

## Research and Application of Airlift Pump to Operate Aquaponics

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### ABSTRACT

This paper presents the results of a study on the use of an airlift pump in aquaponics, a model that has been applied and developed for organic food production. Airlift pumps, which are commonly used in the mining industry for pumping liquids such as water and oil, have recently been adopted for use in aquaponics systems. Airlifts offer several advantages over other types of pumps, including a simple and compact design with no moving parts, making them suitable for hanging systems in shallow water. Airlifts also play a dual role in transporting liquids and saturating dissolved oxygen content in water, which is essential for the organisms in the aquaponics system to thrive. To promote these benefits, it is crucial to choose the correct mode of operation for the aeration pump; otherwise, it may decrease efficiency and increase operating costs. In this study, an airlift pump, which combines an aquaponic pump, aerator, and duct system into one compact unit, was used. The experiment was conducted using a riser pipe of different diameters ( $D = 24, 30, 36, 48$  mm), a height ( $h + H$ ) of 2000 mm, an air pipe with a diameter of 15 mm, compressed air pressure ranging from 0.5 to 4.0 kg/cm<sup>2</sup>, gas consumption ( $V$ ) between 0.1 to 1.0 m<sup>3</sup>/h, and a pump capacity ( $Q$ ) of 5-39 L/min. The results show that the greatest lifting height can be achieved with a riser pipe diameter of 30-36 mm. At an airflow rate of 0.8-0.9 m<sup>3</sup>/h and various compression pressures, the dip coefficient of 0.285 produces a maximum pumping capacity of 25-30 L/min.

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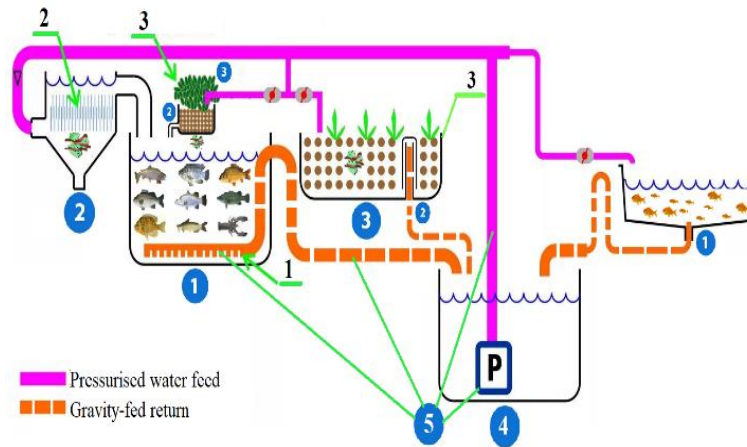
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## 1. Introduction

Aquaponics, a sustainable ecosystem, has been widely adopted in organic farming in many countries around the world, based on the circular economy model. The system comprises of three fundamental components: aquaculture (1), biofilters (2), and hydroponics equipment (3) (Figure 1). Additionally, the system includes a sump tank (4), a pump, and a pipe that connects the primary components, as well as an aerator unit (5). Aquaponics is considered to be a dependable, water-saving ecosystem that is suitable for freshwater shortages caused by climate change [1]. Aquaponics does not rely on chemical fertilizers or pesticides and generates no waste, making it a safe option for consumers. Waste from the aquaculture component consists of uneaten food and  $\text{NH}_3/\text{NH}_4^+$ , which is converted into nitrite  $\text{NO}_2^-$  by aerobic bacteria (Nitrosomonas, Nitrobacter) in the biofilter. The nitrite is then converted into nitrate  $\text{NO}_3^-$ , a nutrient that is beneficial for plants in the hydroponic system. Simultaneously, aquatic animals raised in the aquaculture component are fed by plants grown in the hydroponic system, which also absorb and convert greenhouse gas  $\text{CO}_2$  and nutrients from the biofilter into biomass, while providing the necessary oxygen for the entire system, including aerobic bacteria in the biofilter, aquatic animals in the aquaculture component, and plants in the hydroponic system [2]-[6].

The use of such systems, which is becoming increasingly popular, allows for the provision of oxygenated water to both aquarium plants and aquatic life simultaneously. However, the amount of information available on the design and operation of aeration pumps is limited [7]-[9], leading to low efficiency. Therefore, the structural and technological parameters required for the design and operation

of aerolifts in aquaponics, such as lift pipe diameter ( $d$ ), embedded coefficient ( $\alpha = \frac{h}{h+H}$ ), and the required gas flow rate ( $V$ ), should be selected based on experimental data.

