Low-Cost Automatic Filling Machine Based on the 8-Bit Microcontroller for the Fish Canning Process

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Abstract: The Ministry of Maritime Affairs and Fisheries (KKP) report shows that the national fish consumption rate in 2020 is 56.39 kg/capita. This figure increased by 3.47% compared to the previous year, which was 54.5 kg/capita. Domestic market needs include fresh fish and canned fish. The considerable market potential of canned fish products opens up business opportunities for fish canning production for household consumption. Through the blue economy program, the government also encourages the maximum utilization of fishery products. Politeknik Negeri Jember, a vocational institution, also represents government programs in various policies, one of which is the Teaching Factory Canning program, which produces canned fish from marine catches. Teaching factory Fish Canning has machines to produce large-scale canned fish with 425 mL packaging. With a large production capacity (1200 cans per production process), the entire production process must be carried out precisely and efficiently. If a processing delay is too long, it has the potential for bacterial/microbial activation in canned fish. One process that causes a holding time that is too long (about 60 minutes) is the process of filling the sauce. Sauce filling that is done manually also can cause the inefficiency of raw materials. This research developed an automatic filling machine based on a gravity system. The filling system has advantages in terms of speed, good filling accuracy, and ease of maintenance. The filling machine uses microcontroller-based precision timing with electric valve actuators. The machine is integrated with the canning system at the Politeknik Negeri Jember's TEFA Canning and is expected to shorten the holding time.

1 INTRODUCTION

TeFa Fish Canning at Politeknik Negeri Jember is a business unit that produces canned fish for consumption. Based on the results of study (Virgantari F, Koeshendrajana S, Arthatiani F Y, Faridhan Y E, Wihartiko F D 2022), the resulting map of fish consumption shows that in most provinces in Indonesia the level of consumption, participation rate, and level of fish expenditure is quite high. The household consumption patterns in Indonesia are grouped into consumption of fresh seawater fish at 22.10 kg/capita/year, fresh/brackwater fish at 16.75 kg/capita/year, fresh shrimp at 9.58 kg/capita/year and fish processed by 4.22 kg/capita/year. If the household is an upper-middle income class, it will increase the demand for canned processed fish (Arthatiani F Y, Kusnadi N dan Harianto 2018). In a previous study(Suryaningsih W, Bakri A, Kautsar S, Hariono B, Brilliantina A, Wijaya R 2022), the research team designed an exhausting device that utilizes hot steam from an autoclave to sterilize fish in 115mL cans. Utilizing steam heat from the autoclave also streamlines the electricity requirement for the production process by 30%. Teaching factory Fish Canning besides producing canned fish in 115mL packaging also produces large-scale canned fish in 425mL packaging. The increase in production capacity compared to before also impacted the need for labor for the production process, even with large-scale production machines (1200 cans per production process).

The duration of the sterilization process with the canning process, which must be under 30 minutes (to prevent bacterial/microbial activation)(Holdsworth S D 1997)-(Speranza D 2013), makes it difficult for workers to work optimally, especially in the sauce filling process. The sauce filling process is still done manually. Sterilization process is aimed to inactivate potentially harmful microorganisms. To that purpose

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the packaged food is subject to a time/temperature profile. In the canning industry such profiles are chosen based on the experience of the operator (Vilas C, Alonso A A 2018). The design an automatic filling machine, with a filler mechanism using a screw-driven piston technology, where the thread is rotated by an electric motor integrated with the timer. This machine is equipped with an easy charging method that is operated using only 1 button. the productivity of performance machine has been increased twice (Syah S S, Maulana M I, Ainurroji A F, Ardiansyah M R, Reynaldi A 2018). Automatic control systems can control quality of fish and fish products. Automated systems receive, freeze, sort, cut, wash, salt, dry, smoke, press, cool, package and store fish and fish products (Komlatsky V I, Podoinitsyna T A, Verkhoturov V V and Kozub Y A 2019). In addition to causing a holding time that is too long, it also has the potential for cross-contamination of canned fish sauce. Therefore, in this study, a prototype automatic sauce filling machine will be developed to help optimize the production process of 425mL packaged fish.

