functions of the vase.

through the filter. Subsequently, the purified water returns to the vase, maintaining optimal flower freshness. Additionally, LED mood lights (WS2812B light strip) adorn the vase, enhancing the home ambiance. These lights, combined with a wireless charging module, eliminate wire entanglement during vase cleaning, ensuring convenience in daily use. The detail components of the developed water circulation filtration device are illustrated in Fig. 2.

3.2 Program design of water circulation filtration vase

An automatic water circulation filtration system is used to achieve timed water filtration with a mini water pump driven by a developed circuit board. The system is equivalent to that of water circulation. Figure 3 shows the assembly of electrical components.

The required sensors and the components of the water circulation filtration system are assembled and driven by scripting. Table 1 shows the programs of sensors, and the practical functions are as follows.

(1) The LED light strip is set to synchronize with the start of water circulation.
(2) The time is set as follows: circulate water for 3 min to filter impurities through filter cotton, then turn off the water pump for 1 h because it does not need to be operated continuously.
(3) The wireless charging module can clean the entire vase. The vase and base can be separated.
(4) The base is equipped with a lithium battery, so the vase can be moved freely without worrying about wires.

4. Vase experiments with cross-domain integration design

4.1 Experimental materials

The purpose of this experiment is to investigate the mechanism and rules of the effects of water circulation filtration devices on the lifespan of cut flowers of different types and varieties.

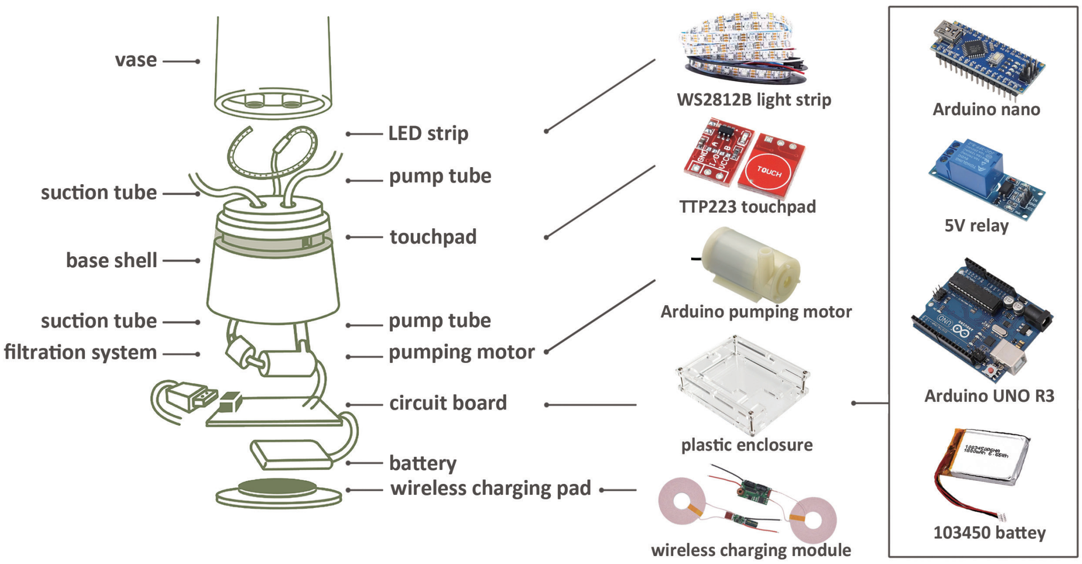

Fig. 2. (Color online) Sensors and components of the water circulation filtration vase.

Fig. 3. (Color online) Assembling electrical components on a circuit board.

Four common types of cut flowers were selected for the experiment: roses, lilies, carnations, and chrysanthemums. Two treatment methods, water circulation filtration device and traditional water replacement method, were investigated, and a control group (no water replacement) was set up. The following parameters were measured in this experiment: degree of flower opening, water content, bacterial count, ethylene content, and antioxidant capacity. The experiment lasted for 14 days with the daily measurement of parameters and the recording of changes in the appearance of cut flowers.

4.2 Experimental methods

The primary objective of this study is to validate the automatic water circulation filtration method as a replacement for the traditional water replacement approach. Therefore, in the filtration cycle setting, we assume a hypothetical parameter of 3 min of filtration followed by 1 h of rest; future research can focus on exploring the parameters for optimal filtration efficiency. The experimental procedure is as follows.