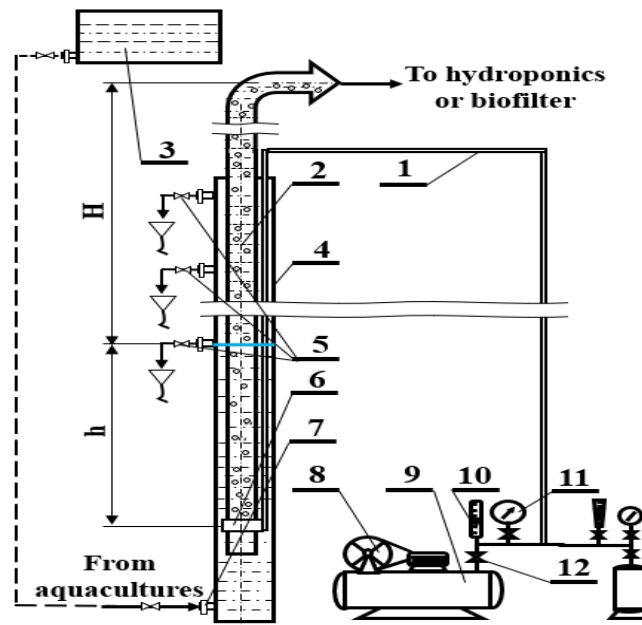


**Figure 1.** Structure of aquaponics: 1-aquaculture; 2-biofilters; 3-hydroponics equipment; 4-sump tank; 5-aerator unit

## 2. Experimental Equipment and Methods

### 2.1. Experimental diagram

The experimental setup and schematic diagram are depicted in Figure 2. Aerolifts were utilized, consisting of a riser pipe (2) with dimensions of  $D \times H$ , which housed the cylindrical air nozzle (6) measuring  $15 \times 20$  mm and an air pipe (1). These components were located in the cylindrical pump well (4) with a diameter of 90 mm. A liquid level adjustment valve (5) was included in the pump well (4) to regulate the embedded height ( $h$ ) and embedded coefficient ( $\alpha$ ).



**Figure 2.** Experimental diagram: gas pipe (1), lift pipe (2), high-performance container (3), pump well (4), level adjustment valve (5), air diffuser (6), water supply pipe from aquaculture (7), compressor (8), compressed air tank (9), gas flow meter (10), compressed air pressure gauge (11), and pressure adjustment valve (12)

Gas with a pressure of  $P$  ( $\text{kg}/\text{cm}^2$ ) was supplied by a 1.5 Hp compressor (8) and a 500-liter gas tank (9). The gas was dispersed into the foam to form an emulsion system, the density of which decreased with increasing gas flow rate  $Q$  (measured by gas flowmeter 10). The emulsion mixture rose in the riser pipe (2) and separated into gas and liquid streams that flowed into the hydrologic or biofilter.

### 2.1. Experimental method

When operating aquaponics, two main quantities must be determined: liquid flow  $Q_3$  ( $m^3/h$ ) and lifting height ( $h+H$ ) to achieve maximum capacity and efficiency. This requires the consideration of a complex three-phase flow consisting of solid, liquid, and gas, which depends on several factors, with the most important being lift pipe diameter, dip coefficient, and gas flow rate. These dependencies must be determined experimentally.

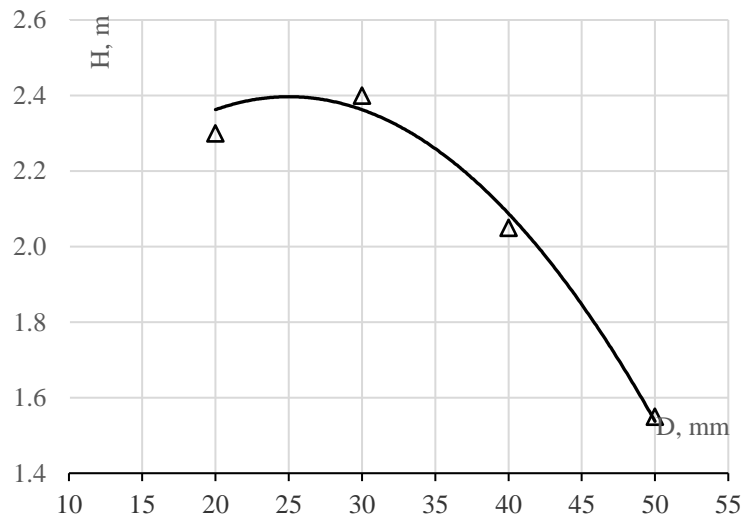
The experiment was conducted in several steps, as shown in Figure 2. First, three lift pipes with different diameters ( $D$ ) of 24mm, 30mm, 36mm, and 48mm were installed. Second, valve 5 was opened to adjust the dip depth ( $h$ , mm) for each lift pipe size, resulting in corresponding dip coefficients of 0.285, 0.210, and 0.135 for sizes 24mm, 30mm, and 36mm, respectively. Third, water was taken from tank 3 and maintained at the level of regulator valve 5. Fourth, the compressed air pressure was adjusted from 0.5 to 4.0  $kg/cm^2$  in increments of 0.5  $kg/cm^2$ . Finally, gas flow ( $V$ ,  $m^3/h$ ) was adjusted through manometer 11 and valve 12 to values of 0.1, 0.2, 0.4, 0.6, 0.8, and 1.0 for each value of gas flow  $V$ , the liquid flow  $Q$  (liters/min) was measured three times to obtain the average value and the measurement results are analyzed by analysis of variance (ANOVA) with confidence probability greater than 95% ( $p < 0.05$ ).