Automatic sauce filling is designed based on an integrated microcontroller. The texture of the sauce is not too runny. It will cause reading problems if the flowmeter sensor passes it. Therefore, a gravity-based filling system will be used. This research is expected to increase efficiency in the fish production process at TEFA canning.

2 RELATED WORK

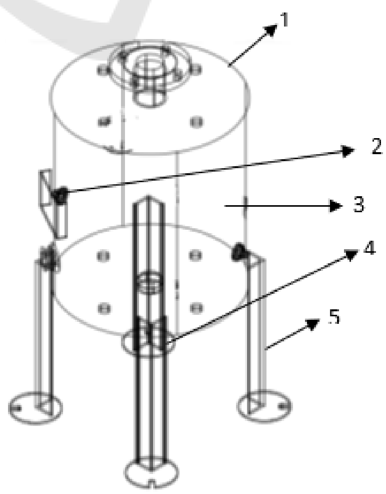
In industry, the filling process can be carried out in several ways, either manually, semi-automatically, or automatically (Gharte M 2016). The design of the filling machine also varies depending on the material and volume used. In 2020, (Zhang S K, Ji J and Li Y H) designed an automatic filling machine for water filling with a weight sensor reference. This filling machine is made based on PLC. However, the weight sensor-based filling machine design requires recalibration for different materials. This system will be difficult to implement in the fish canning process, where the condition of the cans already has its weight (filled with fish), and the sauce's viscosity varies according to the taste used. (Zhang D and Li S Design) also made a filling machine design regarding the flow meter sensor. In low viscosity liquid conditions, the flow meter can work well. However, if the viscosity of the liquid is high, it can interfere with the flow meter's performance.

In 2018, (Qiao Q and Zhang J 2009) made a filling machine design by utilizing the rotation of the motor. This system has the advantage that it can be controlled digitally with a closed-loop control system. However, the maintenance and operation of this system are relatively more difficult. For this reason, the proposing team will develop a sauce filling system using a compressed air system in this study. According to (Speranza D, 2013), the piston filling system has the advantages of this filling technology: high filling speed and accuracy in terms of volume/dose. However, additional equipment such as an air compressor is required for operation. This system can be used to fill any container, either in glass or PET or cans.

This study used a chamber with an electric valve faucet at the bottom. This system is integrated with a microcontroller so that it can work automatically. The design of the filling machine will be adapted to the mini exhausting machine made in previous research at TeFa Canning. The system will fill the canned sauce in batches according to the input from the operator.

3 SYSTEM DESIGN

The filling tube is made with a capacity of 30 liters. The material used is food-grade stainless 304. The design of the automatic filling machine is shown in Figure 1. The top is a cylindrical tube with a diameter of 30cm and a height of 50cm. The bottom is a cylindrical support leg with a height of 50cm. The lower end of the cylinder is designed to be conical in shape with a 0.5-inch pipe connection. The output pipe is connected to a 220 VAC electrical valve of 304 stainless.



a) Front View

1. **Specification**
   1. Tube cover
   2. Panel Control
   3. Tube
   4. Pump
   5. Beam

Figure 1: Low-cost filling machine design.

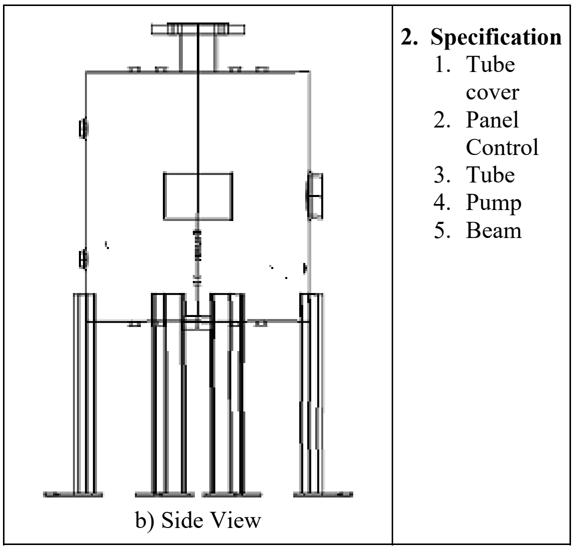


Figure 1: Low-cost filling machine design (cont.).