(1) Randomly distribute each type of cut flower into 3 groups, each containing 3 stems. These groups correspond to the water circulation filtration system, conventional water replacement, and the control group (no water change).
(2) Place cut flowers from each group into identical vases, adding 500 ml of tap water to each.
(3) Connect vases to the water circulation filtration system, configuring filtration parameters to circulate water hourly with 3 min cycles.
(4) For the group with conventional water replacement, trim stems of the flowers daily by 1 cm and replace water.

Table 1
Developed components of water circulation filtration device.

(a) Initial program setup

```
#include <FastLED.h>
#define senser_Pin 3 // sensor pins
#define Pump_PIN 6      // pump terminals
#define LED_PIN 9    // LED light pins
#define NUM_LEDS 60  // How many LEDs are there
#define BRIGHTNESS 100  // brightness setting
#define LED_TYPE WS2811
#define COLOR_ORDER GRB

void setup() {
   delay( 3000 );
   FastLED.addLeds<LED_TYPE, LED_PIN, COLOR_
   ORDER>(leds, NUM_LEDS);
   FastLED.setBrightness(BRIGHTNESS);
   Serial.begin(9600);
   pinMode(senser_Pin, INPUT);
   pinMode(Pump_PIN, OUTPUT);
   digitalWrite(Pump_PIN, ledState);
   PLStartTime = millis();
}

void loop() {
   int reading = digitalRead(senser_Pin);
   if (reading != lastButtonState) {
      lastDebounceTime = millis();
   }
   if ((millis() - lastDebounceTime) >
debounceDelay) {
      if (reading != buttonState) {
         buttonState = reading;
         if (buttonState == HIGH) {
         ledState = !ledState;
         }
      }
   }
   if (ledState == HIGH) {
      digitalWrite(Pump_PIN, HIGH);
      turnoff();
   }
   else if (ledState == LOW) {
      LedPump();
   }
   lastButtonState = reading;
}
```

(b) Timer switch for water pump settings

```
// Customize the pump 'on' time (1000=1 second)
int PLOnTime = 5000;
// Customize the pump 'off' time (1000=1 second)
int PLOffTime = 3000;
int PLstate = HIGH;
int PLStartTime ;
int PLDuration;

void LedPump() {
   PLDuration = millis() - PLStartTime;
   // Serial.println(PLDuration);

   if (PLDuration >= PLOnTime && PLstate == HIGH
   ) {
      Serial.println("pump stop!");
      digitalWrite(Pump_PIN, HIGH);

      // Red, Green, Blue
      fill_solid(leds, NUM_LEDS, CRGB(200, 200,
      200));
      // adjust the brightness of the light
      strip
      FastLED.setBrightness(BRIGHTNESS);
      FastLED.show();

      PLstate = LOW;
      PLStartTime = millis();
   }
   else if (PLstate == HIGH) {
      breath();
   }
   else if (PLDuration >= PLOffTime && PLstate
   == LOW ) {
      Serial.println("pump start!");
      digitalWrite(Pump_PIN, LOW);
      PLstate = HIGH;
      PLStartTime = millis();
   }
}
```

(5) The control group vase remains untreated.
(6) Maintain all vases in the same indoor space at around 25 ℃ with consistent lighting.
(7) Measure the following parameters daily:
   (7.1) *Flower opening degree*: Measure the maximum and minimum diameters of flower blooms with a ruler and calculate their average.

Table 1
(Continued) Developed components of water circulation filtration device.

(c) Parameters for light

```
// Change the light color here
const TProgmemPalette16 myProgmemPalette
PROGMEM = {CRGB::DarkSlateBlue};

int breathing = 0;
int fadeAmount = 5; // Adjust breathing
variation (non-speed)
CRGB leds[NUM_LEDS];

int ledState = HIGH;   // the current state of
the output pin
int buttonState; // the current reading from the
input pin
// the previous reading from the input pin
int lastButtonState = LOW;
// the last time the output pin was toggled
unsigned long lastDebounceTime = 0;
// the debounce time; increase if the output
flickers
unsigned long debounceDelay = 50;
```

(d) Scripting for light (strip)

```
void breath() {
   breathing = breathing + fadeAmount;
   if (breathing <= 0 || breathing >= 255) {
      fadeAmount = -fadeAmount;
   }
   delay(30);
   fill_palette (leds, NUM_LEDS, 0, 0,
   myProgmemPalette, breathing, LINEARBLEND );
   FastLED.show();
}

// Turn off the light strip
void turnoff(){
   fill_solid(leds, NUM_LEDS, CRGB(0, 0, 0));
   FastLED.show();
}
```

(7.2) *Cut flower water content*: Weigh cut flowers on an electronic balance to determine their fresh and dry weights, and calculate their water content.