The results of the experiment are presented in Figures 3, 4, and 5.

## 3. Results and Discussion

### 3.1. The effects of lifting pipe diameter on lifting height

The diameter of the lift pipe ( $D$ ) is a parameter that affects the lifting height ( $H$ ) of the pump and must be determined experimentally. The experimental data obtained is presented in Figure 3.

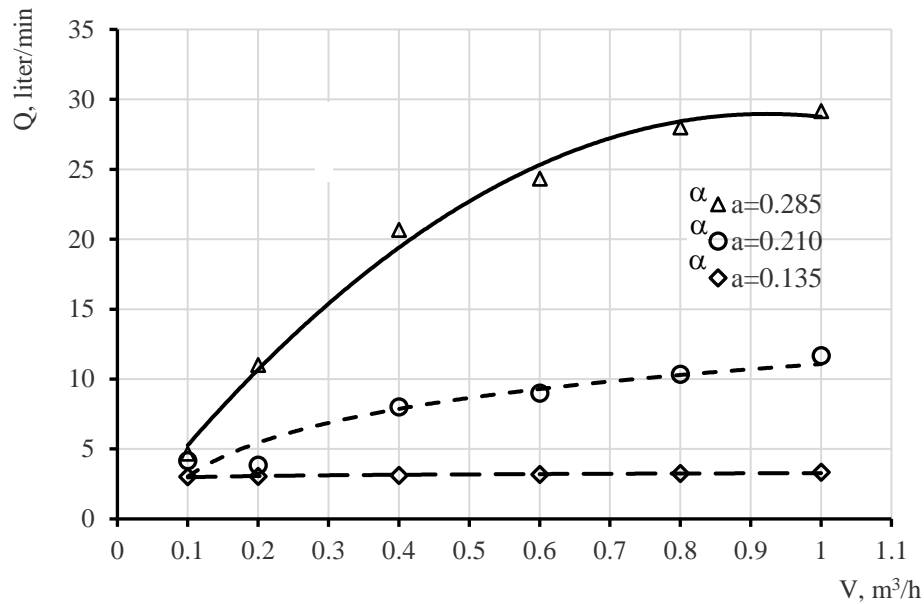


**Figure 3.** The dimensional dependence on the lifting pipe diameter ( $\alpha = 0.285$ ;  $P = 1.5 \text{ kg/cm}^2$ ;  $V = 1.0 \text{ m}^3/h$ ).

The obtained results indicate that increasing the pipe diameter, from 24 mm to 48 mm, leads to an initial decrease in the lifting height of the aeration pump, followed by a rapid decrease. To achieve the hydroponic device's height in aquaponics with values of 2.0-2.5 m, we recommend using an aerator pump with a lifting tube diameter of approximately 24-30 mm. It is crucial to note that the experiment was conducted under constant atmospheric pressure and temperature, while the other parameters such as water density and viscosity remained unchanged. As the pipe diameter increases, the increased liquid volume in the pipe combines with the inlet gas volume, forming an emulsion with a decreased gas concentration, which increases the density of the emulsion and decreases the lifting height. Furthermore, as the pipe diameter of the lifting doubles, the cross-sectional area and volume of the tube increase quadruple, resulting in a rapid decrease in the lifting height due to the substantial increase in the liquid amount.

### 3.2. The effects of dip coefficient on pump efficiency

When the dip coefficient  $\alpha=h/(h+H)$  is changed, the pump's efficiency varies as shown in the graph of Figure 4.



**Figure 4.** Variation of pump capacity according to airflow with different dip coefficients ( $P = 1.5 \text{ kg/cm}^2$ ;  $D = 30 \text{ mm}$ )

The results presented in Figure 4 indicate that the productivity of the aeration pump increases initially with an increase in gas flow for each dip coefficient, but reaches a maximum value beyond which further increase in gas flow causes a decrease in productivity.

An increase in gas flow led to an increase in gas content in the mixture, thereby reducing the density of the gas-liquid emulsion in the lifting tube. This reduction in density led to an increase in lift force and flow rate, resulting in an increase in the flow of liquid transported by the pump.