An electrical panel is mounted on the bottom of the cylinder. The panel contains controller components, sensors, and drivers for the actuator. The controller uses an ATMega328 microcontroller. The sensors are push buttons, toggle switches, and VL53L0X proximity sensors. A 5volt relay driver activates the actuator. A 220 VAC indicator light is connected in parallel to the electrical valve. This light indicates if the valve is in the active position. The system block diagram of the filling machine is shown in Figure 2.

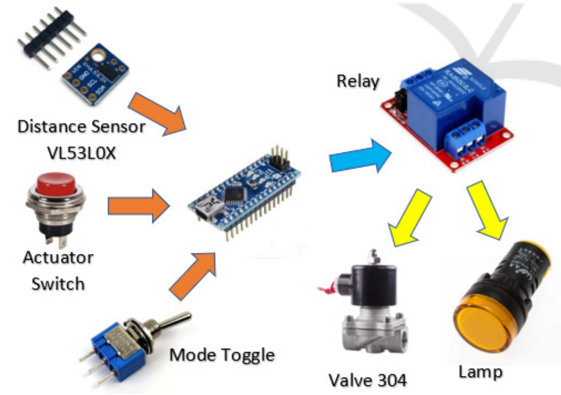


Figure 2: Block Diagram System.

The automatic filling machine has 2 working modes: working mode and delay setting mode. The operating mode is the mode for charging automatically. At the same time, the delay setting mode is a mode to set the length of time for the valve to be active. The electric valve can be activated in 2 ways, by using a push button or based on the VL53L0X proximity sensor readings. The valve activation delay can be adjusted flexibly by the operator. The valve activation delay is stored in the EEPROM so that the data is retained even when the controller power supply is turned off. Figure 3 is a controller work flowchart.

For setting the valve activation delay, it is done through several steps. First, the toggle switch is activated. After the toggle switch is active, the controller will enter the delay setting mode. To set the length of the delay, by pressing the button. Once the desired water volume is reached, the button can be released. Then the toggle switch can be disabled again. The microcontroller will store the delay in the EEPROM. The delay range that can be stored is 10mS – 250 seconds (+-4 minutes). 2 EEPROM addresses are used to store data >255. The microcontroller's timer feature is used to obtain precise results during storage and charging. The timer one feature is a timing feature that utilizes the timer register so the delay timing can be more accurate. Here is the equation for EEPROM storage according to the stored data:

$$EEPROM(10)hundreds = delay / 100 \quad (1)$$

$$EEPROM(11)dozens = delay \% 100 \quad (2)$$

For delay readings based on 2 EEPROM addresses, the following equation is used:

$$delay = (EEPROM(10)*100)+(EEPROM(11)) \quad (3)$$

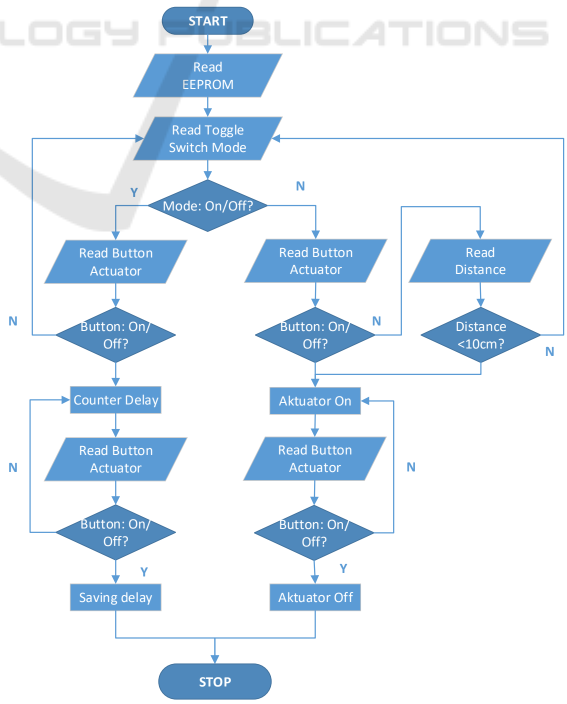


Figure 3: Flowchart filling machine controller.