(7.3) *Bacterial count at flower ends*: Measure the bacterial count at the cut ends of the stems by the microbiological agar plate method and calculate the bacterial count per gram of fresh weight.

(7.4) *Ethylene content in flower blooms*: Measure the ethylene content in flower blooms by gas chromatography and calculate the ethylene content per gram of fresh weight.

(7.5) *Antioxidant capacity of cut flowers*: Measure the antioxidant capacity of flower blooms by the 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical scavenging method and calculate the antioxidant capacity per gram of fresh weight. Record daily flower changes and take photos for documentation.

The following methods were employed to measure the bacterial count, antioxidant capacity, and ethylene content in the water of the vases:[17]

(1) Bacterial Count: Bacterial counts at the cut ends of the flowers were determined by the microbiological agar plate method, and the bacterial count per gram of fresh weight was calculated.[17,18] This method involved diluting water samples from the cut ends of the flowers, plating them on agar plates containing a suitable medium for bacterial growth, and incubating them in a constant-temperature chamber for a specified period. The breeding bacteria were observed and counted.

(2) Antioxidant Capacity: The antioxidant capacity of the flowers was measured by the DPPH free radical scavenging method, and the antioxidant capacity per gram of fresh weight was calculated. Water samples from the flowers or ethanol extracts were mixed with a solution containing DPPH free radicals, and the absorbance was measured in an ultraviolet/visible

spectrophotometer. The free radical scavenging rate was then calculated using the changes in absorbance.

(3) Ethylene Content: The ethylene content at the flowers was measured by gas chromatography and the ethylene content per gram of fresh weight was calculated.[17] The flowers were placed in a sealed container, and a specific volume of gas sample was extracted with a syringe and injected into a gas chromatograph. The ethylene content was calculated from the peak area in the chromatogram.

5. Results and Discussion

The water circulation filtration vases with an automatically timed water filtration system used in this study are shown in Fig. 4. To maintain consistency in the experimental conditions and parameters, four vases were produced, one for each of the four varieties: roses, lilies, carnations, and chrysanthemums. These were used simultaneously in the experiments to reduce inconsistencies arising from factors such as time and environment, thus enhancing the reliability of the experimental data.

Tables 2–5 show the results for roses, lilies, carnations, and chrysanthemums. According to the data in these four tables, it is evident that the water circulation filter device has a significant effect on the longevity of carnations and can improve their physiological or biochemical status. Among the flowers, carnations showed the most notable response, with significant improvements in aperture, water content, and antioxidant capacity. The water circulation group outperformed

(a) (b)

Fig. 4. (Color online) Flower vases with water circulation device.

Table 2
Results for roses.

Variety	Color	Treatment method	Aperture (cm)	Water content (%)	Bacterial count (/g)	Ethylene content (μg/g)	Antioxidant capacity (%)
rose	red	water circulation filtration system assembly	6.5 ± 0.3	86.2 ± 1.2	$1.2 \times 10^4 \pm 0.8 \times 10^4$	0.8 ± 0.1	72.3 ± 2.1
rose	red	traditional water replacement method set	5.8 ± 0.4	82.5 ± 1.5	$3.5 \times 10^4 \pm 1.2 \times 10^4$	1.2 ± 0.2	65.4 ± 3.2
rose	red	control group (no water change)	4.6 ± 0.5	76.3 ± 2.3	$9.8 \times 10^4 \pm 2.5 \times 10^4$	2.1 ± 0.3	54.6 ± 4.3

Table 3
Results for lilies.

Variety	Color	Treatment method	Aperture (cm)	Water content (%)	Bacterial count (/g)	Ethylene content (μg/g)	Antioxidant capacity (%)
lily	white	water circulation filtration system assembly	7.2 ± 0.4	88.4 ± 1.4	$1.5 \times 10^4 \pm 0.9 \times 10^4$	0.7 ± 0.1	74.5 ± 2.3
lily	white	traditional water replacement method set	6.6 ± 0.5	84.7 ± 1.6	$4.2 \times 10^4 \pm 1.3 \times 10^4$	1.1 ± 0.2	67.6 ± 3.4
lily	white	control group (no water change)	5.3 ± 0.6	78.5 ± 2.4	$11.3 \times 10^4 \pm 2.8 \times 10^4$	2.3 ± 0.4	56.8 ± 4.5

Table 4
Results for carnations.