When the dip coefficient increased from 0.135 to 0.210 and 0.285, the pumped liquid flow increased correspondingly. The maximum yield was achieved at an dip coefficient of 0.285, which agrees with the theoretical prediction [8] that the optimal value is around 0.225 for an ideal suspension without solid particles. However, in practical aquaponics systems, solid particles such as leftover feed or feces can be present, which may cause deviations from the experimental results obtained with pure water [7], [8].

### 3.3. The effects of airflow on pump efficiency

The airflow rate had a significant impact on the efficiency of the aeration pump, as demonstrated by the experimental results presented in Figure 5.

The results presented in Figure 5 demonstrate that the efficiency of the aeration pump varies with changes in the gas flow rate, reaching a maximum value at a certain flow rate. Increasing the gas flow rate resulted in an increase in gas concentration, leading to a reduction in the density of the gas-liquid emulsion in the lifting tube. This reduction in density increases the lifting force and the flow rate, which in turn increases the flow of liquid transported by the pump. Additionally, the compressed air pressure has a significant impact on the pump's efficiency. Experimental data indicate that the maximum pumping capacity is achieved when the gas flow rate is between 0.7 to 0.9 m³/h. This value is lower than that reported in [8,9], possibly due to the presence of a solid phase content of (5 - 10)% in the suspension used in this experiment. Furthermore, the diameter of the lifting pipe in mining applications is typically larger, ranging from 40 to 300 mm.

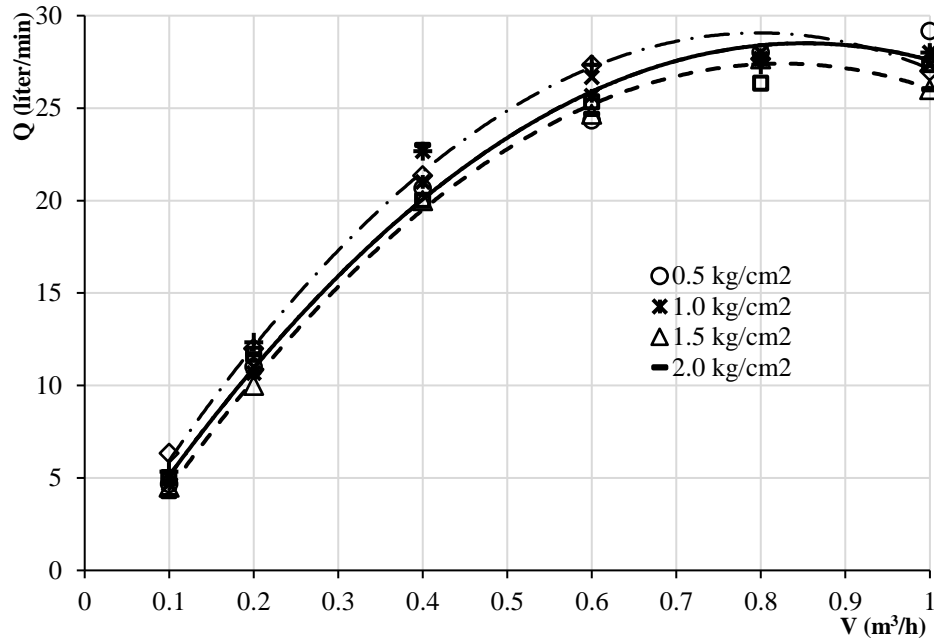


Figure 5. Dependence of pump capacity on airflow at different compression pressure ( $\alpha = 0.285$ ;  $P = 1.5$   $\text{kg/cm}^2$ ;  $D = 30$  mm)

#### 4. Conclusions

Based on the experimental results obtained, the following conclusions can be drawn:

- Using an aeration pump to transport water in an aquaponics system is convenient as it can transport the suspension liquid from aquacultures and saturate oxygen for beneficial water aerobic bacteria in the biofilter to perform the nitrification process  $\text{NH}_3/\text{NH}_4^+$  and aid in the growth of plants in hydroponics, as well as aquatic life in the aquacultures themselves.
- The liquid in aquaponics contains a small density of solid phase leftovers from aquatic life, about (5 - 10) %, making the use of an aeration pump appropriate.
- For the flow of water to be transported between aquaponics equipment that is not large, it is recommended to use a lifting tube with a diameter of 30 - 36 mm and a dipping coefficient of about 0.285 for optimal pump productivity and efficiency. The peak efficiency for this type of pump is achieved with a dipping coefficient of 0.225.
- These findings provide a basis for the design and operation of aeration pumps for aquaponics, as well as other hydroponic or aerobic equipment.

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