4 RESULT AND DISCUSSION

4.1 Hardware Realization

All components are made of 304 stainless metal according to food grade standards. Figure 4 is a display of the filling machine that has been made. When empty, the machine weighs about 3kg. Although it is made for fish sauce in cans, the filling machine can also be used for various liquids such as milk, soy, etc (Kurnianto M F, Wibowo M J, Hariono B, Wijaya R and Brilliantina A 2020).

Figure 4: Automatic filling machine hardware.

4.2 Testing Result

After the process of making the tool, the testing process is carried out. The test is carried out by storing data and measuring the amount of liquid released according to the delay stored in the EEPROM. Measurements were made using 150cc & 500cc measuring cups. The first test is carried out with the liquid position in the maximum volume (approximately 30L). Figure 5 is a comparison photo between the volume during storage and the volume when charging. It can be seen that the filling result is the same as the volume during storage. Table 1 is the data from the controller performance test results on the automatic filling machine. To test the EEPROM function, deactivate the power on the filling machine, then retrieve data again. Based on the test, the filling volume remains the same, so it can be concluded that the charging data has been stored in the microcontroller memory.

$$P = \rho . g . h \tag{4}$$

According to the fluid pressure equation in equation 4, the liquid level affects the pressure at the outlet. The higher volume of the liquid makes, the greater the pressure at the outlet. It will affect the velocity of the fluid when it exits. Because the filling machine uses the delay principle, the height can affect the filling volume. Therefore, the filling volume was measured based on the height of the liquid in the chamber. Table 2 is the test result using a 125cc data store.

(a) (b)

Figure 5: a) Volume saving b) Volume filling.

Table 1: Testing data of the same volumes.

Data saving	Measurements	Result
250cc	1	250cc
	2	250cc
	3	250cc
	4	250cc
	5	250cc
	6	250cc
250cc (after power shutdown)	1	250cc
	2	250cc
	3	250cc
	4	250cc
	5	250cc
	6	250cc

Table 2: Testing data of the different volumes.

Volume	Measurement	Result
125cc Volume 15 liter	1	125cc
	2	125cc
	3	125cc
	4	125cc
	5	125cc
	6	125cc
125cc Volume 5 liter	1	110cc
	2	110cc
	3	110cc
	4	110cc
	5	110cc
	6	110cc

Based on the test data in table 2, the results obtained that the measurement volume decreases according to the decrease in the liquid level in the chamber. Therefore, treatment can be carried out by maintaining the volume of the chamber, such as using a stainless floating valve from the main chamber. The next test was tested using sauce ingredients at 80 degrees (Wijaya R and Hariono B 2020). Figure 6 is the result of filling the sauce in the cans used for fish canning. The results of the sauce filling matched the storage data.

Figure 6: Filling test.

Table 3: The cost of making a filling machine.

Filling machine Electric Valve			Filling machine piston
No	**Items**	**Price (IDR)**	**Price (IDR)**
1	Stainless steel 304 chamber	1.250.000	
2	Valve electric	750.000	
3	Microcontoller	250.000	
4	Panel & electrical components	350.000	
	Total	2.600.000	20.300.000 (marketplace)

The cost of making a filling machine in this study is shown in table 3. Compared with piston filling sold in the market, the filling machine is 7 times cheaper. Piston filling with a piston system also requires an additional compressor engine. Filling machines with electric valves is also lower in terms of electricity usage.

5 CONCLUSION

Based on the research that has been done, the automatic filling machine can work well. From the experiments that have been carried out, the machine can fill liquids accurately and stably. By using an 8-bit microcontroller, as well as the use of an electric valve, the cost of making the device can be more affordable. When compared to the price of a piston-based filling machine, the manufacturing cost is 30% cheaper. It is just that the operation of a valve-based filling machine needs to maintain the volume of the chamber when filling.

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