Variety	Color	Treatment method	Aperture (cm)	Water content (%)	Bacterial count (/g)	Ethylene content (μg/g)	Antioxidant capacity (%)
carnation	pink	water circulation filtration system assembly	5.9 ± 0.3	85.6 ± 1.3	$1.3 \times 10^4 \pm 0.7 \times 10^4$	0.9 ± 0.1	70.2 ± 2.2
carnation	pink	traditional water replacement method set	5.3 ± 0.4	81.8 ± 1.4	$3.8 \times 10^4 \pm 1.1 \times 10^4$	1.3 ± 0.2	63.3 ± 3.3
carnation	pink	control group (no water change)	4.2 ± 0.5	75.6 ± 2.2	$10.5 \times 10^4 \pm 2.6 \times 10^4$	2.4 ± 0.3	52.5 ± 4.4

Table 5
Results for chrysanthemums.

Variety	Color	Treatment method	Aperture (cm)	Water content (%)	Bacterial count (/g)	Ethylene content (μg/g)	Antioxidant capacity (%)
chrysanthemum	yellow	water circulation filtration system assembly	5.4 ± 0.2	83.9 ± 1.1	$1.4 \times 10^4 \pm 0.6 \times 10^4$	1.0 ± 0.1	68.7 ± 1.9
chrysanthemum	yellow	traditional water replacement method set	5.2 ± 0.3	81.2 ± 1.3	$3.9 \times 10^4 \pm 1.0 \times 10^4$	1.4 ± 0.2	61.8 ± 2.8
chrysanthemum	yellow	control group (no water change)	4.1 ± 0.4	74.3 ± 2.1	$10.7 \times 10^4 \pm 2.7 \times 10^4$	2.5 ± 0.3	50.6 ± 3.9

the traditional water replacement group in these aspects. Additionally, bacterial counts and ethylene content were lower in the water circulation group than in the traditional water replacement group. The benefits of using a water circulation filter device are significant.

According to the data tables, the water circulation filter device has a relatively weak effect on the longevity of chrysanthemums and does not significantly improve their physiological or biochemical status. Among the flowers, yellow and white chrysanthemums showed a general response, with no significant differences in aperture, water content, and antioxidant capacity compared with traditional water replacement methods. However, bacterial counts and ethylene content were slightly lower in the water circulation group than in the traditional water replacement group. It was also found that the water circulation filter device can reduce the triviality of traditional water replacement methods and save water resources while maintaining the same duration of cut flower growth.

Overall, the water circulation filter device has a significant effect on the longevity of different types and varieties of cut flowers and can improve their physiological or biochemical status. Among them, lilies and carnations showed more significant responses, with higher aperture, water content, and antioxidant capacity than with other treatment methods, while bacterial counts and ethylene content were lower than with other treatment methods. The response of chrysanthemums was relatively weak, with no significant differences in aperture, water content, and antioxidant capacity compared with traditional water replacement methods. However, bacterial counts and ethylene content were slightly lower than with traditional water replacement methods. Therefore, it is proved that an automatically timed water filtration vase has benefits greater than or equal to traditional water replacement methods for all four flower species. It also minimizes the use of preservatives, reduces water usage and bacterial growth, produces viable water, and does not harm larval survival.

6. Conclusions

The vase presented herein combines a water circulation filtration system with an innovative design to extend the lifespan of cut flowers while augmenting their aesthetics. Its key attributes encompass a cylindrical shape with inlet and outlet water holes, ensuring connection to the filtration system for improved physiological conditions. The frosted ceramic surface conceals stems, enhances visual appeal, and complements floral color schemes. Additionally, its removable base enables easy cartridge replacement and maintenance, with separate water channels facilitating internal water circulation. The vase features a minimalist design adaptable for various occasions, and its color and size flexibility cater to diverse flower arrangements. This product not only extends flower lifespan and enhances quality but also serves as an interdisciplinary example for teaching and learning.

The water circulation filter device significantly impacts the longevity and physiological status of various flowers. Lilies and carnations exhibit marked improvements in aperture, water content, and antioxidant capacity while reducing bacterial counts and ethylene content. Chrysanthemums, although showing a weak response, exhibit lower bacterial counts and ethylene content than with traditional water replacement methods. The timed water filtration vase proves equally beneficial or superior to traditional methods across flower species, minimizing the use of preservatives, reducing water usage, inhibiting bacterial growth, promoting a more natural environment, and sustaining larval survival.

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